EPA Master Thesis Project
Ariel Goldin Marcovich
Chair: Dr. Neelke Doorn
1st Supervisor: Dr. Jazmin Zatarain Salazar
External Supervisor: Dr. Edmundo Molina-Pérez

How to Distribute Water Fairly When there's not Enough:

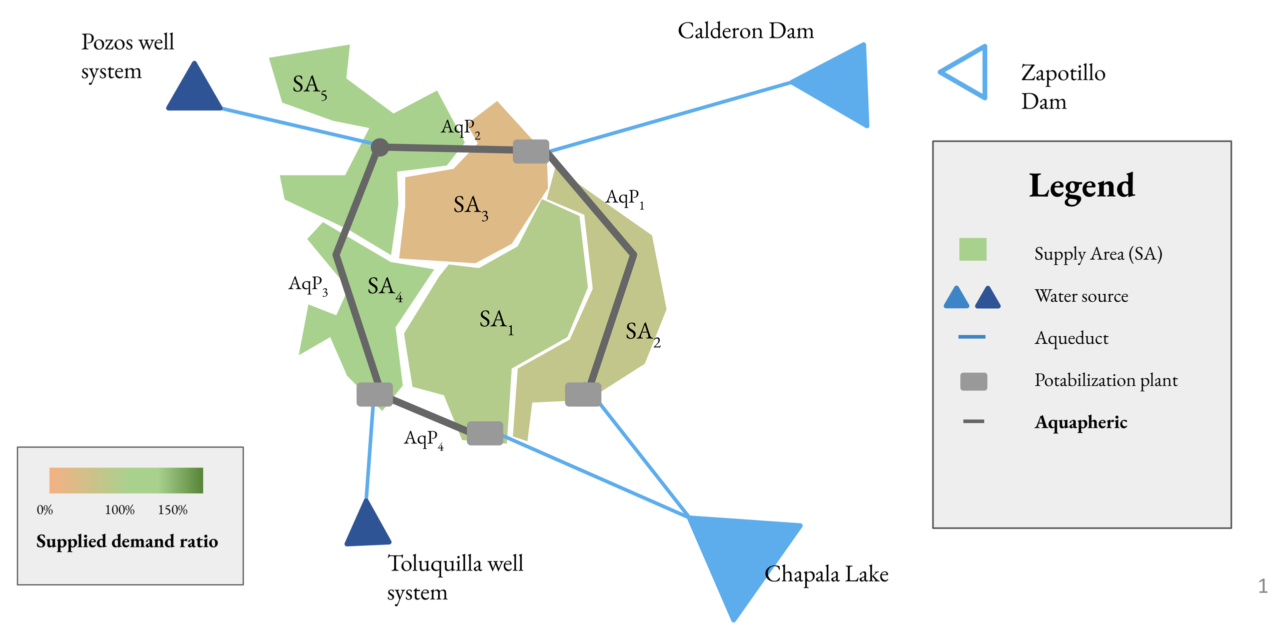
A Participatory and Simulation-Based Process Towards Distribution Policies for Guadalajara's Aquapheric with a Distributive Justice and Deep Uncertainty Approach

TU Delft
Escuela de Gobierno y Transformación Pública
Tecnológico de Monterrey

THE DECISION-MAKING PROBLEM

Fair distribution of water during drought using the Aquapheric in Guadalajara, Mexico

In 2020, due to a severe drought and a spike in consumption due to COVID, the Calderon dam reached critical levels and had to be shut down. Because the system is **compartimentalized**, meaning that each source supplies only one area of the city, the other sources couldn't compensate leaving around **500,000** inhabitants without water supply for more than **3 months**..



In response to this vulnerability, in 2022, the Government built the **Aquapheric** (AqP): a circular aqueduct that interconnects the five supply areas and can pump up to **1 m3/s** of water in both directions in each of its four segments independently. This infrastructure can significantly increase the city's resilience to drought, however, an operation policy has not yet been made.

RESEARCH QUESTION

How can we design distribution policies for Guadalajara's Aquapheric to distribute water fairly during drought?

The complexity of the problem further increases due to uncertainties associated and the constrains on the possible distribution.

Uncertainties

- **Values**: Lack of agreement of who should get how much during drought
- **System**: Leakage, demand, extraction, etc
- **The future**: Availability, new infrastructure, economic and population increase

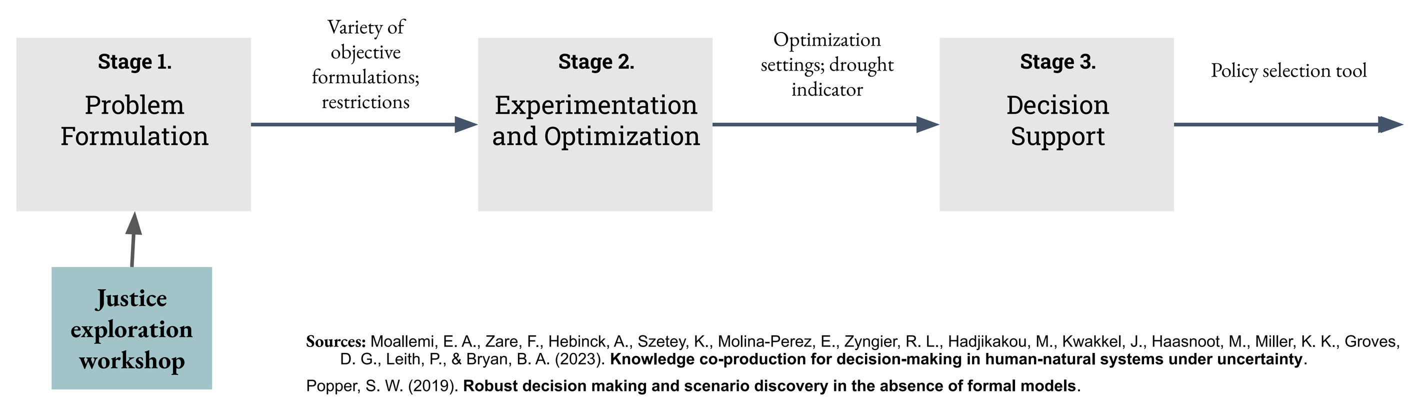
Constraints

- **Distribution**: Non homogeneous Supply Areas, emergent measures
- **Political**: Legal frameworks, agreements, contracts
- **Infrastructure**: Maximum flows, energy consumption

THE PROPOSAL

Participatory & simulation-based process for designing distribution policies

The research is proposed in 3 stages:



Sources: Moallemi, E. A., Zare, F., Hebinck, A., Szetey, K., Molina-Perez, E., Zyngier, R. L., Hadjikakou, M., Kwakkel, J., Haasnoot, M., Miller, K. K., Groves, D. G., Leith, P., & Bryan, B. A. (2023). **Knowledge co-production for decision-making in human-natural systems under uncertainty**.

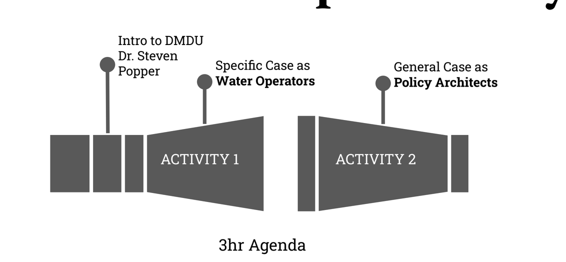
Popper, S. W. (2019). **Robust decision making and scenario discovery in the absence of formal models**.

Helgeson, C., Srikrishnan, V., Keller, K., & Tuana, N. (2021). **Why Simpler Computer Simulation Models Can Be Epistemically Better for Informing Decisions**.

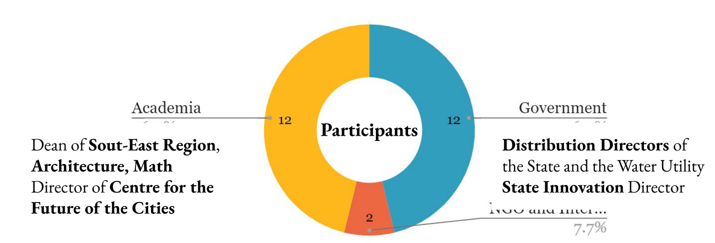
Stage 1

Problem formulation

1.1. Workshop summary



Non-prescriptive, non-convergent structured* participatory workshop design



Sources: *Afsar, B., Silvennoinen, J., & Miettinen, K. (2023). A Systematic Way of Structuring Real-World Multiobjective Optimization Problems.

1.2 Participatory formulations for exploration

	Principle	Indicator	Drought conditions
Table 1	Egalitarian	Supply per capita	All drought conditions
	Sufficientarian (100l)		
Table 2	Energy efficiency	Costs per m3 per segment	Low drought
	Utilitarian	Supply per capita	
	Sufficientarian (non specified)*	Supplied demand	Mid drought
	Prioritarianism	Non-specified	Severe
Table 3	Egalitarian	Supply per capita	All drought conditions
Table 4	Utilitarian	Flow deficit	Low drought
	Sufficientarian (127l)	Supply per capita	
	Sufficientarian (100l)		Mid drought
	Sufficientarian (50l)		Severe
	Prioritarianism	Marginalization Index	
	Egalitarian	Supplied demand	

Key insights

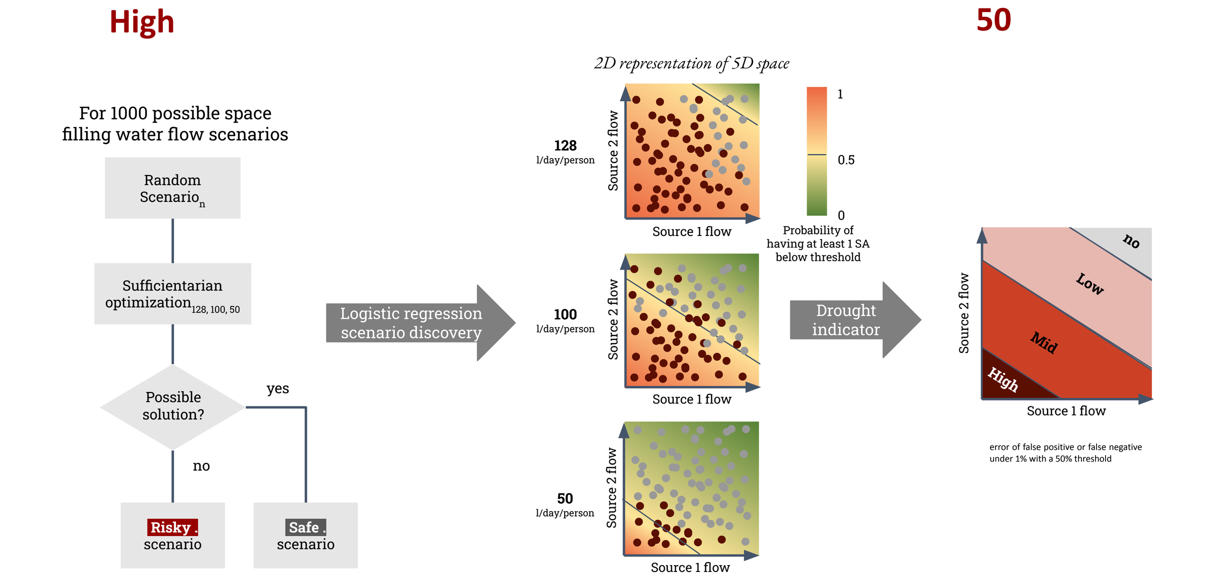
- Set of objectives is **non-definitive** and non-sufficient → **useful for exploration**
- **Egalitarian** principle with supply per capita is **most recurrent**
- **Prioritarian** principle **non-formalized**
- **Cost objective** could be relevant
- **Sufficientarian** principle associated with drought (**128, 100 or 50** l/day/person)

Stage 2

Optimization and experimentation

2.1 Assumption-based Socioeconomic drought indicator

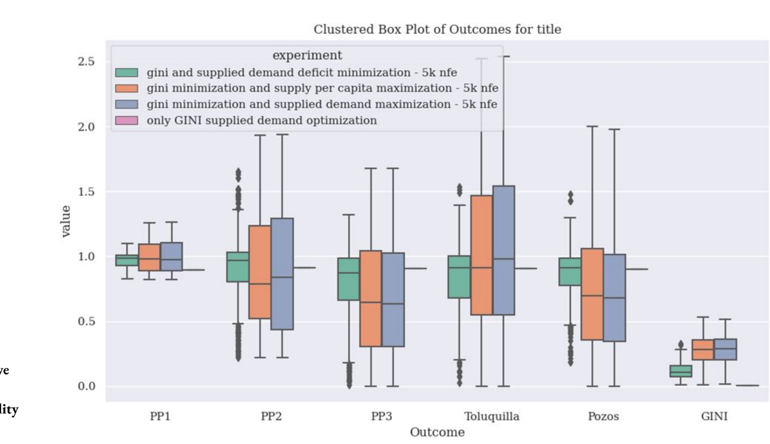
Low / Mid / High drought means that it is likely that at least one SA falls below 128 / 100 / 50 l/day/ person



2.2 A priori formulation for posteriori efficacy

What a priori formulation can reliably provide adequate compromise and best-performing policies for different objectives and for the complete scenario space?

How: Assess distance between policies found with a priori and a posteriori.



Sources: Znabei, M. (2023). **Exploring Distributive Justice In Many-Objective Optimization**

Sarva, S., Kwakkel, J., Salazar, J. Z., & Doorn, N. (2021). **Operationalising stability and fairness in transboundary water resource allocations.**

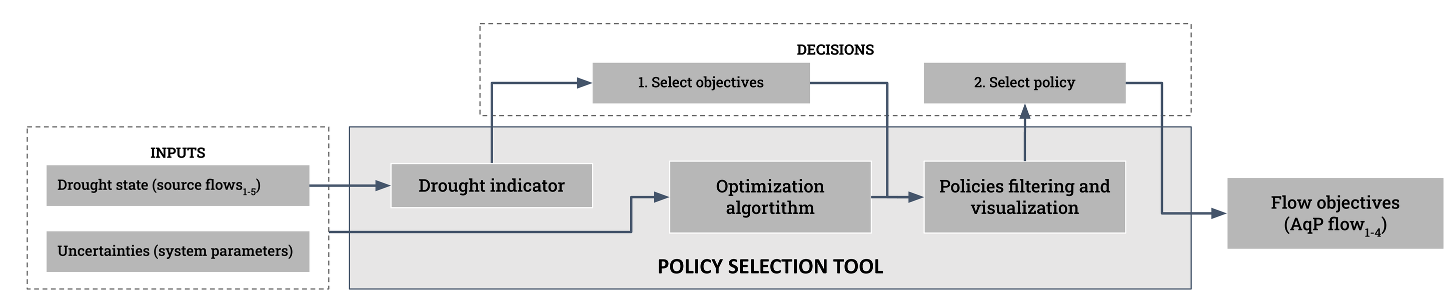
Rimon, F. (2023). **Exploring distributive justice in water resource allocation.**

Stage 3

Decision support

The final tool will enable decision makers to **select objectives** informed by the **drought indicator.** The tool will filter the results of an optimization to identify just policies in an a **posteriori approach**.

We propose **flexibility, learning capacity and knowledge co-creation** as key to support decision making under deep uncertainty for water management.



Uncertainties

- **Values**: **Non-definitive** objective set; Participative and numerical **exploration** of justice interpretation
- **System** / **The future**: Easy-to update model parameters and relations
- **The future**: **All** drought conditions considered

Limitations

- **Infrastructure**: Optimization **constrains**
- **Political**: **Non-prescriptive** policy selection
- **Distribution**: Comprehensive scarcity management **vision**