Dirk Helbing (ETH Zurich)
dhelbing@ethz.ch

On Impacts of Disruptions of Transport and Logistic Systems

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The World Is Suffering from a Polycrisis

https://www.weforum.org/agenda/2023/01/polycrisis-global-risks-report-cost-of-living/

Some Examples of Possible Disruptions of Transport Systems (incomplete list)

- Building sites
- Accidents
- Failures of critical infrastructures
- Terror attacks
- Earthquakes
- Extreme weather
- Supply shortages
- Cyberattacks, Internet outages
- Blackouts
- Lockdowns
- Collapse of the petrodollar fiat currency system
- Explosion of energy prices
- Economic meltdowns
- Political or military coups

Some Examples of Possible Impacts and Who Is Concerned (incomplete list)

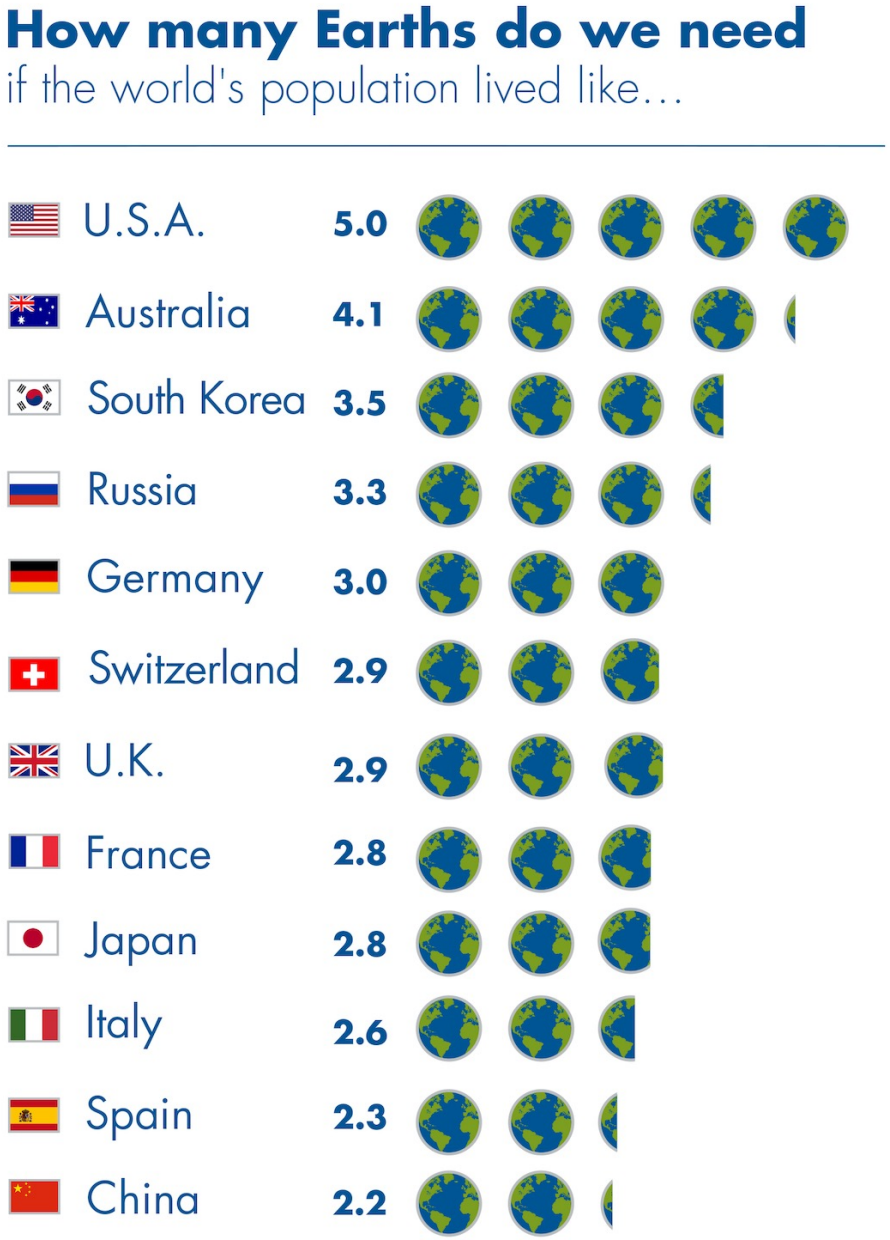
- Depending on the size and location of the discruption(s) and possible cascading effects, the scale of impacts can range from local to global effects, and from single entities to everyone.
- In the very worst case, the functioning of entire socities or civilizations may be at stake. Even though pretty unlikely, according to standard threat analyses, in principle supply chains and public order could break down.
- Overreactions and actionism can make things worse!

Some Examples of Possible Impacts and Who Is Concerned (incomplete list)

- Producers
- Consumers
- Transport and logistic service providers
- Traffic participants
- Public infrastructures and institutions
- Etc.

Are the impacts unevenly distributed over different groups in society and industries?
Yes. Some people and institutions are particularly vulnerable.

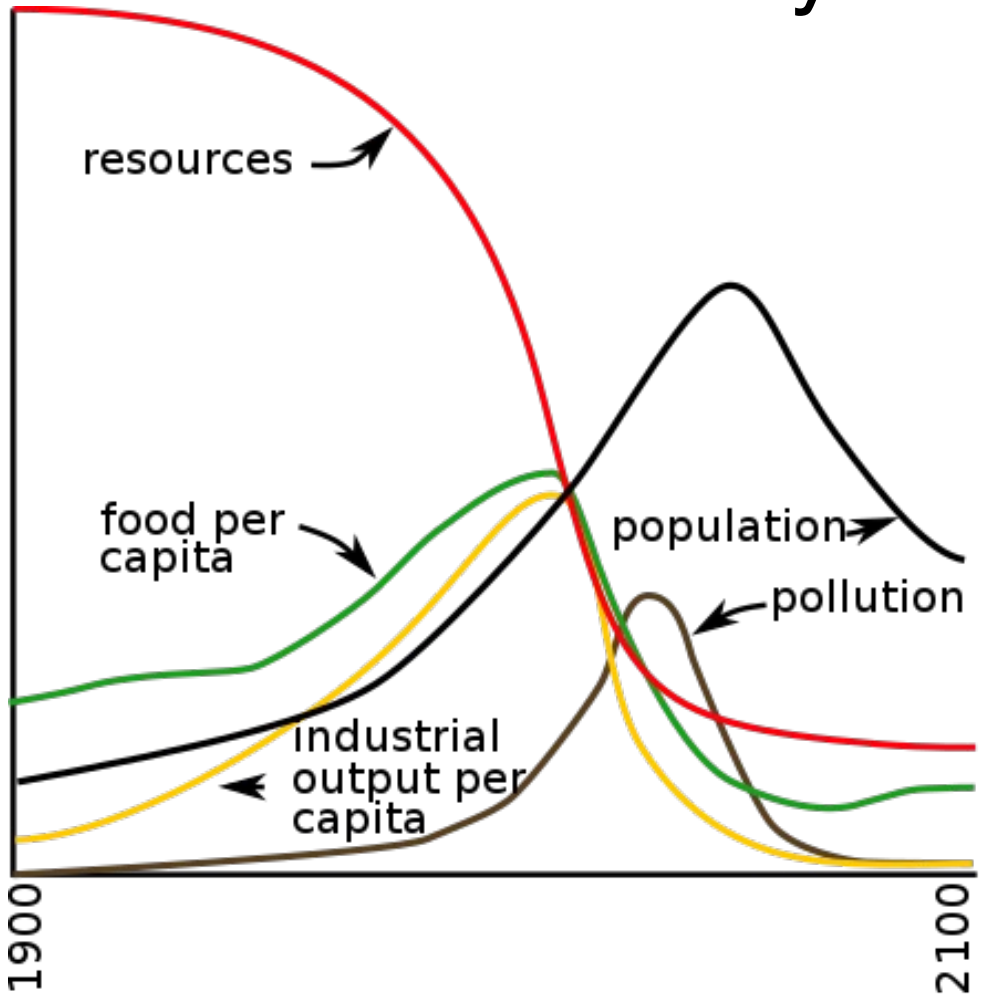
Are certain impacts associated with specific transport modes, geographic areas, or institutional features, ...?
Yes. But this cannot be summarized in 20 minutes.

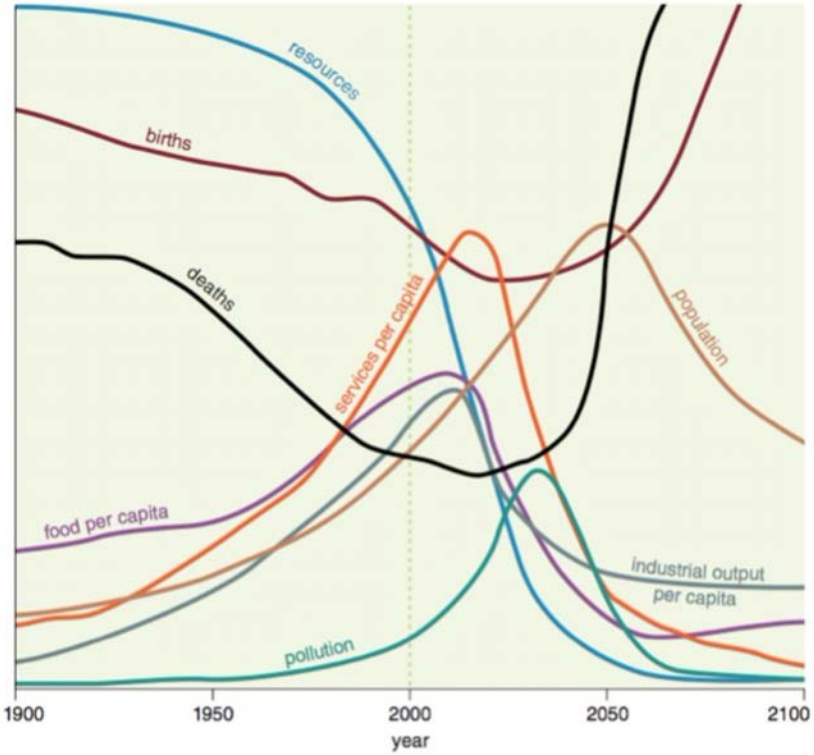


Our main problem is the lack of sustainability

https://commons.wikimedia.org/wiki/File:How_many_earths_2018_English.jpg

The Limits to Growth (1972): We had 50 years to prepare!





https://i0.wp.com/ourfiniteworld.com/wp-content/uploads/2011/11/slide-6-ltg-graph.jpg

https://en.wikipedia.org/wiki/The_Limits_to_Growth

September 25, 2015

https://sdgs.un.org/goals

Big data, meet Big Brother

China invents the digital totalitarian state

https://www.economist.com/briefing/2016/12/17/china-invents-the-digital-totalitarian-state

The worrying implications of its social-credit project

Central Bank Digital Currencies (CBDCs)

"We don't know who's using a $100 bill today... The key difference with the CBDC is the central bank will have absolute control on the rules and regulations that will determine the use of that expression of central bank liability, and also we will have the technology to enforce that."

Agustin Carstens, General Manager, Bank for International Settlements

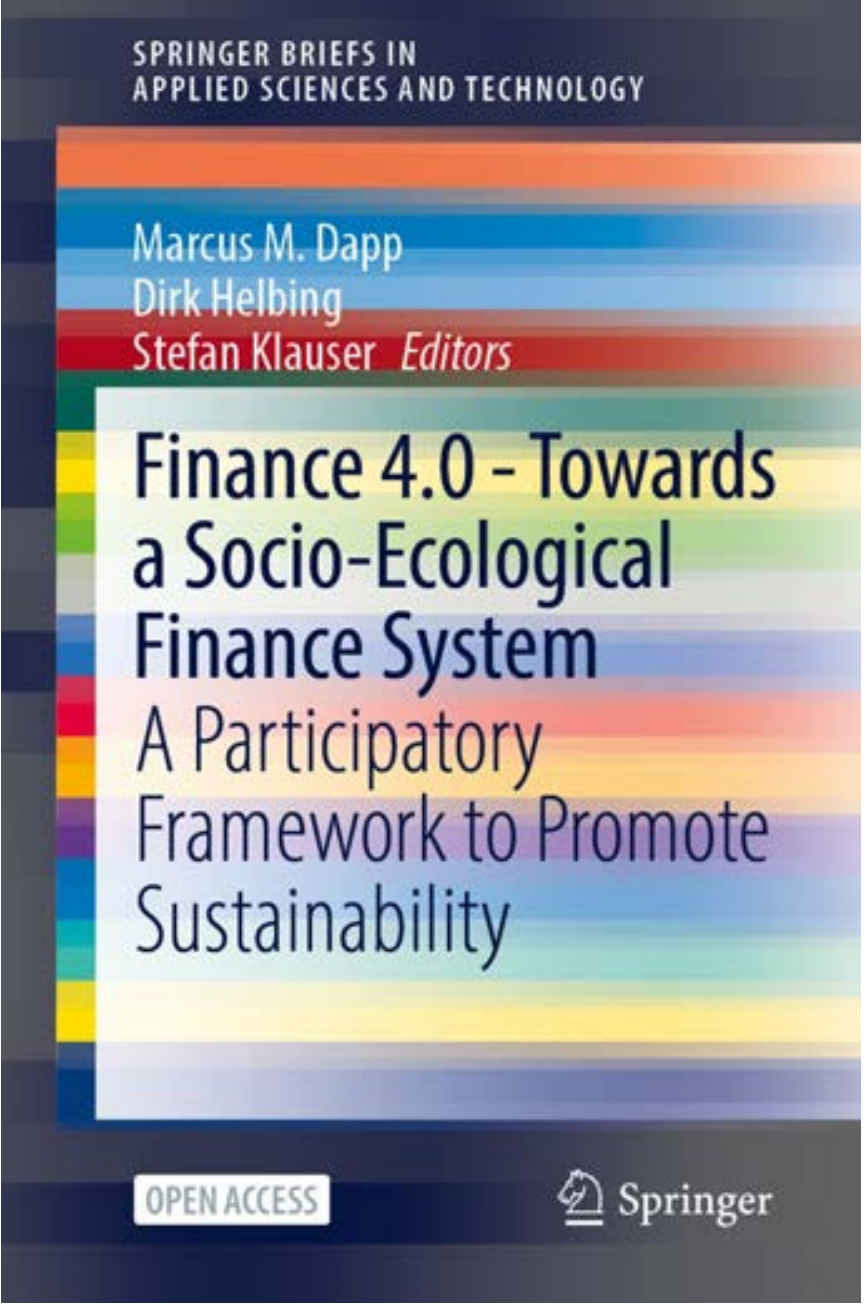
2011

»Geld ist viel zu eindimensional«: Börsenhändler an der New York Stock Exchange

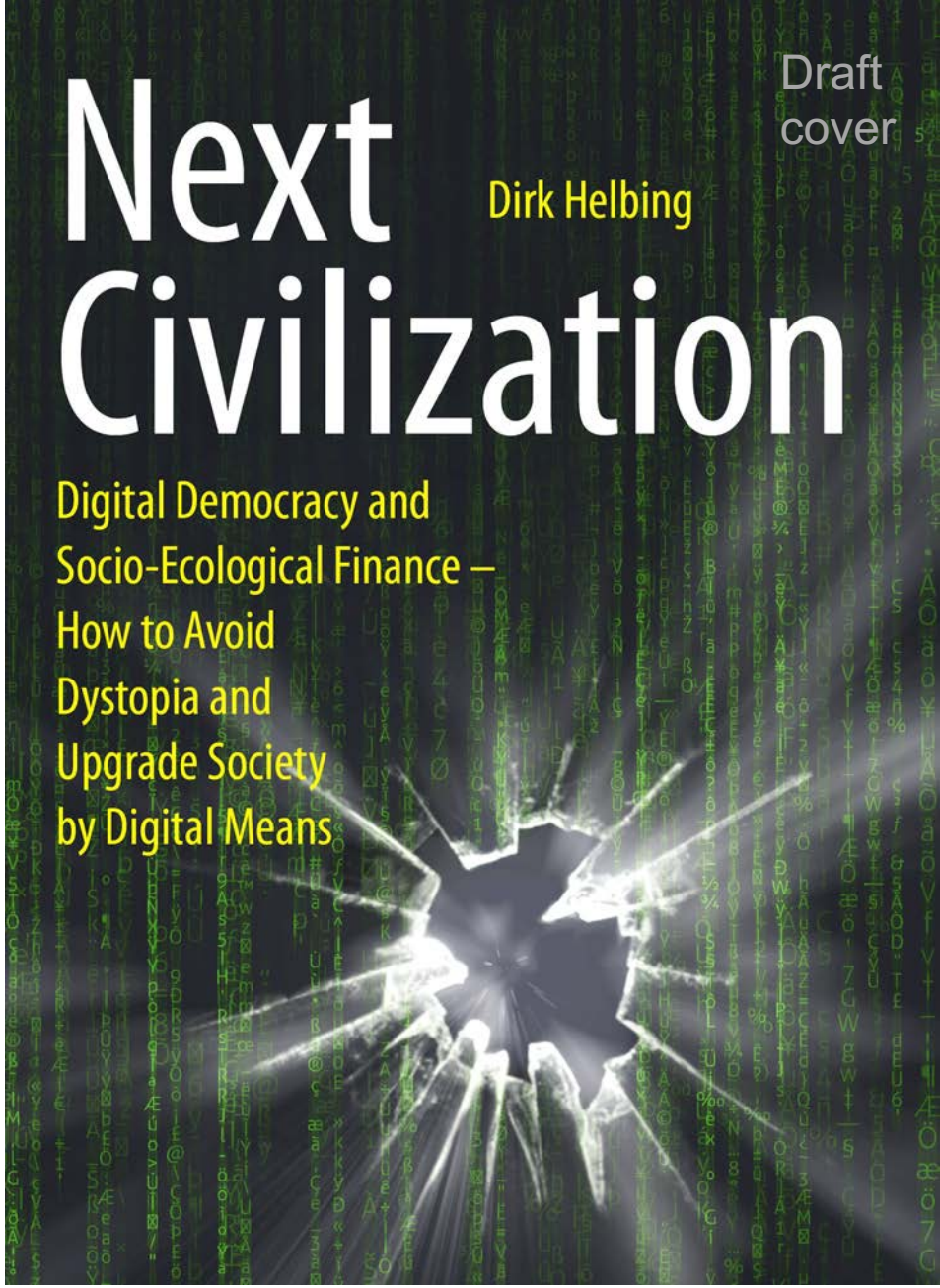
»Es braucht ein neues Finanzsystem«

Zwei ETH-Wissenschaftler erklären, warum die Weltwirtschaft krank ist, Adam Smith unrecht hatte – und wir ganz anders über Geld nachdenken müssen

https://www.zeit.de/2011/33/CH-Oekonophysik



https://link.springer.com/book/10.1007/978-3-030-71400-0



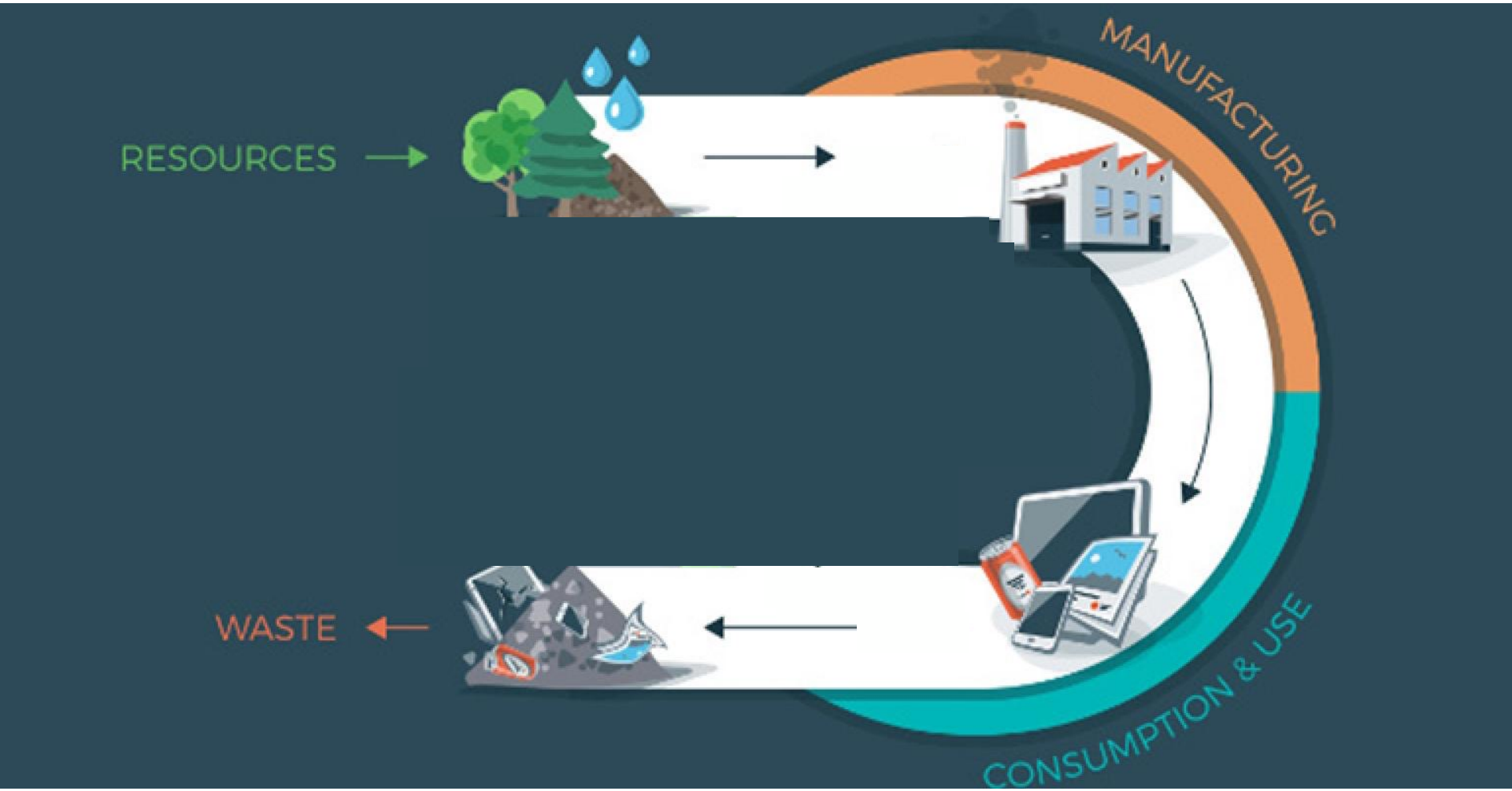
https://link.springer.com/book/10.1007/978-3-030-62330-2

Fixing the World, Yes, But How?

- Digital Enlightenment
- Peace Rooms
- Digital Democracy
- Platform for Informational Self-Determination
- City Olympics/Challenges
- Democratic Capitalism
- Finance 4.0+
- Digitally Assisted Self-Organization

Socio-Ecological Finance FIN4+:
Participatory Sustainability

Turn Wasteful Supply Chains…



Derived from:
https://www.istockphoto.com/de/vektor/kreisförmige-wirtschaft-gm510477626-86262363

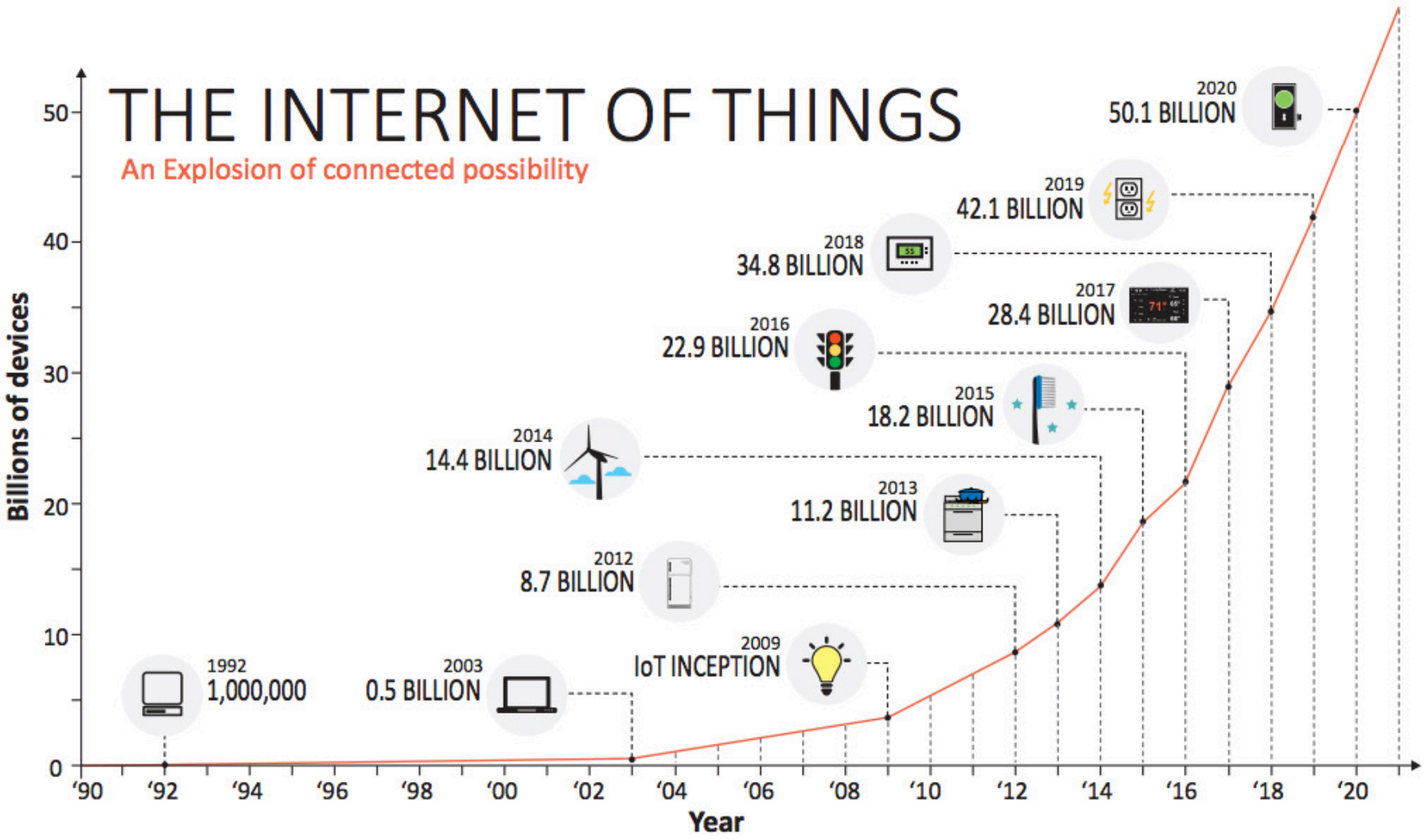
… into a Circular Economy. But How?

https://www.istockphoto.com/de/vektor/kreisförmige-wirtschaft-gm510477626-86262363

Nature has already solved the problem of circularity.

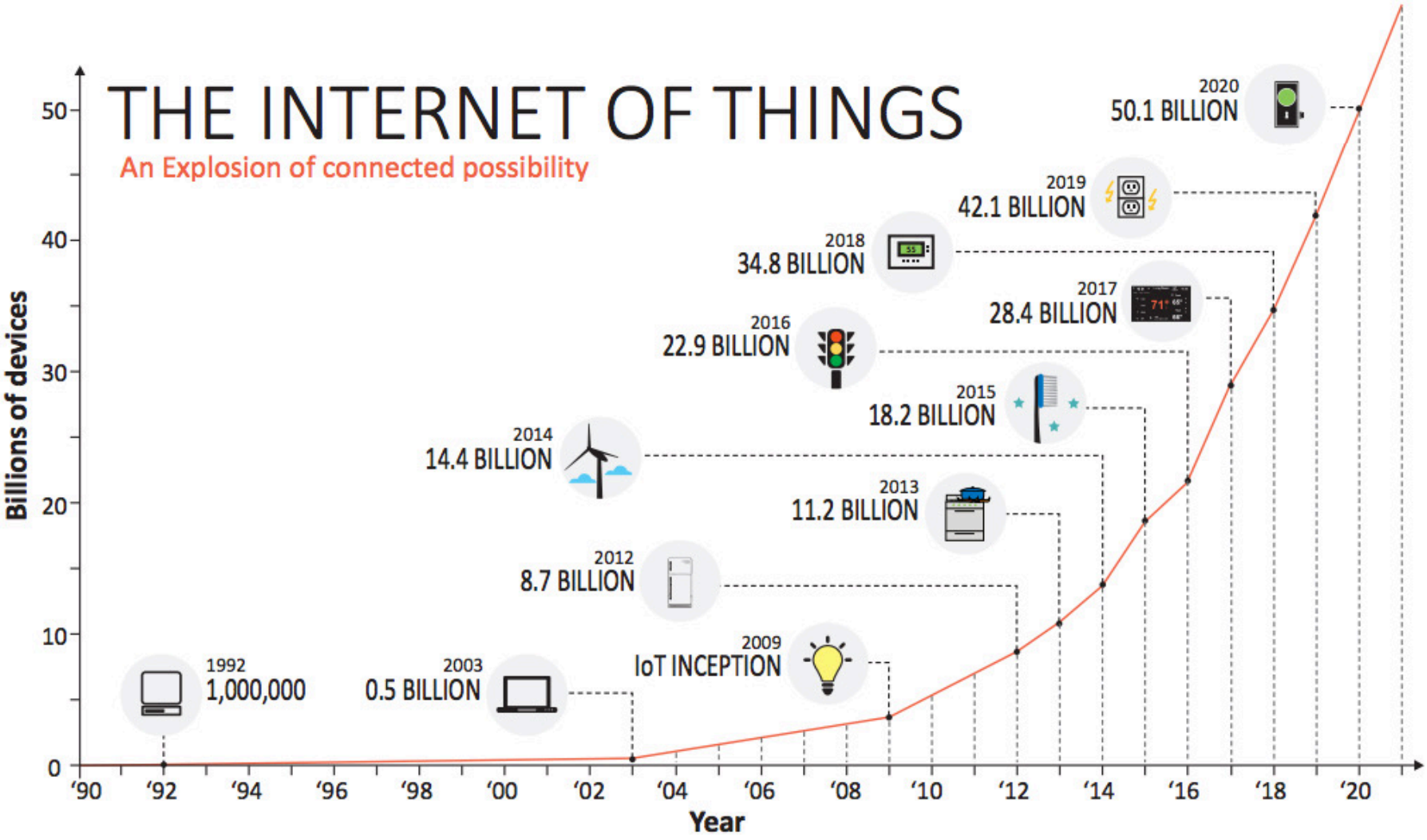
Use nature-inspired solutions!

Use the Internet of Things!



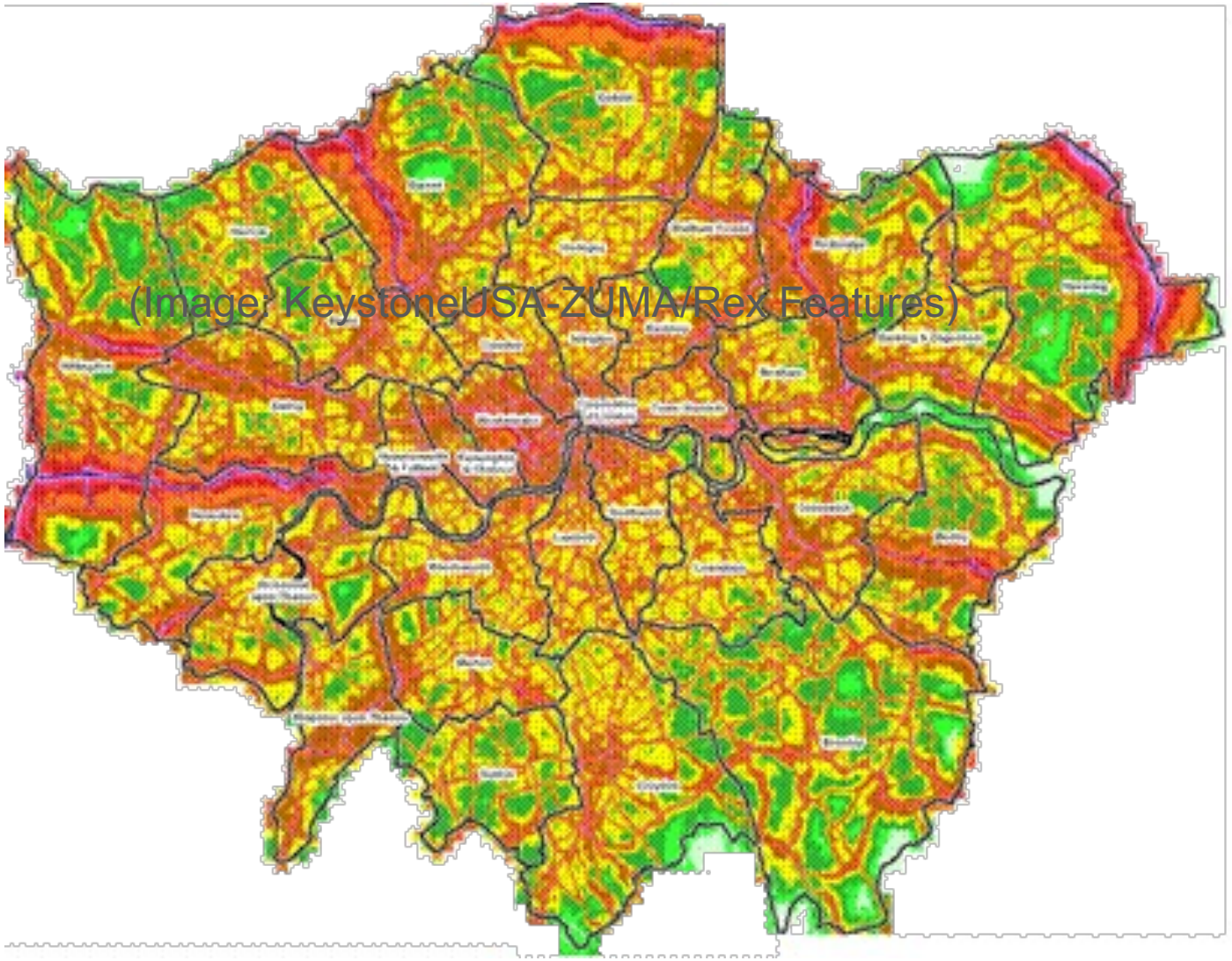
https://smartbear.com/blog/internet-of-things-101/

Use the Internet of Things!
But in a Participatory Way!



https://smartbear.com/blog/internet-of-things-101/

Mapping Noise and Other Externalities



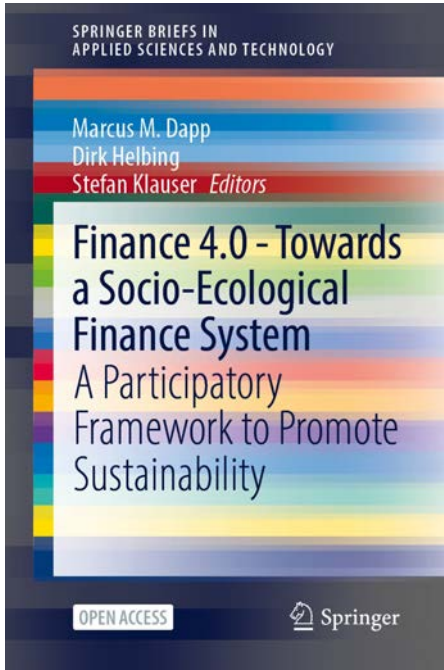
https://www.newscientist.com/gallery/sonic-doom-noise-in-pictures/

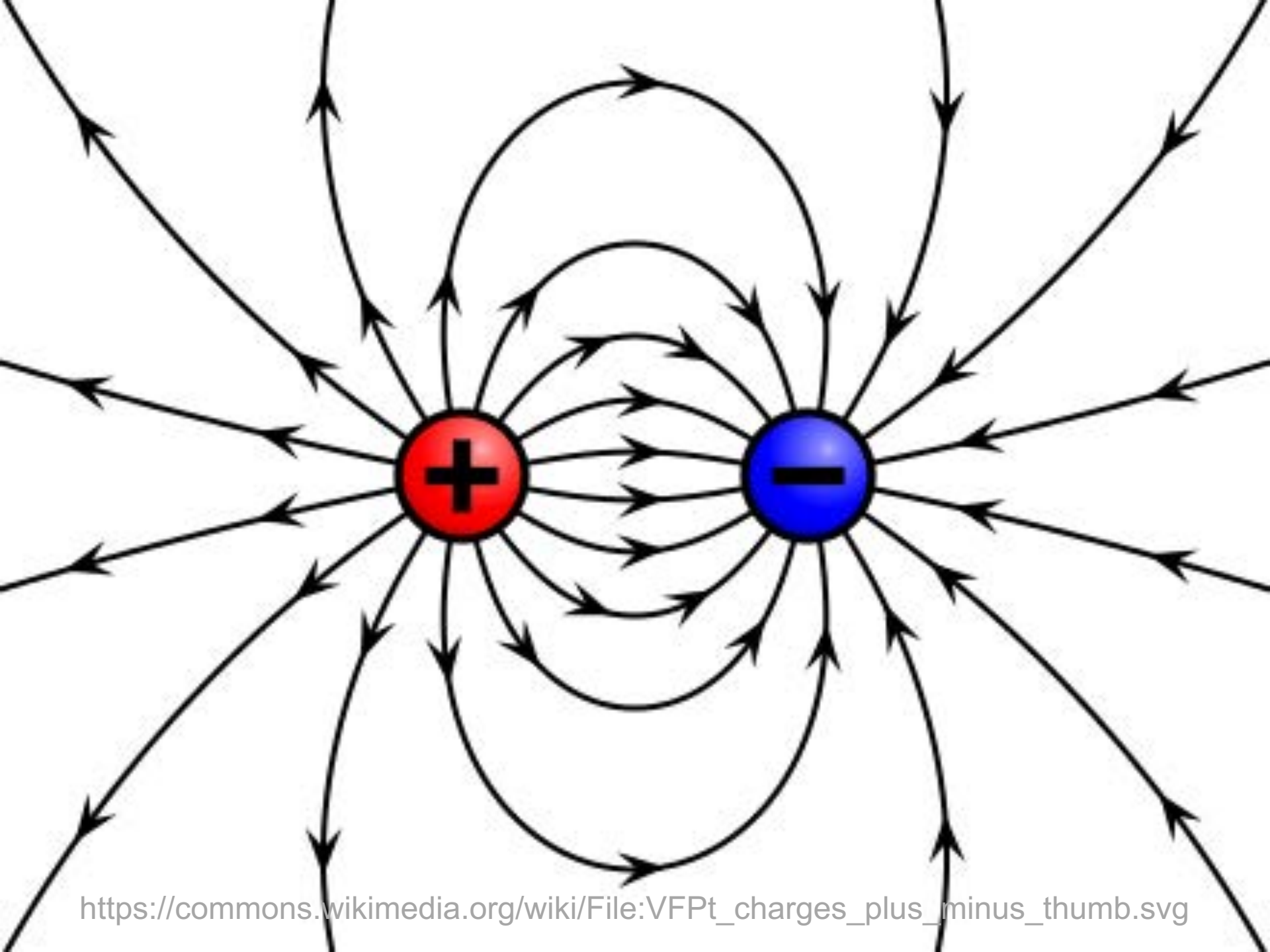
The No. 1 Principle

Increase positive externalities, reduce negative ones, and ensure fair compensation

FIN4+: Sensor-Based Measurements of Externalities, Combined with Incentives

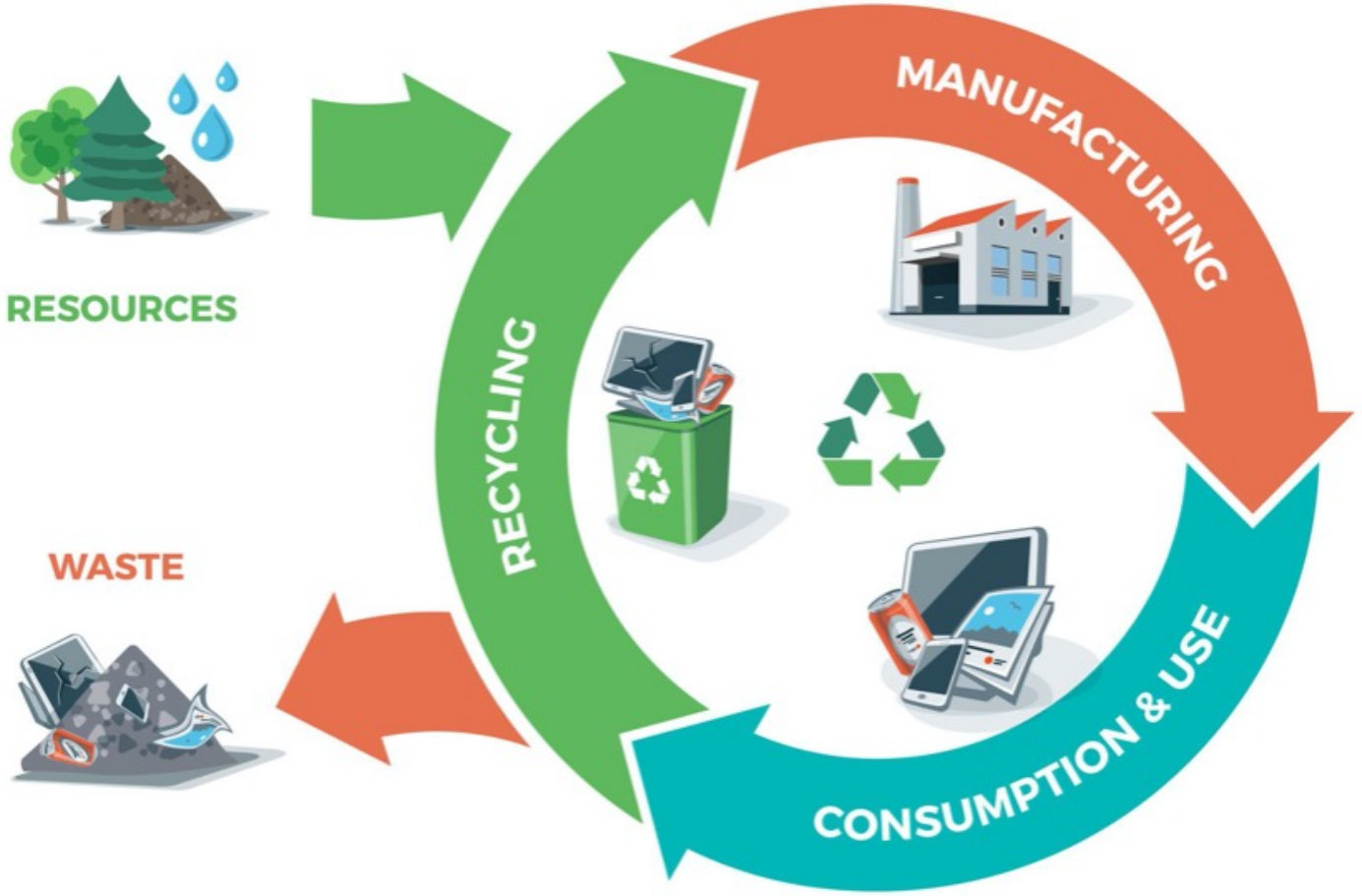
https://commons.wikimedia.org/wiki/File:Gold_coin_icon.png





https://commons.wikimedia.org/wiki/File:VFPt_charges_plus_minus_thumb.svg

Circular and Sharing Economy



https://proclim.scnat.ch/de/current/news/uuid/i/3ab5f988-94ca-5f61-bac1-3ed39dd5edf2-Kreislaufwirtschaft_Versorgung_mit_kritischen_Rohstoffen_und_Indikatoren

Can the World be Saved with a "War Room" Approach?

https://www.theguardian.com/commentisfree/2013/sep/15/nsa-mind-keith-alexander-star-trek

Inside the mind of NSA chief Gen Keith Alexander

Glenn Greenwald

A Digital Twin of the World and Its People

Sentient world: war games on the grandest scale

Sim Strife

Mark Baard

The Register®

Sat 23 Jun 2007 // 09:02 UTC

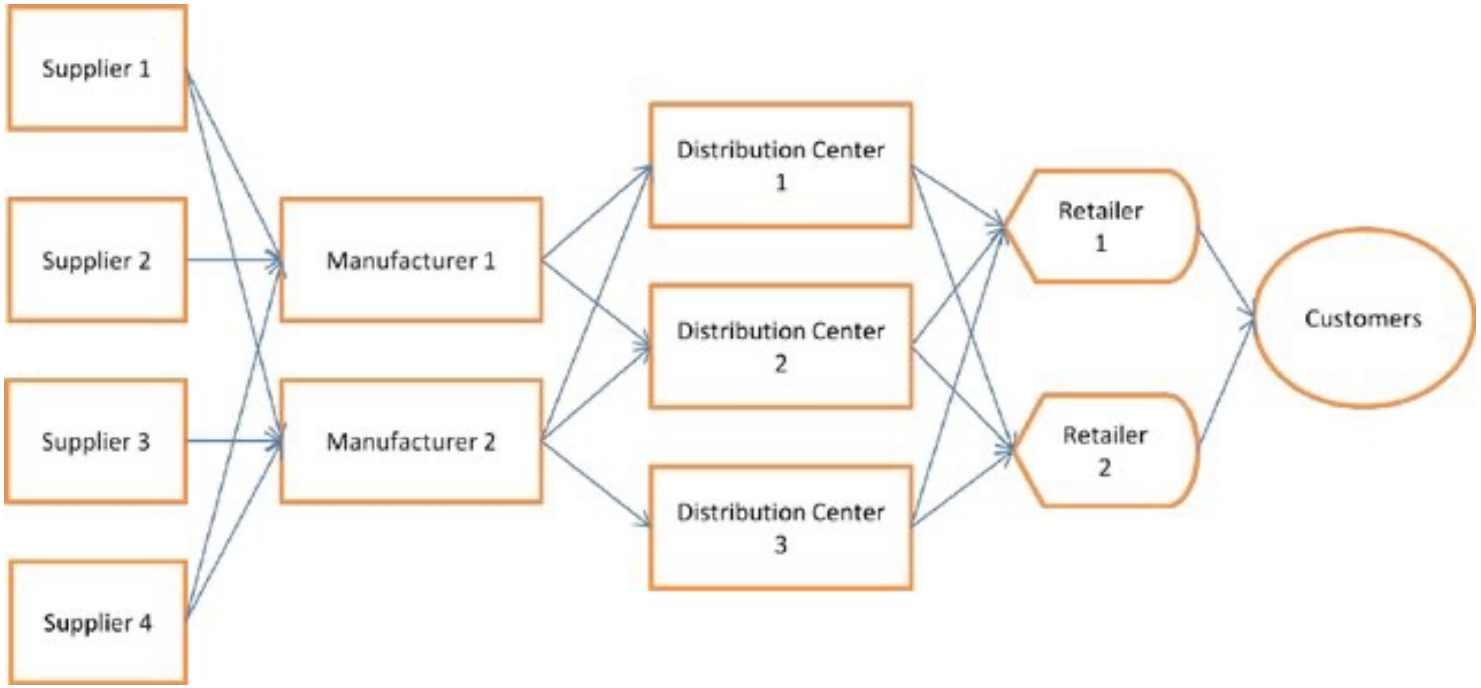
Sentient World Simulation (SWS)

“provides an environment for testing Psychological Operations (PSYOP),”

the paper reads, so that military leaders can ”develop and test multiple courses of action to anticipate and shape behaviors of adversaries, neutrals, and partners”.

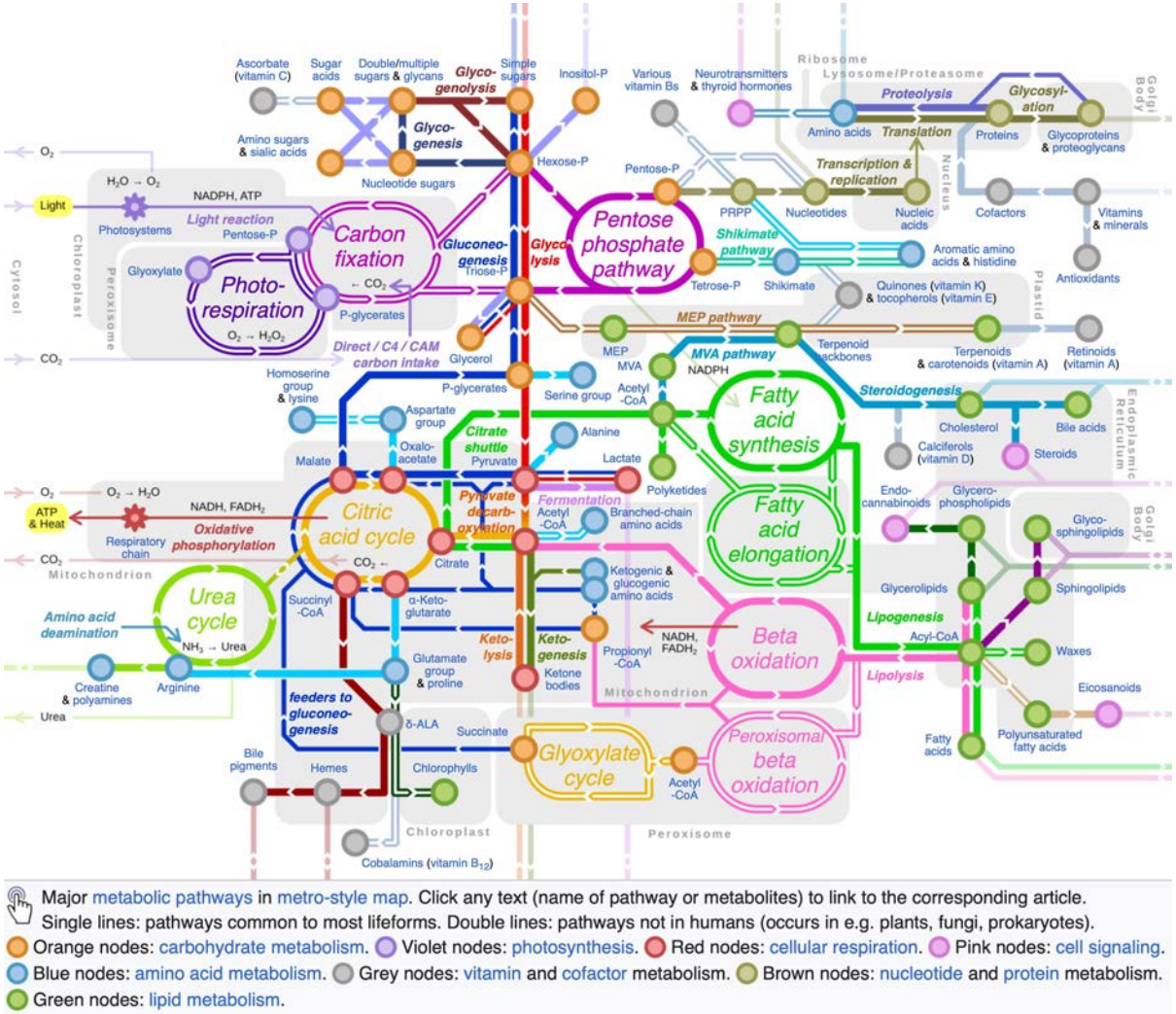
https://www.theregister.com/2007/06/23/sentient_worlds/

A Typical Supply Network Today

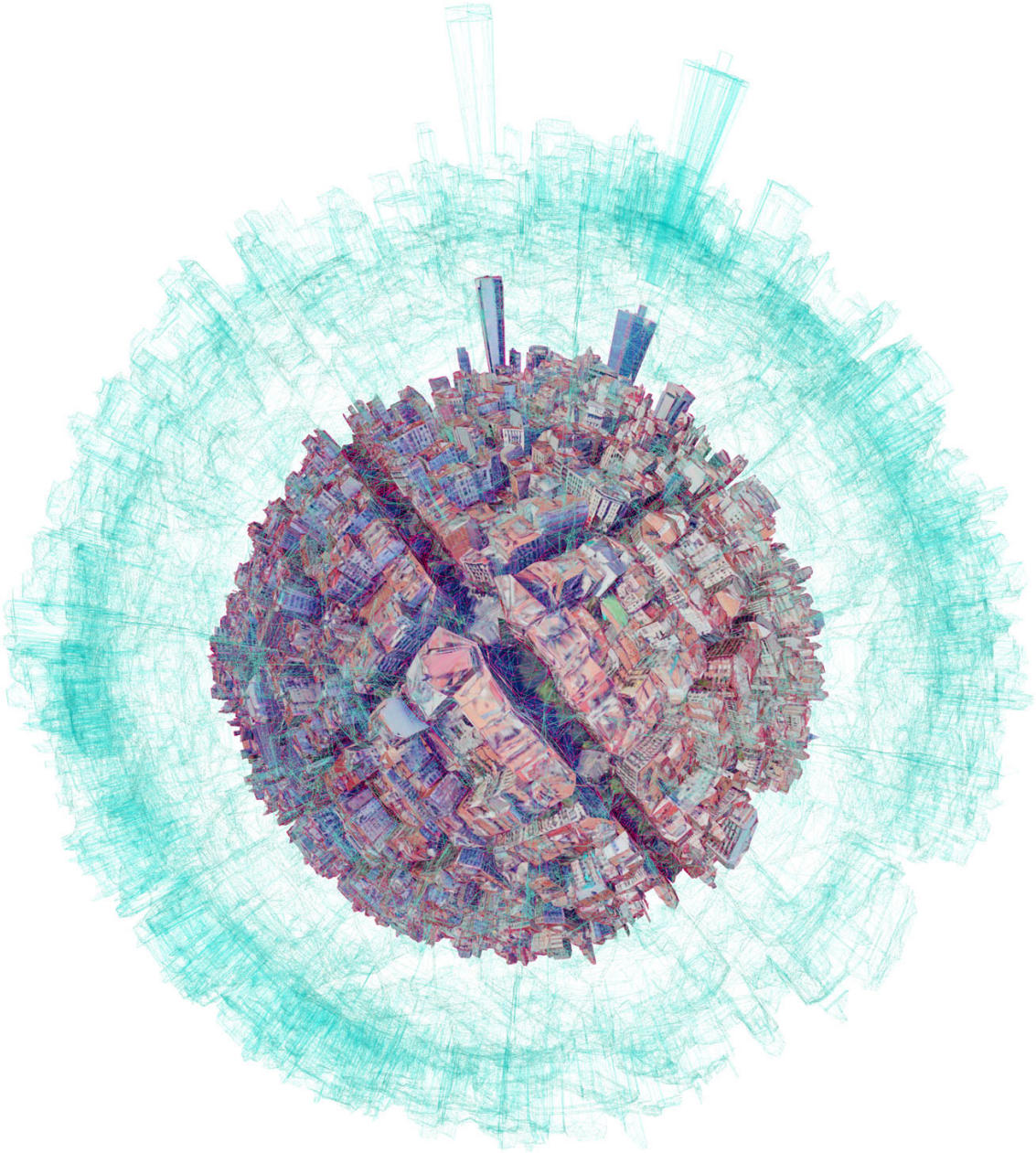


https://www.researchgate.net/publication/280158117

A Typical Metabolic Network



https://en.wikipedia.org/wiki/Metabolic_network



Digital Twins Are Lacking Complexity Science!

https://www.researchgate.net/publication/365852772

https://www.nature.com/articles/s43588-023-00431-4

Design: Javier Argota Sanchez-Vaquerizo

There is not only a Price of Anarchy.

There is also a Price of Optimization and Control!

The Price of Optimization is that all goal(s) but the ones optimized for are ignored.

The Price of Control is the loss of freedom, diversity, creativity, innovation...

PERSPECTIVE

doi:10.1038/nature12047

Globally networked risks and how to respond

Dirk Helbing[1,2]

2014

Today's strongly connected, global networks have produced highly interdependent systems that we do not understand and cannot control well. These systems are vulnerable to failure at all scales, posing serious threats to society, even when external shocks are absent. As the complexity and interaction strengths in our networked world increase, man-made systems can become unstable, creating uncontrollable situations even when decision-makers are well-skilled, have all data and technology at their disposal, and do their best. To make these systems manageable, a fundamental redesign is needed. A 'Global Systems Science' might create the required knowledge and paradigm shift in thinking.

Globalization and technological revolutions are changing our planet. Today we have a worldwide exchange of people, goods, money, information, and ideas, which has produced many new opportunities, services and benefits for humanity. At the same time, however, the underlying networks have created pathways along which dangerous and damaging events can spread rapidly and globally. This has increased systemic risks[1] (see Box 1). The related societal costs are huge.

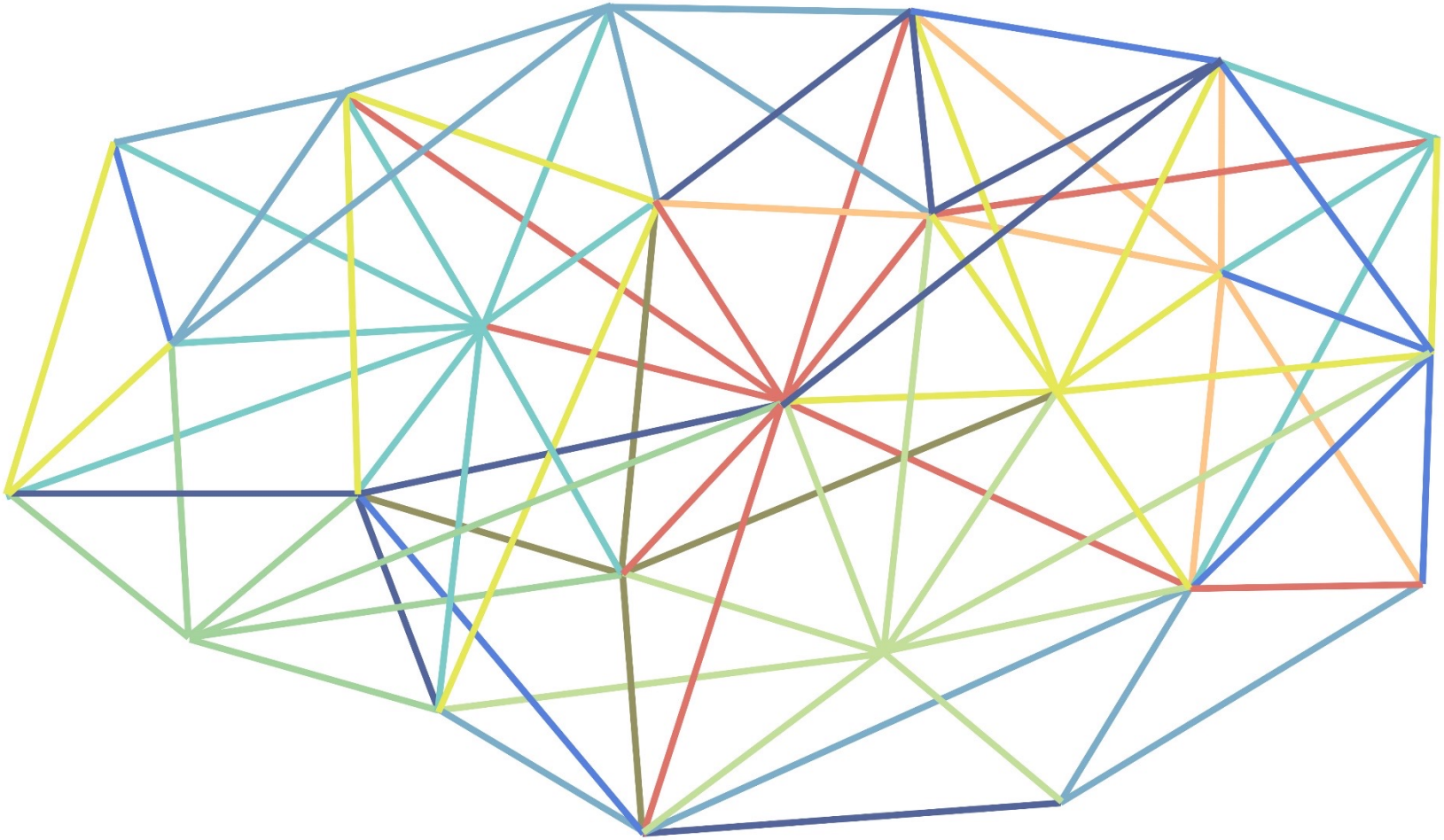
When analysing today's environmental, health and financial systems or our supply chains and information and communication systems, one finds that these systems have become vulnerable on a planetary scale. They are challenged by the disruptive influences of global warming, disease outbreaks, food (distribution) shortages, financial crashes, heavy

'Global Systems Science', in order to understand better our information society with its close co-evolution of information and communication technology (ICT) and society. This effort is allied with the "Earth system science"[10] that now provides the prevailing approach to studying the physics, chemistry and biology of our planet. Global Systems Science wants to make the theory of complex systems applicable to the solution of global-scale problems. It will take a massively data-driven approach that builds on a serious collaboration between the natural, engineering, and social sciences, aiming at a grand integration of knowledge. This approach to real-life techno-socio-economic-environmental systems[8] is expected to enable new response strategies to a number of twenty-first century challenges.

The Nodes Lose Importance ...

... As Interaction Effects Dominate ...

... And Network Effects Prevail



Cause and Effect in Networked Systems

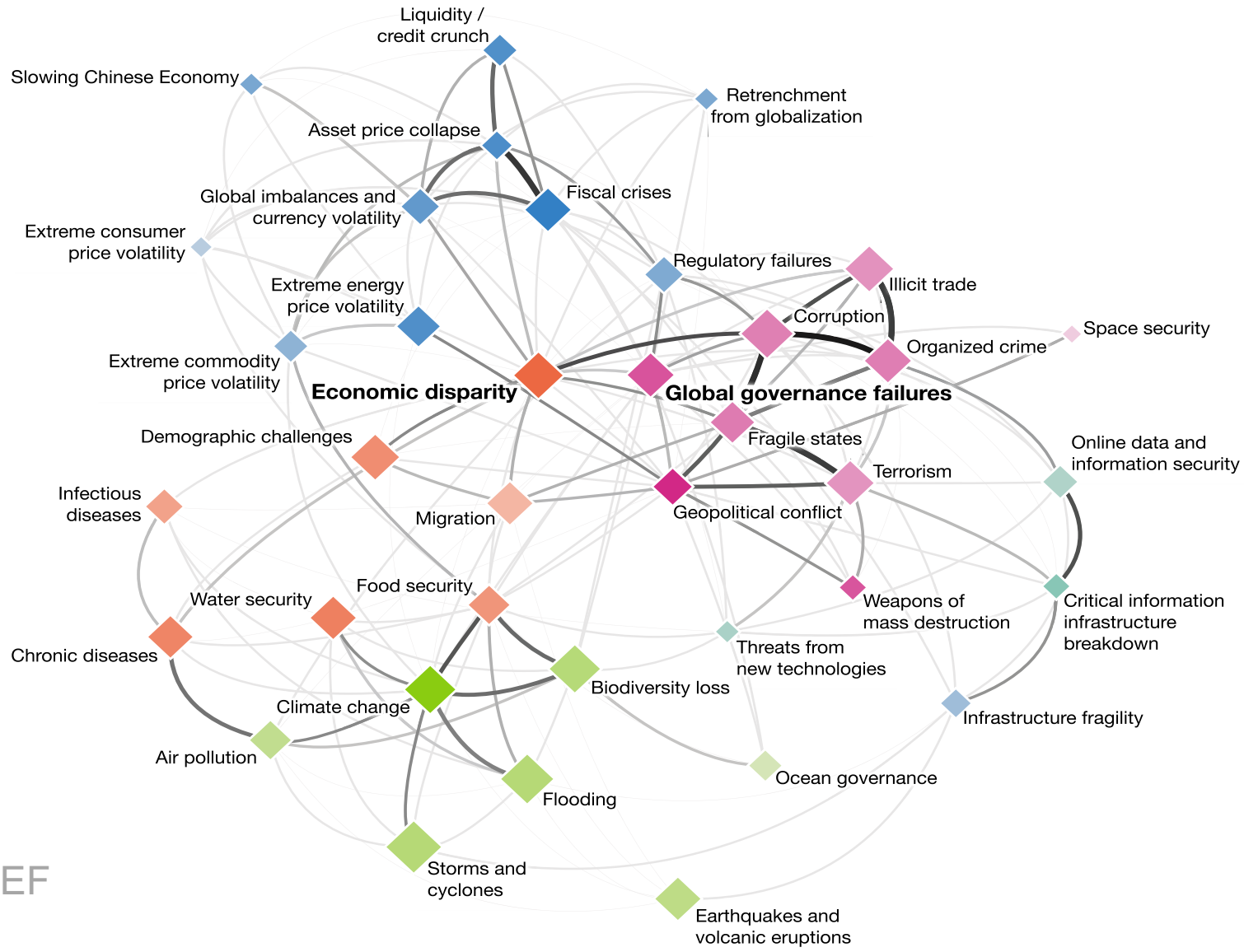
Intended effect

Side effect

Feedback effect

Cascading effect

Networked Risks



Source: WEF

Loss of Control through Cascading Effects

Mousetrap fission, by Gerhard G. Paulus, University of Jena, https://www.youtube.com/watch?v=Wiz1VVLYgI4

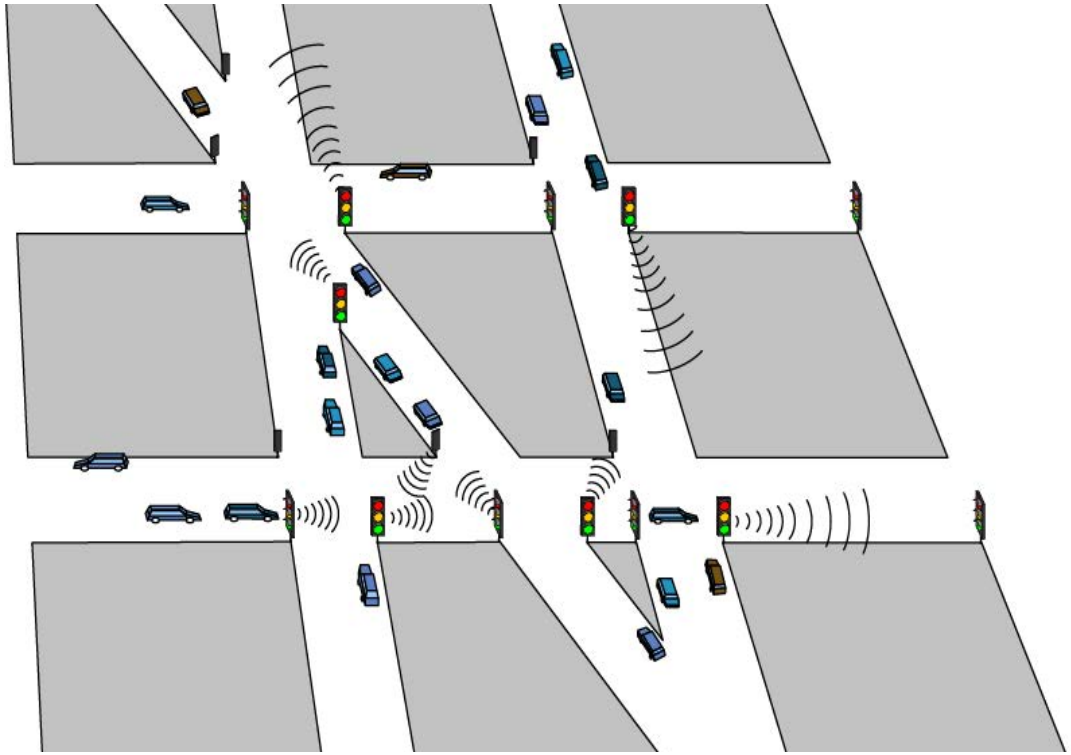
Cascading Effects During Financial Crises

Video by Frank Schweitzer et al.

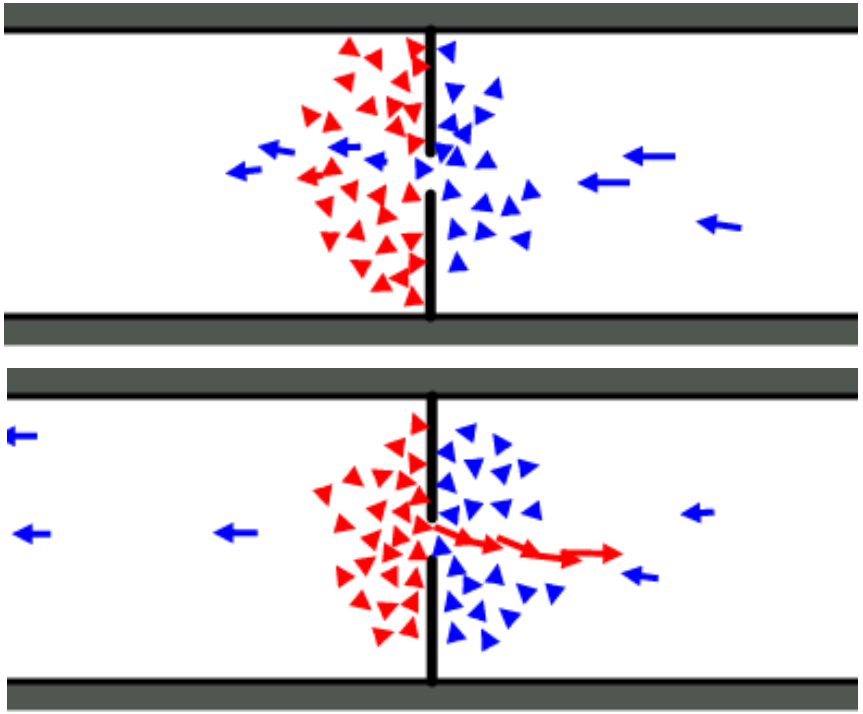
Let us discuss
the example of
traffic flows in
road networks!

Let's Have A Look at the Challenge of Adaptive Traffic Light Control!

- for complex street networks
- for traffic disruptions (building sites, accidents, etc.)
- for particular events (Olympic games, pop concerts, etc.)

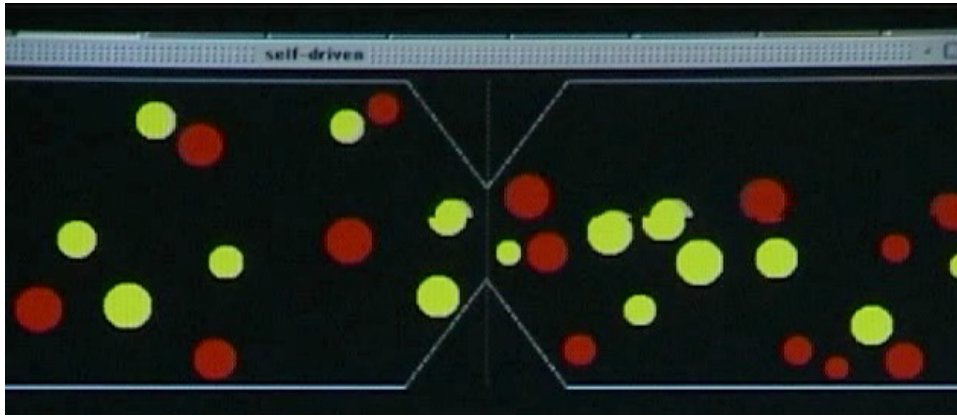


Self-Organized Oscillations at Bottlenecks and Synchronization

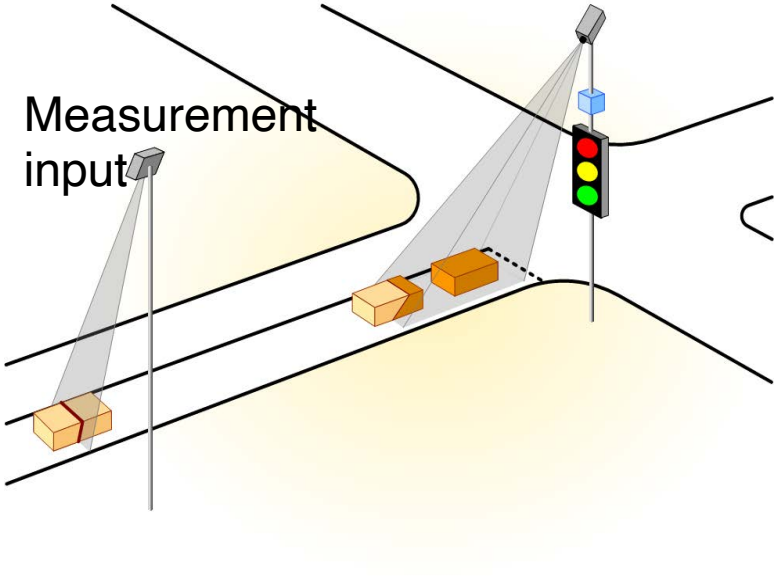


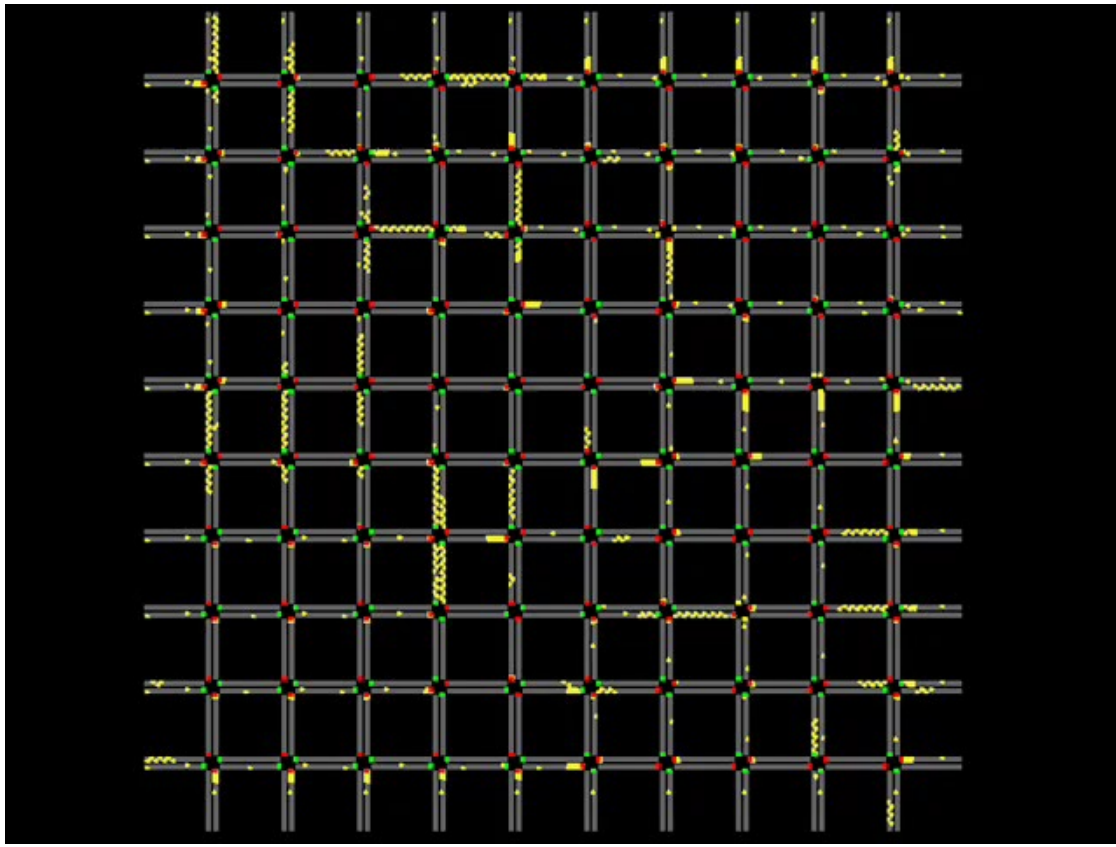
https://journals.aps.org/pre/abstract/10.1103/ PhysRevE.51.4282

- Pressure-oriented, autonomous, distributed signal control:
  - Major serving direction alternates, as in pedestrian flows at intersections
  - Irregular oscillations, but 'synchronized'
- In huge street networks:
  - 'Synchronization' of traffic lights due to vehicle streams spreads over large areas



Harnessing Complexity by Flexible Adaptation and Decentralization





Stefan Lämmer and DH

Self-regulating green waves.
Patent available.

Journal of Statistical Mechanics: Theory and Experiment

Self-control of traffic lights and vehicle flows in urban road networks

Stefan Lämmer[1] and Dirk Helbing[2,3]

Published 16 April 2008 • IOP Publishing Ltd

Journal of Statistical Mechanics: Theory and Experiment, Volume 2008, April 2008

Citation Stefan Lämmer and Dirk Helbing *J. Stat. Mech.* (2008) P04019

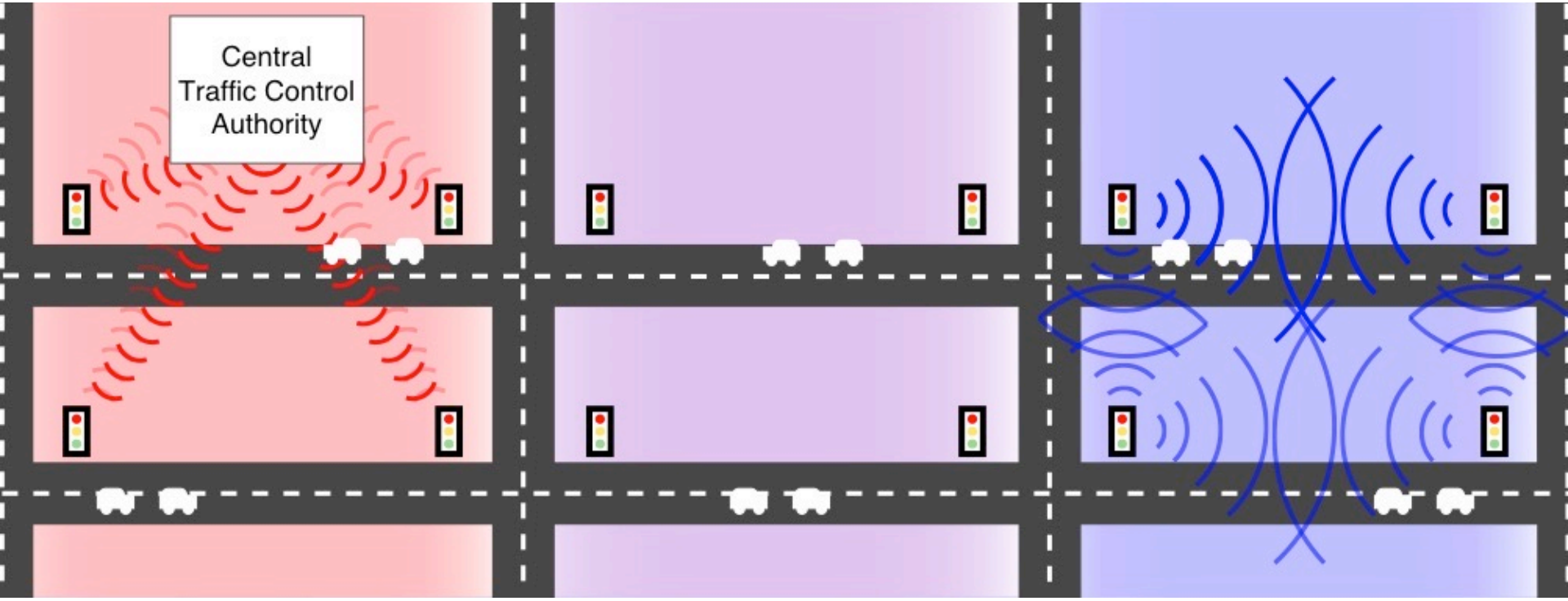
https://iopscience.iop.org/article/10.1088/1742-5468/2008/04/P04019/meta

Self-Stabilizing Decentralized Signal Control of Realistic, Saturated Network Traffic

Stefan Lämmer
Dirk Helbing

https://www.santafe.edu/research/results/working-papers/self-stabilizing-decentralized-signal-control-of-r

Comparing 3 Ways to Organize a Complex System

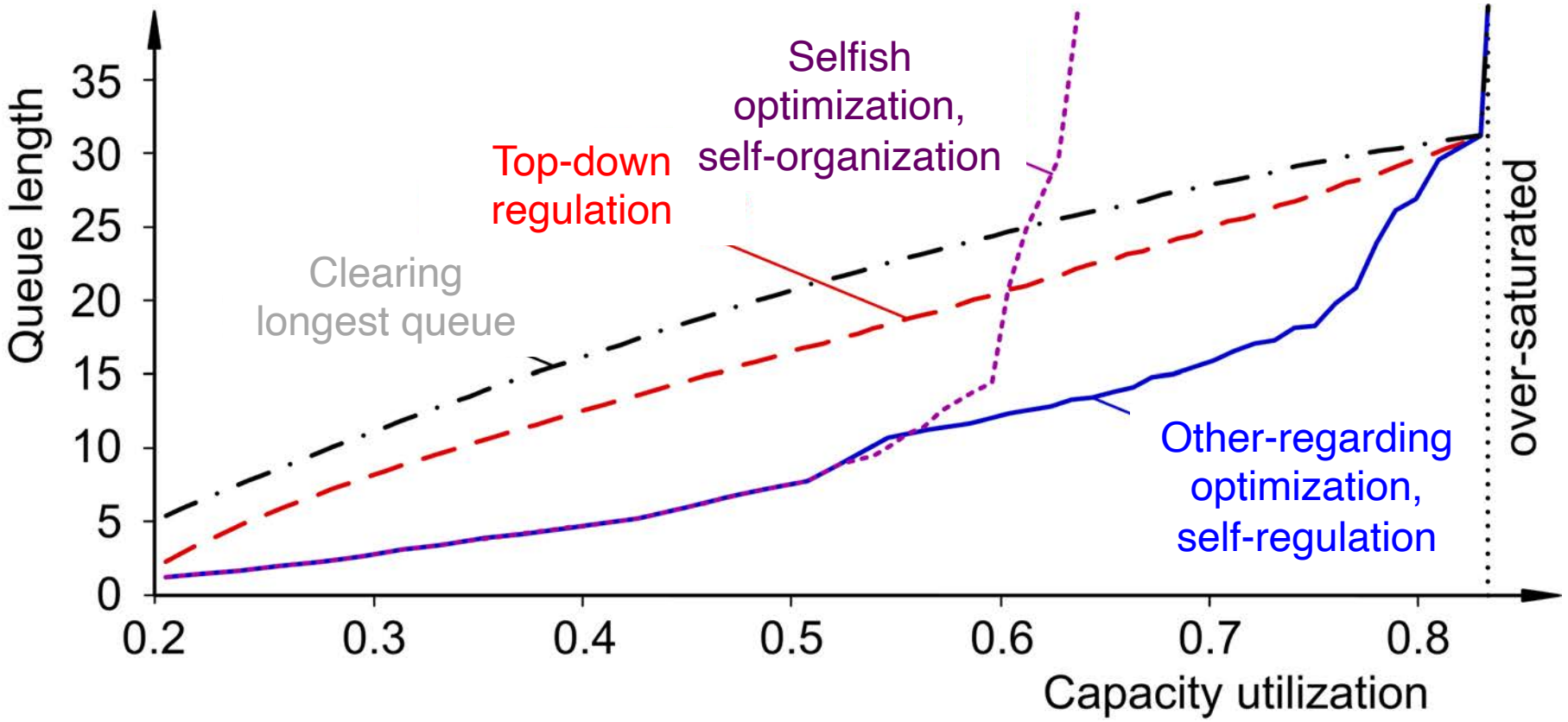


Central control, "benevolent dictator"

Travel time minimization, "homo economicus"

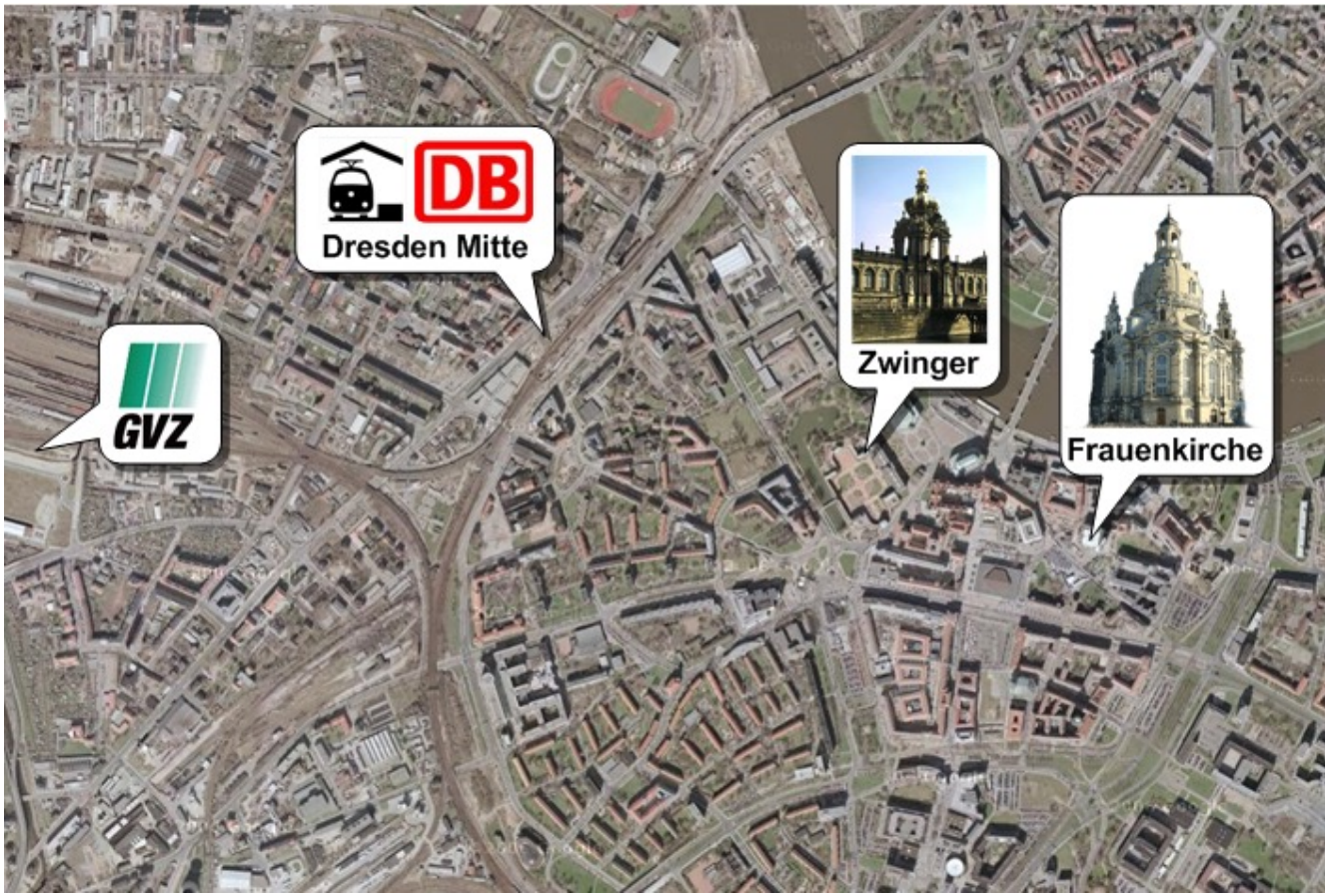
Same, but other-regarding coordination with neighbors

Bottom-Up Self-Organization Can Outsmart Optimal Top-Down Control



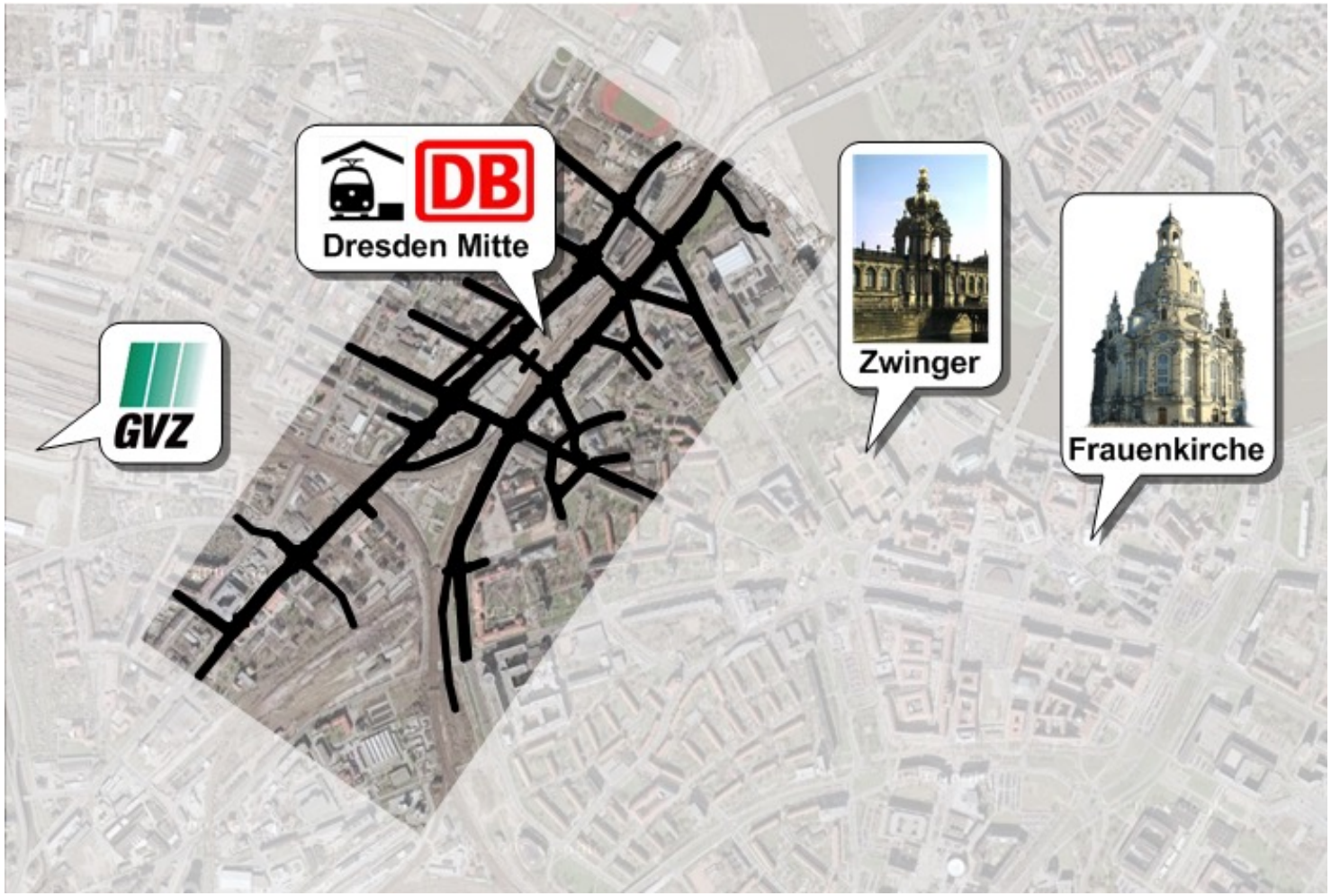
Stefan Lämmer and Dirk Helbing

Towards Self-Organized Traffic Light Control in Dresden

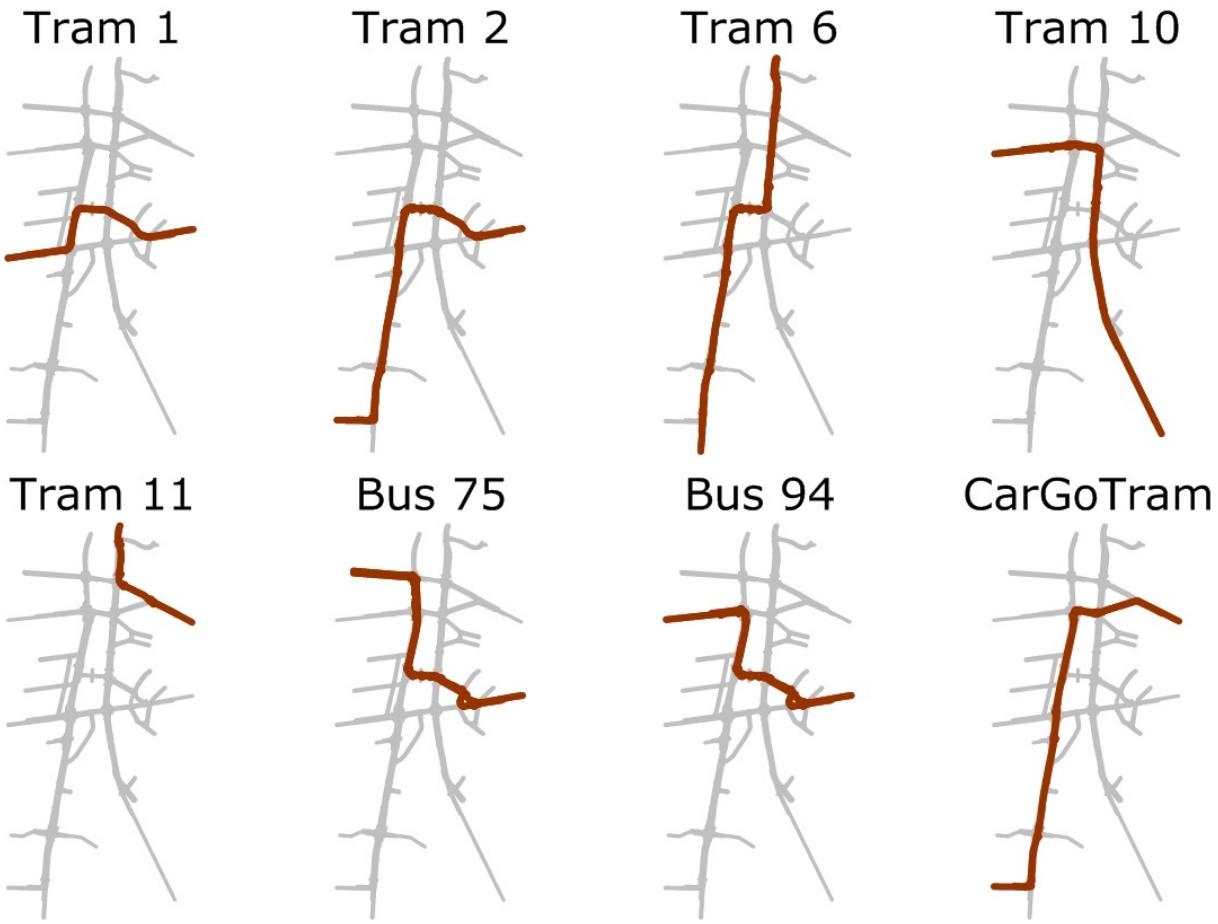


Stefan Lämmer and Dirk Helbing

The Measurement and Control Area



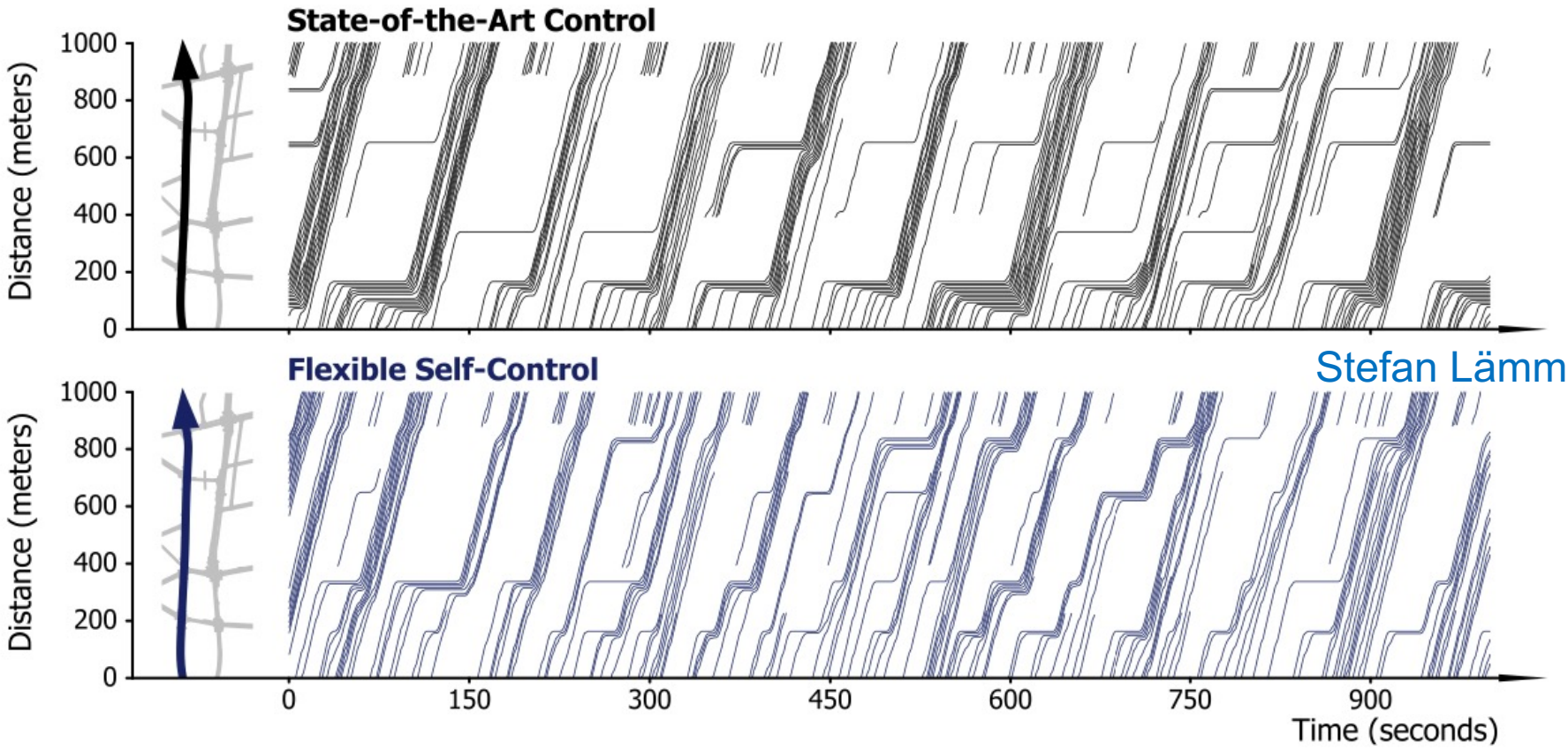
Disturbance of Traffic Coordination by Bus and Tram Lines



Stefan Lämmer

https://sfi-edu.s3.amazonaws.com/sfi-edu/production/uploads/sfi-com/dev/uploads/filer/b4/3c/b43c20b4-7c08-489b-aa7f-a914add4e5aa/10-09-019.pdf

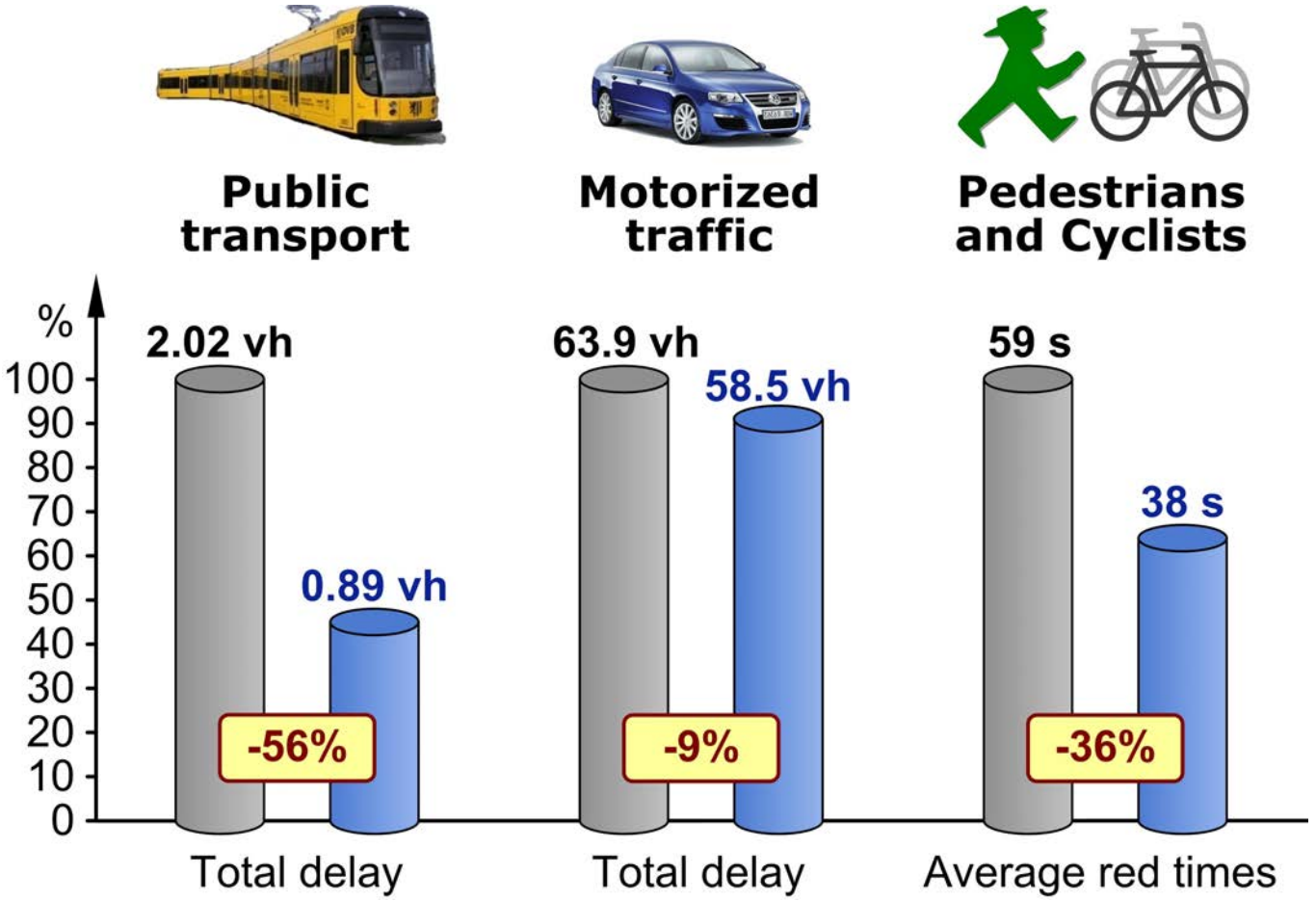
Synchronize Traffic by Green Waves or Use Gaps as Opportunities?



Stefan Lämmer

https://sfi-edu.s3.amazonaws.com/sfi-edu/production/uploads/sfi-com/dev/uploads/filer/b4/3c/b43c20b4-7c08-489b-aa7f-a914add4e5aa/10-09-019.pdf

Gain in Performance



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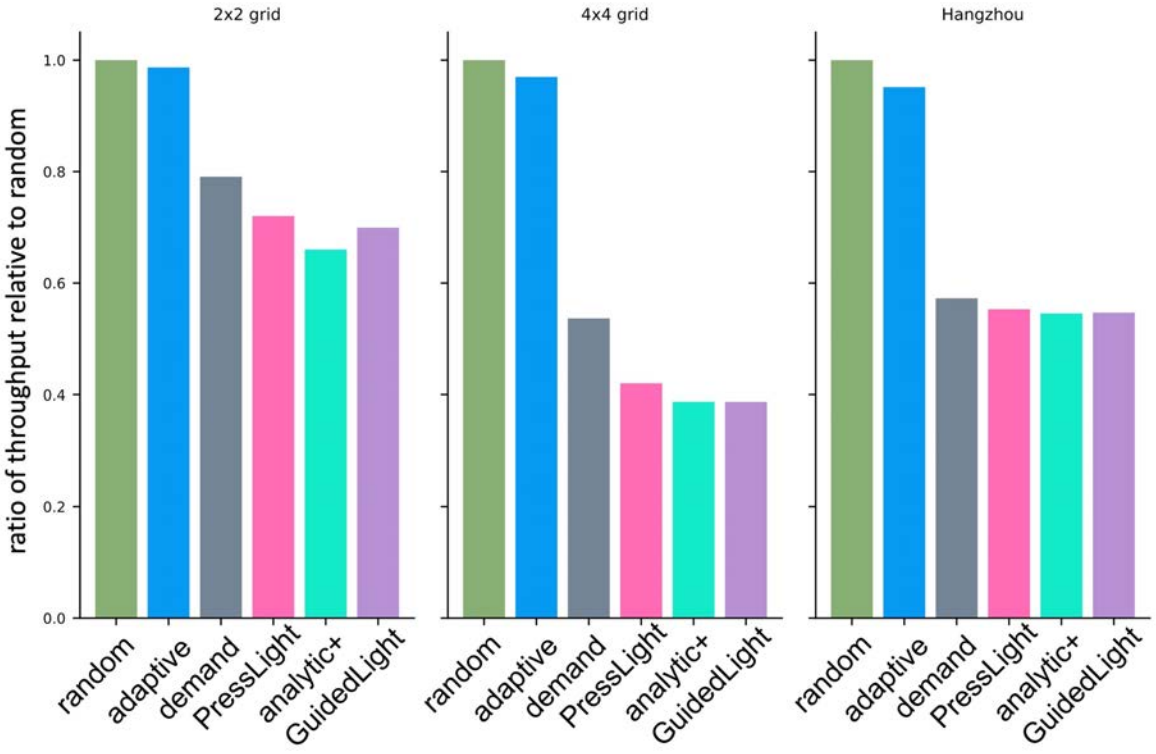
Comparison of Various Control Approaches



Work with Marcin Korecki et al.

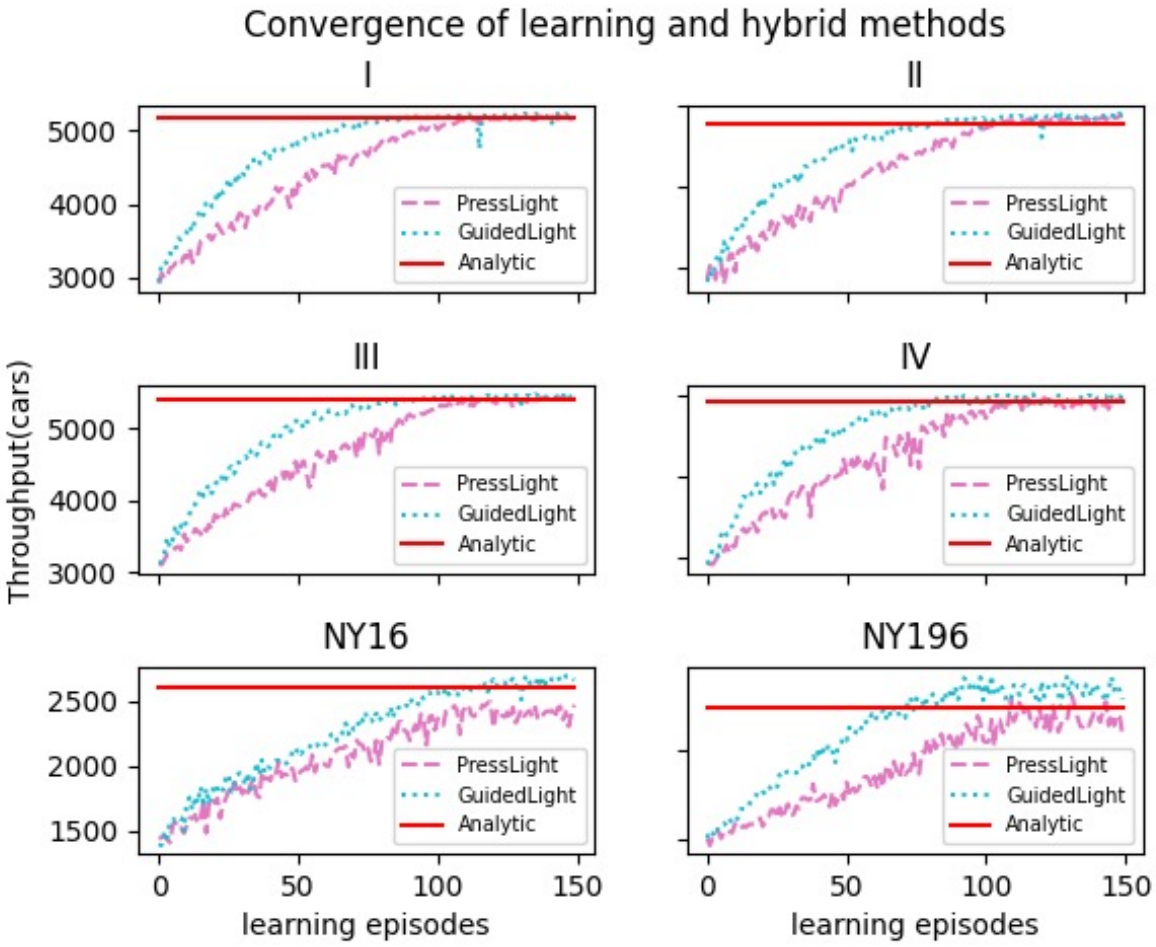
Classical:
- Random
- Adaptive
- Demand

Self-Organizing:
- Analytic+

Machine Learning:
- PressLight
- GuidedLight

Machine learning approaches use pressure as reward

Would Machine Learning Do Any Better?



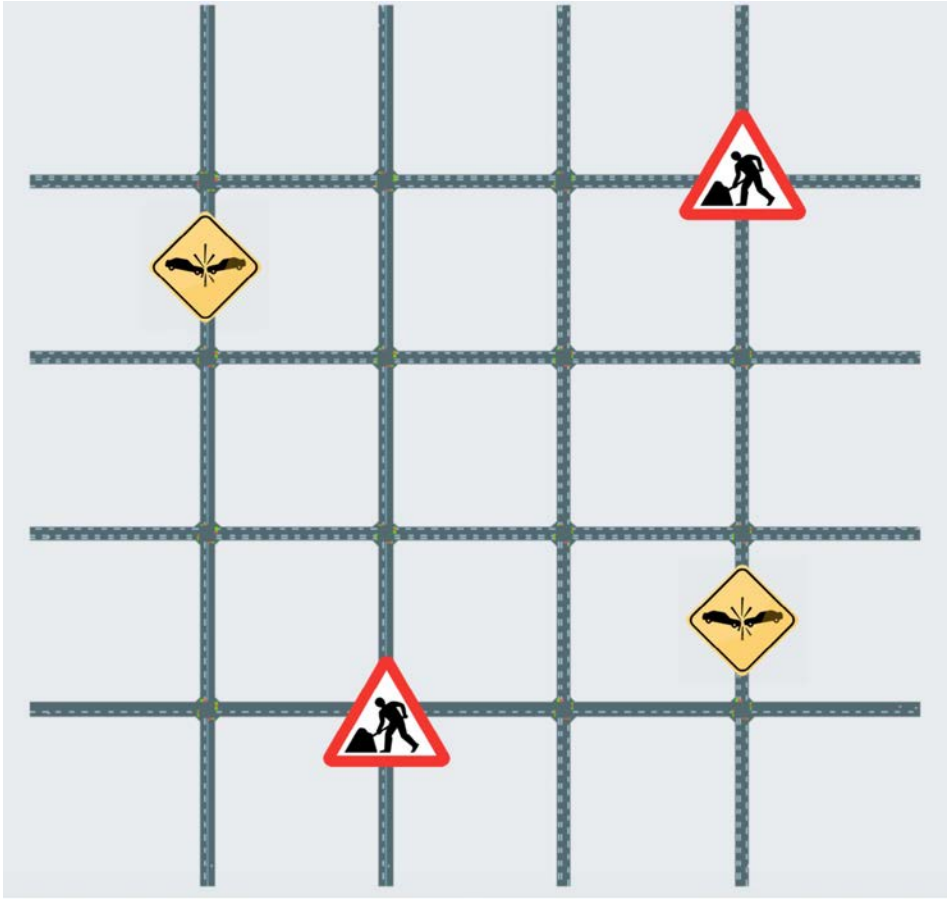
1) Self-organization approaches perform surprisingly well when compared to machine learning solutions.

2) Combining both methods deliver superior performance and much shorter convergence times.

3) Analytical is not dead – hybrid approaches are best.

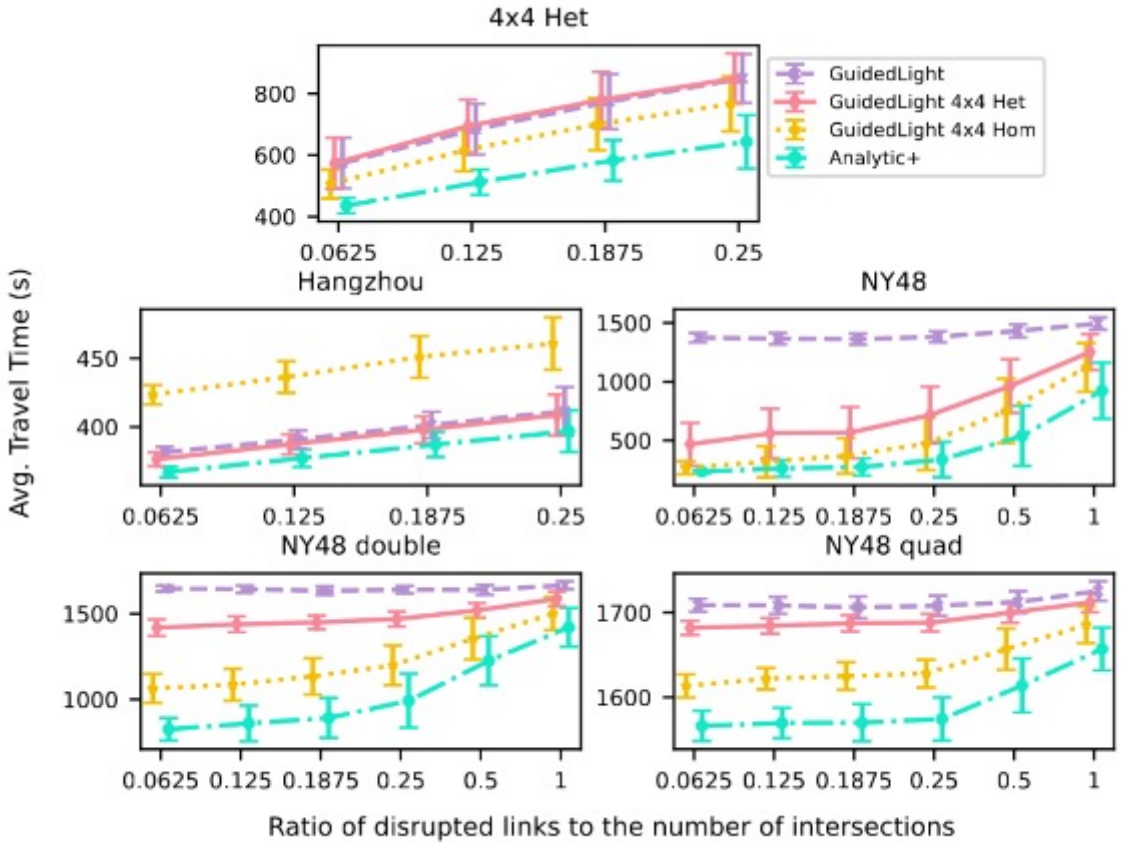
https://ieeexplore.ieee.org/abstract/document/9875292

Managing Disrupted Systems: Do Approaches Based on Self-Organizing or Machine Learning Work Best?



https://www.researchgate.net/publication/366249147

Managing Disrupted Systems: Do Approaches Based on Self-Organizing or Machine Learning Work Best?



https://www.researchgate.net/publication/366249147

“We cannot control every-thing top-down”

Interview ■ Professor Dr. Dirk Helbing, Full Professor of Sociology at the Swiss Federal Institute of Technology in Zurich (ETH) and former traffic scientist at the TU Dresden, speaks about the phenomenon of self-organization in complex systems and about the possibilities of using modern sociological insights for optimizing road traffic.

https://web.archive.org/web/20210707093250/http://webarchiv.ethz.ch/soms/news/ITS_magazine_1-09_S4-11_engl_Fokus.pdf

NEWS VERKEHR

Alle Farben gleichzeitig wird auch die neue Ampelsteuerung nicht anzeigen. (Bild: Adobe Stock)

Pilotversuch an der Tribschenstrasse

Luzern prüft die Super-Ampel

2 min Lesezeit 1 Kommentar

18.10.2019, 10:03 Uhr

Die Stadt Luzern führt kommende Woche den landesweit ersten Test mit einer neuartigen Steuerung für Lichtsignalanlagen durch. Diese berücksichtigt auch die Wartezeiten und soll für eine flüssigere Verkehrsabwicklung sorgen.

REDAKTION
Redaktion zentralplus
→ @ZENTRALPLUS FOLGEN

An den heutigen Ampelanlagen können Reihenfolge, Grünzeiten und Prioritäten für jede Fahrspur definiert werden. Die Wartezeiten hingegen können nur bedingt berücksichtigt werden. Dies führe auf Strecken mit hohem Busaufkommen dazu, dass Fahrzeuge auf Nebenachsen und Fussgängerinnen und Fussgänger teilweise lange Wartezeiten in Kauf nehmen müssen. Das teilt das Tiefbauamt der Stadt Luzern mit.

Die neue Selbst-Steuerung erfasse, aus welchen Richtungen sich wie viele Fahrzeuge der Kreuzung nähern. Sekündlich wird neu berechnet, mit welchen Grünzeiten die wenigsten Fahrzeuge anhalten und warten müssen. Der Verkehrsablauf wird dadurch – bisher zumindest im Modell – laufend optimiert. Durch den flüssigeren Ablauf des Verkehrs soll auch der Schadstoffausstoss reduziert werden.

Test entscheidet über definitive Einführung

Im Pilotbetrieb in der Stadt Luzern muss sich zeigen, ob die Super-Ampel auch in der Praxis funktioniert. Für den Praxistest wählte die Stadt Luzern eine Teststrecke bei der Langensandbrücke: Die beiden Lichtsignalanlagen an den Kreuzungen Tribschen-/Kellerstrasse und Tribschen-/ Werkhofstrasse werden vom Montag, 21., bis Sonntag, 27. Oktober, mit dem neuen Steuerverfahren betrieben. Der Pilotversuch wird von der ETH Zürich mit einer Wirkungsuntersuchung begleitet. Ist der Praxistext erfolgreich, wird die Stadt Luzern die neue Steuerung an diesen beiden Lichtsignalanlagen definitiv einführen.

Wirkungsanalyse Selbst-Steuerung

Open access

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Date
2020-10

Type
Report

ETH Bibliography
yes

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Full text (PDF, 12.47Mb)

Abstract
Im Zuge dieses Forschungsprojektes wurden zwei LSA-Steuerungen in einem Untersuchungsgebiet in der Stadt Luzern untersucht. Dabei wurde die bestehende Steuerung (VS-PLUS) mit der neuartigen Selbst-Steuerung für den FussgängerInnenverkehr (FV), den öffentlichen Verkehr (ÖV) und den motorisierten Ind
Show more

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MEHR GRÜN FÜR ALLE

Dank Superampel müssen alle weniger lang warten

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Das dürfte alle Verkehrsteilnehmer freuen: In Luzern wurde eine neue Ampelsteuerung getestet. Fazit: Alle kommen schneller durch den Verkehr.

von
Gianni Walther

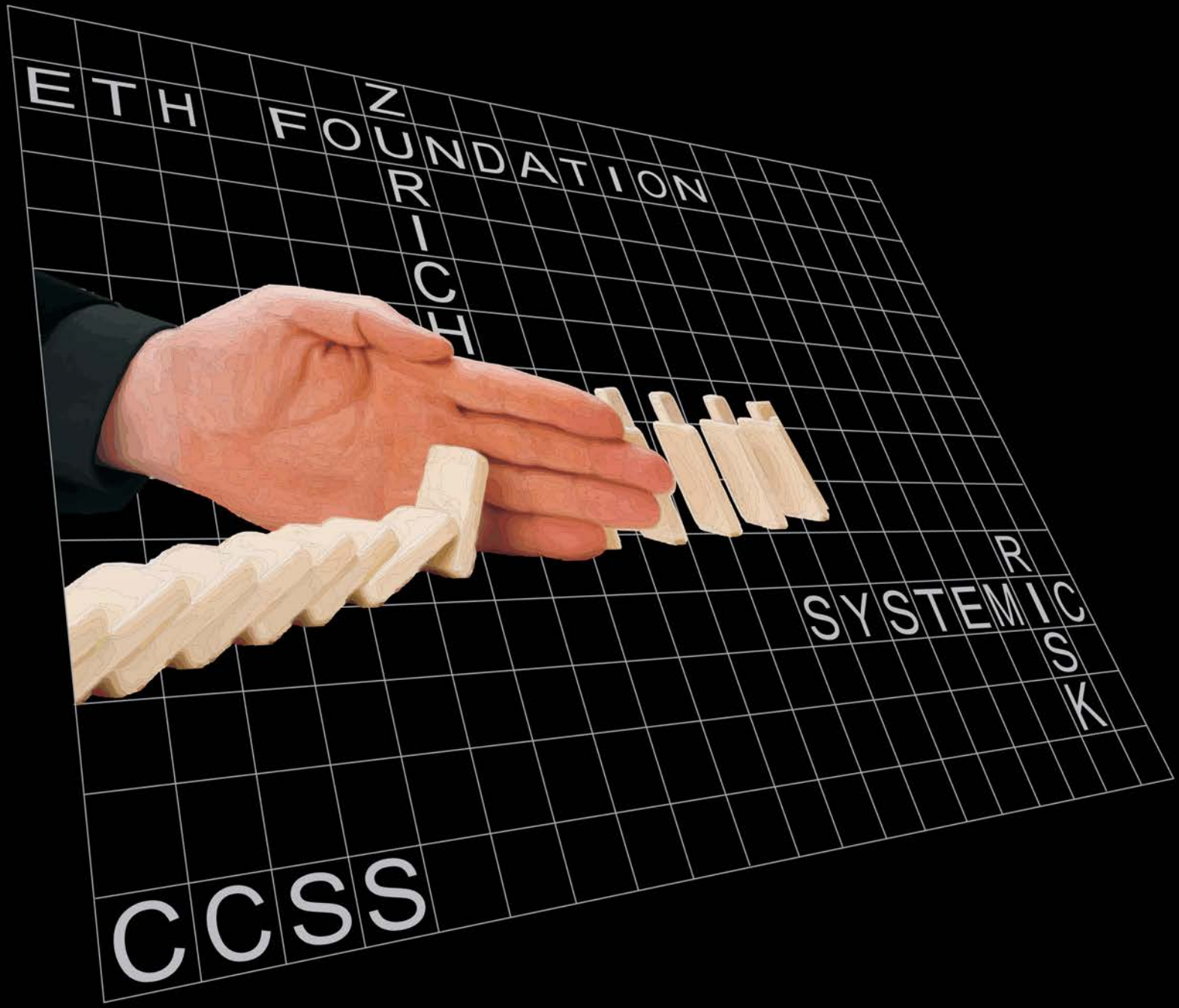
Stefan Lämmer

Die Stadt Luzern hat in einem Pilotversuch ein neues Ampelsteuerungssystem getestet.
gwa

https://www.20min.ch/story/dank-superampel-muessen-alle-weniger-lang-warten-797835241323

What does this mean for the management of a complex world?

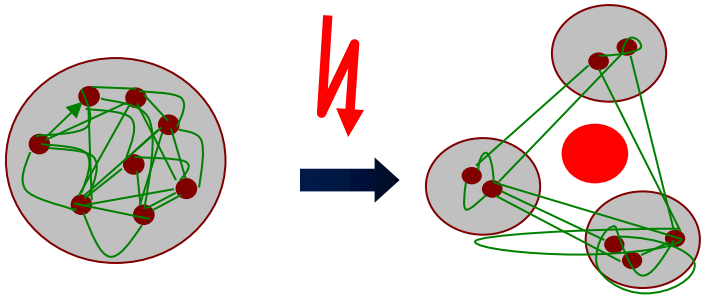
Resilient systems design and operation


ETH ZURICH FOUNDATION
SYSTEMIC RISK
CCSS

Drivers of Systemic Risk and How to Respond

Drivers of systemic risks:

- less redundancies
- more networking
- higher complexity
- faster dynamics
- high pace of innovation



Systemic resilience can be increased by suitably designed mechanisms and systems, protection mechanisms:

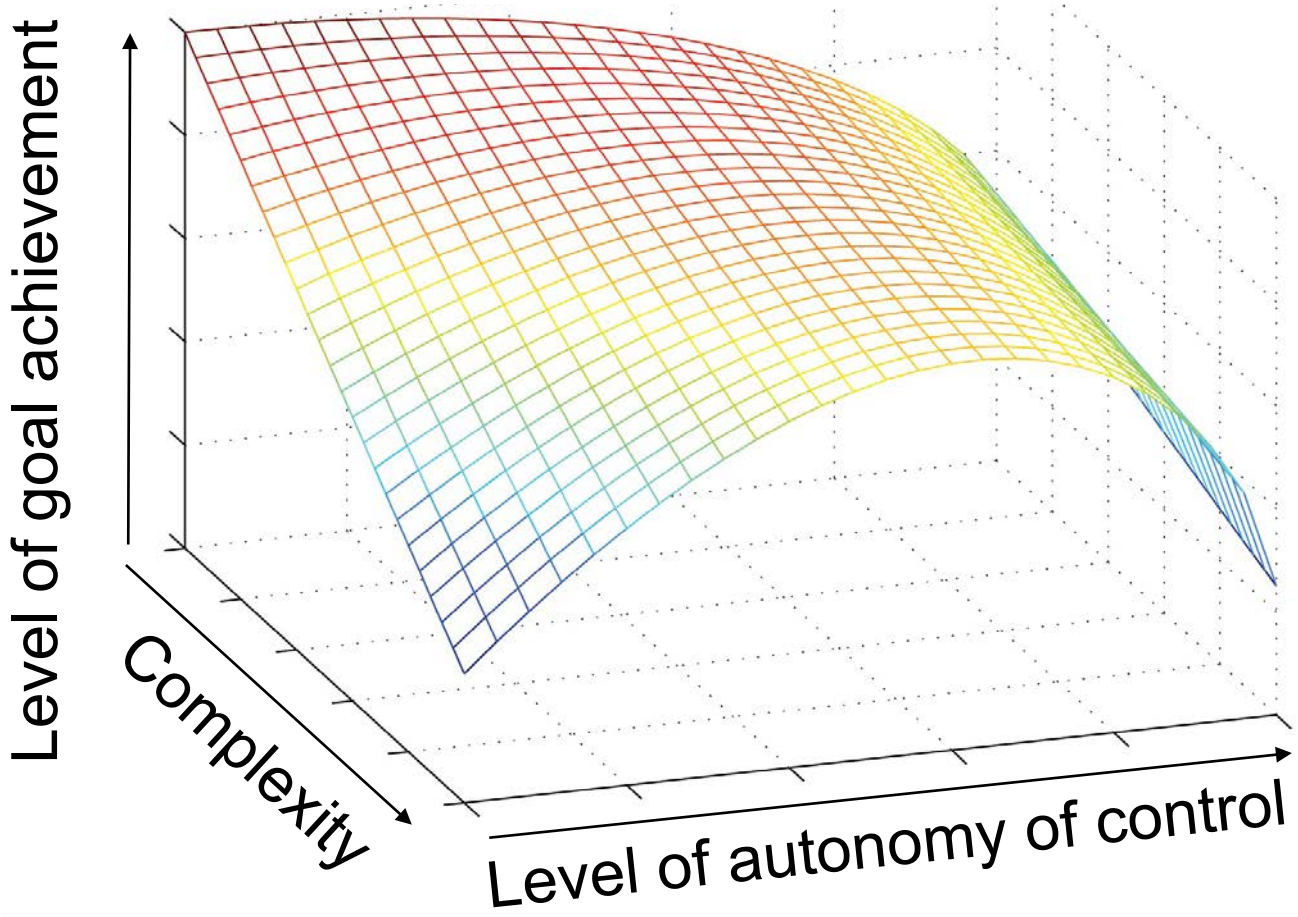
- backup strategies, redundancies, reserves, alternatives (‚plan B‘)
- simplification, limitation of system size
- less connectivity, decoupling strategies
- diversity
- real-time measurements and adaptive feedback, enabling self-regulation, e.g. coordination mechanisms
- transparency and awareness
- accountability and responsibility
- suitable incentives
- collective intelligence


Diversity
Decentralization
Modular Design
Distributed Contro
Subsidiarity

Strengthening Strong Links Does Not Help!

https://www.flickr.com/photos/val_s/8603033695

Better Performance of Complex Systems by More Autonomy and Suitable Interaction Rules

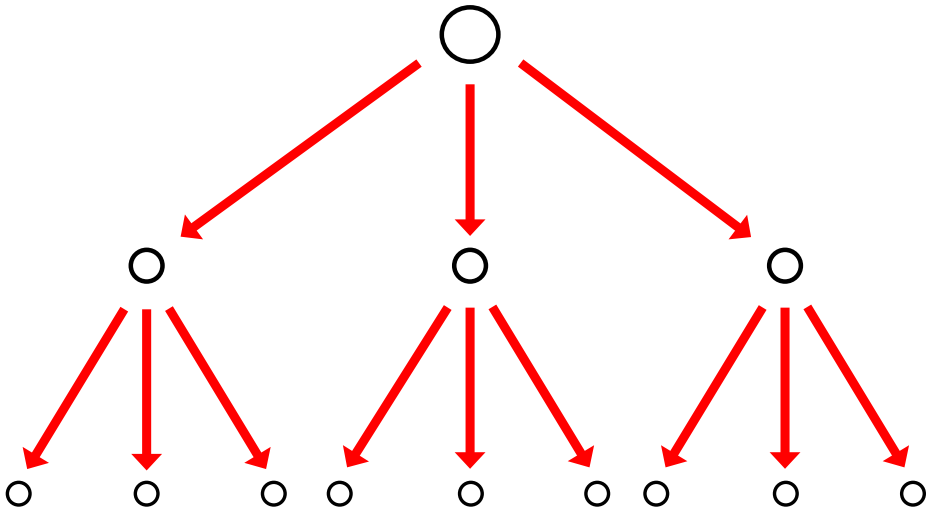


If complex dynamical systems vary a lot, are hard to predict and cannot be optimized in real-time, distributed control can outperform top-down control attempts by flexibly adapting to local conditions and needs.

(Windt, Böse, Philipp, 2006)

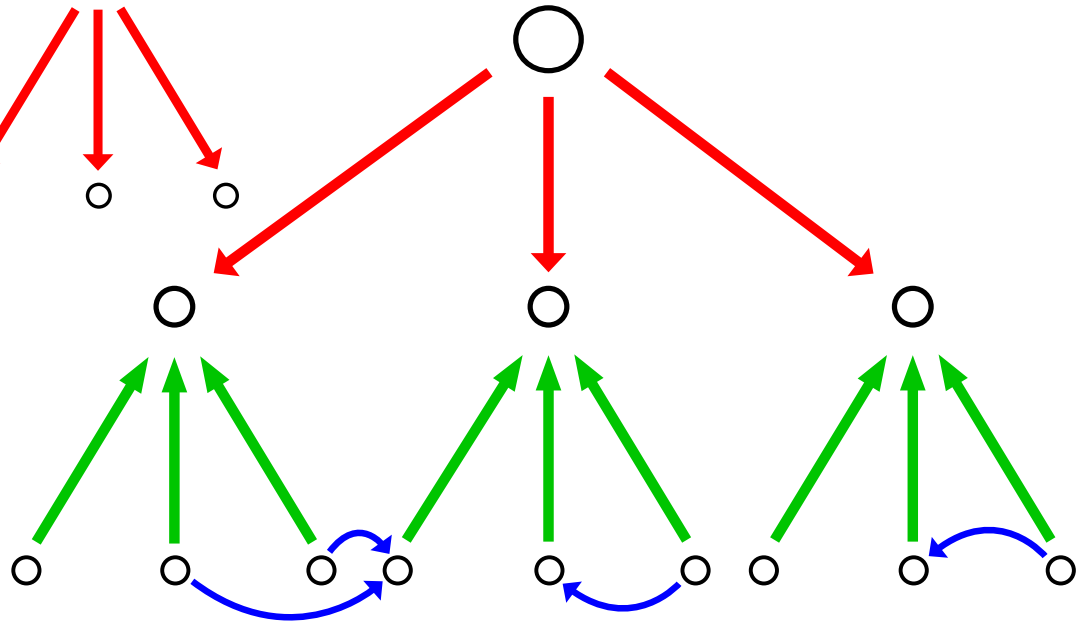
Disaster Response

https://link.springer.com/book/10.1007/978-3-030-62330-2



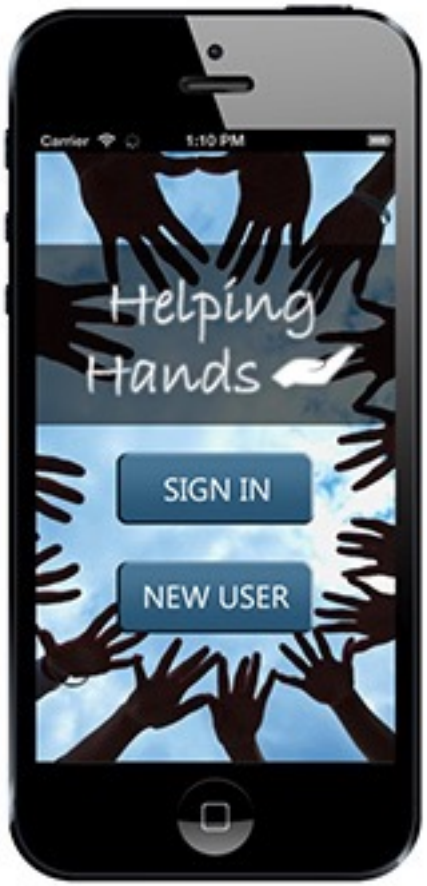
"Do this!"

In a quickly changing world, politics and business becomes increasingly similar to disaster response management!

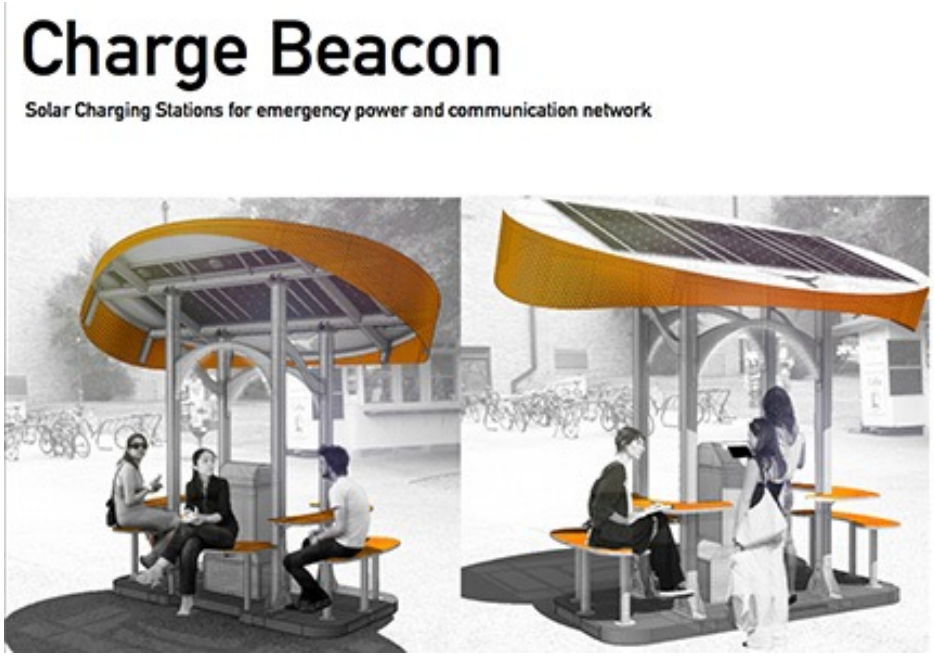


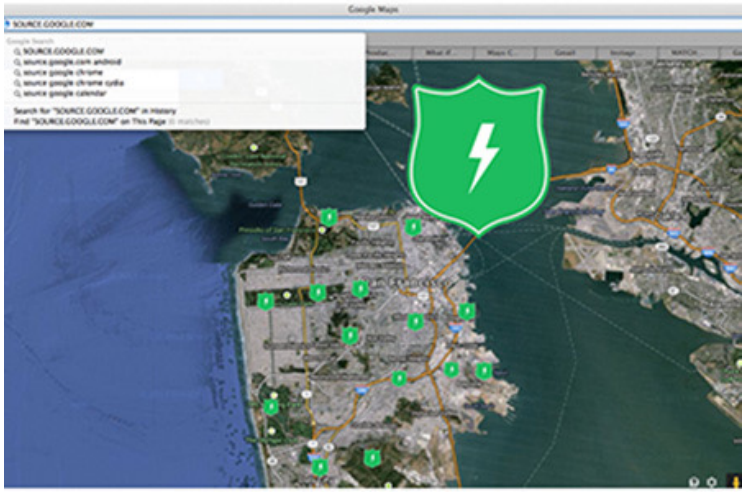
"I can do this!"

Participatory Disaster Response



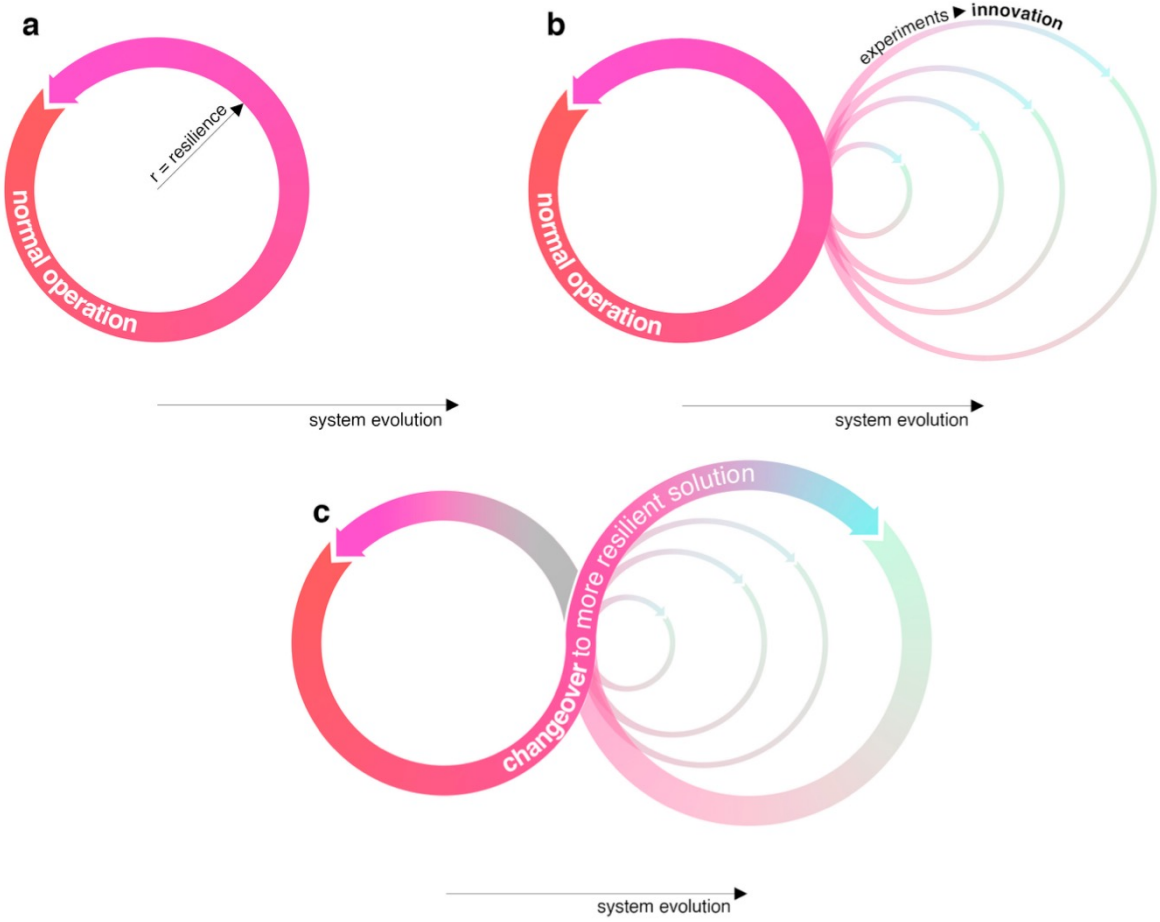
Helping Hands





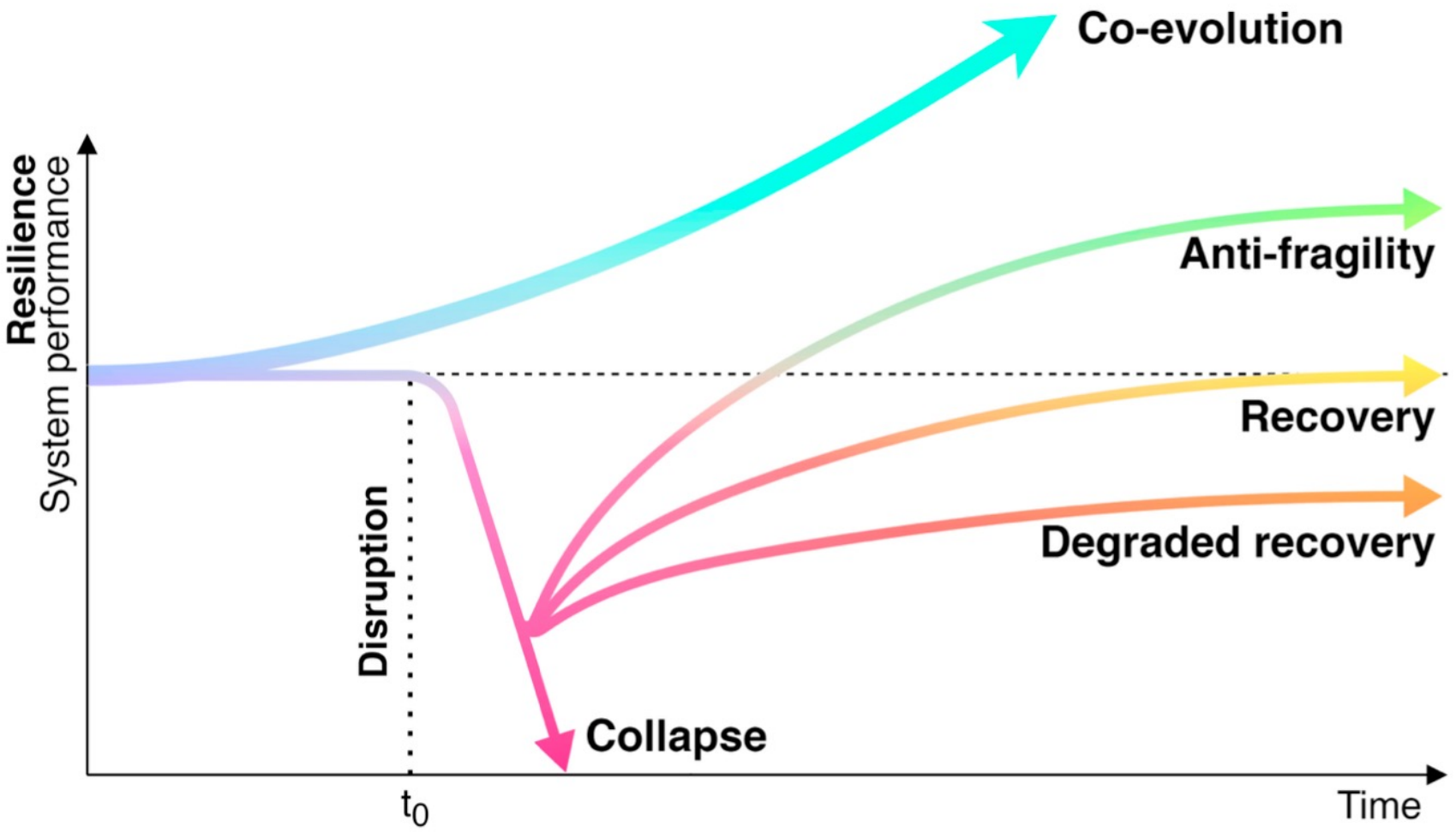
amigocloud

Increasing Resilience through Systemic Innovation



https://www.sciencedirect.com/science/article/pii/S2210670722002633

Resilience: Coping with Disruptions and Disasters



https://www.sciencedirect.com/science/article/pii/S2210670722002633

Introducing participatory fairness in emergency communication can support self-organization for survival

Indushree Banerjee[1,*], Martijn Warnier[1], Frances M.T. Brazier[1], and Dirk Helbing[2,*]

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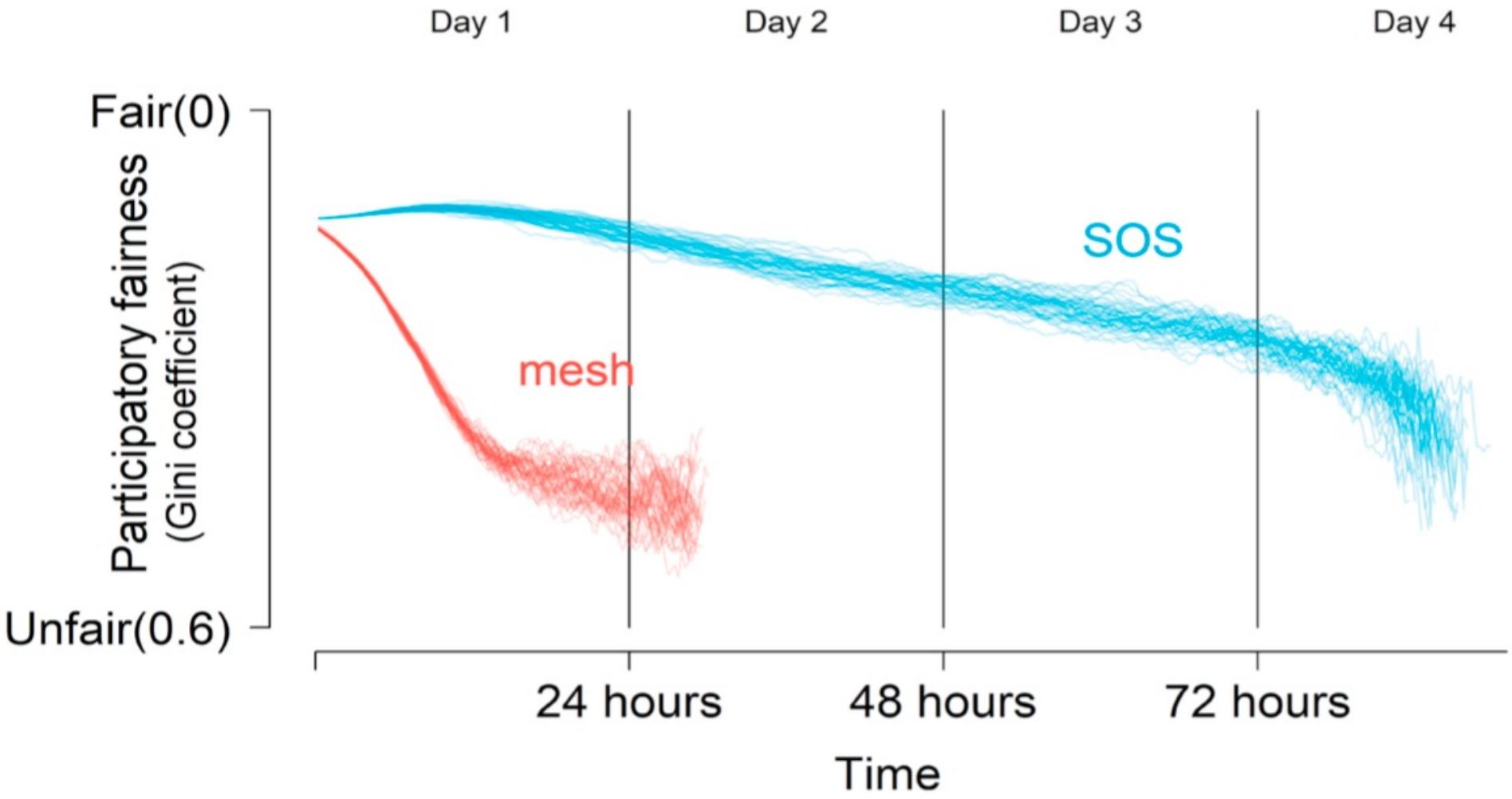
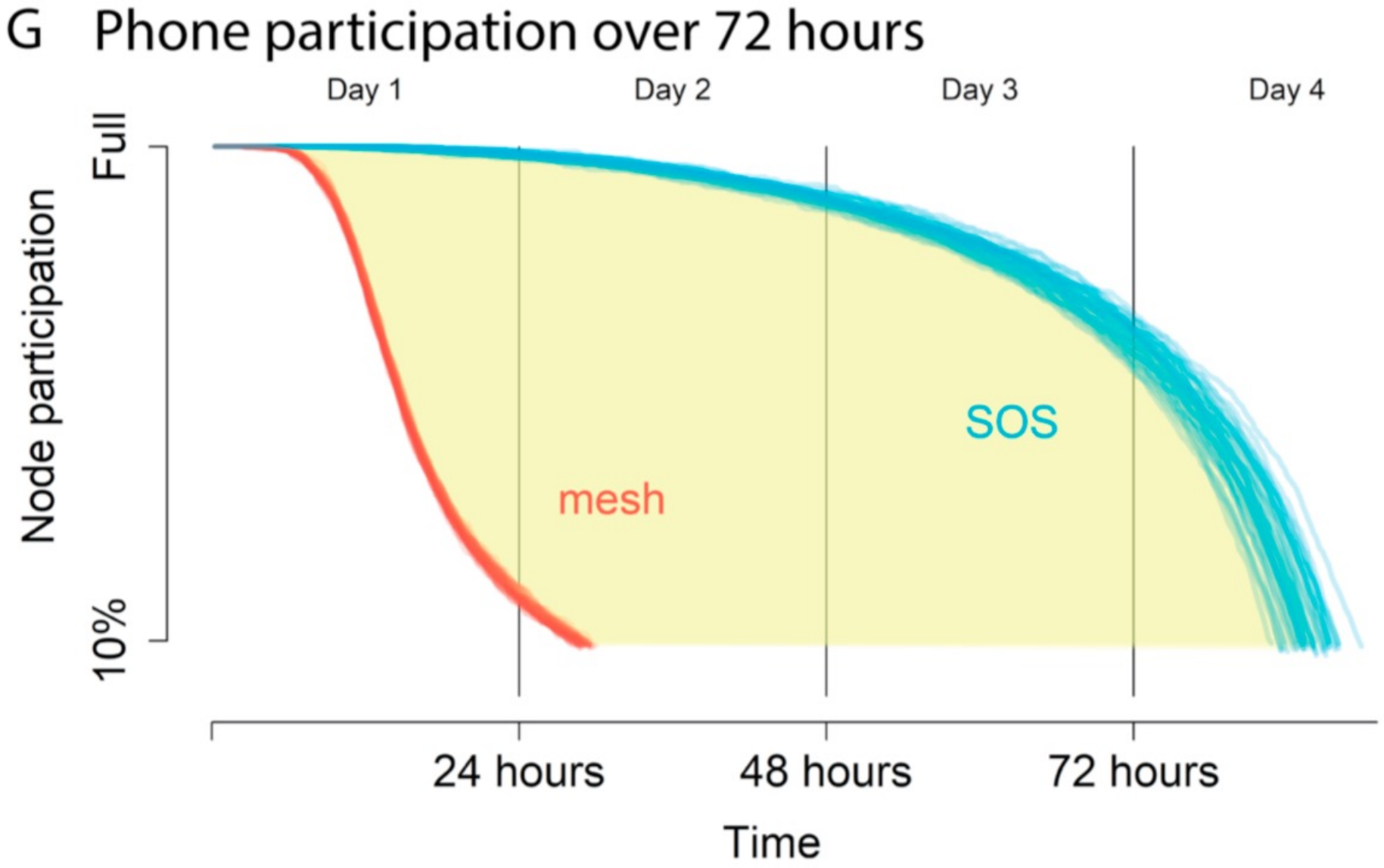
ABSTRACT

Participatory resilience of disaster-struck communities requires reliable communication for self-organized rescue, as conventional communication infrastructure is damaged. Disasters often lead to blackouts preventing citizens from charging their phones, leading to disparity in battery charges and a digital divide in communication opportunities. We propose a value-based emergency communication system based on participatory fairness, ensuring equal communication opportunities for all, regardless of inequality in battery charge. The proposed infrastructure-less emergency communication network automatically and dynamically (i) assigns high-battery phones as hubs, (ii) adapts the topology to changing battery charges, and (iii) self-organizes to remain robust and reliable when links fail or phones leave the network. The novelty of the proposed mobile protocol compared to mesh communication networks is demonstrated by comparative agent-based simulations. An evaluation using the Gini coefficient demonstrates that our network design results in fairer participation of all devices and a longer network lifetime, benefiting the community and its participants.

Battery charge inequality over 72 hours



https://www.nature.com/articles/s41598-021-86635-y



https://www.nature.com/articles/s41598-021-86635-y

FuturICT: Simulator stellt Weltbild auf den Kopf

Lösung globaler Probleme braucht Verstehen unsichtbarer Interaktionen

Galileo 2.0

Um komplexe Syteme zu verstehen, ist ein Paradigmenwechsel erforderlich. "Wir brauchen ein Umdenken weg von der sichtbaren Welt der Komponenten, hin zur unsichtbaren, nur indirekt erschließbaren Welt der Interaktionen. Dieses Umdenken wird vielleicht so radikal sein wie der Wandel vom geozentrischen zum heliozentrischen Weltbild", betont der ETH-Forscher.

Während ohne Letzterem die moderne Physik oder Satelliten im All kaum vorstellbar gewesen wäre, sei das neue Umdenken für die Lösung globaler Herausforderungen wie etwa die Finanzkrise nötig. "Wenn wir die Interaktionen richtig wählen, können wir die Tendenz zur Selbstorganisation nutzen. Das läuft auf mehr Bottom-Up-Ansätze heraus, für die es aber die richtigen Spielregeln braucht. Diese gilt es in Simulationen zu erforschen."

Ampeln steuern sich selbst

«An ungelöste Probleme gingen wir mit dem falschen Verständnis heran»

Komplexitätsforscher Dirk Helbing über Gewaltkonflikte, Epidemien und Datenmissbrauch

Gaza-Konflikt: Gewalt erzeugt Racheaktion

Foto: M. Torokman/Reuters

The world did not sufficiently allow for fundamental socio-economic innovation, thereby producing the perfect recipe for disaster and polycrisis...

What is needed are empowerment, coordination, and self-organization supported by digital assistance.