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Using self-organising models in the planning of large-scale vaccination logistics operations

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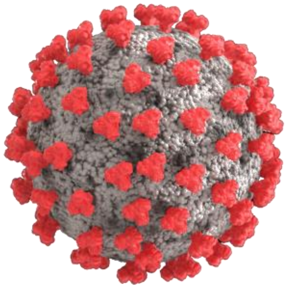
Self-organising models

- Agents that can make decisions
- External conditions or constraints
- Whole-system effects



What’s the problem?

- Nationwide vaccination
  – Complex
  – Highly coupled
- Optimal supply chain for effective distribution of medical supplies and staffing
- Getting it right could save lives and reduce peak pressures on a country’s health service

Current state of play

- COVID-19 pandemic has exposed under-preparedness and lack of joined-up plans for rapid rollout
- Many countries have approached in a piecemeal, haphazard
- Inefficient use of resources, vehicle fleets, underused capacity
- Excessive carbon emissions

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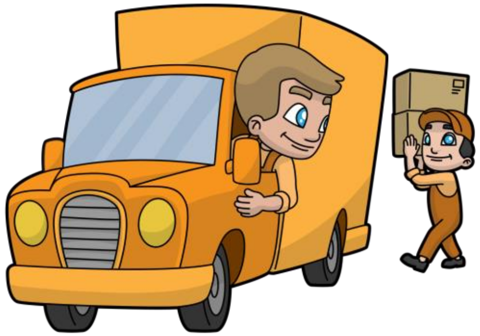
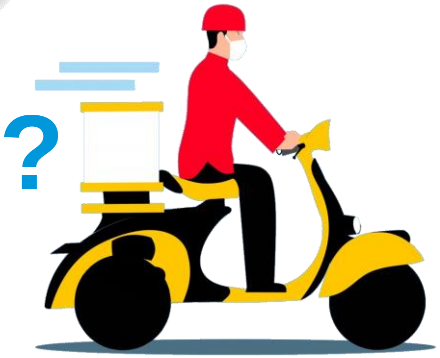
What should be possible?

- Input: description of country's infrastructure and facilities
- Output: "ready reckoner" for nationwide logistics rollout
- **Doesn't have to be detailed**
- Could apply to any country given a basic description of infrastructure
  - "Anything's better than what was there before"
- Doesn't have to be a vaccine
  - Large scale, logistics, limited timeframe



What would this look like?



Inputs (for any country)

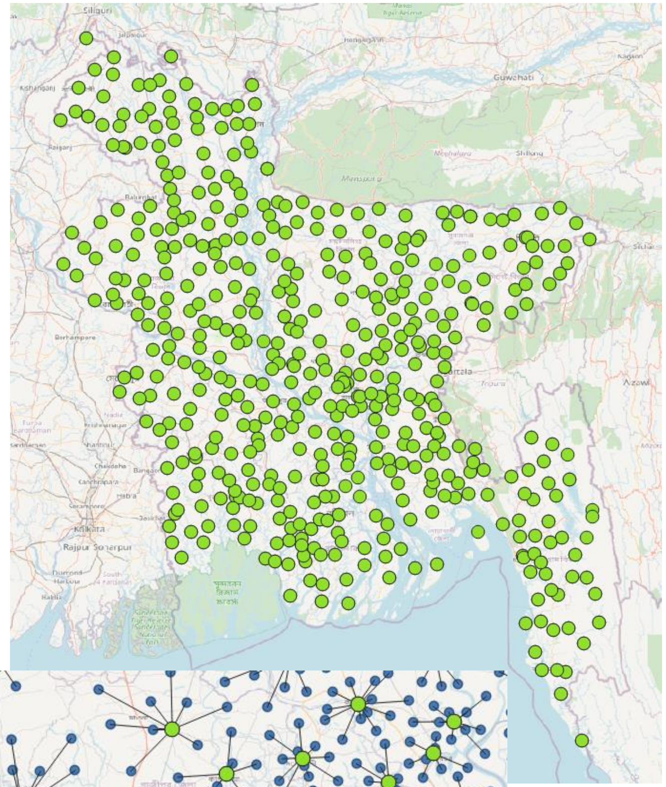
- Basic census description of population
- Transport topology (roads, rail, waterways, ports)
- Mission target (*X*% of population in *N* days)
- [Clinics / distribution hubs]

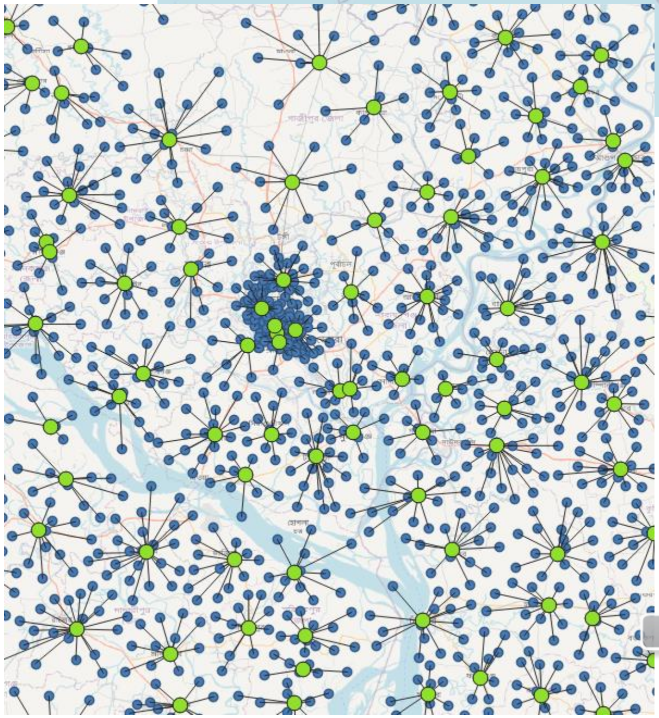
Outputs

- Facility locations
- Utilisation levels
- Plans for macro-logistics and local fulfilment
- Size of vehicle fleet, staff, inventory (e.g. fridges)
- Flag for any infeasible conditions
- Overall costs

Example: Bangladesh

- Census population data (142.3 mil) to granularity of Union (20k-30k, 5160 locations)
- Existing medical centre locations (504)
- GIS layer to understand topology (OpenStreetMap)





Applications of agent simulation

Agent based models	Application to vaccination logistics

Example: facility inventory decisions

Total catchment population: 125,000

Mission target: “20% of residents vaccinated within 50 days”

Total catchment daily demand: 500

4 teams @ 150 doses/team/day

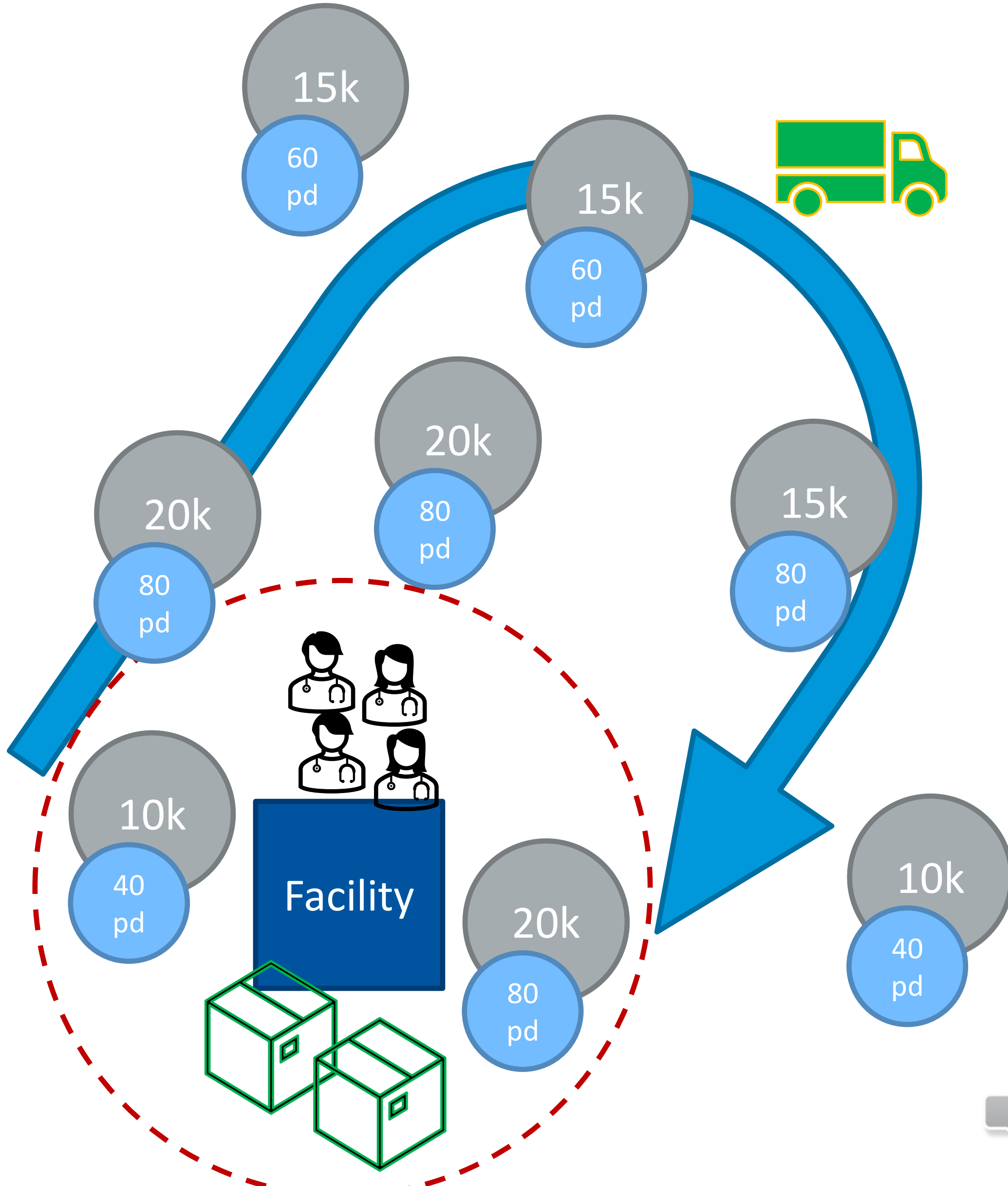
If a fridge holds 5000 doses:

- 1 fridge, deliver every 10 days?
- 2 fridges, deliver every 20 days?

Walkable population: 120 per day

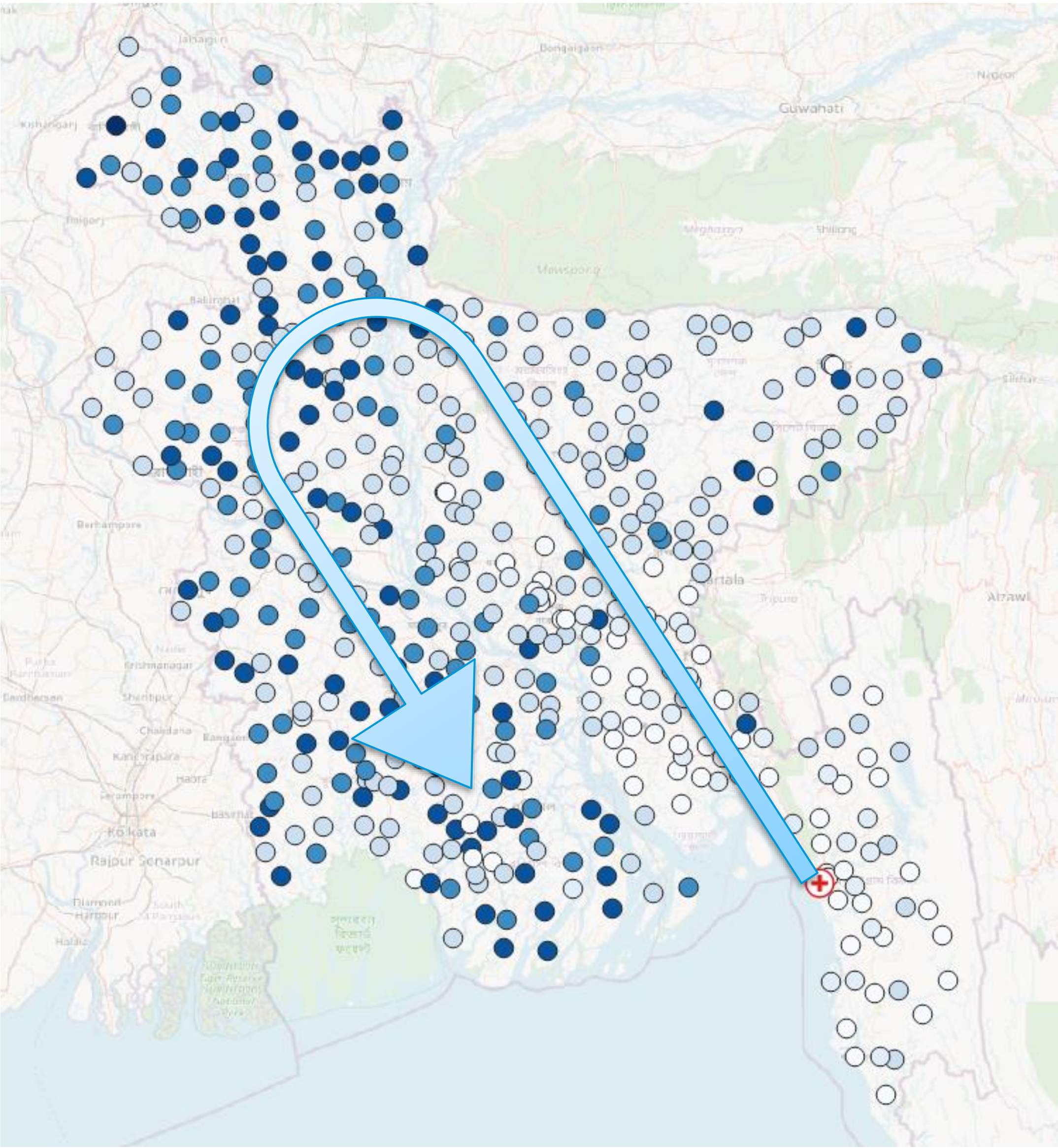
Provide local delivery service:

- To all catchment populations, or just some?
- Subsidise some private travel?
- How often?



Example: facility inventory decisions

- Setting the main sea port (marked) as an example source for vaccine stock
- Scaling the delivery costs by the travel time to reach facility
- Map shows inventory choice taken by agents for number of fridges on site
- Inventory choices get larger (darker markers) as delivery costs begin to dominate



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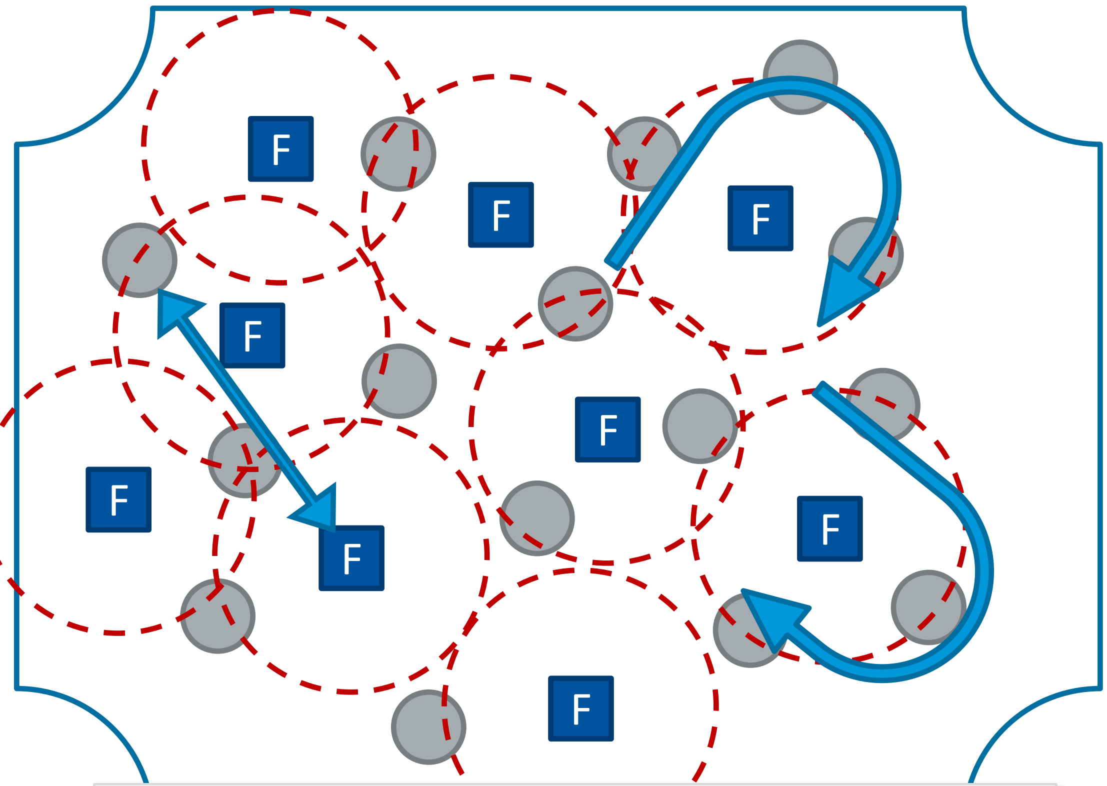
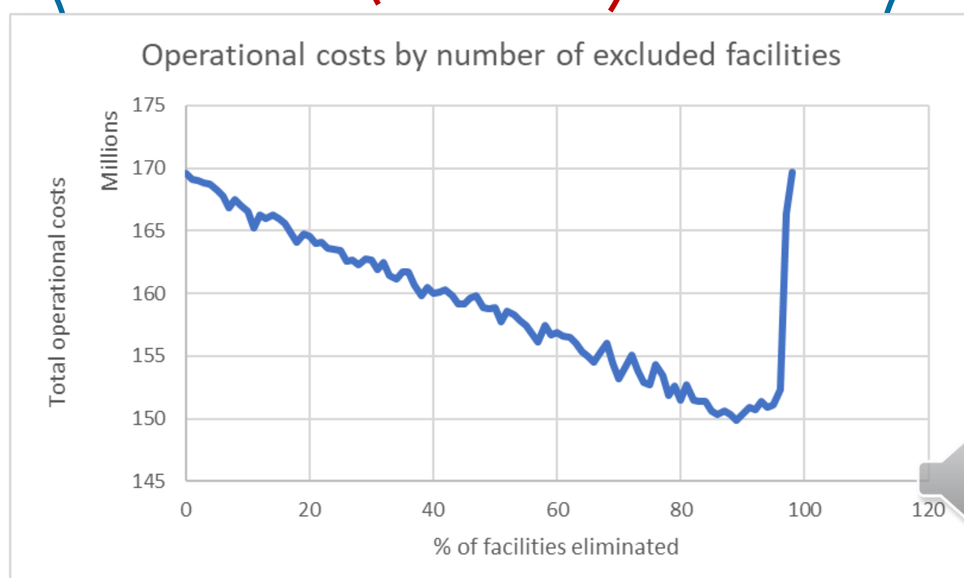
Example: facility exclusion

How many facilities could be economically closed before the cost of travel makes it uneconomical?

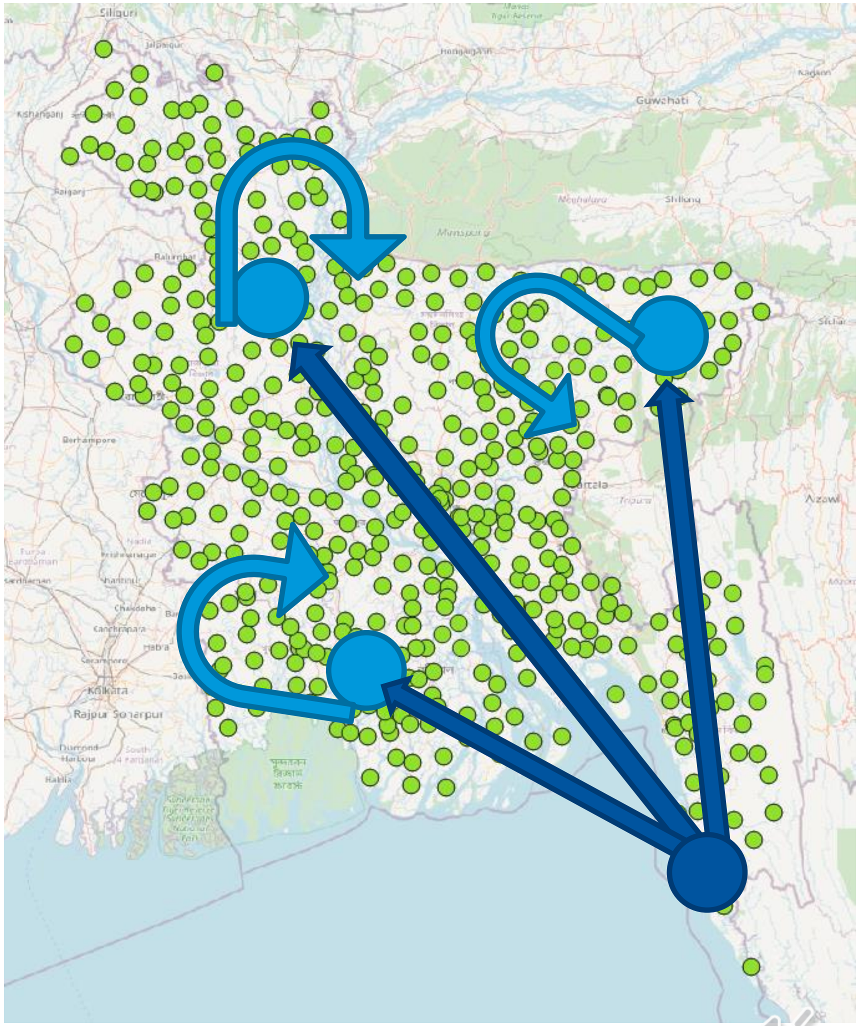
1. Initial case
2. Facilities excluded from simulation
3. Too many facilities have been excluded, no longer economical





Future work

- Improve cost models for local delivery
- Incorporate two-tier delivery system with designated long-haul distribution warehouses
- Fully dynamic model with inter-facility bidding



Thank you

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