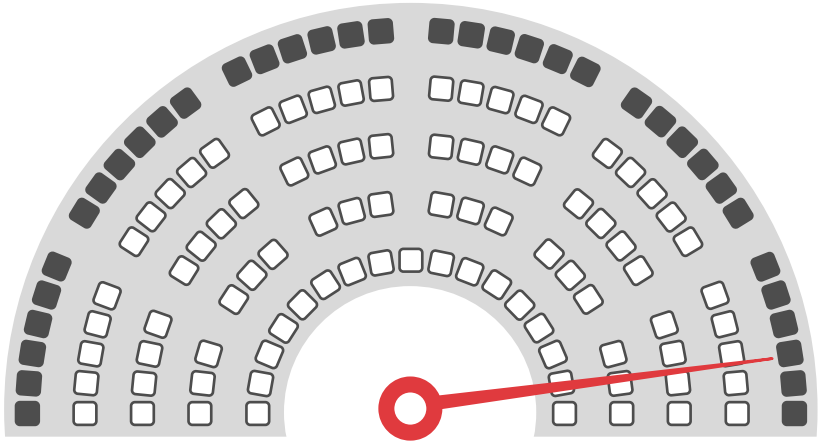


Optimized Democracy

Spring 2023 | Lecture 9

Participatory Budgeting

Ariel Procaccia | Harvard University

PARTICIPATORY BUDGETING

Allocation of a city's budget based on the votes of residents

PARTICIPATORY BUDGETING

Porto Alegre
Brazil
Since 1989

Paris
France
€82M (2022)

Madrid
Spain
€50M (2022)

Boston
USA
Office of PB (2021)

EXAMPLE BALLOT: BOSTON

You have selected **2 / 4** projects.

Water Bottle Refill Stations at Parks
Multiple installations of the water fountain and bottle refill designs at different parks in Boston.

Estimated Cost: $260,000

Location: Parks around Boston, West roxbury, Dorchester,South Boston, Roslindale, Downtown, Fenway

✔ Selected | Remove

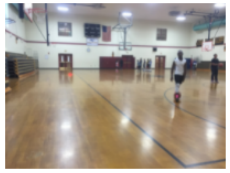
Click image for slide show

BLA Gym Renovations
No more netless hoops and broken bleachers--the BLA gym will be revamped to include newly painted hoops and floors, and repaired bleachers.

Estimated Cost: $475,000

Location: 205 Townsend Street, Roxbury

Select



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Ringer Park Renovation
Renovate the main path in Ringer Playground so it is no longer cracked and safer to walk on.

Estimated Cost: $280,000

Location: Ringer Park, Brighton

✔ Selected | Remove

Click image for slide show

Bike Lane Installation
After a study, bike lanes will begin to be installed around Charlestown Navy Yard, Bunker Hill housing, and Charlestown High.

Estimated Cost: $200,000

Location: Charlestown

Select

Click image for slide show

Wicked Free Wifi 2.0
Wicked free Wi-Fi 2.0 provides Wi-fi at locations with young people.

Estimated Cost: $119,000

Location: Various High Schools and Community Centers, Dorchester, Roxbury, East Boston, Charlestown

Select

Click image for slide show

Track at Walker Park
Build a track that goes around the field that is behind Walker Playground.

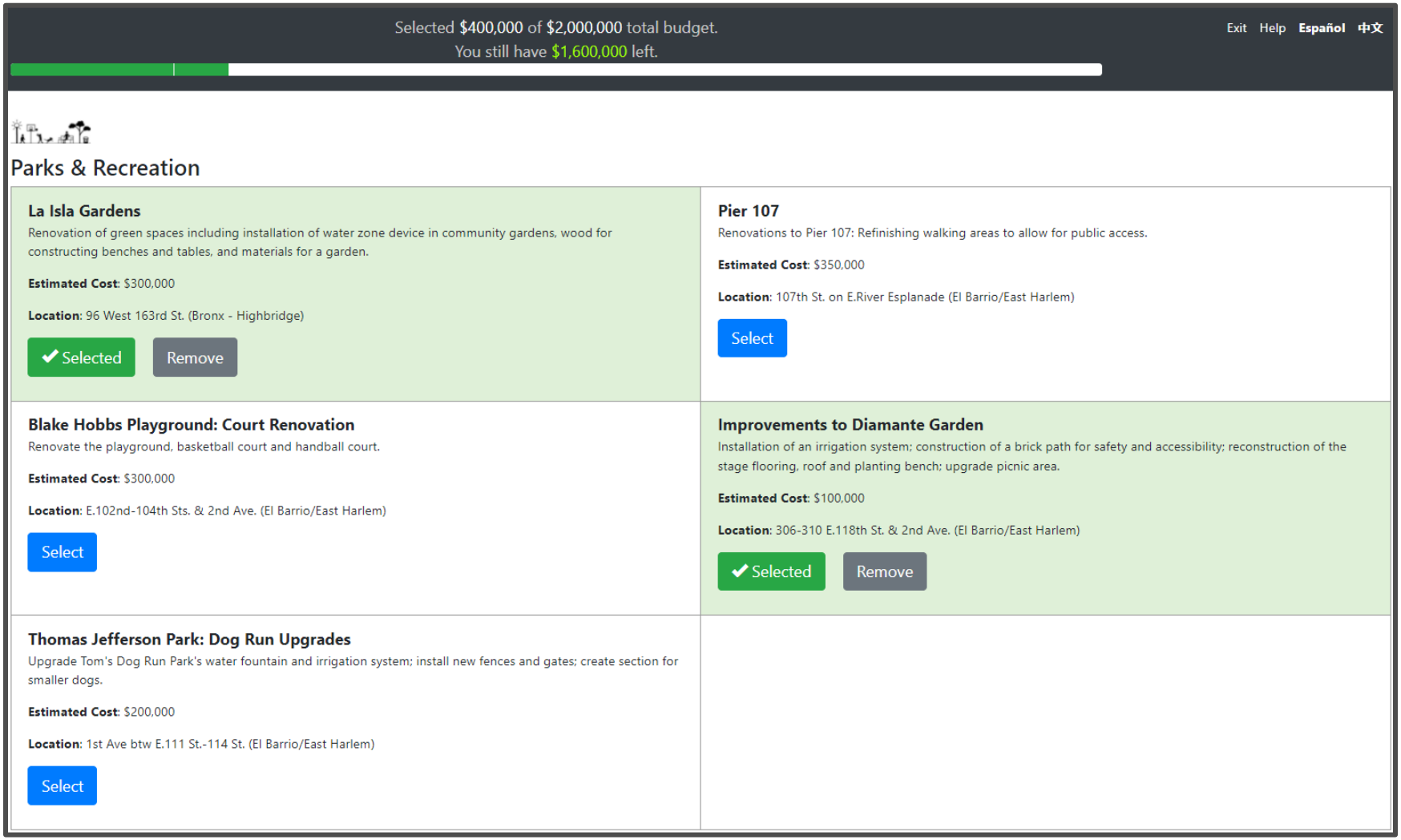
Estimated Cost: $240,000

Location: Walker Playground on Norfolk St. and Astoria St., Mattapan

Select

Click image for slide show

EXAMPLE BALLOT: NYC



PARTICIPATORY BUDGETING MODEL

- Each voter $i \in N$ still casts an approval vote $\alpha_i \subseteq A$
- Each $x \in A$ has a cost $c(x)$, and there is a budget B
- The outcome is a budget-feasible subset $W \subseteq A$ such that $c(W) = \sum_{x \in W} c(x) \leq B$
- For now, we still assume that the utility of voter $i \in N$ for $W \subseteq A$ is $u_i(W) = |\alpha_i \cap W|$

APPROVAL VOTING, REVISITED

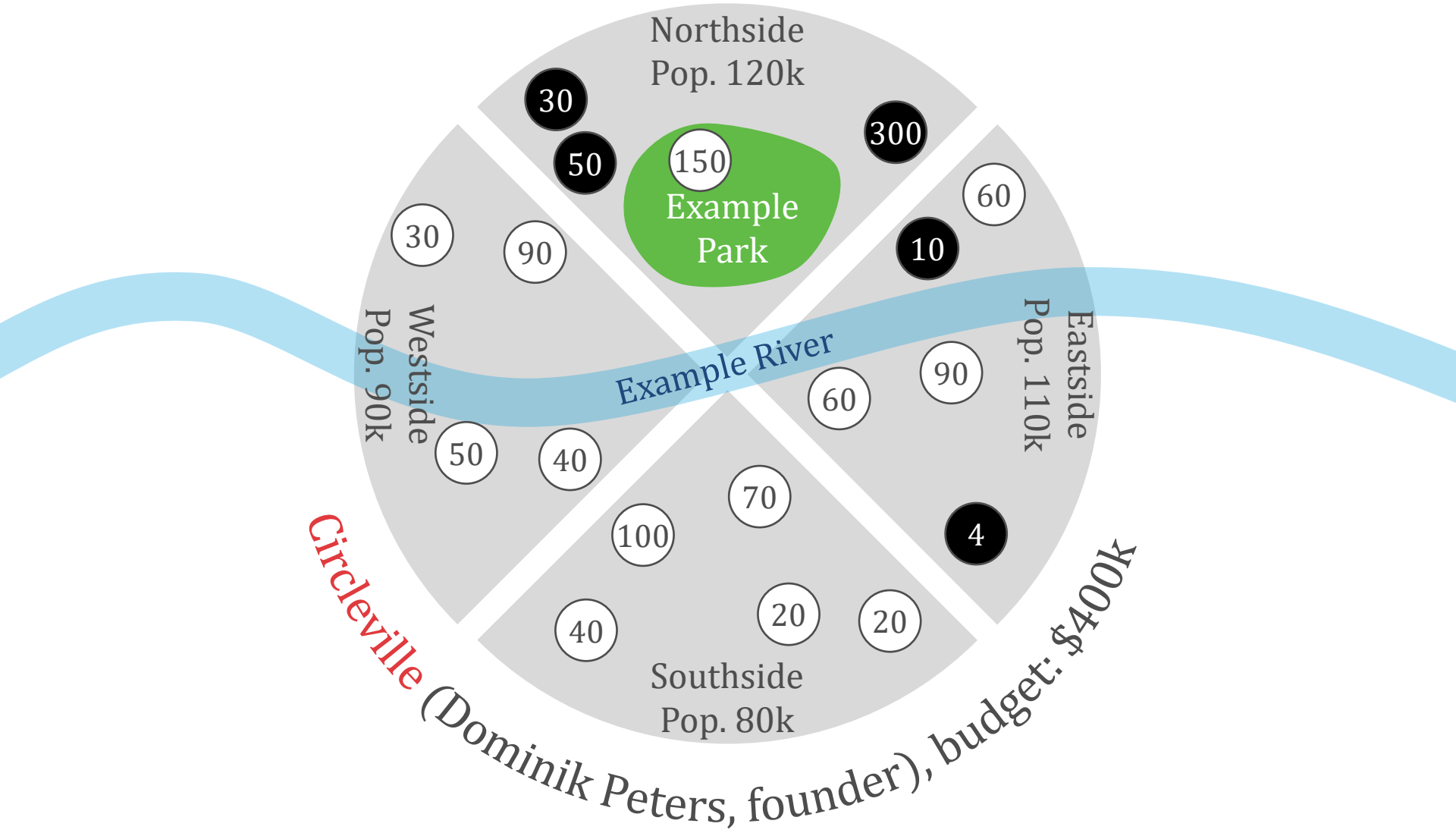
- A natural interpretation of approval voting is to maximize $\sum_{i \in N} u_i(W)$ subject to the budget constraint, which amounts to a knapsack problem
- In practice, a greedy algorithm is often used, which adds alternatives in order of approval score, skipping those that are unaffordable

GREEDY AV: EXAMPLE

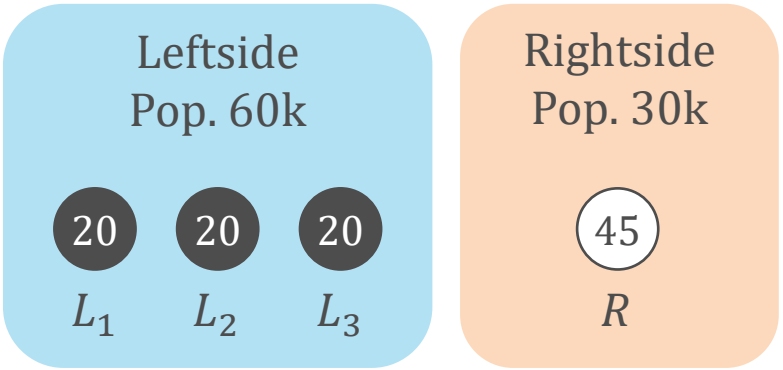
Paris, 4th District, 2019

Votes	Cost (€)	Greedy	Optimal
788	30,000	✓	✓
706	15,000	✓	✓
702	300,000	✓	✓
655	1,000,000	✓	
649	120,000	✓	✓
630	200,000		✓
528	20,000		✓
491	15,000		✓
473	20,000		✓
453	5,000		✓
410	150,000		✓
315	350,000		✓
265	30,000		✓
240	10,000		✓
228	120,000		✓
	Total:	1,465,000	1,385,000

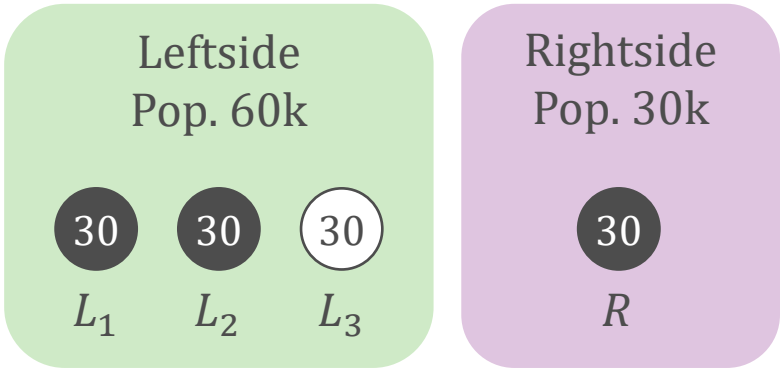
GREEDY AV: EXAMPLE



PAV TO THE RESCUE?



Rectangleville, budget: \$90k



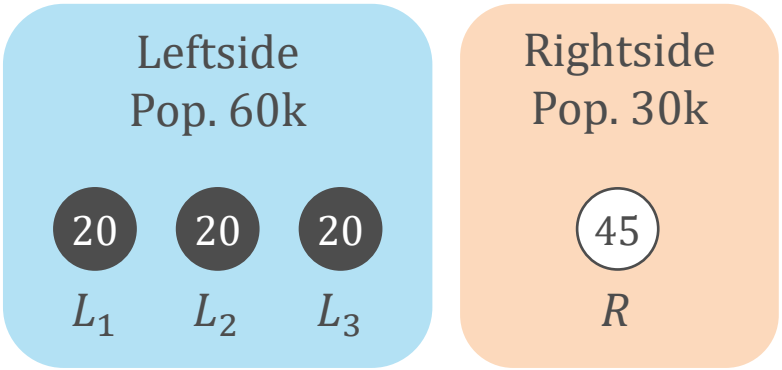
New Rectangleville, budget: \$90k

Poll

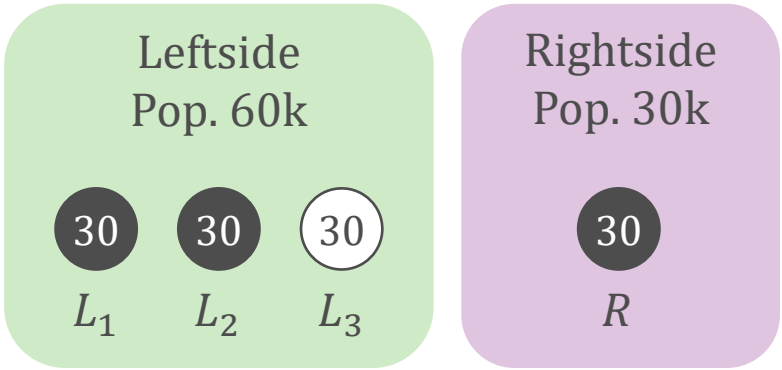
In which of the two towns (R and NR) does PAV give the proportional outcome shown in black?

- Only R
- Only NR
- Both
- Neither

PAV TO THE RESCUE?



Rectangleville, budget: \$90k

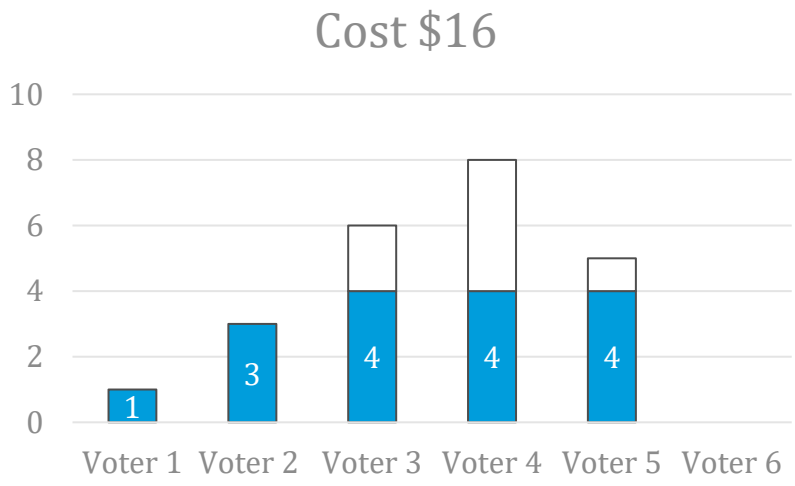


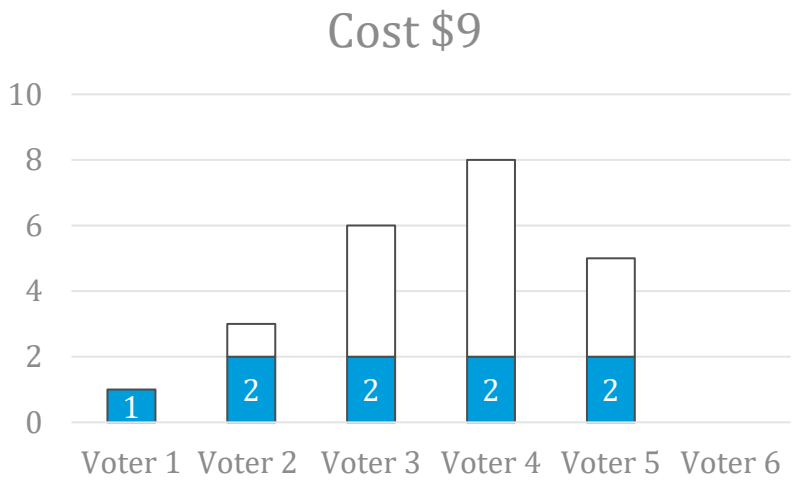
New Rectangleville, budget: \$90k

- PAV can't distinguish between the two examples and therefore cannot identify which outcomes are proportional
- Theorem: Every voting rule that only depends on the collection of budget-feasible subsets must fail proportionality, even on instances with a district structure

METHOD OF EQUAL SHARES

- Give a budget of B/n to each voter
- Do until the budget runs out:
  - For each alternative, divide its cost as evenly as possible among its supporters
  - Fund an affordable alternative with the lowest max payment





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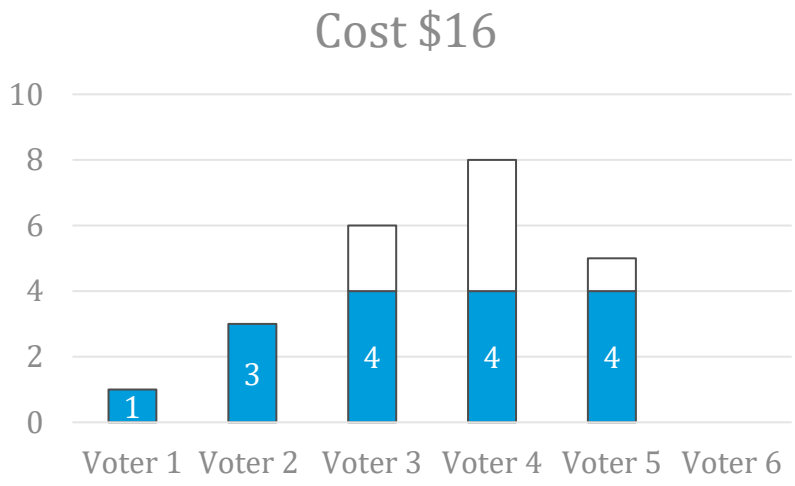
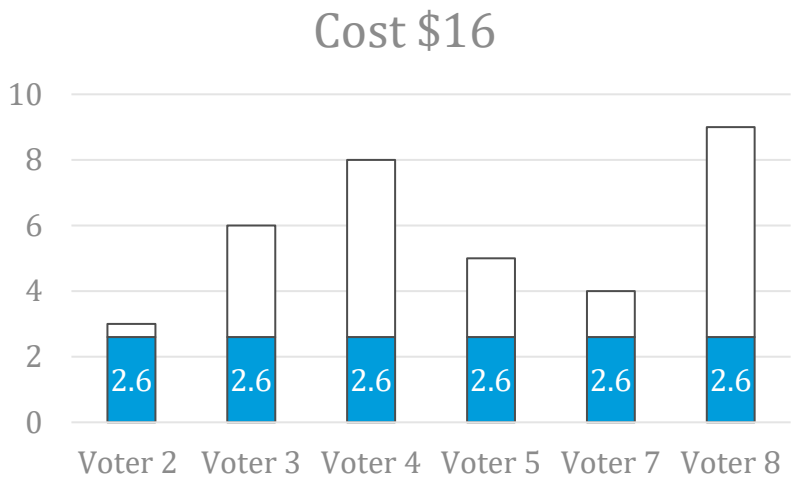




METHOD OF EQUAL SHARES

- Give a budget of B/n to each voter
- Do until the budget runs out:
  - For each alternative, divide its cost as evenly as possible among its supporters
  - Fund an affordable alternative with the lowest max payment
- Extended justified representation (for participatory budgeting): For all $S \subseteq N$ such that $|S| \geq \gamma \cdot n$ and $T \subseteq \bigcap_{i \in S} \alpha_i$ such that $c(T) \leq \gamma \cdot B$ there is $i \in S$ such that $u_i(W) \geq u_i(T)$
- Theorem: The Method of Equal Shares satisfies EJR
- To be used in 2023 in Aarau (Switzerland) and Wieliczka (Poland)

A DIFFERENT PERSPECTIVE

- In the 2019 PB election of Paris' 16th District, a refurbishment of a sports facility received 775 votes and cost €560k, and materials for a school project received 670 votes and cost €3k
- Let us consider general additive utilities, i.e., $u_i(W) = \sum_{x \in W} u_i(x)$, where $u_i(x) \in \mathbb{R}^+$
- The goal is to find $W \subseteq A$ that maximizes the social welfare $\text{sw}(W, \boldsymbol{u}) = \sum_{i \in N} u_i(W)$ subject to the budget constraint $c(W) \leq B$
- But we don't necessarily want to ask voters to explicitly report utilities
- Instead, we'll ask voters to cast votes in some input format

INPUT FORMATS

Ranking by value

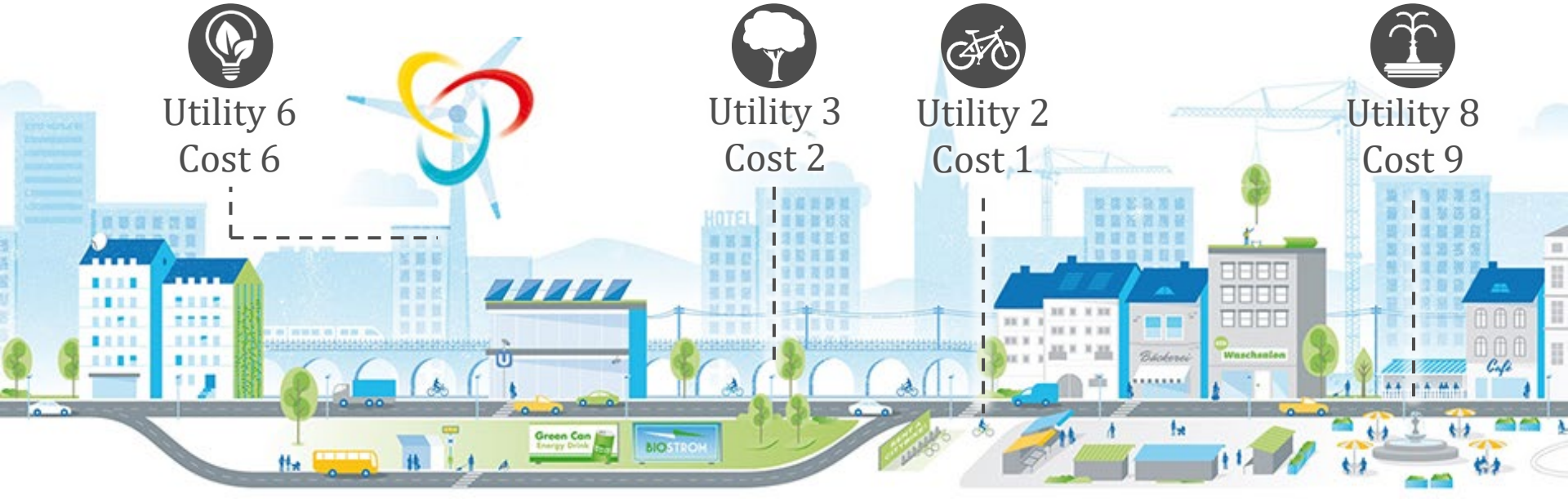
Knapsack voting

Budget
9

Ranking by VFM

Threshold approval

Threshold
5



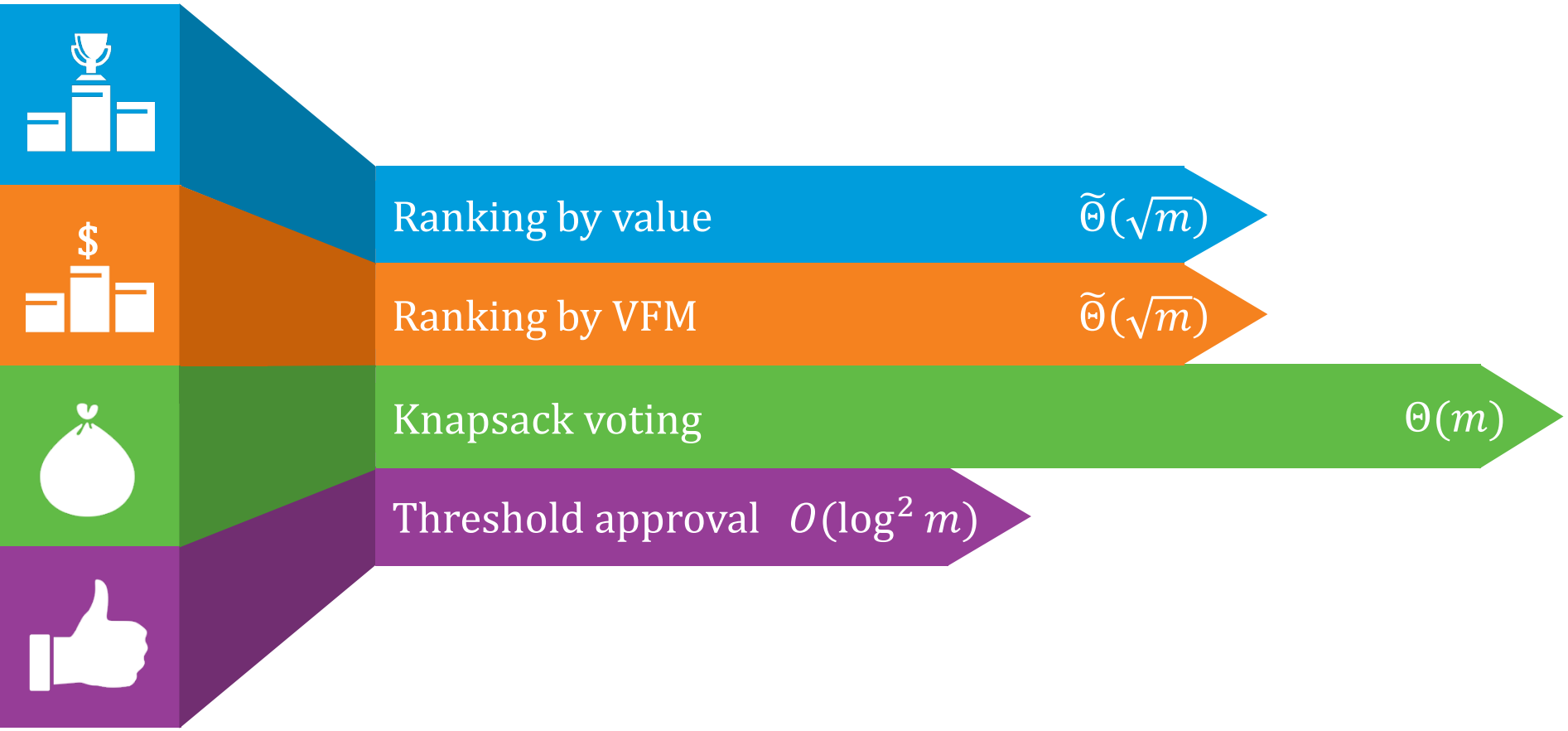
IMPLICIT UTILITARIAN VOTING

- Voter i reports a vote σ_i that is consistent with u_i; denote $u_i \rhd \sigma_i$
- A randomized voting rule f maps an input profile $\boldsymbol{\sigma}$ to a distribution over budget-feasible subsets of alternatives
- The distortion of f on $\boldsymbol{\sigma}$ is

$$\max_{\boldsymbol{u} \rhd \boldsymbol{\sigma}} \frac{\max_{W \subseteq A : c(W) \leq B} \mathrm{SW}(W, \boldsymbol{u})}{\mathbb{E}[\mathrm{SW}(f(\boldsymbol{\sigma}), \boldsymbol{u})]}$$

- Associate an input format with the worst-case distortion of the best voting rule

THEORETICAL DISTORTION



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