Disruptive Technologies or Disrupting the Narratives? Transdisciplinary Challenges and Opportunites in Smart Cities

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Modeling and Optimization for Vehicle Electrification, Mobility, Energy and Novel Topics (MOVEMENT) Research Group

Christmas 2024 with my colleague Prof. T. Hofman (left)

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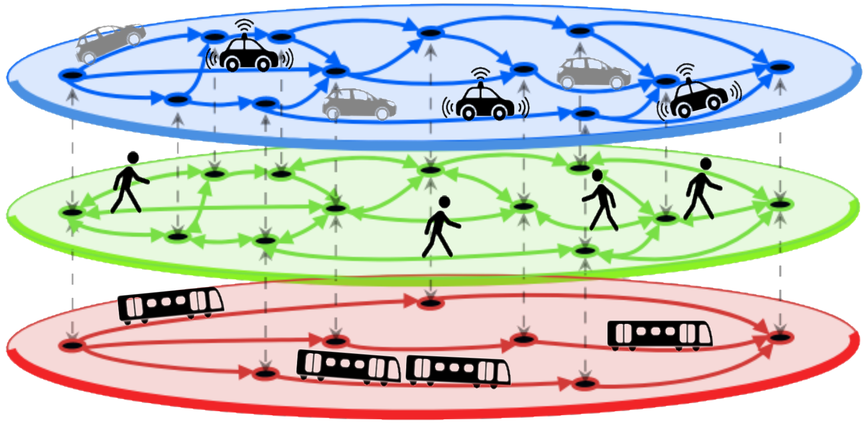
Prof. Huub Brouwer

Dr. A. Piazza

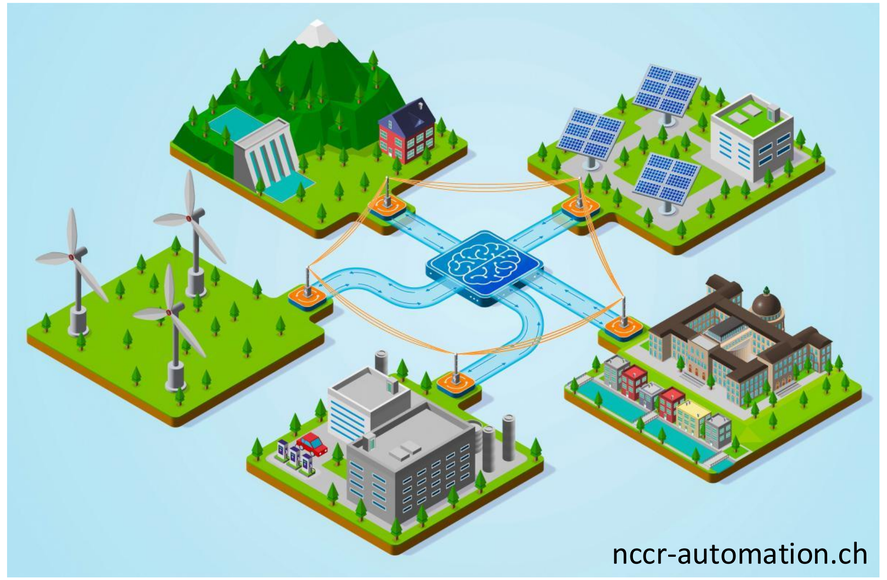
MOVEMENT RESEARCH GROUP

Focus Areas of the TC Smart Cities



Interfacing technology, society, and the environment in **interdisciplinary socio-technical** systems:

- Transportation and mobility
- Energy and power grid
- Water management
- ...



SCAN ME

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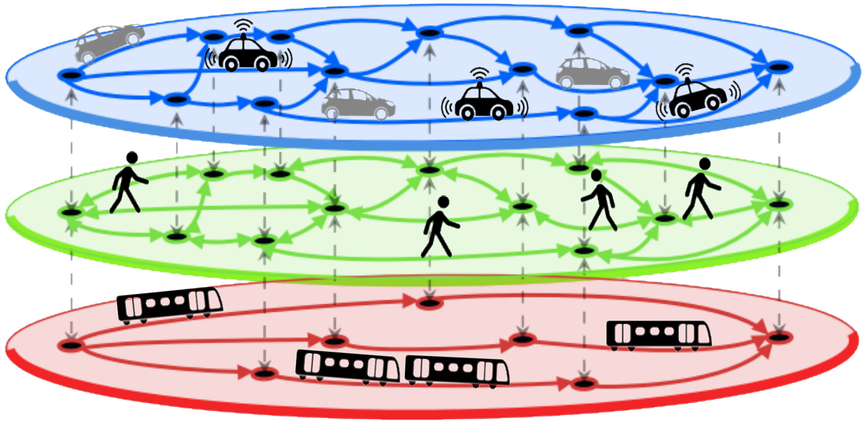
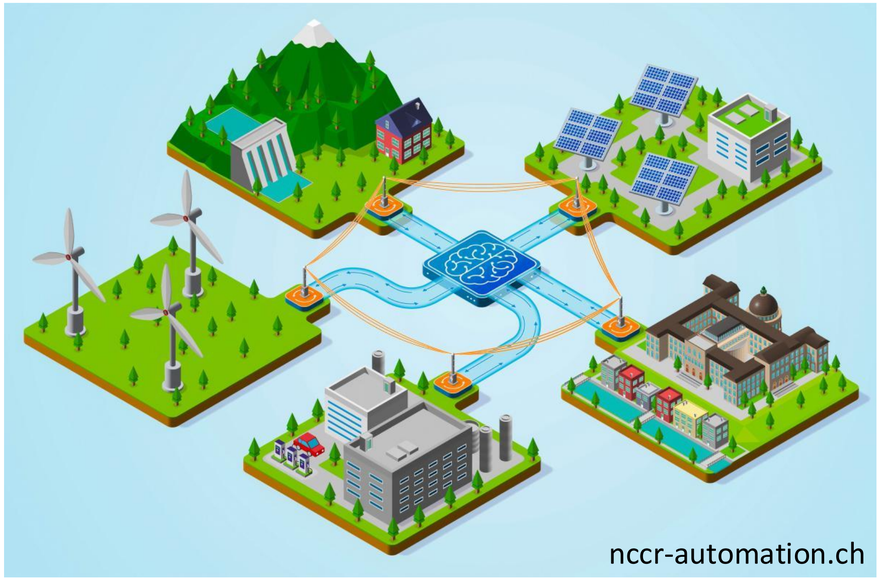
“Artifacts have politics”



L. Winner (1980):
The technological artifacts we deploy in society can be a mechanism for setting the affairs of a community!



LANGDON WINNER

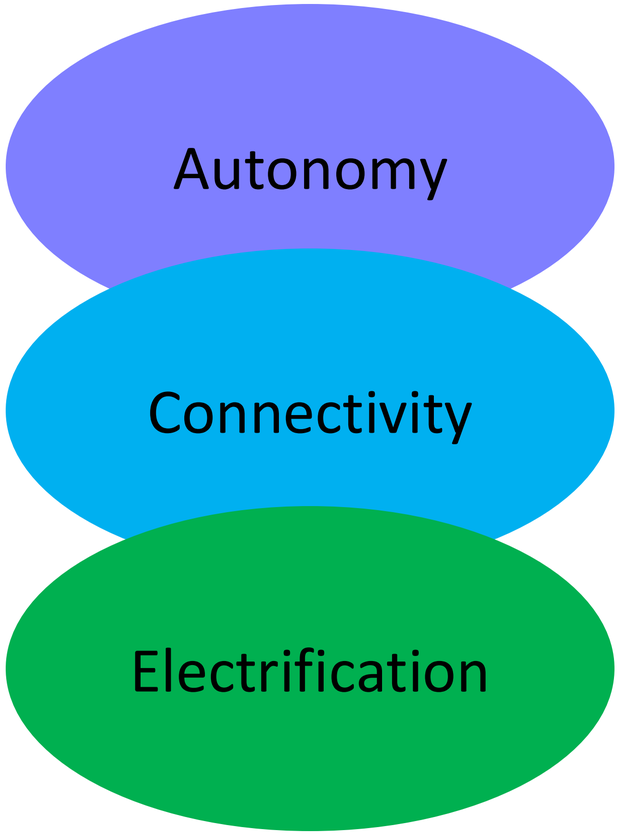
Do Artifacts Have Politics?

IN CONTROVERSIES ABOUT TECHNOLOGY AND SOCIETY, there is no idea more provocative than the notion that technical things have political qualities. At issue is the claim that the machines, structures, and systems of modern material culture can be accurately judged not only for their contributions of efficiency and productivity, not merely for their positive and negative environmental side effects, but also for the ways in which they can embody specific forms of power and authority. Since ideas of this kind have a persistent and troubling presence in discussions about the meaning of technology, they deserve explicit attention.[1]

L. Winner (1944-)

Use technology to solve societal problems?

The Engineering Trap



?

Disruptive technologies = societal solutions?

E.g., a decade ago, TNCs (E.g., Uber and Lyft) promised to address congestion, emissions and justice issues.

Instead, they ended up making the situation worse…
Erhardt et al. Science Advances 2019
Diao et al. Nature Sustainability 2021
Turón Entrepreneurship and Sustainability Issues 2021

Now, we are risking to fall into another **engineering trap**, engineering **disruptive answers** to the **wrong question**…

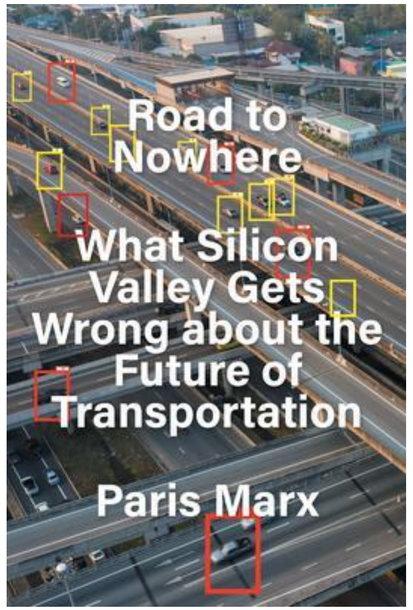
This is also because of the Collingridge dilemma…

WSJ

TRANSIT

MTA Blames Uber for Decline in New York City Subway, Bus Ridership

Usage dips for mass transit coincided with taxi and ride-hailing trips, data shows



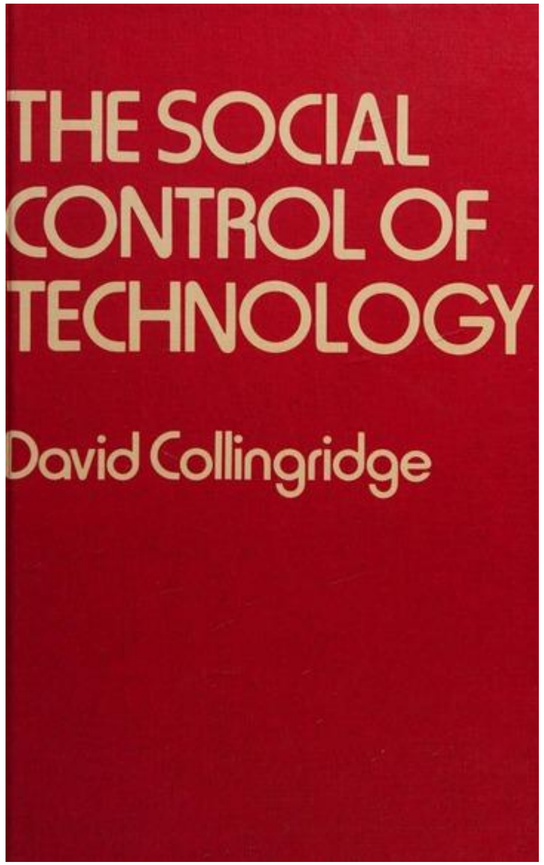
The Collingridge Dilemma and our Responsibility

- Ex-ante, **lack of information**: societal impacts cannot be easily predicted until a technology is extensively developed and widely used.

- Ex-post, **lack of control power**: control or change is difficult when the technology has become entrenched in society.

Potential approach: Infusing societal and environmental responsibility **ex-durante**, throughout the design and planning process?

Paris, 1793: “Ils doivent envisager qu’une grande responsabilité est la suite inséparable d’un grand pouvoir.”

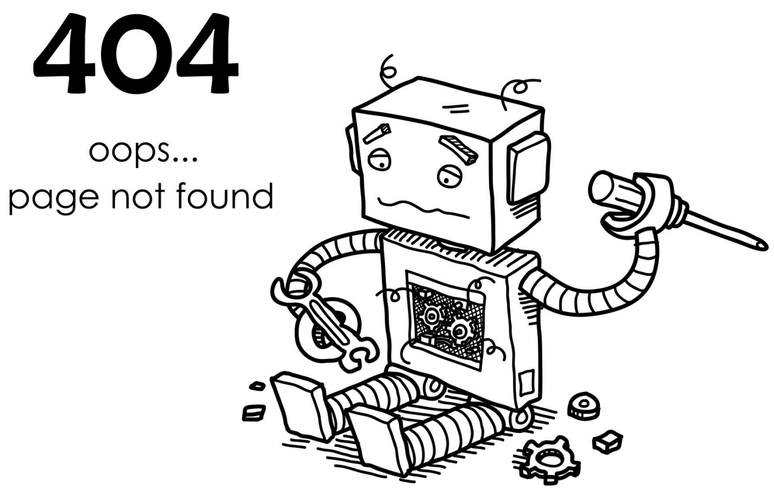


David Collingridge, “The Social Control of Technology”, St. Martin's Press, 1980

A Double **How**

How can we integrate all these technologies within **smart cities**?

1. In line with which principles?



Ethics? Justice? Wellbeing?

2. What are implementable solutions?

A Moral Compass for Smart Cities?

A Moral Compass for Smart Cities?

Fundamental Human Rights
Article 1: *All individuals **free and equal** in dignity and rights.*
Article 3: *Right to life, liberty and security of person.*
Article 13: *Right to freedom of movement.*
Article 23: *Right to work and just conditions.*
Article 25: *Right to an adequate standard of living.*
…

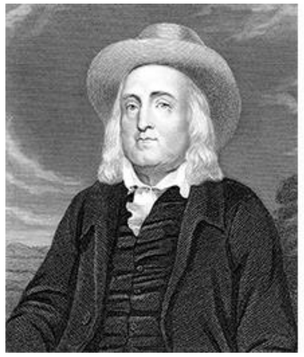
Uncontroversial because quite **abstractly** framed…
…the devil is in the **details**!

For instance, what is just? What is adequate?
Is one good more important than another?

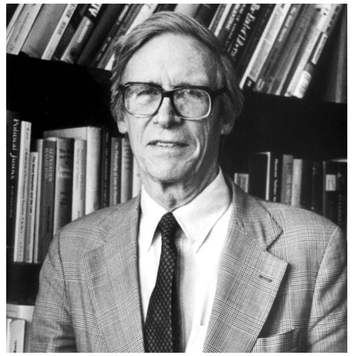
Philosophy?

Conceptual Principles from Philosophy

Theories of Justice (incomplete)

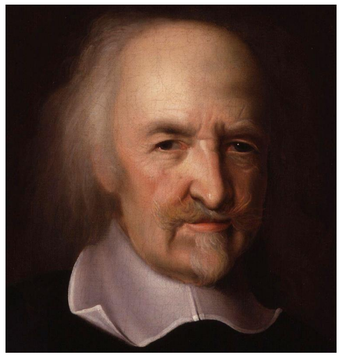


Utilitarianism
J. Bentham (1748-1832) and J. Stuart Mill (1806-1873)



(Luck) Egalitarianism
J. Rawls (1921-2002) and R. Dworkin (1931-2013)

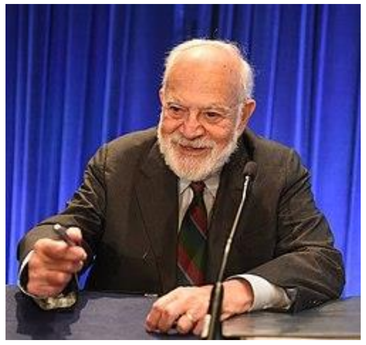
Theories of Wellbeing (incomplete)



Hedonism
T. Hobbes (1588-1679)

Eudaimonia
Aristotle (384-322 BC)

Desire-satisfaction
Heathwood (1977-)



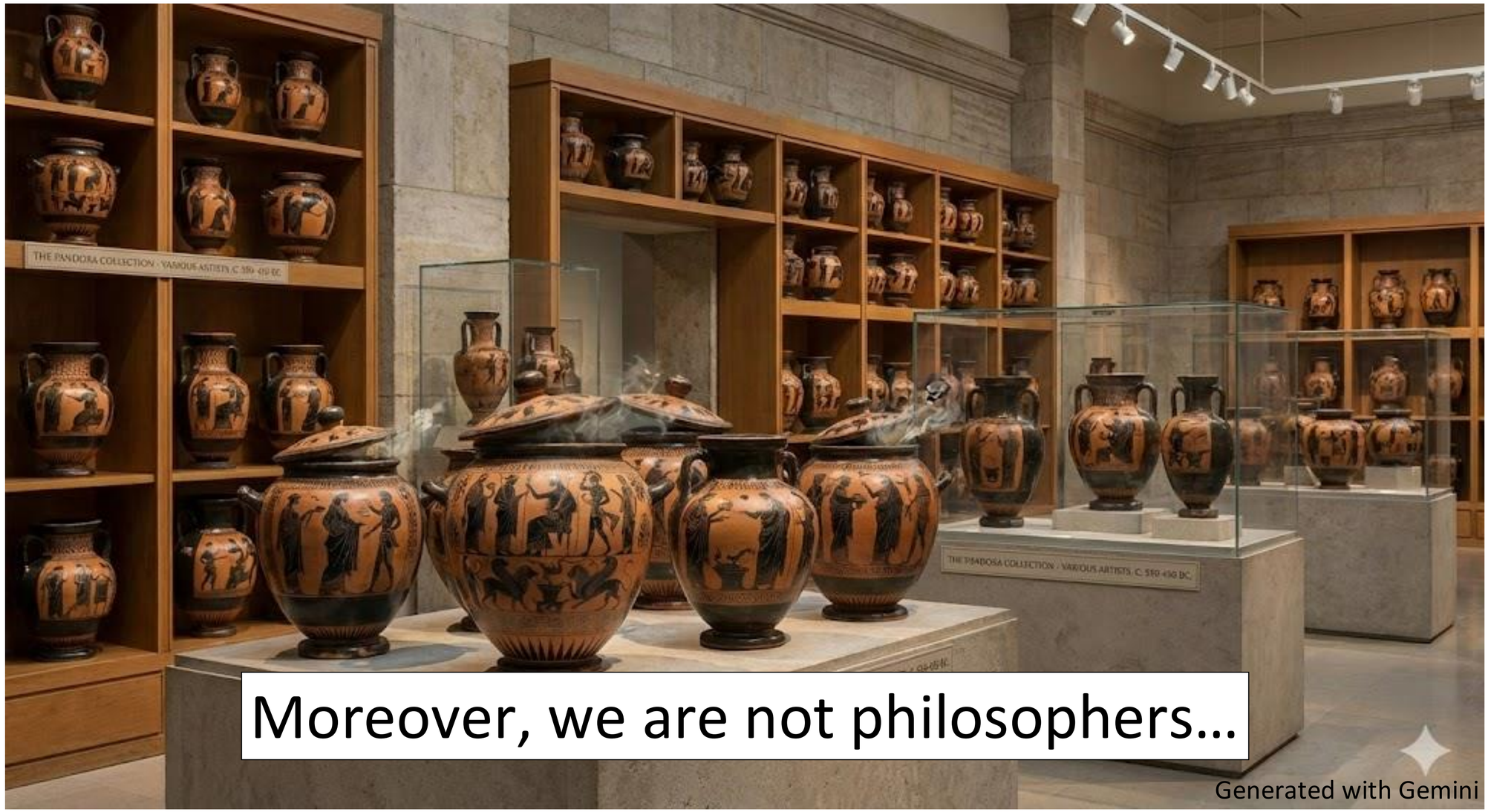
Sufficientarianism
H. Frankfurt (1921-2002)

Limitarianism
I. Robeyns (1972-)

Relational Egalitarianism
E. Anderson (1959-)

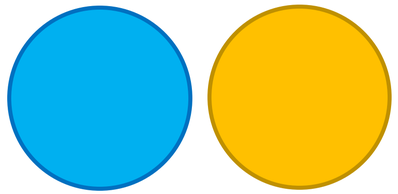
Capabilities Approach
A. Sen (1933-) and M. Nussbaum (1947-)

Caution: Often more Questions than Answers…

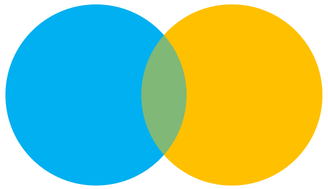


Feels like a Pandora vases' library…

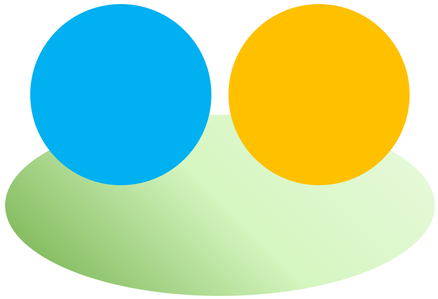
Need for a Transdisciplinary Perspective Transcending Engineering



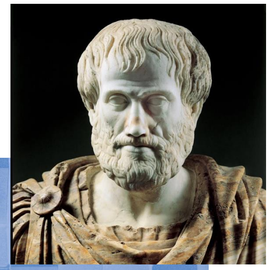
Multidisciplinarity

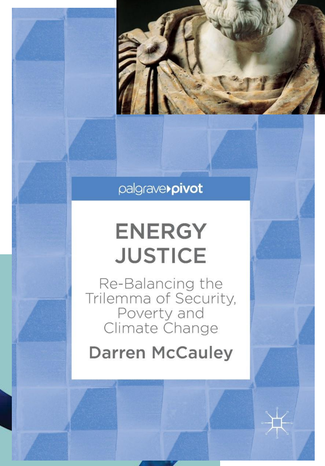


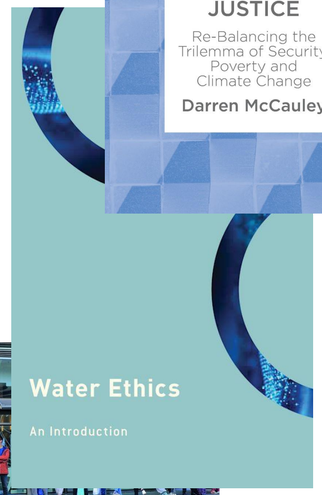
Interdisciplinarity

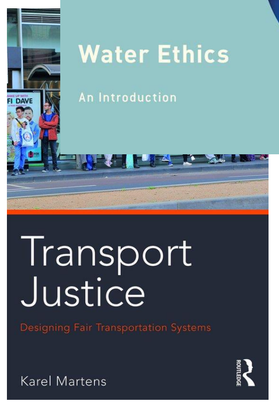


Transdisciplinarity







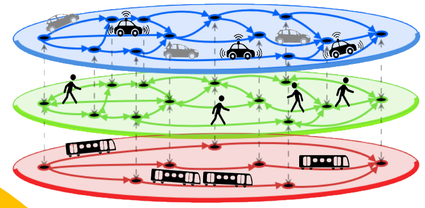


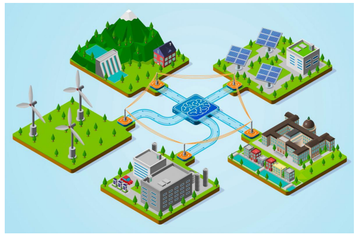
Social Sciences and Humanities
Justice and wellbeing
Principles
Quantitatively descriptive
Qualitatively prescriptive

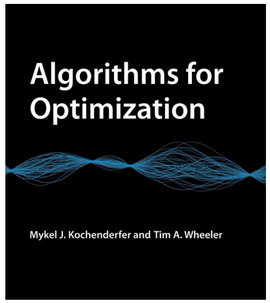
Engineering

Control and optimization models and methods
Quantitatively descriptive and prescriptive

Nexus
for a responsible control and optimization frameworks for smart cities



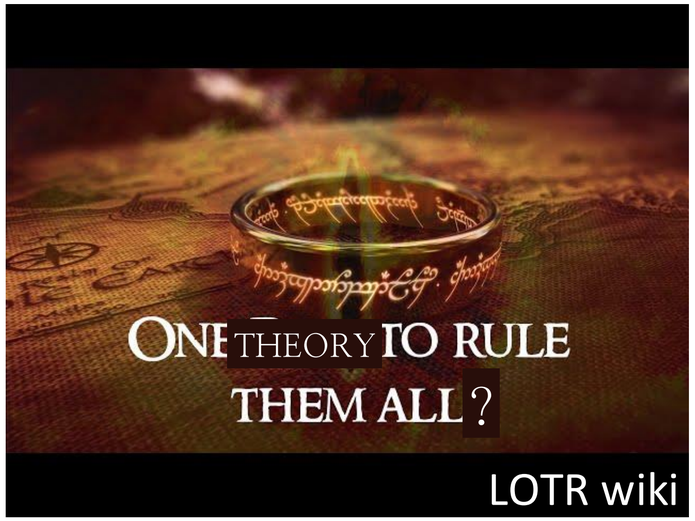


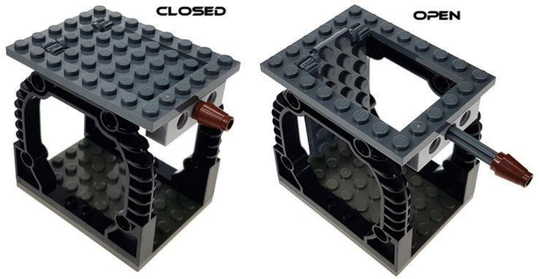


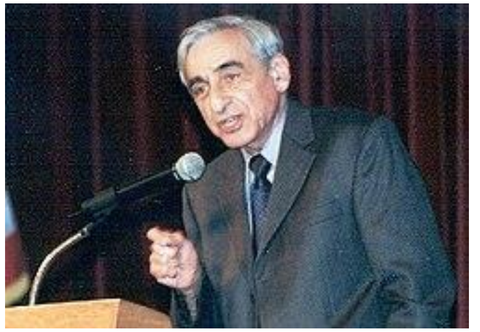
Principles for Smart Cities?

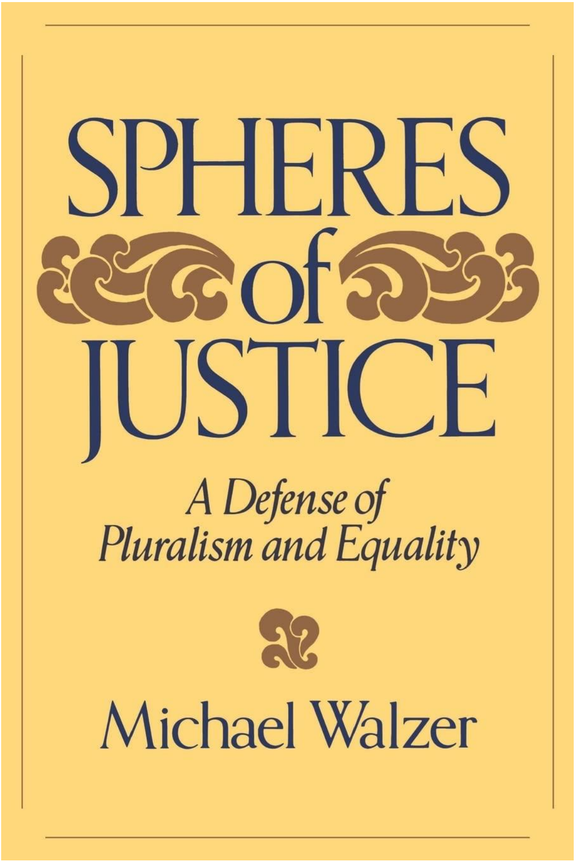
For instance, to reason on the allocation of social goods beyond prosperity, income and wealth…

…we need **operationalized principles of justice!**





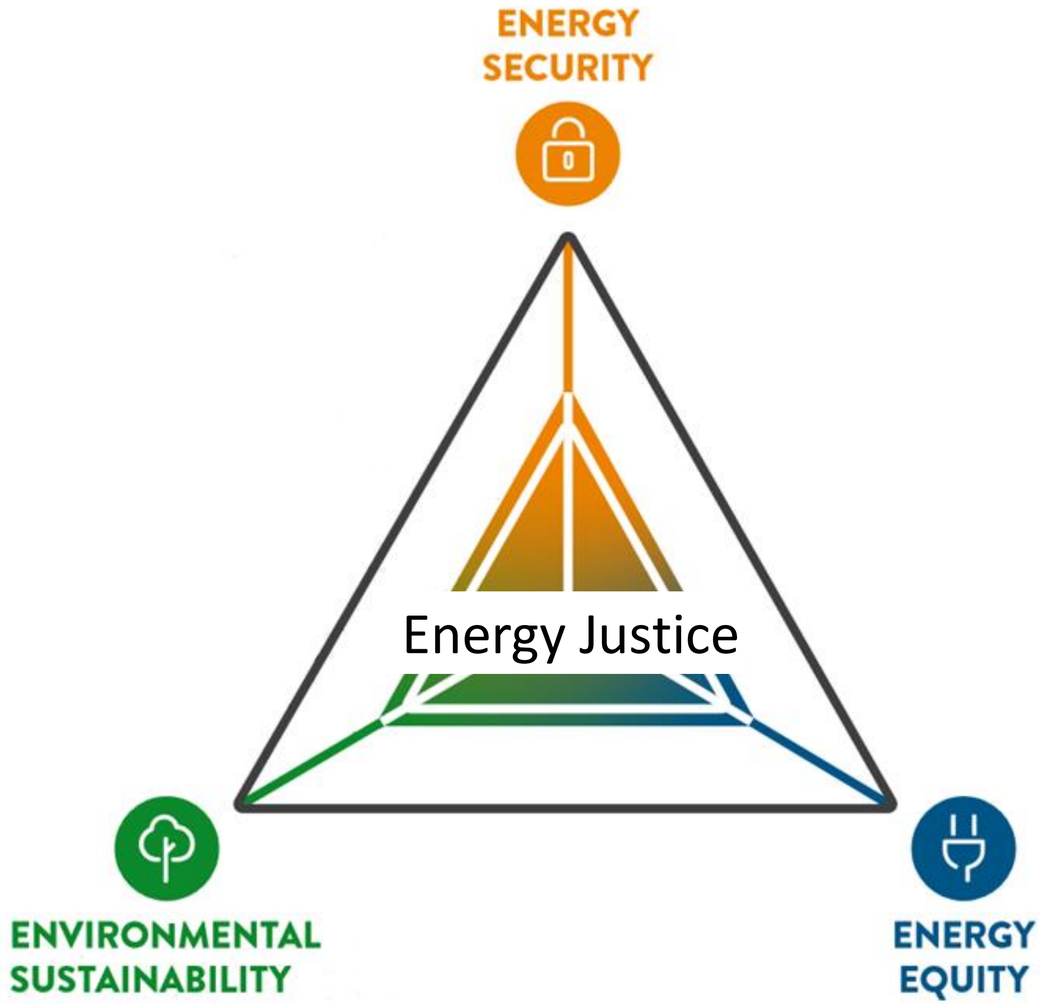


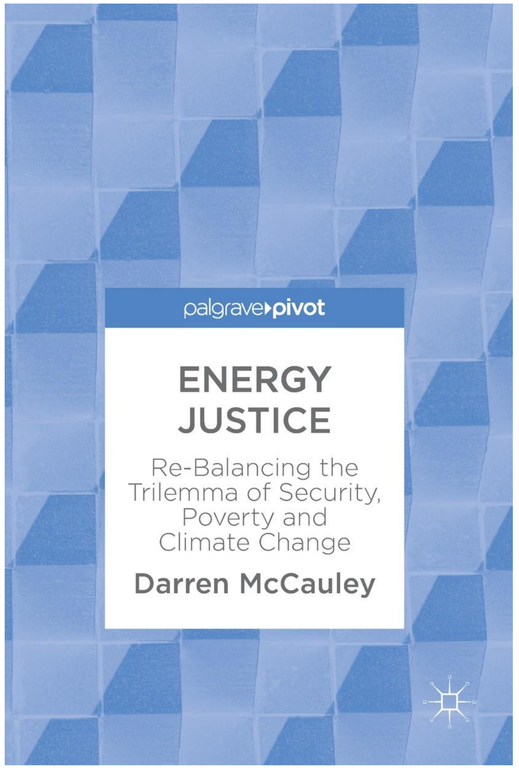


M. Walzer: “different social goods should be distributed according to different principles”

Michael Walzer, “Spheres of Justice – A Defense of Pluralism and Equality”, Basic Books, 1983

The Energy Justice Trilemma





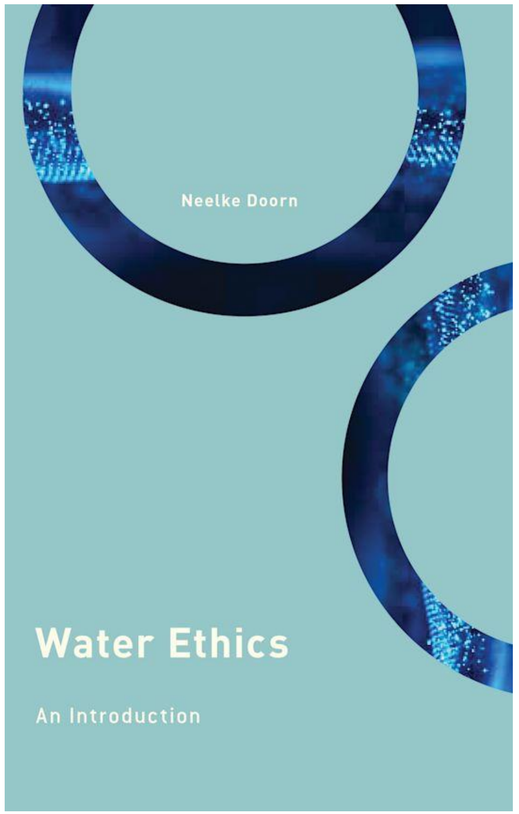
D. McCauley, “Energy Justice: Re-Balancing the Trilemma of Security, Poverty and Climate Change”, Springer, 2017

Water Ethics

Water ethics reframes water not as a mere resource but as a shared, sacred, and ecological foundation for life.

It challenges technocratic and market-driven paradigms, advocating for justice, sustainability, and cultural respect in policy and practice.

Multiple dimensions of justice
Distributive justice: Fair distribution of water to the population
Procedural justice: Inclusive decision-making with multiple stakeholders
Restorative justice: Address historical dispossession and inequities



N. Doorn, “Water Ethics”, Bloomsbury, 2019

What about Transportation?

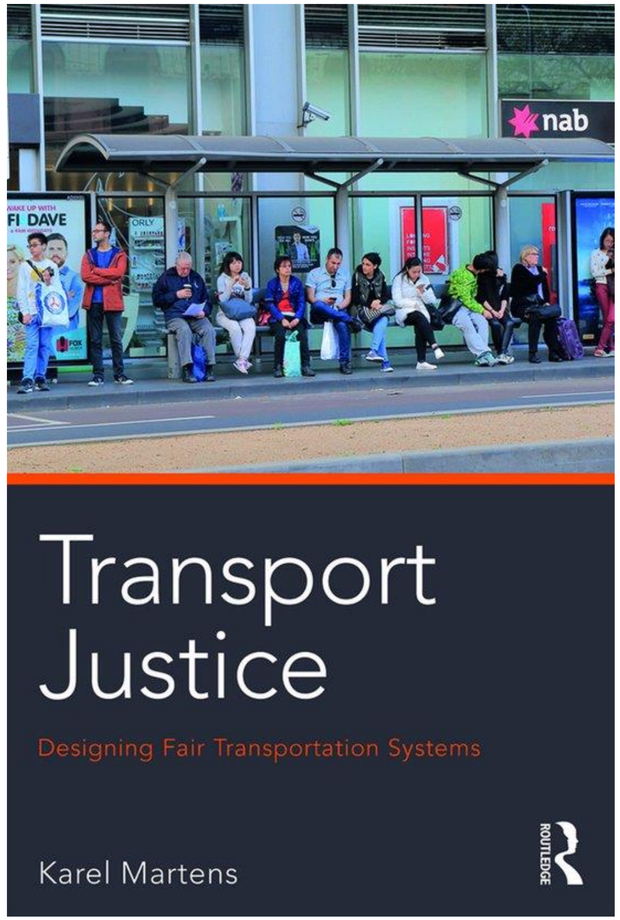
Is minimizing average travel time the right objective?

The purpose of transportation is to provide **accessibility**

What is **accessibility**? Measure of **freedom** to get to places

For instance, destinations reachable **reasonably** (e.g., in 20min)…

How should we distribute it?



Martens, “Transport Justice – Designing Fair Transportation Systems”, Taylor Francis - Routledge, 2017
Ryan, Martens, “Defining and Implementing a Sufficient Level of Accessibility: What’s Stopping Us?”, TRPA, 2023

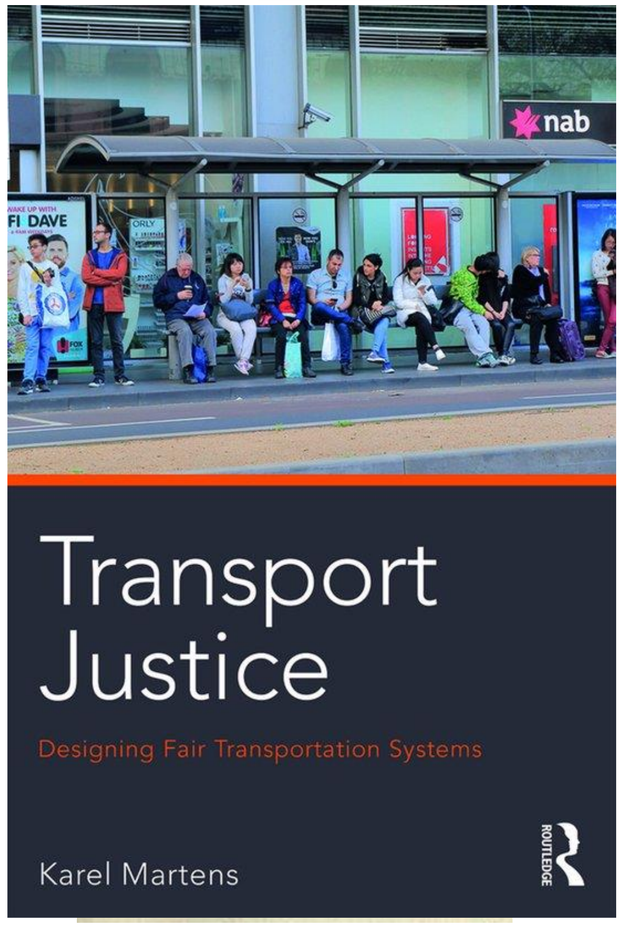
Which principle of justice?

Utilitarianism:*"greatest good for the greatest number"*, Bentham and Stuart Mill 1800s:
*Maximize good / Minimize bad **on average***

But what about the **worse off**? Often, they are the ones **suffering** from utilitarian principles

Sufficientarianism: *"make sure everyone has enough"*, Walzer 1983, Crisp 2003 and Martens 2017:
*Minimize **deficit** to a **sufficiency** threshold*

Beyond **utilitarian efficiency** by **mobilizing transport justice: Sufficientarian** perspectives on **accessibility**

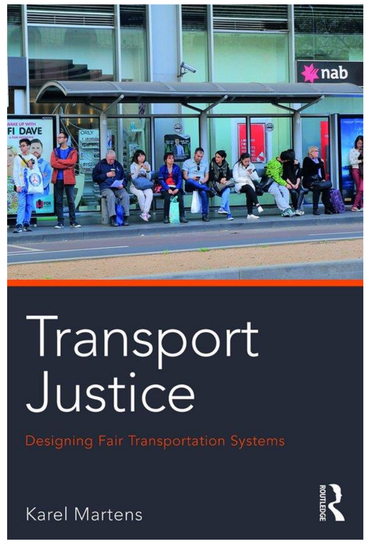


Stuart Mill, "Utilitarianism", Parker, Son, and Bourn, 1863
Martens, "Transport Justice – Designing Fair Transportation Systems", Taylor Francis - Routledge, 2017
Salazar, Betancur Giraldo, Paparella, Pedroso, **Martens**, "Mobilizing Transport Justice: A Sufficientarian Optimization Framework for Intermodal Mobility Systems", NPJ Sustainable Transport and Mobility, 2025

Example on Intermodal Autonomous Mobility-on-Demand

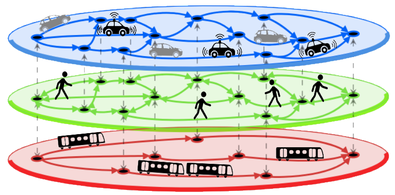
Sufficientarianism:
Provide enough reachable destinations

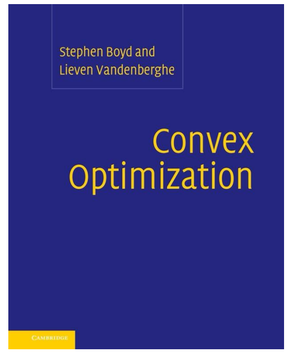
(MI) Convex network flow model:
$\min \sum \max\{0, N_{\text{suff}} - N_r\}^2$



Social Sciences and Humanities
Justice and wellbeing principles for evaluation

Engineering
Optimization models and methods for co-design

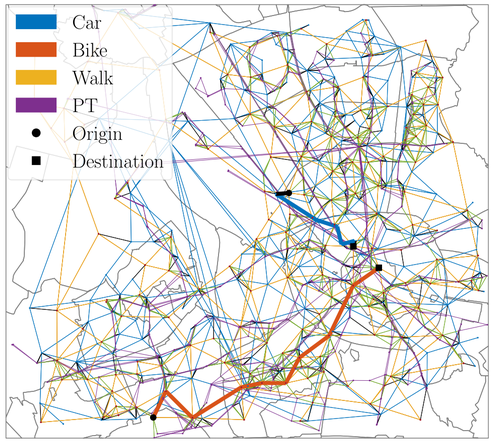




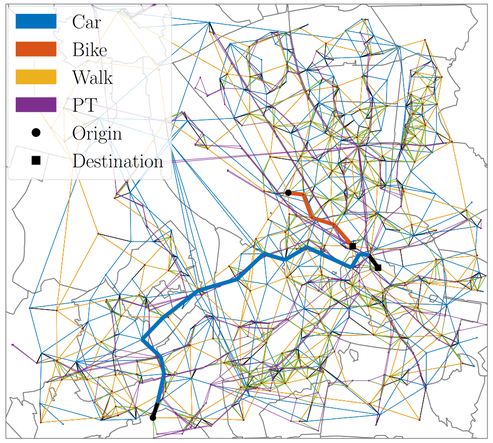
Nexus
Nexus for a conceptual, modeling and optimization framework

Other examples?

Utilitarian Status Quo



Sufficientarian Approach



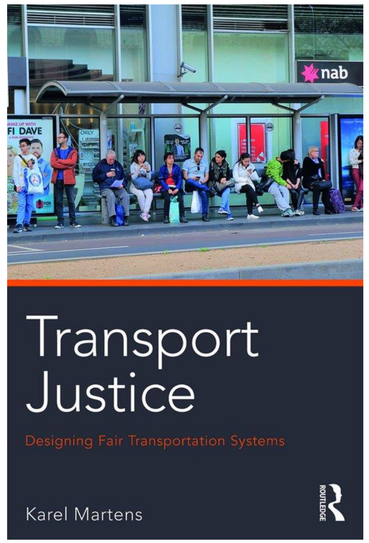
Can be **FAIR** without loosing **EFFICIENCY!**

Salazar, Betancur Giraldo, Paparella, Pedroso, “On Accessibility Fairness in Intermodal AMoD Systems”, IFAC CTS, 2024
Salazar, Betancur Giraldo, Paparella, Pedroso, **Martens**, “Mobilizing Transport Justice: A Sufficientarian Optimization Framework for Intermodal Mobility Systems”, NPJ Sustainable Transport and Mobility, 2025

Example on Cycling Infrastructure Upgrade

Sufficientarianism:
Provide sufficient level of safety

Bi-level network design model:
$\min \sum \max\{0, S_{\text{suff}} - S_r\}^2$



Social Sciences and Humanities
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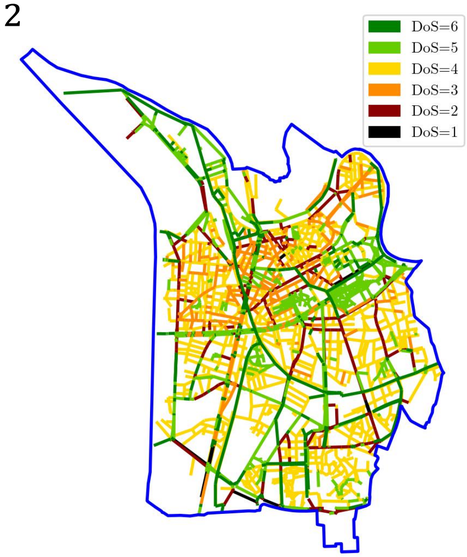
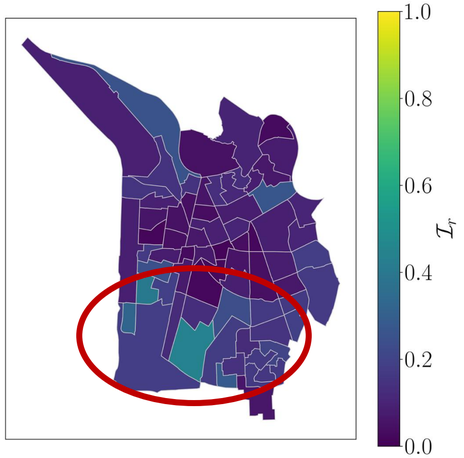
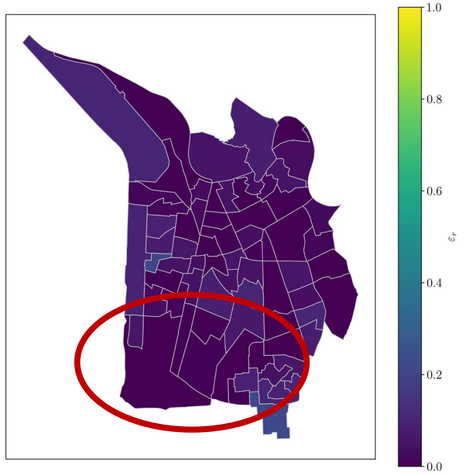


Safety Insufficiency Map





Problem solved?

Can be **FAIR** without loosing **EFFICIENCY!**

Campero Jurado, De Nunzio, Canudas De Wit, **Salazar**, “On Transport Justice and Safety in Bicycle Network Design Optimization”, IEEE CDC 2025

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Even More Questions Open?

Behrendt, Sheller, “Mobility data justice” Mobilities, 19(1), 151–169, 2023

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MOVEMENT RESEARCH GROUP

Conclusion: No clear answers, but more of an alpine path towards **Responsible Innovation**

- **Transdisciplinary** efforts required
- We have the right **forma mentis** to do so
- **Value-driven** and **consciously partial** efforts
- **Ex-durante** approach vs Collingridge Dilemma
- Crossing a room of **Pandora vases**

Link to the IEEE CSS TC on Smart Cities

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"Before being engineers, we are first and foremost humans"