

## Optimal Drinking Water Delivery

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### 1. Introduction



- Despite its tremendous success, no country depends exclusively on centralized drinking water provision.
- Many entities distribute drinking water – but what are the different water provision choices and how effective are they?
- Our goal is to organize the problem of selecting water distribution methods for planners and managers.

### 2. Systems Definition

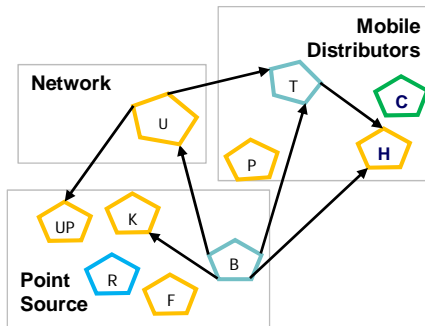
Drinking water delivery options include several types of vendors which have different infrastructure needs and rely on different types of water sources

**Potable water vendors include**

- U: Utility.** Distribute via piped network.
- UP: Utility with Point of Use Treatment.** User purifies utility delivery at home.
- B: Boreholes.** Extract from drilled holes.
- T: Tanker Trucks.** Deliver water in trucks.
- R: Rainwater Harvesting.** Capture precipitation in cisterns.
- P: Packagers.** Sell small packages such as bottles or sachets, wholesale.
- K: Kiosks.** Sell water via an operator at stationary distribution points.
- H: Carriers.** Haul water in buckets or small containers by hand.
- C: Carters.** Cart water or ice by animal, bicycle or motorbike.
- F: Fetchers.** Individuals that fetch directly from local water supply.

**Delivery infrastructure includes**

- Networks** - that bring water to the customer via a network, such as a central utility,
- Mobile Distributors** - that deliver water to customers via mobile distribution, such as tanker trucks,
- Point Sources** - vendors that are stationary such that customers travel to the vendor to pick up water.
- Re-sellers** - vendors that re-sell water from others, linked in the figure with arrows



Source: Augmented from the small water enterprises literature (Opryskko et al., 2009)(Kariuki and Schwartz, 2005).

**Water supply options include**

- Groundwater (Shallow or Deep, including Springs)
- Surfacewater (River or Reservoir or Lake)
- Rainwater
- Surfacewater and Groundwater

### 3. Non-Utility Alternatives: Scapegoats or Heroes?

**Heroes?**

- Offer some combination of a more reliable, affordable or potable alternative to nonexistent, unsanitary, unreliable, or inconvenient utility service, or,
- Offer potable water at prices less than that of a utility

**Scapegoats?**

- Enable rent-seeking and bad institutional behavior of central utilities, or,
- Exploit customers to pay higher-than-utility prices, so
  - Customer use less because of higher prices, or
  - Customer welfare losses from the utility cost-savings
- Often disproportionately affect the poor

### 4. Optimal Provider Choice

Objective: Minimize the cost and maximize the reliability of a population's drinking water supply

$$Objective\ z = \sum_n \sum_i \frac{\alpha_n X_n}{R_{i,n}} C_{i,n}$$

- $\alpha_n$  = user-defined weight of reliability importance
- $X_n$  = proportion of population served by vendor n, ( $\sum_n X_n = 1$ )
- $C_{i,n}$  = cost of water delivery to the population for each water vendor n discounted for each time period i.
- $R_{i,n}$  = reliability of the delivery to the population for time period i for each n. Reliability is an index ranging from 0-1 that considers infrastructure integrity, corruption, trust, and management and maintenance feasibility.

Decision variables  $X_n$  are the proportion of the population to be served by each vendor n.

Each vendor is constrained by available water supply, operational labor, capital, and public health requirements, and the minimum and maximum population size for which they can operate.

### 5. The Past and Future Outlook

The historical push to centralized service delivery has brought great benefit, but for cases that cannot guarantee access to safe reliable potable water, decentralized delivery can be better suited. This includes remote rural and mountain places like the high Alps and US Midwest farmlands, places with specific contamination problems like the Tulare Basin, and cities with failing central systems like Nablus, Faisalabad and Jamshedapur.

