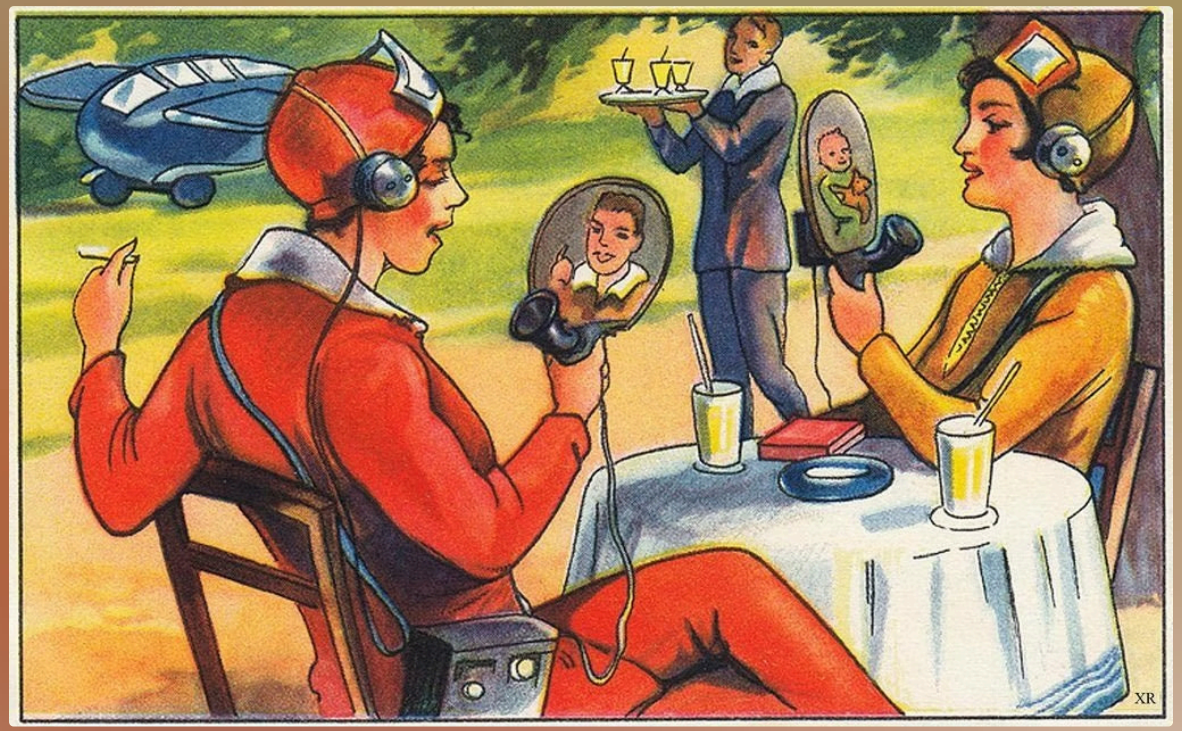
Planning for the Future in the Face of Uncertainty

Kirils Makarovs

21.04.2026



Agenda for Today

1	2
Critical Studies of Science (a.k.a. overview of the sociology of science / scientific knowledge)	Decision Making Under Deep Uncertainty and Future Scenario Planning

Part I. Critical Studies of Science

What is Going on Here?

Some Context

1. **Harry Collins:** British sociologist
2. **Respondents 3 and 5:** astrophysicists
3. **Supernova 1987A:** celestial object, type II supernova in the Large Magellanic Cloud, a dwarf satellite galaxy of the Milky Way

3) *Collins*: In 1982 there was a paper published by Weber and Pizzella claiming to see some gravitational radiation. Do you remember that paper?
Respondent 3: The '82 one – they had an excess of coincidences – I don't remember it much, much more attention was paid to the stuff on the supernova 1987A which came later, but I do remember, remember, that – not well.
Collins: So, I mean, from the fact that you don't remember it very well it sounds as though it didn't have a big impact on the community.
Respondent 3: It didn't have much impact on me. I'm afraid that I am much influenced by theorists' prejudices about what is plausible out there, and also by the degree to which this field has shown an ability to show excess coincidences when, in fact, much deeper examinations later showed that they were not there, and I was just sceptical of this at the time. It didn't really smell likely to be real gravitational waves, and so while I recall it being presented, probably I first heard it presented at the Texas symposium on relativistic astrophysics in Chicago, which would have been around '82, or so, and I discussed it with people at the time, and I just wasn't ready to get excited by it.
Collins: Right, now, do you happen to remember what level of significance they reported?
Respondent 3: No, I don't, I don't remember. I have much better memory of the 87A . . .
. . .
I think most people's attitude was 'this is curious but it will work itself out in the end' – were very sceptical and that was that.

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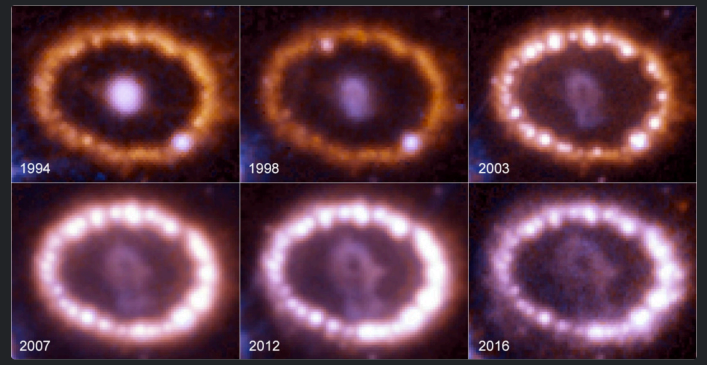
5) *Collins*: In 1982 a paper was published by Lee, Weber, Ferrari and Pizzella saying they'd found some coincidences. Do you remember this paper?
Respondent 5: Yeah!
Collins: Do you remember reading it?
Respondent 5: No – I just know about it.
Collins: Do you remember what level of significance they claimed?
Respondent 5: No.
Collins: What did you make of it at the time?
Respondent 5: I thought it was bullshit. I'm sorry to say, I by that time had become so polarized that I didn't trust anything . . . . And I said to myself if it isn't going to be a joint experiment of . . . people of the calibre of [named experimenters] I was not going to pay any attention to it. I'm sorry, I had a real prejudice.

Collins's Study of Gravitational Science (1999)



Collins reconstructed conversations that occurred in conferences and informal communication between gravitational scientists.

What counts as "real signal" **becomes stabilized** through collective judgement, rather than **objectively verified** facts.

Developed the idea of **"experimental regress"**:

Tantalus and the Aliens:

Publications, Audiences and the Search for Gravitational Waves

H.M. Collins

> "This is a paradox which arises for those who want to use replication as a test of the truth of scientific knowledge claims. The problem is that, since experimentation is a matter of skilful practice, it can never be clear whether a second experiment has been done sufficiently well to count as a check on the results of a first. Some further test is needed to test the quality of the experiment - and so forth." *(Collins 1992: p.5)*

Wait, so are scientists only humans after all??

"Big impact on the community"

"I'm much more influenced by theorists' prejudices"

"It didn't really smell likely to be real gravitational waves"

"I thought it was bullshit"

"I by that time had become so polarized that I didn't trust anything"

"I'm sorry, I had a real prejudice"

“People of the calibre of the [named experimenters]”

“It will work itself out in the end”

Central Question of the Sociology of Science

How are scientific facts and knowledge **produced**, **stabilized**, and **legitimized** through social practices, institutions, and interactions within scientific communities?

Produced

How are new scientific findings generated through experiments, observations, and data analysis?

Stabilized

How and why do some findings become widely accepted as reliable scientific facts, while others are discarded?

Legitimized

How do scientists decide which claims are credible and worthy of acceptance?

Social Practice

How do everyday research practices (e.g., experimentation, measurement, replication, having lunch with your colleagues) shape the creation of scientific knowledge?

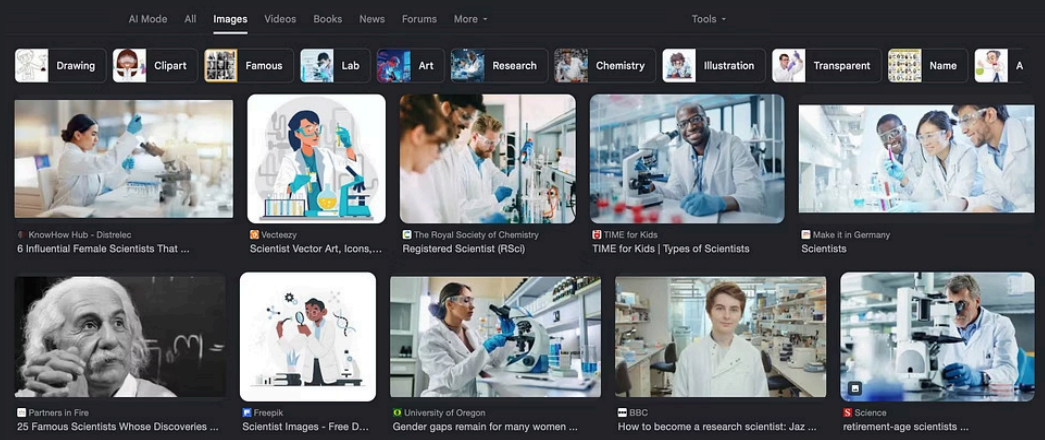
Institutions

How do institutions such as universities, journals, and funding bodies influence what knowledge is produced and recognized?

Interactions

How do discussions, collaborations, and debates among scientists influence the development of scientific knowledge?

And of Course: What Does It Really **Mean** to Be a Scientist / Researcher?



Standard View of Science

Popular understanding of science / mythic framework for scientists themselves.

The philosophy of the "standard" science is rooted in **logical positivism** (Vienna Circle) and Karl Popper's **falsificationism principle**.

> In this picture, science is a formal activity that creates and accumulates knowledge by directly confronting the natural world. That is, science makes progress because of its systematic method, and because that method allows the natural world to play a role in the evaluation of theories. While the scientific method may be somewhat flexible and broad, and therefore may not level all differences, it appears to have a certain consistency: different scientists should perform an experiment similarly; scientists should be able to agree on important questions and considerations; and most importantly, different scientists considering the same evidence should accept and reject the same hypotheses. The result is that scientists can agree on truths about the natural world.

(Sismondo 2011: p.1)

Logical Positivism (1920s)

> "What makes a statement scientifically meaningful?"

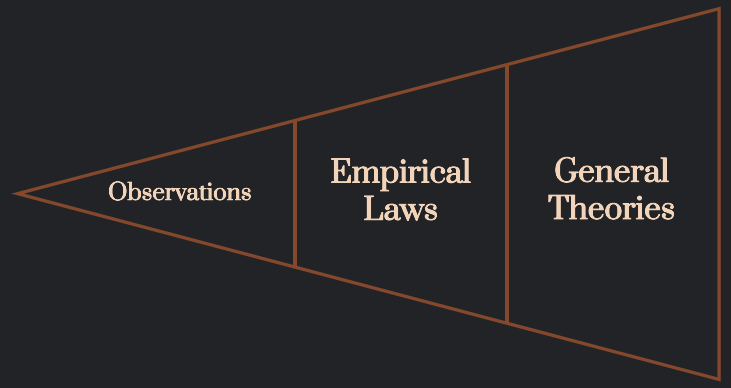
Verification Principle

A statement is meaningful if:

1. it is **analytic** (true by logic or definition), or
2. it is **empirically verifiable**

Science is a logical system of statements; it is grounded in empirical observations.

Theory is a condensed summary of possible observations.



Reject Metaphysics and Idealism

Refuse from making statements such as: *Civilizations emerge and disappear in a cyclical way.*

David Hume and the Problem of Induction (1739)

Logical positivists could not overcome it.

Other areas of critique of the verification principle:

- Self-refutation problem
- Universal scientific laws
- Observations are not neutral

The *problem of induction* arose with David Hume's general questions about evidence in the eighteenth century. Unlike classical skeptics, Hume was interested not in challenging particular patterns of argument, but in showing the fallibility of arguments from experience in general. In the sense of Hume's problem, induction extends data to cover new cases. To take a standard example, "the sun rises every 24 hours" is a claim supposedly established by induction over many instances, as each passing day has added another data point to the overwhelming evidence for it. Inductive arguments take *n* cases, and extend the pattern to the *n+1*st. But, says Hume, why should we believe this pattern? Could the *n+1*st case be different, no matter how large *n* is? It does no good to appeal to the regularity of nature, because the regularity of nature is at issue. Moreover, as Ludwig Wittgenstein (1958) and Nelson Goodman (1983 [1954]) show, nature could be perfectly regular and we would still have a problem of induction. This is because there are many possible ideas of what it would mean for the *n+1*st case to be the same as the first *n*. *Sameness* is not a fully defined concept.

(Sismondo 2011: p.3)

Karl Popper's Falsification Principle

Popper's **falsification principle** serves as a **demarcation criterion**, providing a rule to distinguish between genuine science and non-science.

Popper introduces the **deductive** rather than inductive approach as the problem of induction has no solution.

According to the falsification principle, the defining feature of a scientific theory is that it is **falsifiable**, meaning it must make "risky predictions" that:

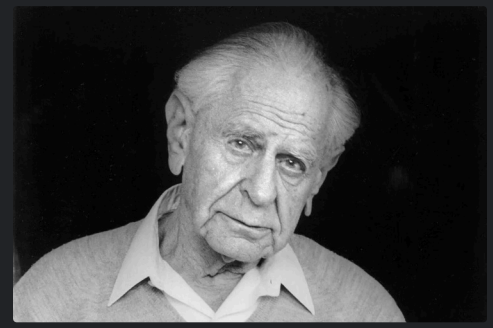
- 1) are empirically testable, and
- 2) could potentially be proven wrong by empirical evidence.

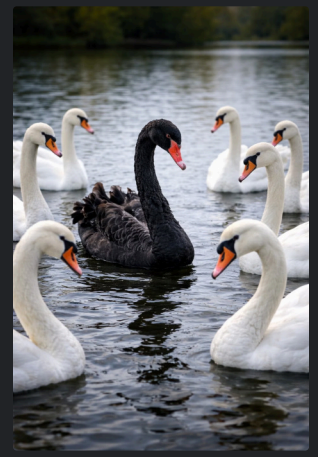
Science as a formal activity is driven by a process of **"conjectures and refutations"**. A theory that survives testing is never considered "proven" but is instead provisionally accepted until new evidence comes along that might refute it.

> No number of white swan observations can prove that "all swans are white", but a single black swan proves it false.

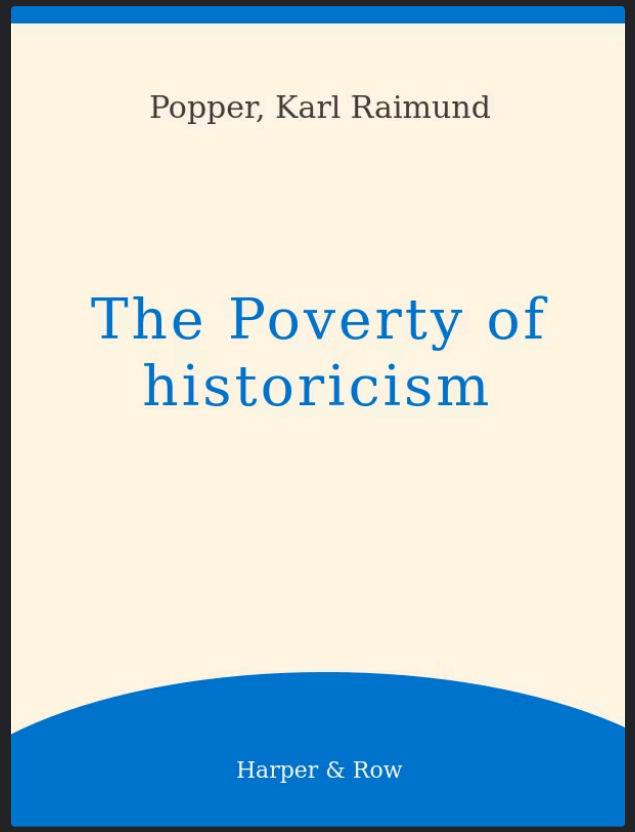
Remember your null (H0) and alternative (H1) statistical hypothesis?

This is where it comes from!





The poverty of historicism (1944)



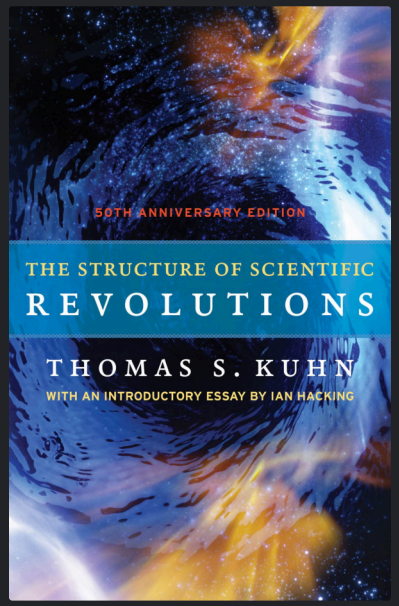
> "Pseudo-sciences, among which Popper includes Marxism and Freudianism, are insulated from criticism, able to explain and incorporate any fact. They do not make any firm predictions, but are capable of explaining, or explaining away, anything that comes up." (Sismondo 2011: p.4)

Historicism: the belief that history follows discoverable laws that allow prediction of future social development.

Pseudo science by Popper's standards:

- Marxist historical materialism
- August Comte's law of three stages of society
- Oswald Spengler's civilizational cycles

The Structure of Scientific Revolutions (1962)



Thomas Kunh - American historian and philosopher of science.

Kunh draw attention to the **history of scientific developments** rather than methodological or ontological assumptions.

He defies the notion of scientific progress as a **steady** and **cumulative process**. Instead, proposes that science moves forward in a revolutionary way.

Introduces the idea of **paradigm** (a disciplinary matrix). Paradigm dictates to scientist what is accepted in the '**normal science**':

- shared assumptions
- exemplary problems
- standards of evidence
- legitimate methods and instruments
- criteria for success and failure

Once the **anomalies** - results, observations, or persistent problems that do not fit comfortably within the paradigm - accumulate, scientific discipline plunges into **crisis**.

Crisis then opens up the space for methodological experiments and reconsideration of the foundational assumption which leads to a **revolution**.

> "‹...› theories belonging to different paradigms are **incommensurable** – lacking a common measure – because people working in different paradigms see the world differently, and because the meanings of theoretical terms change with revolutions ‹...›" (Sismondo 2011: p.16)

Think of: The Copernican revolution in Astronomy; Relativity replacing Newtonian physics; The contemporary AI turn in many field.

The Structure of Scientific Revolutions (Bell 2009, p.198-199)

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Stage 4.

The stage of *beginning of doubt* occurs as inconsistencies and uncertainties are no longer easily resolved within the dominant paradigm and become recognized as persistent anomalies. Some members of the scientific community begin to ask questions that have no apparent answer within the dominant paradigm, to depict other scientists as dopes, and to treat some aspects of the paradigm as questionable.

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Stage 5.

A scientific revolution is the next stage and takes place when a new and competing paradigm is proposed as an acceptable alternative to the old paradigm. This is a period of struggle between the adherents of the old and the new paradigms over disciples and control of the professional journals, textbooks, research grants, and the programs of meetings of professional organizations. In Kuhn's conception of process and change there are many specific scientific revolutions.

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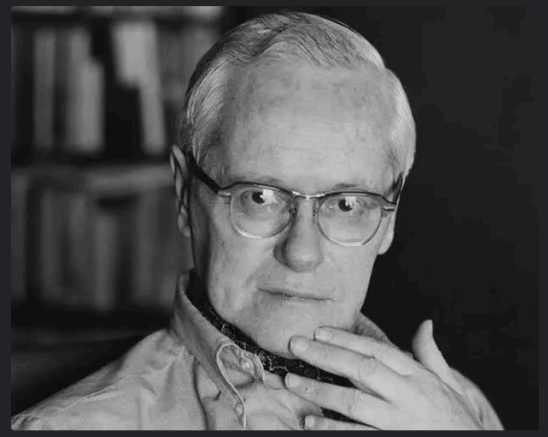
Stage 6.

The recurrence of normal science is the final stage which comes about when the new paradigm becomes dominant in the field. The core of the field, its boundaries, and its membership are again clearly defined. Once again, efforts are focused on the problems generated by the science, and puzzles are defined and solved within a reigning paradigm, but now the new one. Great progress again occurs with a mopping-up operation within the new paradigm. The unconverted scientists have died, retired, become college deans or presidents, returned to undergraduate teaching, or simply defined themselves—or have been defined by others—out of the field. Then, of course, doubt may begin again and the whole process repeated (Kuhn 1962; Friedrichs 1970; Blum 1970).

Robert Merton and the Ethos of Science (1942)



13

The Normative Structure of Science

1942

Merton, R. (1973). The Normative Structure of Science. In N. Storer (Ed.), The Sociology of Science: Theoretical and Empirical Investigations. Chicago: University of Chicago Press.

Science, like any other activity involving social collaboration, is subject to shifting fortunes. Difficult as the notion may appear to those reared in a culture that grants science a prominent if not a commanding place in the scheme of things, it is evident that science is not immune from attack, restraint, and repression. Writing a little while ago, Veblen could observe that the faith of western culture in science was unbounded, unquestioned, unrivaled. The revolt from science which then appeared so improbable as to concern only the timid academician who would ponder all contingencies, however remote, has now been forced upon the attention of scientist and layman alike. Local contagions of anti-intellectualism threaten to become epidemic.

American sociologist.

Structural functionalism: each institution (science, religion, education) serves a necessary function.

What is the primary institutional goal of science? **The extension of certified knowledge**.

How can scientists achieve this goal? By adhering to four **institutional norms**.

The Matthew Effect in Science

The reward and communication systems of science are considered.

Robert K. Merton

This paper develops a conception of ways in which certain psychosocial processes affect the allocation of rewards to scientists for their contributions—an allocation which in turn affects the flow of ideas and findings through the communication networks

image and the public image of scientists are largely shaped by the communally validating testimony of significant others that they have variously lived up to the exacting institutional requirements of their roles.

A number of workers, in empirical

reers are more productive later on than those who do not. And the Coles have also found that, at least in the case of contemporary American physics, the reward system operates largely in accord with institutional values of the science, inasmuch as quality of research is more often and more substantially rewarded than mere quantity.

In science as in other institutional realms, a special problem in the workings of the reward system turns up when individuals or organizations take on the job of gauging and suitably rewarding lofty performance on behalf of a large community. Thus, that ultimate accolade in 20th-century science, the Nobel prize, is often assumed to mark off its recipients from all the other scientists of the time. Yet this assumption is at odds with the well-known fact that a good number of scientists who have not received the prize and will not receive it have con-

The Ethos of Science

- **Universalism.** This norm requires that the criteria used to evaluate scientific claims should be impersonal and independent of the researcher's identity. Factors such as race, nationality, religion, and class are considered irrelevant to the truth or falsity of a scientific claim.
- **Communism.** Merton argued that scientific knowledge is commonly owned. While researchers are recognized for their creativity, they cannot dictate how their ideas are used, and results must be publicized so the entire community can build upon them.
- **Disinterestedness.** Scientists are expected to have a form of integrity that demands they **disengage their personal interests** from their professional actions and judgments. This norm is intended to rule out fraudulent behavior like fabricating data.
- **Organized Skepticism.** This is the tendency for the scientific community to **disbelieve new ideas** until they are well established. It involves both public challenges at conferences and an internalized reserve of judgment by individual scientists.

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Scientists adhering to these norms get rewarded, those who don't - punished. **Right?**

Critique of Mertonian Norms and Further Developments

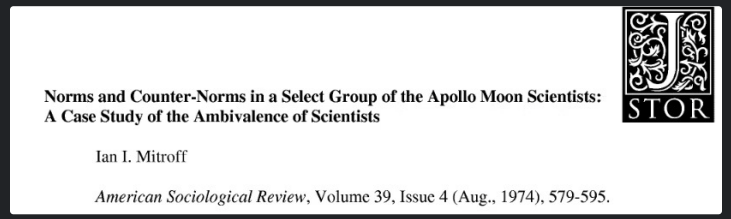
Mertonian norms for scientific enterprise look more like an ideal type and struggle to hold against the reality test.

Mitroff's counternorms:

- ~~**Universalism**~~ → **Particularism** (who makes the claim?)
- ~~**Communism**~~ → **Solitariness** (protective control over one's discoveries)
- ~~**Disinterestedness**~~ → **Interestedness** (self-interest, e.g. satisfaction or prestige)
- ~~**Organized skepticism**~~ → **Organized dogmatism** (the scientist must believe in his own findings with utter conviction while doubting those of others with all his worth)

Macfarlane's DECAY:

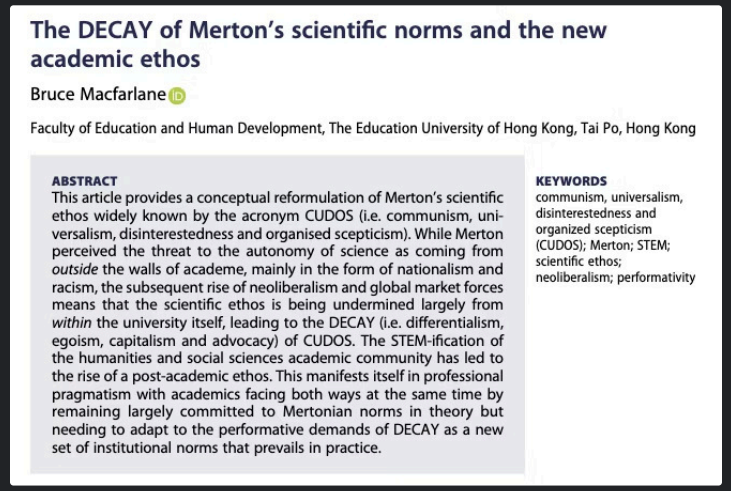
- **D — Differentialism** (relativism)
- **E — Egoism** (personal achievements)
- **C — Capitalism** (academic capital)
- **A — Advocacy** (commitment to agenda)



Norms and Counter-Norms in a Select Group of the Apollo Moon Scientists: A Case Study of the Ambivalence of Scientists

Ian I. Mitroff

American Sociological Review, Volume 39, Issue 4 (Aug., 1974), 579-595.



The DECAY of Merton's scientific norms and the new academic ethos

Bruce Macfarlane

Faculty of Education and Human Development, The Education University of Hong Kong, Tai Po, Hong Kong

ABSTRACT

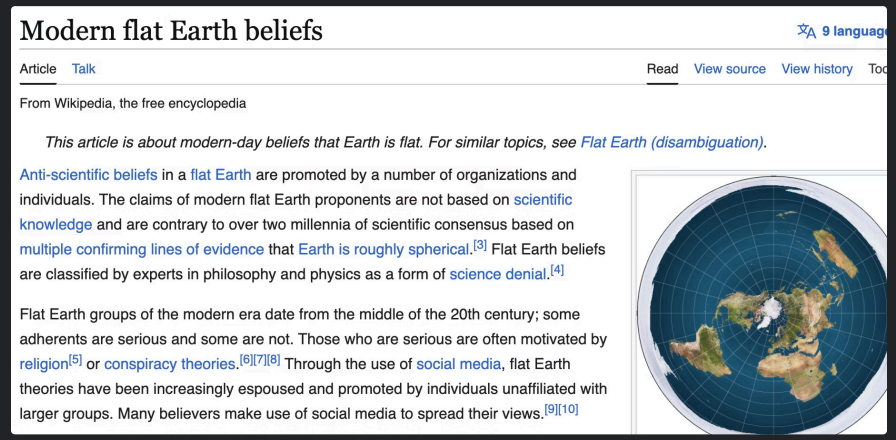
This article provides a conceptual reformulation of Merton's scientific ethos widely known by the acronym CUDOS (i.e. communism, universalism, disinterestedness and organised scepticism). While Merton perceived the threat to the autonomy of science as coming from *outside* the walls of academe, mainly in the form of nationalism and racism, the subsequent rise of neoliberalism and global market forces means that the scientific ethos is being undermined largely from *within* the university itself, leading to the DECAY (i.e. differentialism, egoism, capitalism and advocacy) of CUDOS. The STEM-ification of the humanities and social sciences academic community has led to the rise of a post-academic ethos. This manifests itself in professional pragmatism with academics facing both ways at the same time by remaining largely committed to Mertonian norms in theory but needing to adapt to the performative demands of DECAY as a new set of institutional norms that prevails in practice.

KEYWORDS

communism, universalism, disinterestedness and organized scepticism (CUDOS); Merton; STEM; scientific ethos; neoliberalism; performativity

In essence, Merton and related sociologists of science talk extensively about the social conditions that **facilitate the production of scientific knowledge**. However, they tend to ignore the question of how social conditions impact **what is considered to be scientific knowledge.**

A Small Detour: Flat Earth Theory



Modern flat Earth beliefs

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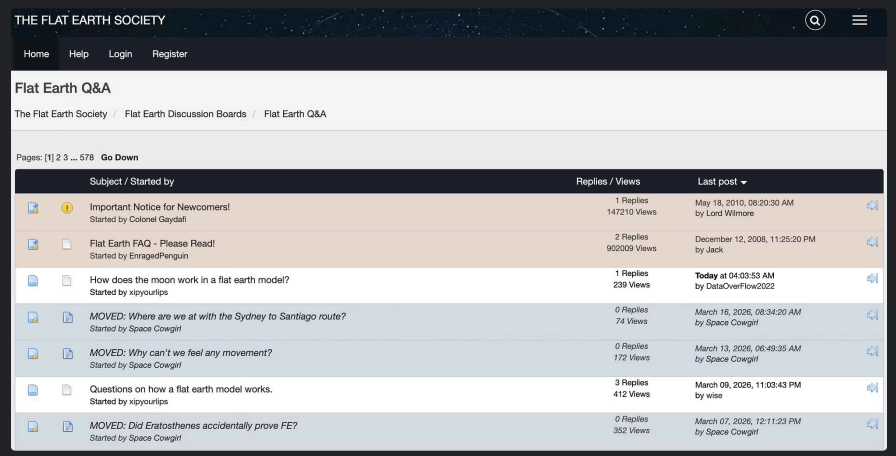
From Wikipedia, the free encyclopedia

This article is about modern-day beliefs that Earth is flat. For similar topics, see Flat Earth (disambiguation).

Anti-scientific beliefs in a flat Earth are promoted by a number of organizations and individuals. The claims of modern flat Earth proponents are not based on scientific knowledge and are contrary to over two millennia of scientific consensus based on multiple confirming lines of evidence that Earth is roughly spherical.[3] Flat Earth beliefs are classified by experts in philosophy and physics as a form of science denial.[4]

Flat Earth groups of the modern era date from the middle of the 20th century; some adherents are serious and some are not. Those who are serious are often motivated by religion[5] or conspiracy theories.[6][7][8] Through the use of social media, flat Earth theories have been increasingly espoused and promoted by individuals unaffiliated with larger groups. Many believers make use of social media to spread their views.[9][10]



THE FLAT EARTH SOCIETY

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Subject / Started by	Replies / Views	Last post
Important Notice for Newcomers! Started by Colonel Gaydafi	1 Replies 147210 Views	May 18, 2010, 08:20:30 AM by Lord Wilmore
Flat Earth FAQ - Please Read! Started by EnragedPenguin	2 Replies 902009 Views	December 12, 2008, 11:25:20 PM by Jack
How does the moon work in a flat earth model? Started by xipyourlips	1 Replies 239 Views	**Today** at 04:03:53 AM by DataOverFlow2022
MOVED: Where are we at with the Sydney to Santiago route? Started by Space Cowgirl	*0 Replies 74 Views*	*March 16, 2026, 08:34:20 AM by Space Cowgirl*
MOVED: Why can't we feel any movement? Started by Space Cowgirl	*0 Replies 172 Views*	*March 13, 2026, 06:49:35 AM by Space Cowgirl*
Questions on how a flat earth model works. Started by xipyourlips	3 Replies 412 Views	March 09, 2026, 11:03:43 PM by wise
MOVED: Did Eratosthenes accidentally prove FE? Started by Space Cowgirl	*0 Replies 352 Views*	*March 07, 2026, 12:11:23 PM by Space Cowgirl*

How would you as a social science researcher explain why some people endorse the flat Earth belief? Discuss with your peer!

A Small Detour: Flat Earth Theory

You would probably attempt to explain these beliefs through the appeal to a wide range of factors, including:

- Lack of scientific literacy
- The effect of cognitive biases
- Distrust in institutions (government, science)
- Social media and echo chambers
- Personal traits e.g. non-conformism, need for uniqueness

However, all these explanations are grounded in the implicit assumption that **the correct belief (the globe Earth theory) needs no special (social) explanation**.

As if rational people simply **converge on truth** when there are no **"distracting" factors** that can distort their reasoning.

Some sociologists wouldn't agree to take this assumption for granted.

Strong Programme in the Sociology of Scientific Knowledge

1970s. Also called the 'Edinburgh school'.

David Bloor, Barry Barnes, Steven Shapin.

Understanding the **content** of scientific knowledge in sociological terms.

Why strong? Opening passage from Bloor's "Knowledge and Social Imagery" (1976):

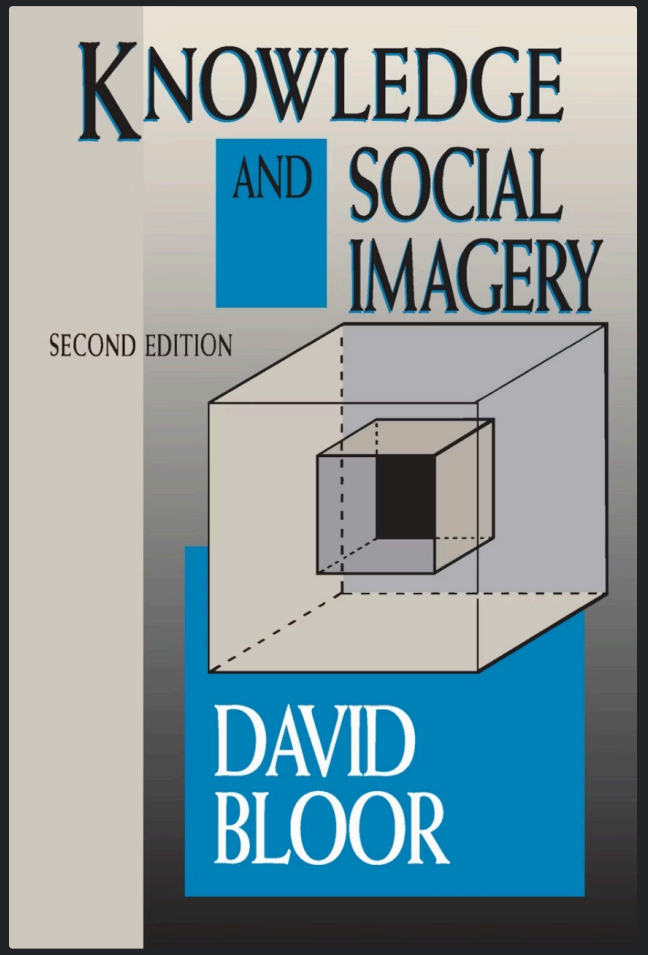
> **Methodological symmetry**: **all beliefs** require the same kind of explanation. **All knowledge** should be explained through the analysis of social factors, not only irrational or false ones.

Can the sociology of knowledge investigate and explain the very content and nature of scientific knowledge? Many sociologists believe that it cannot. They say that knowledge as such, as distinct from the circumstances surrounding its production, is beyond their grasp. They voluntarily limit the scope of their own enquiries. I shall argue that this is a betrayal of their disciplinary standpoint. All knowledge, whether it be in the empirical sciences or even in mathematics, should be treated, through and through, as material for investigation. Such limitations as do exist for the sociologist consist in handing over material to allied sciences like psychology or in depending on the researches of specialists in other disciplines. There are no limitations which lie in the absolute or transcendent character of scientific knowledge itself, or in the special nature of rationality, validity, truth or objectivity.

Rejecting the "Whig history" approach: **true beliefs** result from a rational route to nature while **false beliefs** represent social/psychological/ideological distortions.

Four Principles of the Strong Programme

- **Causality.** The explanation must be concerned with the conditions (social, psychological, or material) that bring about states of knowledge or belief.
- **Impartiality.** It must explain both sides of dichotomies like truth and falsity, rationality and irrationality, and success and failure.
- **Symmetry.** Most importantly, the **same types of causes** must be used to explain both true and false beliefs.
- **Reflexivity.** Its patterns of explanation must be applicable to sociology itself.



Flat Earth Theory: SSK Approach

SSK sociologists would fundamentally reframe the question: instead of only investigating the factors behind the flat Earth theory beliefs, they depart from the idea that **both flat and globe Earth theories are socially produced and embedded**.

This means that the knowledge around the standard view of Earth also:

1. relies on **institutional authority** rather than personal verification
2. is embedded in **epistemic communities** (schools, media, science communication) that reinforce consensus
3. has related **identity and social stakes** in accepting this view and/or mainstream science in general
4. can be susceptible to the same cognitive biases, just directed toward dominant knowledge

According to SSK, the difference between two beliefs is not rationality vs. irrationality per se; rather, the very notion of some kind of knowledge being treated as rational or irrational is embedded within the broader power play between institutions, communities, authorities, and epistemic cultures.

Is Math Socially Shaped? And Logic?

The Azande people (Central Africa) institutionalised what Western observers perceive as a logical fallacy regarding the inheritance of **witchcraft-substance** primarily to **protect their social institutions from collapse.**

According to Azande belief, witchcraft is a physical trait inherited through the male line; therefore, logically, if one man is a proven witch, his entire patrilineal clan must also be witches.

While the Azande recognize the steps of this argument, they **refuse to accept its conclusion.**

Logic, in this case**, is not a self-moving force** that dictates human thought; rather, it is a tool that is **adjusted to fit the stable social practices** that are essential foundation of the culture.

Bloor 1991 p.141

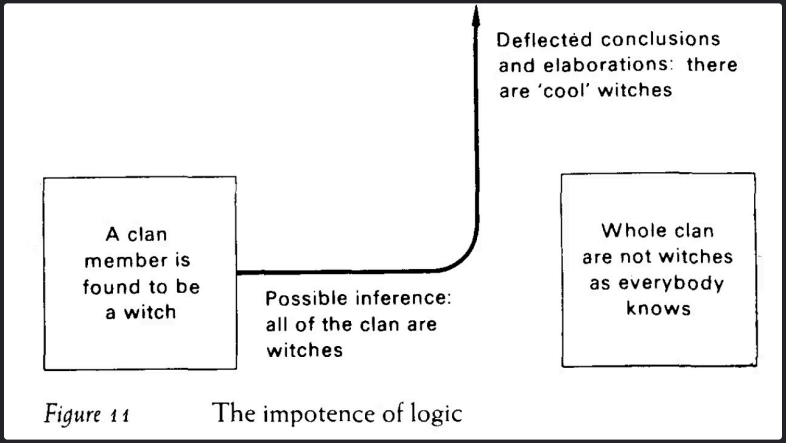


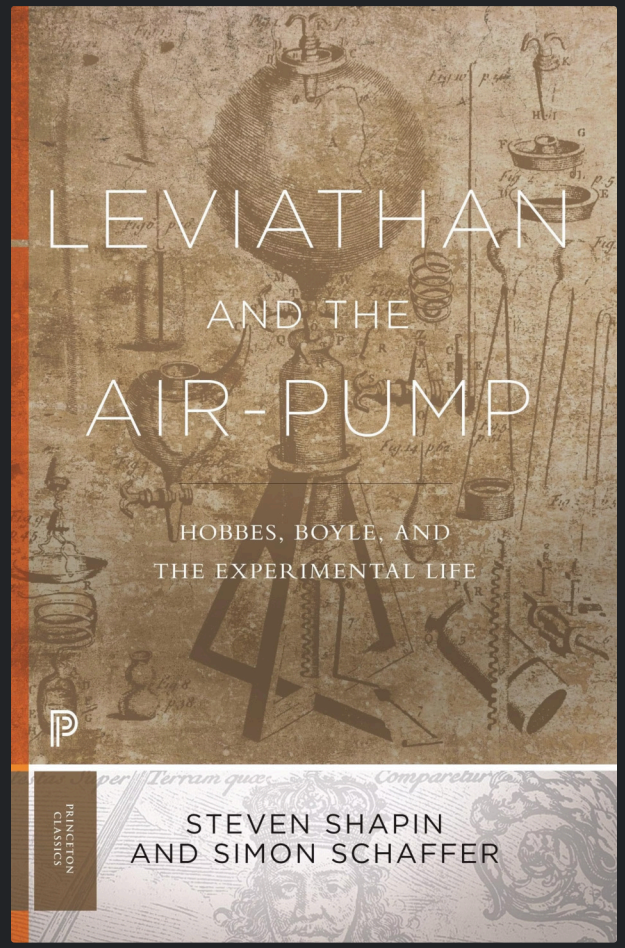
Figure 11 The impotence of logic

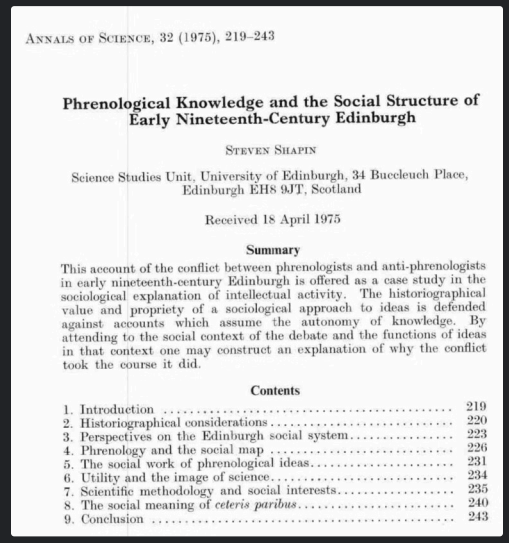
Pearson vs. Yule (Bucchi 2004 p.47)

Is mathematics socially shaped? 47

These dynamics have also been used to analyse the controversy in statistics between Pearson – the leader of the biometrics school – and Yule. The dispute centred on the most appropriate correlation indicator for nominal statistical variables like 'living/dead' or 'high/low'. The index proposed by Pearson – *rt* – was based on the hypothesis that such variables can be considered products of a bivariate normal distribution. Yule instead developed another index – Q – which dispensed with that assumption. In this case, too, the incompatible positions taken up (and backed by opposing 'networks' in the British academic community) can be linked with the different goals that Pearson and Yule believed that statistical theory should pursue. What was assumed to be 'normality', however, depended on the scientist's broader vision of society – which in Pearson's case was centred on eugenics and Fabian socialism (MacKenzie, 1978).

Strong Programme in the SSK: Some Seminal Readings





ANNALS OF SCIENCE, 32 (1975), 219–243

Phrenological Knowledge and the Social Structure of Early Nineteenth-Century Edinburgh

STEVEN SHAPIN

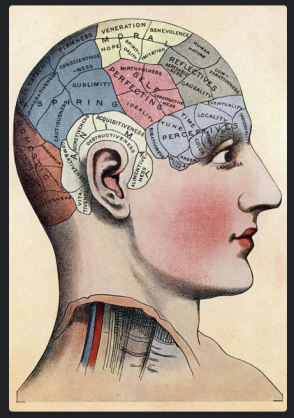
Science Studies Unit, University of Edinburgh, 34 Buccleuch Place, Edinburgh EH8 9JT, Scotland

Received 18 April 1975

Summary

This account of the conflict between phrenologists and anti-phrenologists in early nineteenth-century Edinburgh is offered as a case study in the sociological explanation of intellectual activity. The historiographical value and propriety of a sociological approach to ideas is defended against accounts which assume the autonomy of knowledge. By attending to the social context of the debate and the functions of ideas in that context one may construct an explanation of why the conflict took the course it did.

Contents



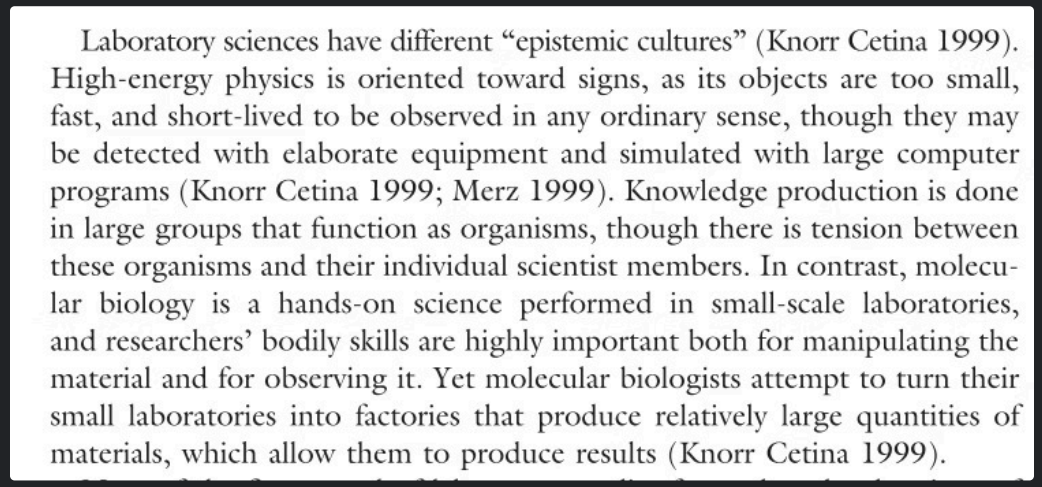
Social Construction(s) of Science

Science and technology are **social** and **active**.

Science does not provide a **direct route** from nature to ideas about nature.

Disciplines are "**epistemic cultures**" (Knorr Cetina 1999) that may have completely different orientations to their objects, social units of knowledge production, and patterns of interaction.

Ethnography of laboratory life - observe scientists at work.



Laboratory sciences have different "epistemic cultures" (Knorr Cetina 1999). High-energy physics is oriented toward signs, as its objects are too small, fast, and short-lived to be observed in any ordinary sense, though they may be detected with elaborate equipment and simulated with large computer programs (Knorr Cetina 1999; Merz 1999). Knowledge production is done in large groups that function as organisms, though there is tension between these organisms and their individual scientist members. In contrast, molecular biology is a hands-on science performed in small-scale laboratories, and researchers' bodily skills are highly important both for manipulating the material and for observing it. Yet molecular biologists attempt to turn their small laboratories into factories that produce relatively large quantities of materials, which allow them to produce results (Knorr Cetina 1999).

(Sismondo 2011: p.117)

Social Construction(s) of Science

Latour's (1984) argument is that Louis Pasteur did not simply *discover* germ theory; he *enrolled* a vast network of allies (hygienists, farmers, the military, the state, journalists) who all had reasons to adopt and spread Pasteur's framework.

The microbe became "real" not because it was found in nature, but because Pasteur successfully **translated the interests** of enough powerful actors that resistance became socially and practically impossible.

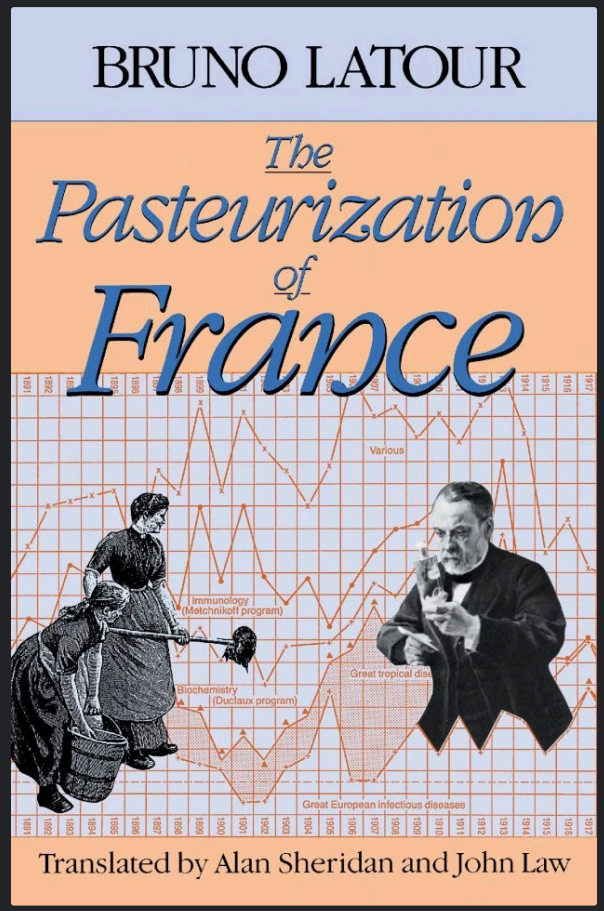
Science is thus alliance-building as much as it is experimentation.

Actor Network Theory (ANT): the interplay between scientists, policy-makers, laboratory equipment, established knowledge, money, and institutions create **technoscience.**

Once a network of alliance becomes stabilized, facts become treated as **black boxes**, ignoring their inner complexity or history.

Thus we go from messy constellations to completed projects and established facts.

Alternative outcomes were *possible*: controversies could have closed differently.



Public Participation in Science

For most of the 20th century, science and society were treated as **separate domains**: experts produce knowledge, the public receives and trusts it. The implicit model was one of *deficit* - the public lacks knowledge, and the solution is better communication and education.

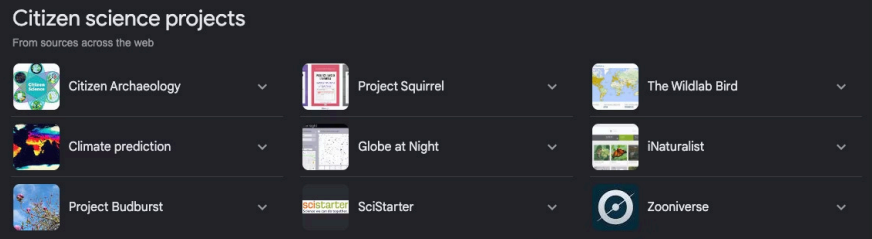
With democratization processes, we are moving towards the "Science IN Society" framework, acknowledging that science and social order are **co-produced** and **co-constructed**.

Three pillars of public participation in science: (applies to the future studies as well)

- **Epistemic:** non-expert publics hold *local, experiential knowledge* that scientists may lack - patients know their symptoms, farmers know their land, communities know their environment
- **Democratic:** decisions shaped by scientific knowledge have political consequences; those affected have a legitimate stake in how knowledge is produced and used
- **Practical:** research involving public input tends to be more relevant and more trusted

Table 1. Paradigms, problems and proposals

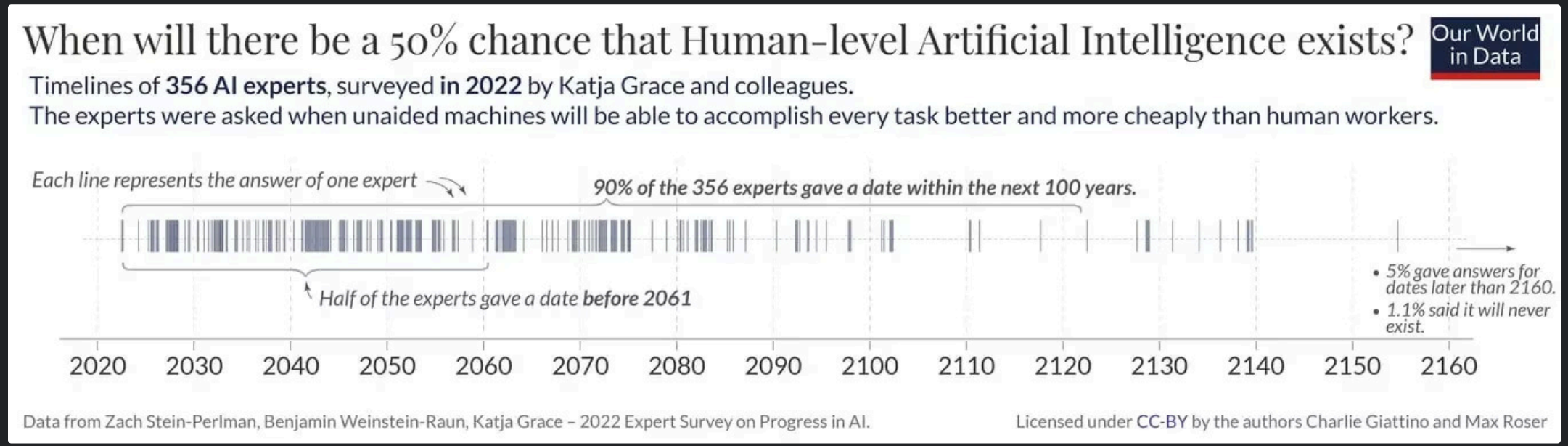
Period	Attribution Problems	Proposals Research
Science Literacy 1960s onwards	Public deficit Knowledge	Literacy measures Education
Public Understanding After 1985	Public deficit Attitudes Education	Knowledge–attitude Attitude change Image marketing
Science and Society 1990s–present	Trust deficit Expert deficit Notions of public Crisis of confidence	Participation Deliberation "Angels" mediators Impact evaluation



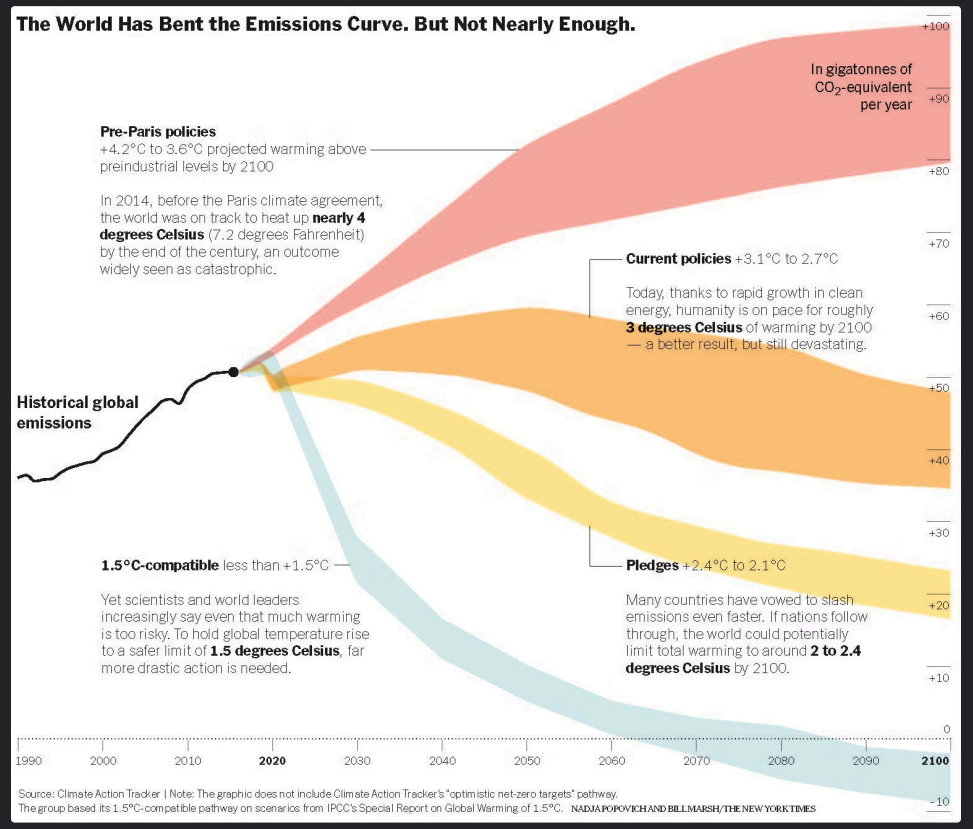
Overview of Part I. Critical Studies of Science

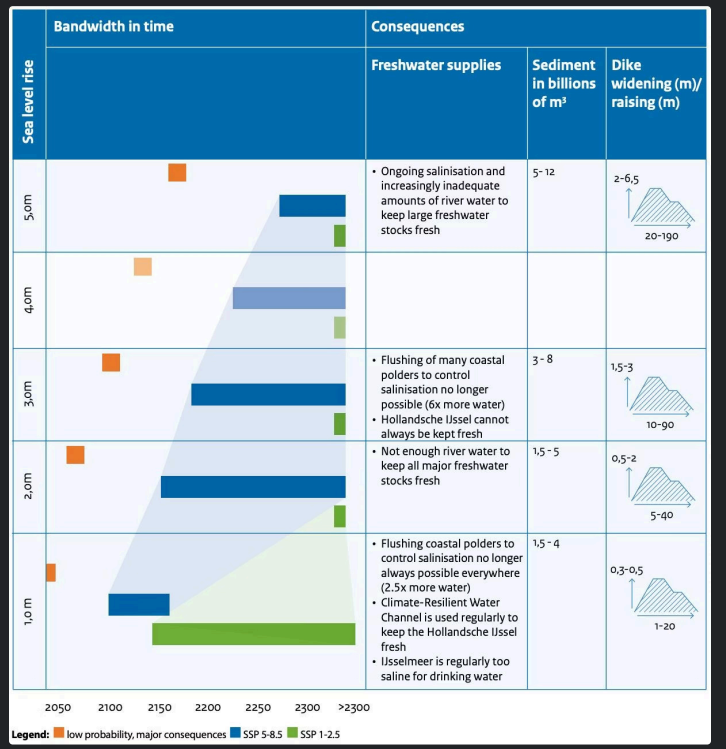
Part 2. Decision Making Under Deep Uncertainty and Future Scenario Planning

The Future is Uncertain and Unpredictable

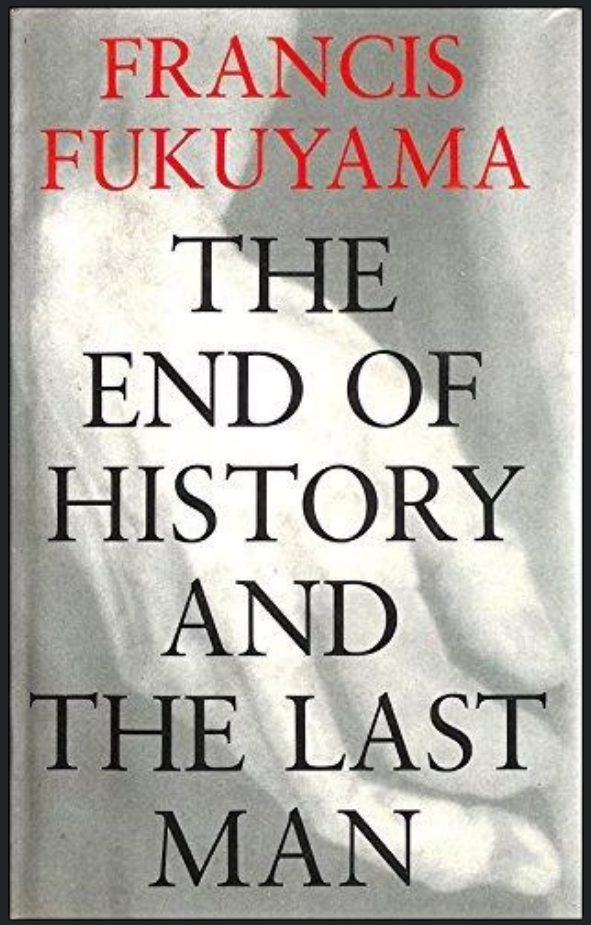


The Future is Uncertain and Unpredictable

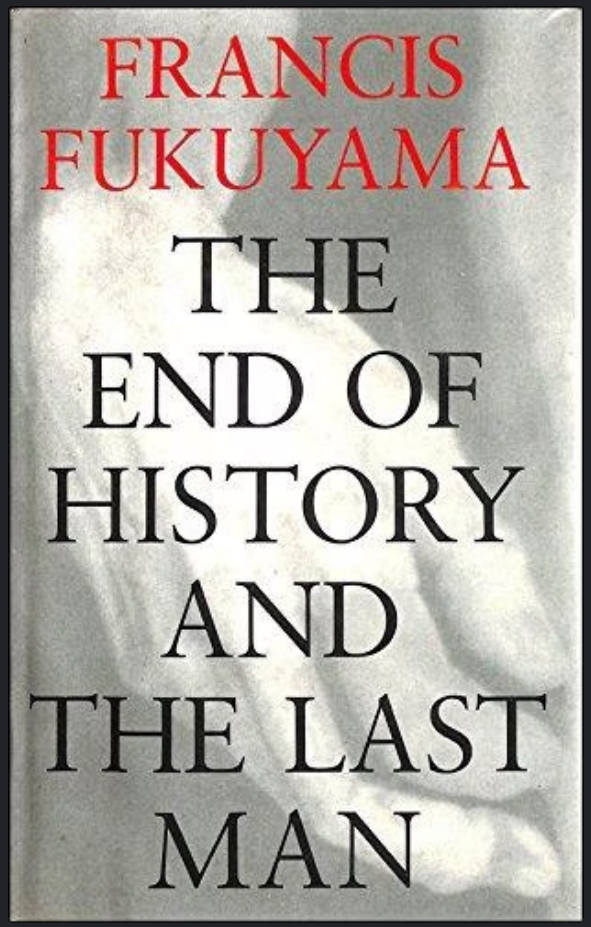




Fukuyama (1992) vs. Year 2026



Fukuyama (1992) vs. Year 2026

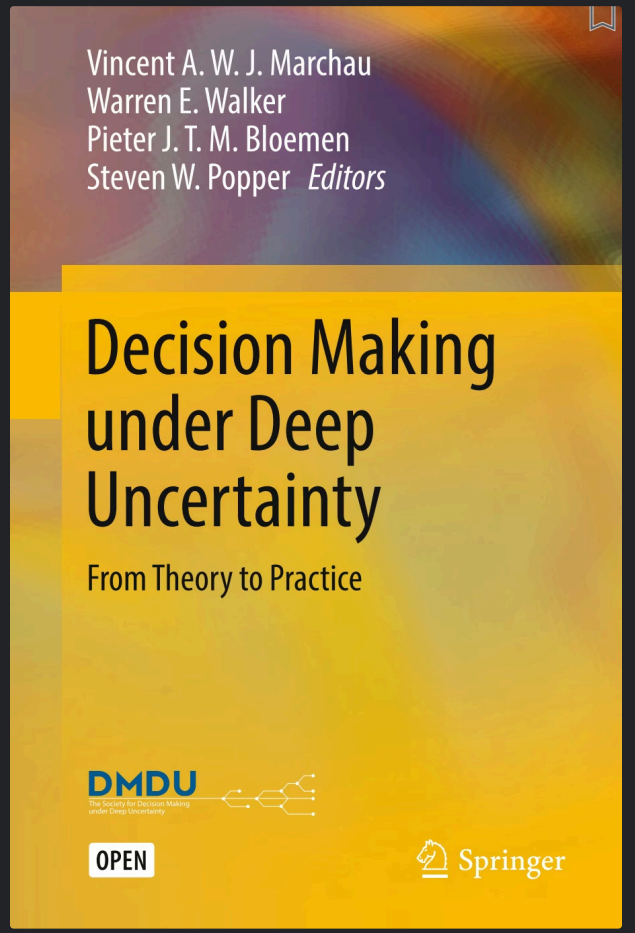


Conceptualizing Uncertainty

> "Decisionmakers, and the analysts upon whom they rely, have had good reason to feel decreasing confidence in their ability to anticipate correctly future technological, economic, and social developments, future changes in the system they are trying to improve, or the multiplicity and time-varying preferences of stakeholders regarding the system's outcomes." (Marchau et al. p.2)

> "Hence, for long-term decisionmaking, **deep uncertainties are in most cases a given**." (Marchau et al. p.4)

Future uncertainty can be treated as a **spectrum** with at least **four levels** identified.



Levels of Uncertainty. Uncertainty Level 1

Level 1 uncertainty represents situations in which one admits that one is not absolutely certain, but one **does not see the need for**, or is not able, to measure the degree of uncertainty in any explicit way.

Usually short-term decisions.

The system of interest is well-defined and it's reasonable to assume that **historical data** can be used as predictors of the future.

Example: ???

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The system of interest is well-defined and it's reasonable to assume that **historical data** can be used as predictors of the future.

Example: mail delivery, garbage collection

Uncertainty Level 2

At **Level 2**, it is assumed that the system model or its inputs can be **described probabilistically**, or that there are a **few alternative futures** that can be predicted well enough (and to which probabilities can be assigned).

Parameters of the system are described **probabilistically**.

The **inferential model** can be used to estimate the probability distributions of the outcomes of interest for these futures.

A preferred policy can be chosen based on the outcomes and the associated probabilities of the futures (i.e., based on “expected outcomes” and levels of acceptable risk).

Example: ???

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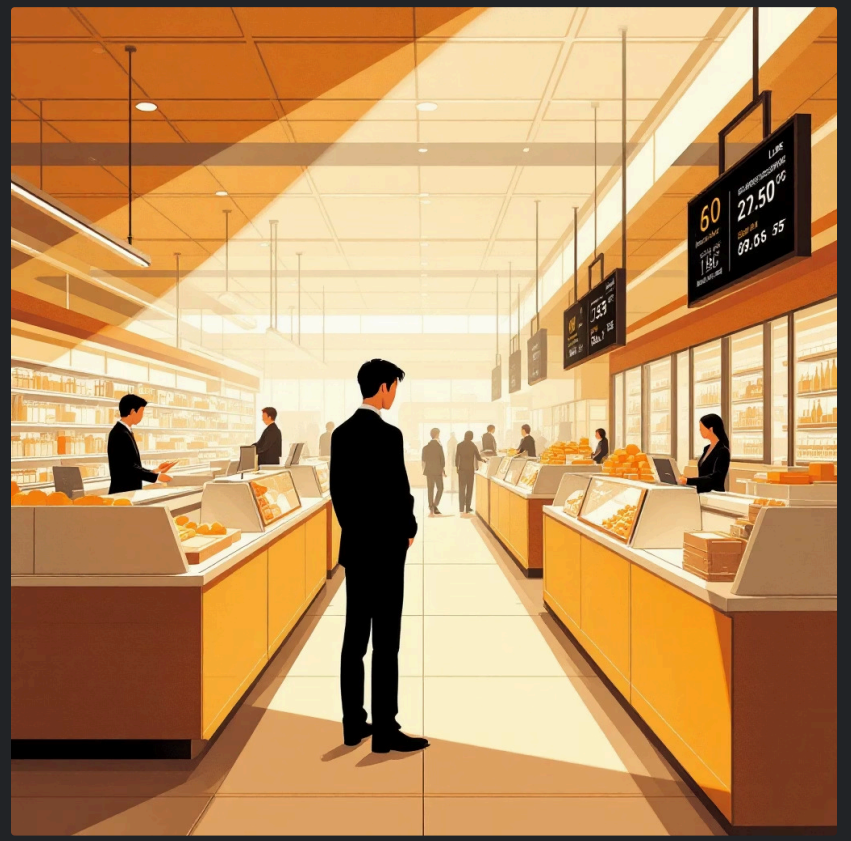
Example: Deciding on which line to join in a supermarket



Uncertainty Level 3

Level 3 uncertainties involve situations in which there are a **limited set of plausible futures**, system models, outcomes, or weights, and **probabilities cannot be assigned** to them — so the tools of neither Level 1 nor Level 2 are appropriate.

Core premise: the future can be predicted well enough to identify policies that will produce favorable outcomes in a few specific, plausible future worlds. (future worlds = future scenarios).

The “best” policy is the one that produces the most favorable outcomes across the scenarios (**robust policy**).

A scenario does not predict what will happen in the future; rather it is a **plausible description** of what can happen.

Example: ???

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A scenario does not predict what will happen in the future; rather it is a **plausible description** of what can happen.

Example: Leaving an umbrella in the trunk of your car in case of rain.

Uncertainty Level 4 (Deep Uncertainty)

Level 4a.:

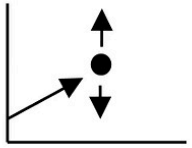
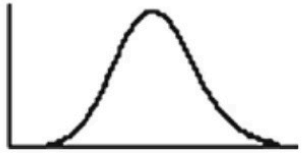
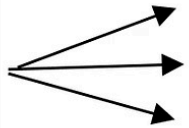
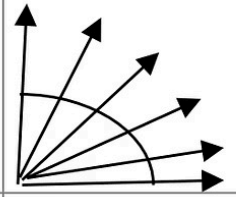
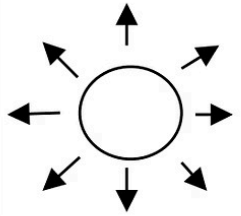
- we are still able (or assume) to bound the future around many plausible futures
- due to a lack of knowledge or data about the mechanism or functional relationships that are being studied
- analysts **struggle** to specify the appropriate models to
  - describe interactions among the system's variables
  - select the probability distributions to represent uncertainty about key parameters in the models
  - and/or value the desirability of alternative outcomes.

Level 4b.:

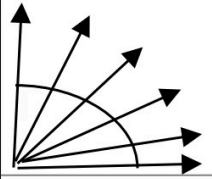
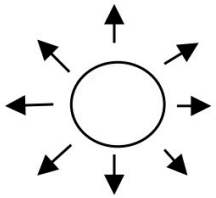
- the situations in which we only know that we do not know
- uncalculable potential for unpredictable, surprising events ("black swans")
- analysts **unable** to specify the appropriate models to
  - describe interactions among the system's variables
  - select the probability distributions to represent uncertainty about key parameters in the models
  - and/or value the desirability of alternative outcomes.

Levels of Uncertainty

Table 1.1 Progressive transition of levels of uncertainty

	Complete determinism	Level 1	Level 2	Level 3	Level 4 (deep uncertainty)		Total ignorance
					Level 4a	Level 4b	
Context (X)		A clear enough future 	Alternate futures (with probabilities) 	A few plausible futures 	Many plausible futures 	Unknown future 	
System model (R)		A single (deterministic) system model	A single (stochastic) system model	A few alternative system models	Many alternative system models	Unknown system model; know we don't know	
System outcomes (O)		A point estimate for each outcome	A confidence interval for each outcome	A limited range of outcomes	A wide range of outcomes	Unknown outcomes; know we don't know	
Weights (W)		A single set of weights	Several sets of weights, with a probability attached to each set	A limited range weights	A wide range of weights	Unknown weights; know we don't know	

Future Scenario Planning

Level 4 (deep uncertainty)	
Level 4a	Level 4b
Many plausible futures 	Unknown future 
Many alternative system models	Unknown system model; know we don't know
A wide range of outcomes	Unknown outcomes; know we don't know
A wide range of weights	Unknown weights; know we don't know

> "Most of the traditional applied scientific work in the engineering, social, and natural sciences assumes that uncertainties result either from a lack of information (i.e., assumes that uncertainties associated with a problem are of Level 1 or 2), which leads to an emphasis on uncertainty reduction through ever-increasing information seeking and processing, or from random variation, which concentrates efforts on stochastic processes and statistical analysis." (Marchau et al. p.6)

Wicked problems: Four criteria for the complex decision making (Chermack 2004 p.297)

1. There are a series of decisions rather than a single decision.
2. The decisions are interdependent—current decisions constrain future decisions.
3. The environment changes autonomously and as a result of decisions made.
4. It is insufficient for the correct decisions to be made in the correct order—they must also be made at a precise moment in real time.

Scenario planning for wicked problems usually takes place at the level of deep uncertainty (levels 4a/4b), where standard statistical prediction models become powerless.

Towards the Definition of Future Scenario Planning

Many definitions for future scenario planning exist.

Neutral: "**A tool for ordering one's perceptions about alternative future environments in which one's decisions might be played out**". (Chermack 2004 p.302)

Poetic: "**A set of organized ways for us to dream about our own future**". (ibid.)

Technical: ''**A process of positing several informed, plausible and imagined alternative future environments in which decisions about the future may be played out, for the purpose of changing current thinking, improving decision making, enhancing human and organization learning and improving performance**''. (ibid.)

Typology of Future Scenarios (Borjeson et al. 2006)

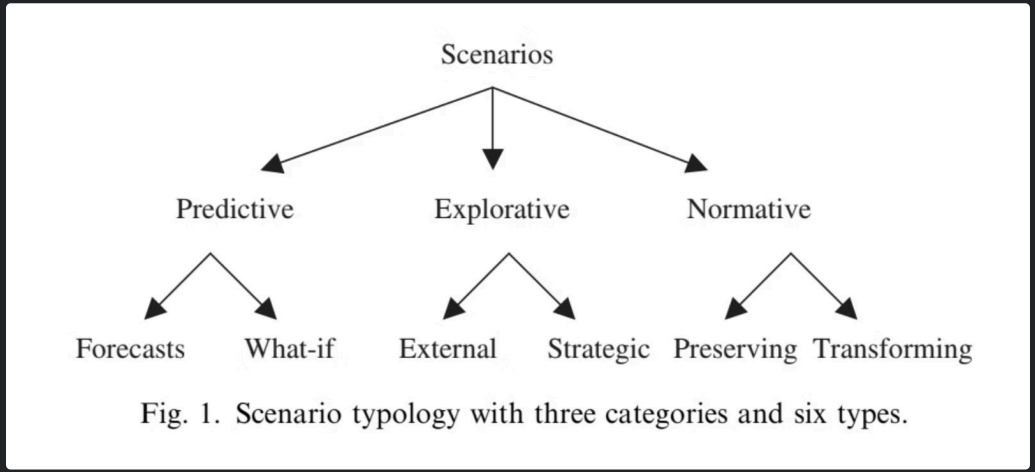


Fig. 1. Scenario typology with three categories and six types.

1 Predictive

"What will happen?"

2 Explorative

"What can happen?"

3 Normative

"How can a certain target be reached?"

Typology of Future Scenarios (Borjeson et al. 2006)

Table 2
Summary of key aspects of scenario types

Scenario category/type	Quantitative/qualitative	Time-frame	System structure	Focus on internal or external factors
PREDICTIVE—what will happen?				
Forecasts	Typically quantitative, sometimes qualitative	Often short	Typically one	Typically external
What-if	Typically quantitative, sometimes qualitative	Often short	One to several	External and, possibly, internal
EXPLORATIVE—what can happen?				
External	Typically qualitative, quantitatively possible	Often long	Often several	External
Strategic	Qualitative and quantitative	Often long	Often several	Internal under influence of the external
NORMATIVE—how can a certain target be reached?				
Preserving	Typically quantitative	Often long	One	Both external and internal
Transforming	Typically qualitative with quantitative elements	Often very long	Changing, can be several	Not applicable

External scenarios respond to the question: *"What can happen to the development of external factors?"*

Strategic scenarios respond to the question: *'What can happen if we act in a certain way?"*

External factors: the forces that are **outside the scope of influence** of the actor (economic events, natural phenomena, etc.).

Internal factors: elements that are controllable by the actor. For example, in strategic scenario modelling, a scenario can "wind-tunnel" some (internal) policy options to see how outcomes vary depending on the (external) environment.

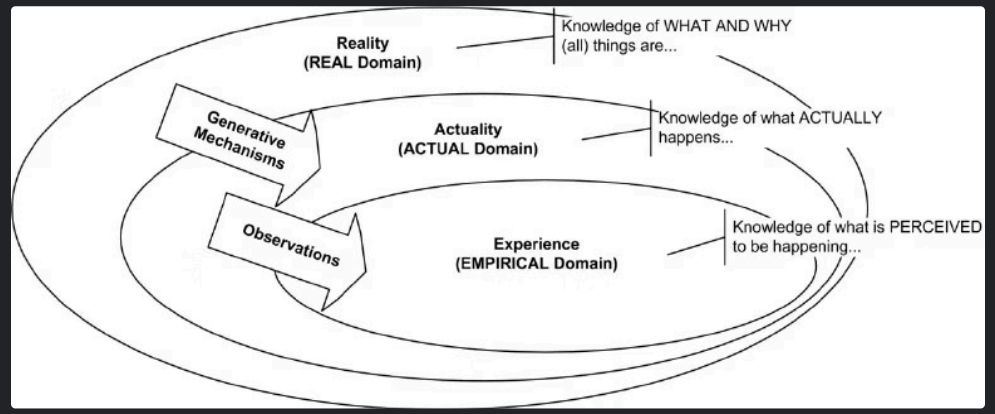
Hold on: But How Really Future Studies are Possible as a Scientific Discipline?

Short answer: it is possible from the perspective of **Critical Realism**.

CR stands somewhere in between **positivism** and **social constructionism**, and tries to bridge both.

> "Thus, unlike postpositivist views, a critical realist view assumes both that **there is a reality that exists** and that we can test many of our ideas about it to see whether they are most likely true or false. Unlike positivist views, though, it emphasizes the **conjectural aspects of knowledge**, the many **threats to validity**, and the **limitations** to knowing with certitude." (Bell 2009: 208)

For the origins and overview of Future Studies as a discipline read Bell, 1996.



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Hold on: But How Really Future Studies are Possible as a Scientific Discipline?

> “<…> critical realists give up the **commitment to certainty**. They accept the **skeptical belief** that we cannot have certain knowledge, if we define knowledge as justified true belief. But they are unwilling to say, therefore, that we must give up trying to know and understand. They redefine knowledge as "**conjectural knowledge**," allowing for the possibility of the fallibility of their conjectures.” (Bell 2009: 210)

Justifying propositions vs. justifying beliefs.

> **“From this perspective there is little philosophical difference in justifying beliefs in assertions about past and present realities on the one hand and beliefs in assertions about the future on the other.” (Bell 2009: 221).**

> This leads to an important distinction between **justifying a proposition** (P) and **justifying a person's belief in it**. They are distinct judgments, because a person may be justified in his or her belief in P without having justified the proposition (P) itself, either conclusively or inconclusively. Critical realists believe that if P withstands serious criticism they are justified in believing P even though P itself is not justified in the traditional sense.

> When critical realists say that the evidence "supports" a proposition, then, they do not mean "proves" or even "makes more probable." They mean that it "**fails to refute**" (Musgrave 1993: 290). (cited by: (Bell 2009: 210-211)).

Exploratory Scenario Planning (XSP) - *What Can Happen?*

Exploratory scenario planning (XSP) is a form of scenario planning that uses multiple **plausible scenarios** to develop broader strategy, action, and policy coordination to achieve goals despite uncertainties in the planning environment.

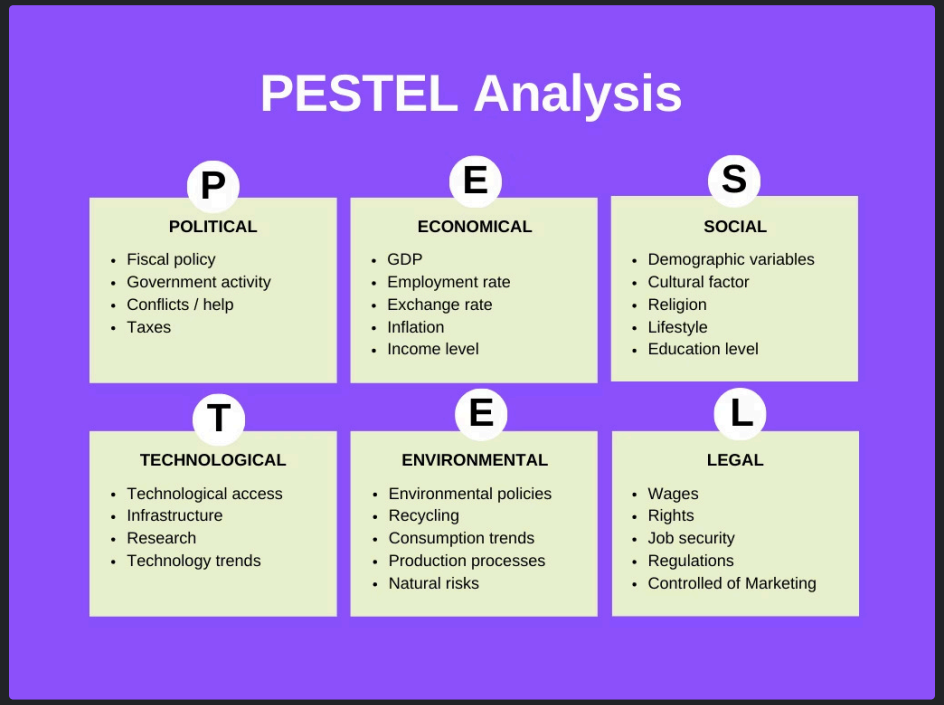
Unlike **traditional planning**, which often relies on a single vision of the future, XSP identifies a range of possible futures — desirable and otherwise — and assesses how to best prepare for them.

Central output: the modelling of the "future worlds" and the creation of the adaptive management plan.

Assumes strong engagement with all the involved stakeholders.

Involves the exploration of the **root drivers of change** to develop robust strategies (effective across all scenarios) and contingent strategies (for specific outcomes).

Exploring root drivers of change: PESTEL or other frameworks.



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Exploratory vs. Normative Scenario Planning

Feature	Normative Scenario Planning	Exploratory Scenario Planning (XSP)
Primary Goal		
Core Assumption	The future can be shaped or reached if a community follows a specific vision and action plan ("predict-and-plan")	The future is fundamentally uncertain and influenced by forces beyond our control, such as climate change or economic volatility
Number of Visions		
Key Question	"What kind of future do we want to achieve?"	"What are the implications of different futures, and how can we best prepare for them?"
Strategic Outcome		
Response to Change	Plans can quickly become irrelevant if social, environmental, or market conditions shift unexpectedly	Crafts an adaptive management plan that allows for real-time responses as the future unfolds
Relationship to Trends		

Exploratory vs. Normative Scenario Planning

Feature	Normative Scenario Planning	Exploratory Scenario Planning (XSP)
Primary Goal	To determine a desired future and establish a specific action plan to achieve that end state	
Core Assumption	The future can be shaped or reached if a community follows a specific vision and action plan ("predict-and-plan")	The future is fundamentally uncertain and influenced by forces beyond our control, such as climate change or economic volatility
Number of Visions	Typically relies on a single shared vision or a desired end state	
Key Question	"What kind of future do we want to achieve?"	"What are the implications of different futures, and how can we best prepare for them?"
Strategic Outcome	A fixed action plan designed to reach a specific destination	
Response to Change	Plans can quickly become irrelevant if social, environmental, or market conditions shift unexpectedly	Crafts an adaptive management plan that allows for real-time responses as the future unfolds
Relationship to Trends	Often assumes past trends are reliable predictors for the future	

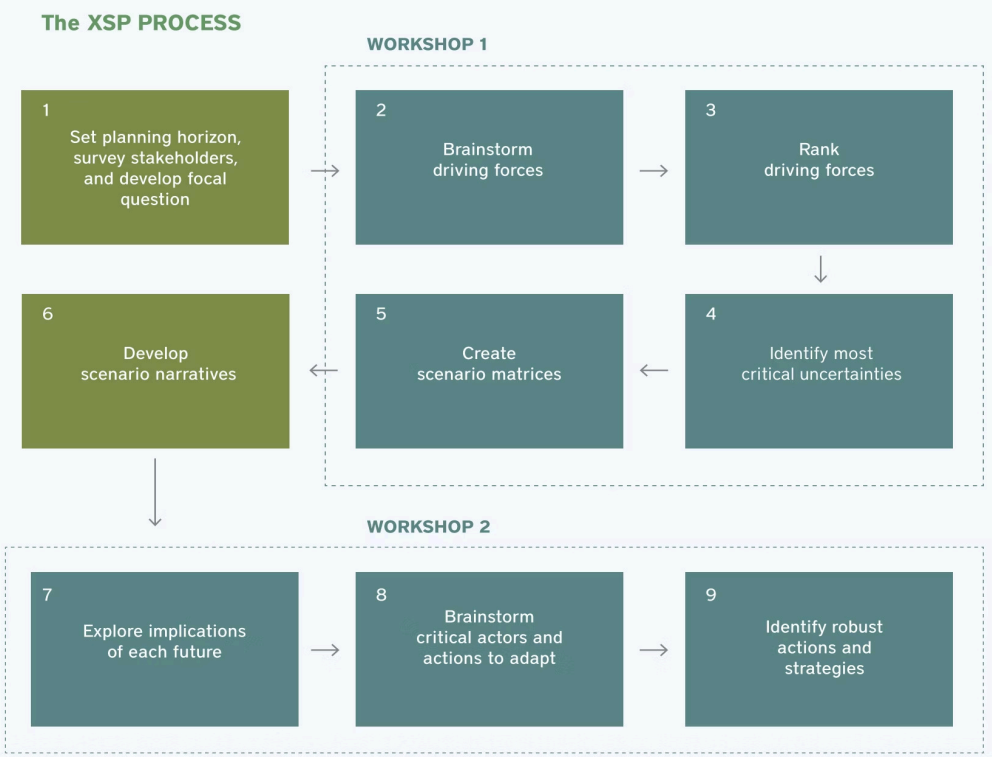
Exploratory vs. Normative Scenario Planning

Feature	Normative Scenario Planning	Exploratory Scenario Planning (XSP)
Primary Goal	To determine a desired future and establish a specific action plan to achieve that end state	To prepare for a range of plausible futures (desirable or otherwise) and build collaborative capacity for what might occur
Core Assumption	The future can be shaped or reached if a community follows a specific vision and action plan ("predict-and-plan")	The future is fundamentally uncertain and influenced by forces beyond our control, such as climate change or economic volatility
Number of Visions	Typically relies on a single shared vision or a desired end state	Develops multiple (usually four) distinct, divergent, and challenging scenario narratives
Key Question	"What kind of future do we want to achieve?"	"What are the implications of different futures, and how can we best prepare for them?"
Strategic Outcome	A fixed action plan designed to reach a specific destination	A mix of robust strategies (effective across all futures) and contingent strategies (reserved for specific outcomes)
Response to Change	Plans can quickly become irrelevant if social, environmental, or market conditions shift unexpectedly	Crafts an adaptive management plan that allows for real-time responses as the future unfolds
Relationship to Trends	Often assumes past trends are reliable predictors for the future	Recognizes that trends of the past are no longer reliable predictors of the future

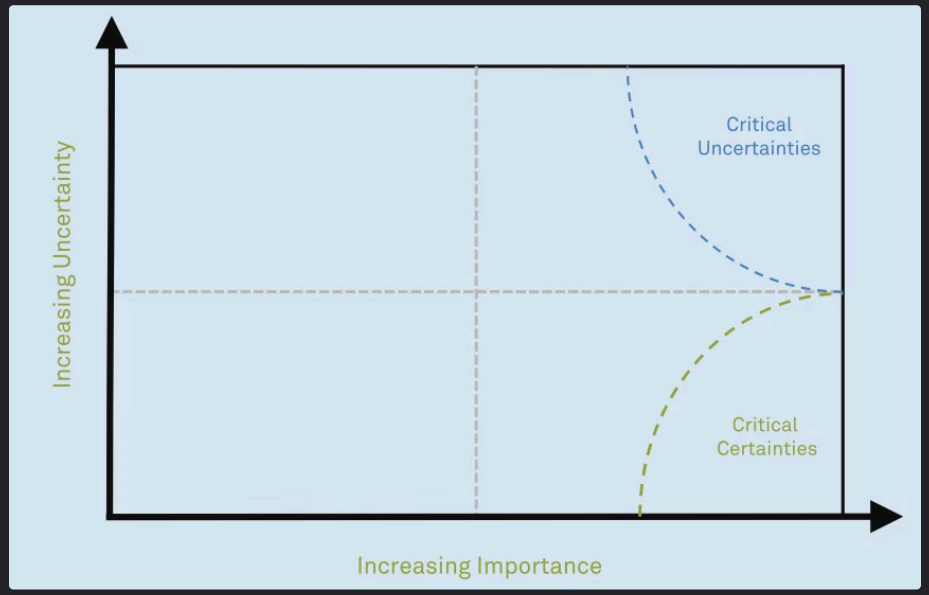
Exploratory Scenario Planning in Action

Figure 1

The Typical XSP Process of Two Workshops, Framed by Careful Preparation and Agenda Setting



Ranking the driving forces:



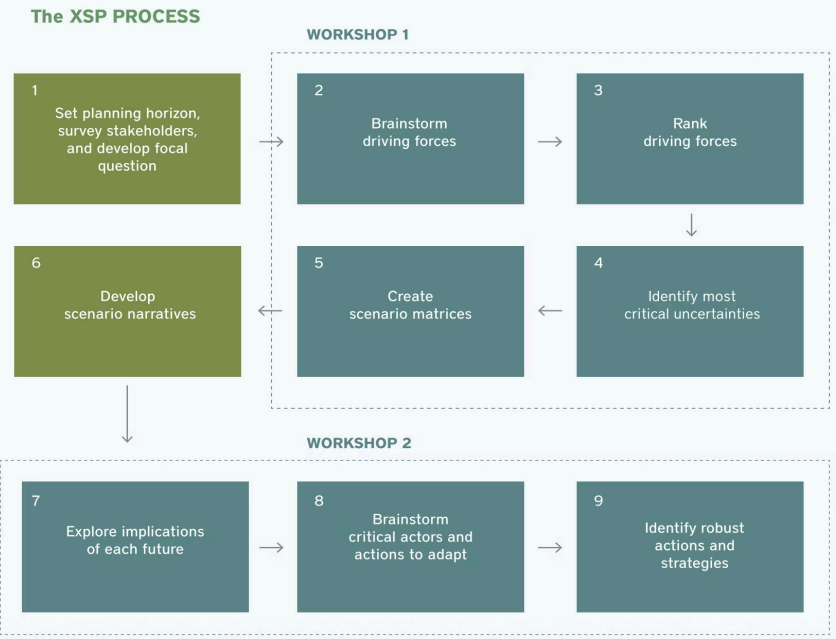
Critical certainties: included in all upcoming scenarios.

Critical uncertainties: used to **differentiate** the futures.

Exploratory Scenario Planning in Action. Part 1

Figure 1

The Typical XSP Process of Two Workshops, Framed by Careful Preparation and Agenda Setting



Explore Implications: Working group members read the narratives and identify specific threats and opportunities **within each future**.

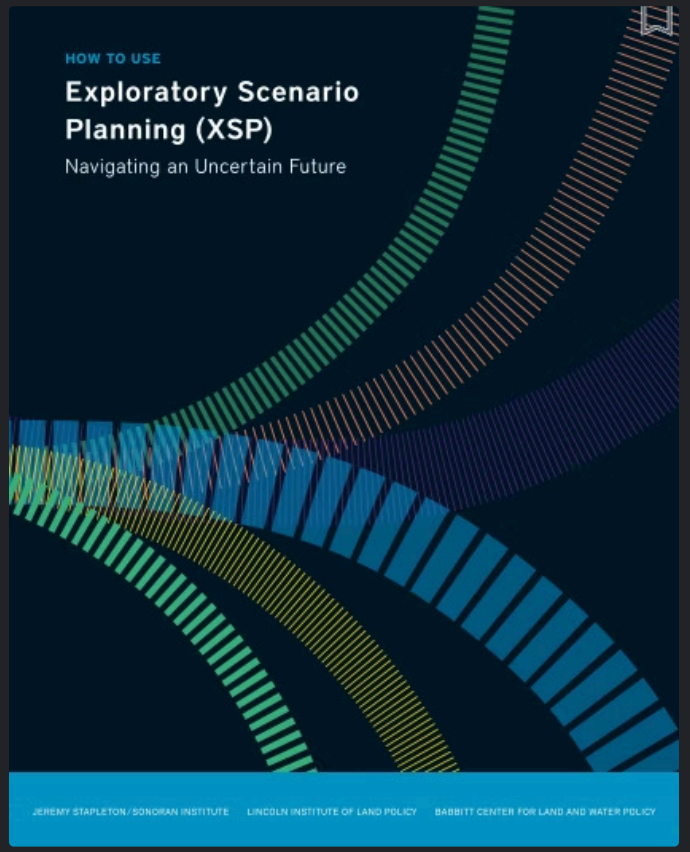
Identify Robust Strategies: These are actions that are effective and appropriate across **all** explored scenarios. Robust strategies avoid undesirable futures while the community begins prompt implementation of no- or low-regret, high-impact solutions.

Develop Contingent Strategies: Actions reserved for specific futures.

Define Tipping Points: Identify **indicators**, specific signals or performance metrics, that tell planners when one future is becoming more likely, signalling the time to pivot or deploy a **contingent strategy**.

Prepare a **final report** summarising the deliberations and conclusions for implementation by the local government or agency.

XSP in Practice: Case Study of Colorado 2040



XSP in Practice: Case Study of Colorado 2040

Context: The goal of the project was to explore how best to steward water resources in Colorado in a time of rapid growth, uncertainty, and a looming water supply gap.

Focal question: How can changes in urban environment and landscaping practices for new growth and redevelopment assist in meeting future urban water demand along the Colorado Front Range?

Stakeholders: local and regional government officials and staff, water providers, land use planners, developers, economic development interests, environmental organizations, and university researchers.

XSP in Practice: Case Study of Colorado 2040

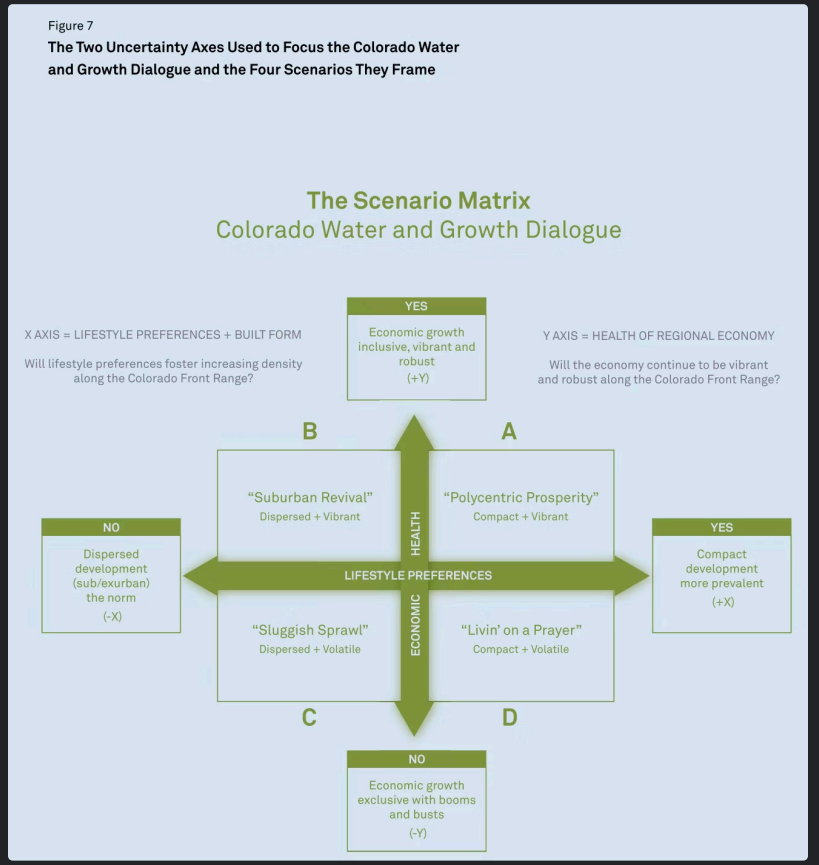
Key drivers for change: Housing affordability, Cost of oil and gas, Access to outdoors and recreation, Transportation network and technology, Economic opportunity, vibrancy, and volatility, Net population growth.

Critical certainties: Net population growth, Impact of distributed employment centers and transit-oriented development, Legacy of taxpayer's bill of rights (TABOR) and its repercussions, Access to the outdoors and recreational tourism remains a core value.

Critical uncertainties: Innovative transportation network technology, Lifestyle preferences, Economic health.

XSP: Four Future Scenarios for Colorado 2040

The XSP process resulted in the identification of over 100 strategies that could mitigate the state's water supply gap - and affirmed that **no one solution or set of actors could save the day**.



The steering committee ultimately designated two critical uncertainties impacting the focal question of water supply: **lifestyle preferences** (x axis) and **economic health** (y axis).

Along these axes, four possible 'future worlds' were identified.

Four Future Scenarios for Colorado 2040

Polycentric Prosperity envisions a future where people strongly prefer living in or near cities, resulting in **more compact development patterns** across the Front Range. This concentrated talent pool supports a **vibrant and robust economy** led by sectors like technology, medicine, and finance, while legal reforms allow for more diverse housing options such as condos. The region becomes **polycentric**, featuring new urban centers where residents can easily walk or bike to work, which in turn fosters the political will to transform regional transportation. While property prices rise due to speculation, the move toward a **"circular economy"** helps the region mitigate waste and inefficiency.

Sluggish Sprawl describes a "drive till you qualify" culture where residents are forced to push the limits of their credit to find housing in a **dispersed, automobile-dependent landscape**. Mass transit usage remains stagnant, freeways remain the dominant mode of travel, and economic growth slows significantly as the region becomes overly dependent on a narrow range of sectors like energy and tourism. Environmental pressures such as **drought and wildfires** disrupt water allocation, causing water to be reallocated from staple crops to higher-value products like meat and marijuana. As other industries move overseas in search of cheaper labor, the region struggles with limited economic mobility and deep economic waves.

Suburban Revival is characterized by a shift toward **less compact development** as Millennials and Gen Xers move to the suburbs to raise children and care for aging parents while working remotely. While suburban areas with transit connections grow quickly, many residents prefer private **"backyard resorts"** over shared open spaces and become increasingly frustrated with regional congestion. A primary challenge in this scenario is **housing affordability**, as high-quality affordable options are scarce outside of older, run-down neighborhoods or remote fringes not served by mass transit. Consequently, residents face **longer and more expensive commutes**, which increases the overall cost of living and reduces disposable income.

Livin' on a Prayer. Front Range that has become **highly urbanized and compact** but also extremely e**xpensive and exclusive**. Because economic volatility prevents the development of new urban cores, growth is restricted to existing centers, leading to **soaring prices, gentrification, and involuntary displacement**. While the region continues to exploit its energy resources, it becomes difficult for many to find living-wage jobs near their homes, creating a class of "super commuters". In this volatile environment, business failure rates are high, and the most desirable urban areas become isolated havens for prosperous retirees and childless families who are better shielded from economic downturns.

Four Future Scenarios for Colorado 2040

Polycentric Prosperity

Suburban Revival

Sluggish Sprawl

Livin' on a Prayer

XSP: Colorado 2040 Call for Action

Common to All Scenarios (2040)
Colorado's population has doubled over the last few decades. Most growth has been on the Front Range, and communities compete for ever-scarcer resources. The supersectors that drive and carry the Front Range economy continue to lure people from within and beyond the United States. Communities that diversified and embraced the sharing economy have fared better through economic cycles. Automation has continued to eliminate jobs, and migration is driven by the pursuit of employment and affordable housing.

Robust Strategies
These strategies were developed by the steering committee. The KPC's final report on the XSP process included a short list of strategies tailored to state legislators' interests, and the Sonoran Institute facilitated the development of a more comprehensive list at the workshop itself on July 28, 2016:

1. Find the sweet spot between density and the point of diminishing returns regarding water demand.
2. Create water-wise land use plans.
3. Measure, monitor, and message market data and success stories.
4. Develop and track new metrics categorized by land use, such as water use per square foot.
5. Develop a suite of stewardship incentives, such as tap-fee credits and small lots.
6. Recommend new design guidelines for government-owned buildings, public spaces, and rights of way.
7. Develop model municipal landscaping codes based on best practices.
8. Adopt a "one-water" approach to water resource management that optimizes efficiency and utility through an integrated, sustainable approach.
9. Develop, track, and compare community water budgets to inform policies, programs, plans, and practices.
10. Scale agricultural efficiency through conservation programs and measures.
11. Increase regional collaboration between Front Range and Western Slope communities and their representatives.
12. Develop a Water in the West Welcome Wagon awareness and engagement campaign for new and existing homeowners, residents, developers, and policy makers.
13. Eliminate barriers to permit and increase water-sharing agreements.
14. Adopt a true-cost water pricing policy.
15. Nurture a water-efficient economy founded on efficient industries.
16. Fund implementation of long-range planning strategies via utility revenues.
17. Include designers such as landscape architects and architects in engineering departments.
18. Partner with trained water stewards, including designers, irrigation system installers, maintenance crews, and watershed management groups (KPC 2017).

XSP: Cross-Impact Balance Analysis (from Tori et all. 2023)

Table 1
Reduced cross-impact matrix of urban mobility transition (Budapest).

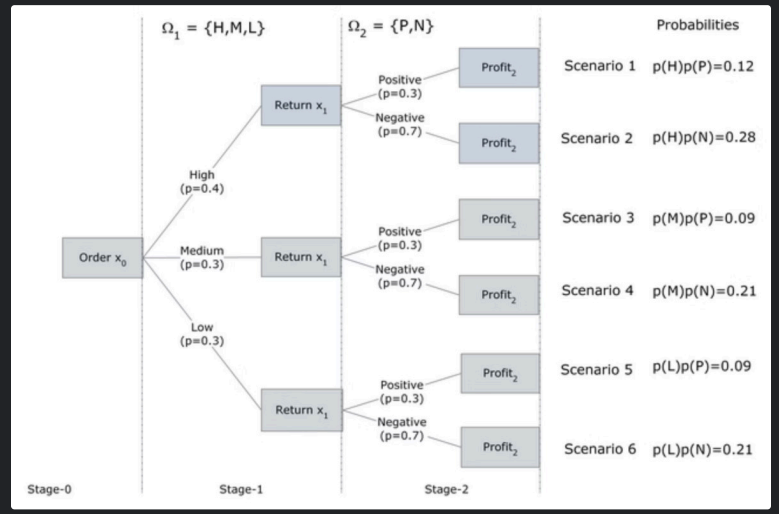
		Ec2		S2		S6		T1		T3		En1		En2	
		Decrease	Increase	Increasing densification	Increasing sprawl	Weak growth	Strong growth	Weak growth	Strong growth	Weak growth	Strong growth	Slight increase	Strong increase	Decrease	Increase
Ec2: Tourism	Decrease			0	0	0	0	0	0	0	0	0	0	-1	1
	Increase			0	0	0	0	0	0	-1	1	0	0	1	-1
S2: Urban structure	Increasing densification	0	0			-1	1	0	0	1	-1	1	-1	-1	1
	Increasing sprawl	0	0			1	-1	0	0	-1	1	-1	1	1	-1
S6: Environmental consciousness (choice of sustainable mode)	Weak growth	0	0	-1	1			0	0	2	-2	-2	2	2	-2
	Strong growth	0	0	1	-1			2	-2	-2	2	2	-2	-2	2
T1: Electrification of mobility	Weak growth	0	0	0	0	1	-1			2	-2	-1	1	-2	2
	Strong growth	0	0	0	0	-1	1			-2	2	1	-1	2	-2
T3: Consumer- and citizen-oriented digitalization	Weak growth	0	0	0	0	1	-1	2	-2			0	0	0	0
	Strong growth	0	0	0	0	-1	1	-2	2			0	0	0	0
En1: Climate change	Slight increase	-1	1	0	0	0	0	0	0	0	0			0	0
	Strong increase	1	-1	0	0	-2	2	-1	1	0	0			0	0
En2: Local environmental quality	Decrease	1	-1	-2	2	-1	1	-2	2	0	0	0	0		
	Increase	-2	2	2	-2	1	-1	0	0	0	0	0	0		
Variant state in hypothesis scenario:		↓	↓	↓		↓		↓			↓		↓	↓	
Impact balances:		-1	1	0	0	-4	4	-3	3	-1	1	0	0	-4	4
Variant state according to CIB:			↑	↑			↑		↑		↑		↑		↑

Can we make the process of future scenario development somehow more structured? Yes!

Cross-impact balance (CIB) analysis is a systematic, **qualitative** method used to build **internally consistent scenarios** by evaluating how different factors in a complex system influence one another.

At the core of the process are experts who estimate the **direct impact** of each variant state on every other state on a one-to-one basis. These impacts are typically rated on a scale (such as -2 to +2), indicating whether the influence is **positive, negative, or non-existent**.

XSP: Scenario Trees



Image

A **scenario tree** is a branching probability structure that maps a set of plausible futures by tracing paths from a shared starting condition through successive uncertain events.

After conducting the analysis of the root drivers of change (e.g. via PESTEL), start from a focal issue and branch at key decision points or uncertainties.

Assign rough probabilities to each branch, and follow paths to distinct plausible future states.

Probabilities here are ***epistemic*** (reflecting expert judgment), not frequentist. Explicit reasoning about likelihood and interdependence of the future states is prioritised over the accuracy of the probabilistic estimations.

Scenario tree approach is especially useful in early-stage planning when you want to identify ***high-probability + high-impact*** scenario clusters worth developing into full narratives.

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