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Humanitarian logistics

A challenge for operations research

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Humanitarian logistics is important

- 2010, Earthquake in Haiti, 316.000 victims
- 2004, Indian Ocean Tsunami, 230.000 – 310.000 victims
- 2008, Nargis Cyclone in Myanmar, 138.000 victims
- 2011, Tohoku earthquake and tsunami in Japan, 15.000 – 20.000 victims
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P.A. Trunick (2005)

"Logistics accounts for 80% of the disaster relief effort"

Humanitarian logistics

Luk Van Wassenhove

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. . . and

co-organized by dozens of stakeholders, each with their own objectives.

Disaster management phases

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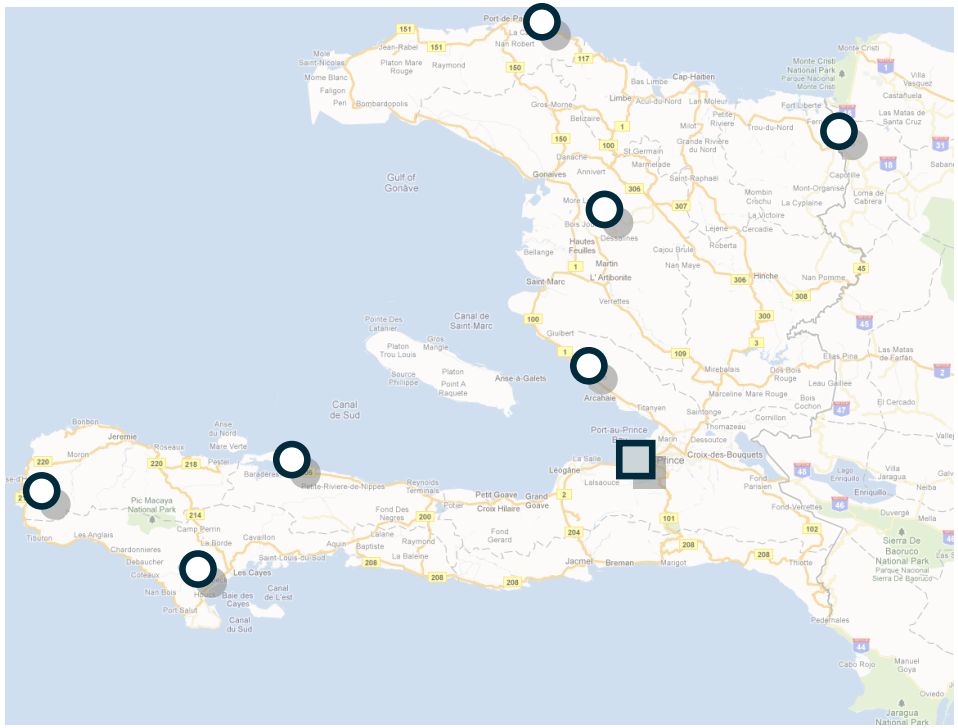
Most important rule

Do not make it worse!

Planning problems

- Operational
  - “vehicle routing”
- Strategic/tactical
  - “network design”
  - “location”
- Integrated



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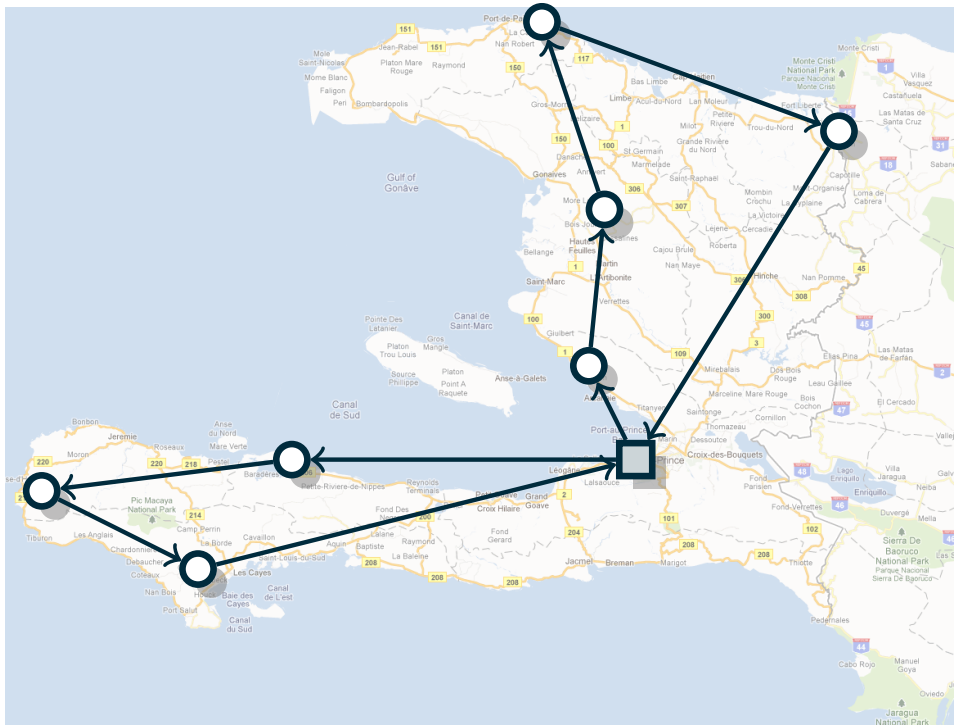

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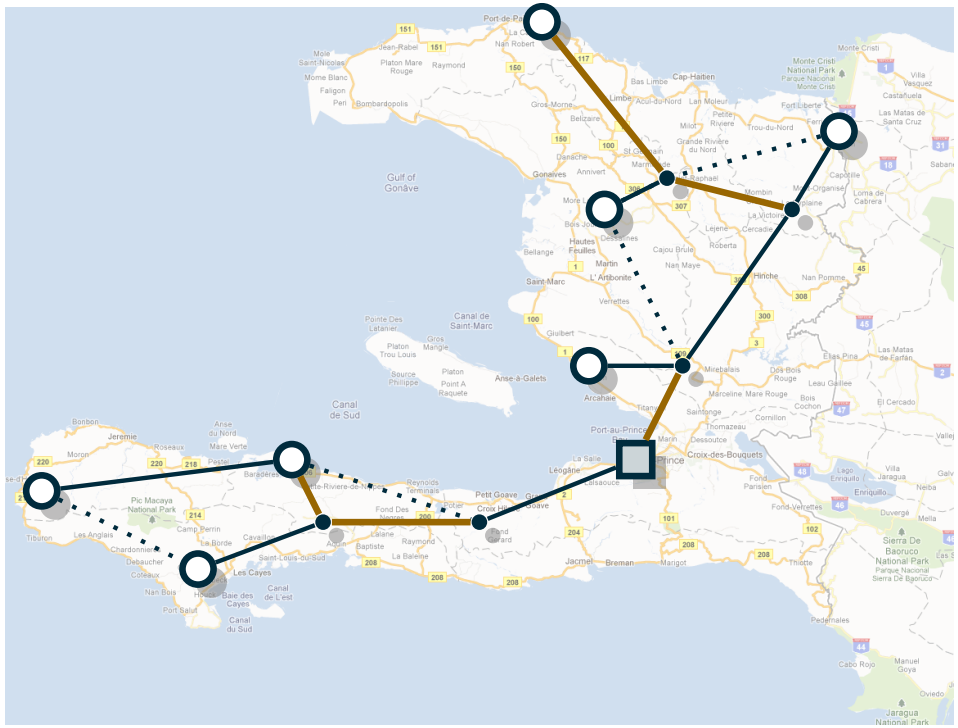

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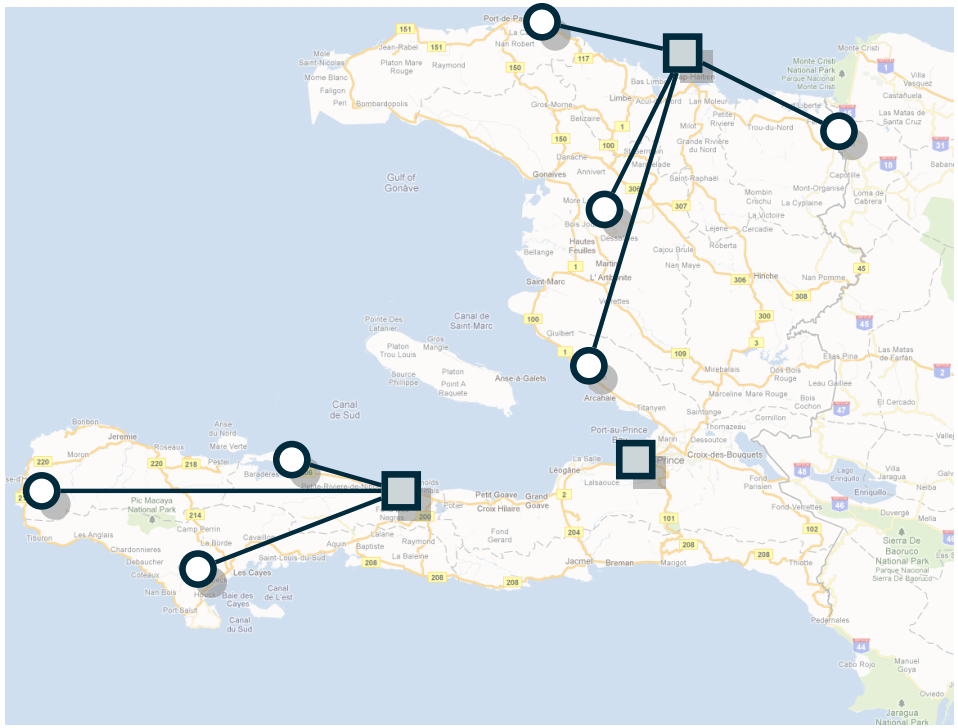

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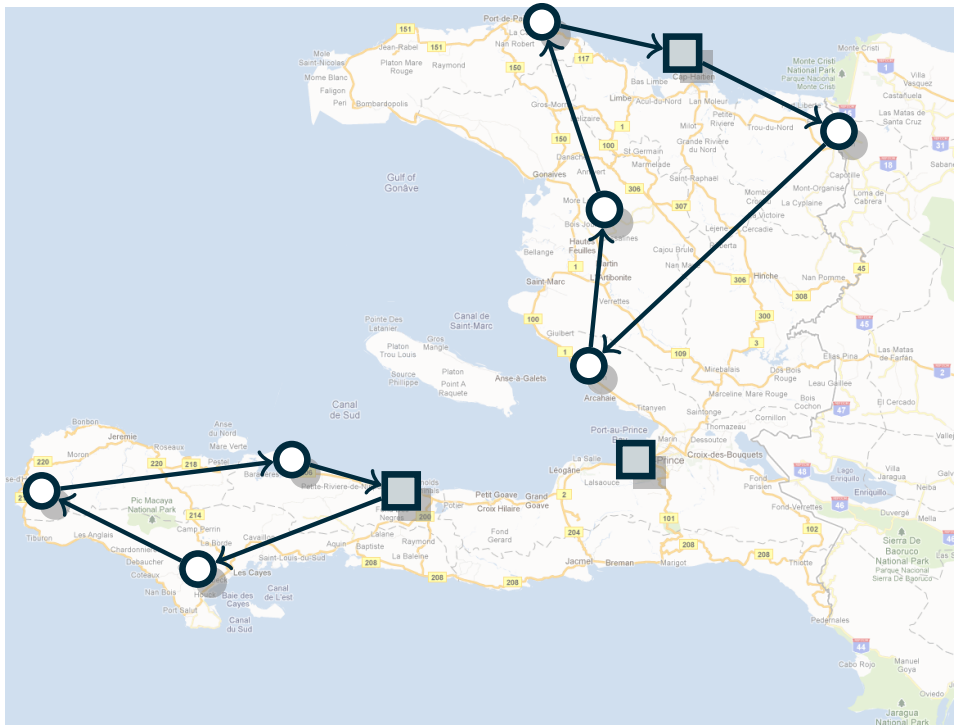

An example: Haïti

- At the time of the disaster
  - Poorest nation in the Western hemisphere
  - 54% live on less than $1 per day
  - Illiteracy of 44%
  - 46% do not have access to drinking water

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  - 54% live on less than $1 per day
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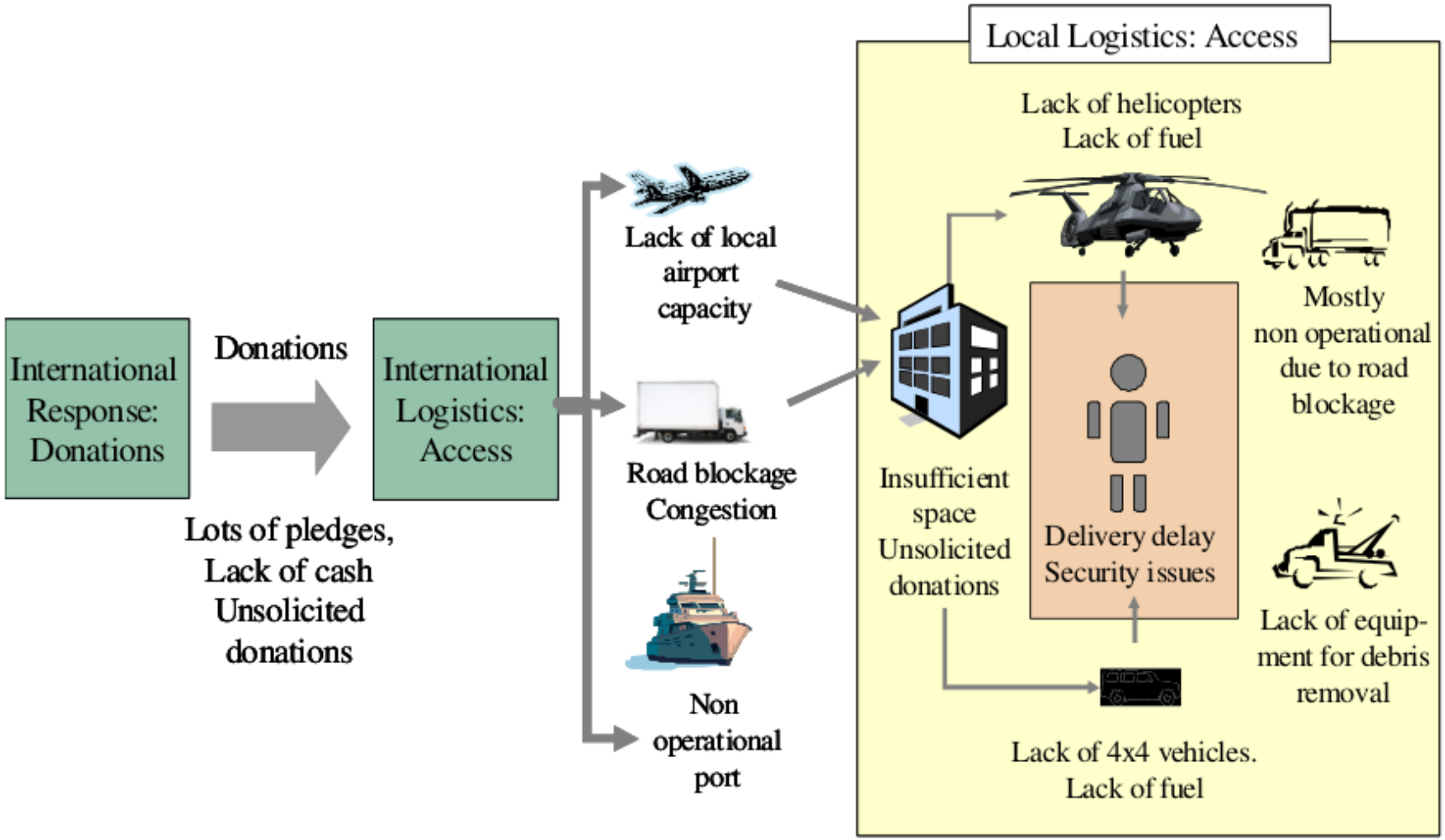
  - 46% do not have access to drinking water
  - $\pm$ **10,000 NGOs active**
- After the disaster
  - Lots of effort towards wrong actions (e.g., rapid disposal of bodies)
  - Donations of unnecessary items, overwhelming local aid (e.g., $\pm$ 500 tonnes of medicines in the first two weeks)
  - "Medical tourism"
  - Well-meaning volunteers with little skills

Haïti: how logistics went wrong



Source: Van Wassenhove, Pedraza Martinez and Stapleton (2010)

Nestlé donates $> \$1{,}000{,}000$

Some thoughts on the use of OR in humanitarian situations

- Operations *Management* is clearly useful
  - Inventory policy
  - Bottleneck identification
  - Global sourcing strategies
  - ...

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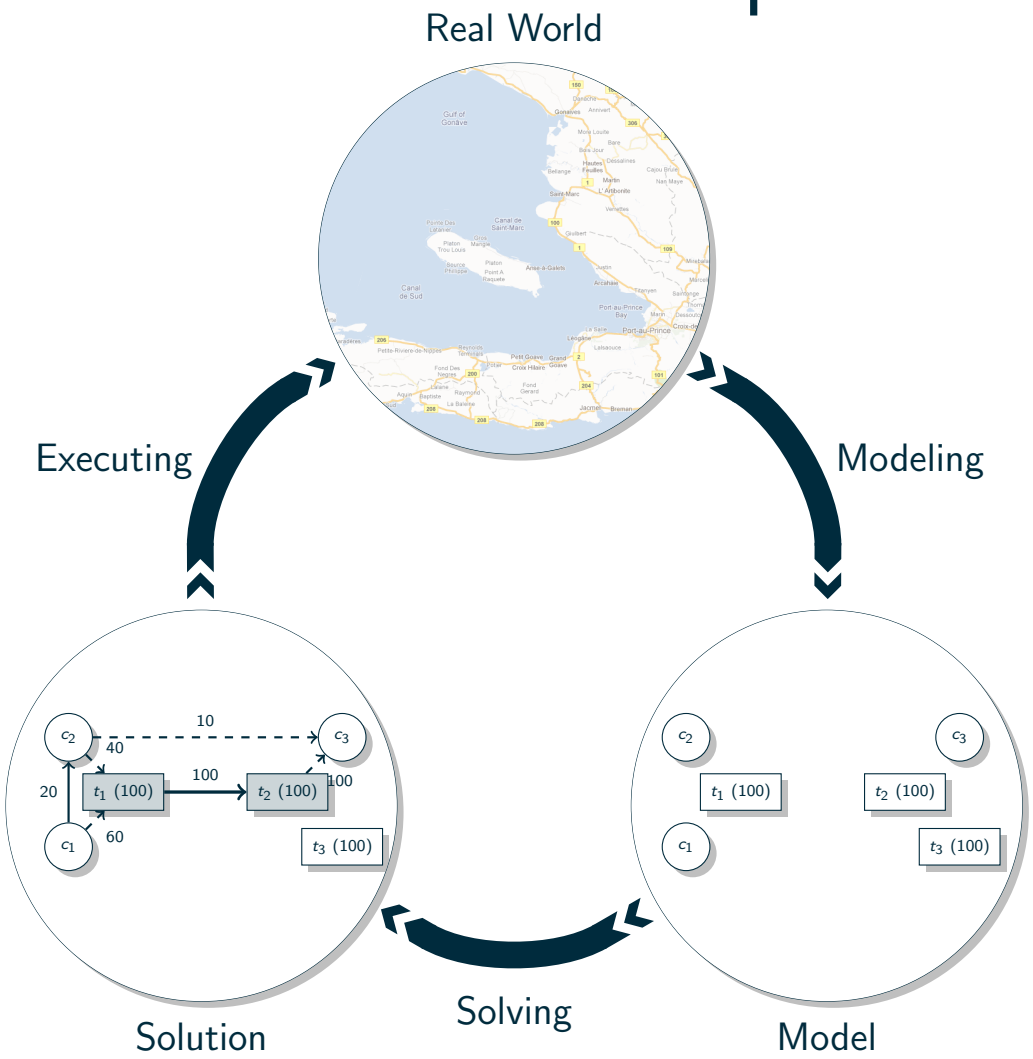
- Operations *Management* is clearly useful
  - Inventory policy
  - Bottleneck identification
  - Global sourcing strategies
  - ...
  - BUT: efficiency is often difficult to achieve
- Use of operations *Research* less clear

When *can* OR be useful

- Strategic/tactical planning
  - *Before* the disaster: preparedness, prepositioning of supplies and materials, building of humanitarian infrastructure (e.g., location of warehouses)
  - *After* the disaster: rebuilding the infrastructure in a sustainable way
- Operational
  - Only after intense preparation
  - Perhaps: use rules of thumb derived from efficient algorithms

The optimization cycle



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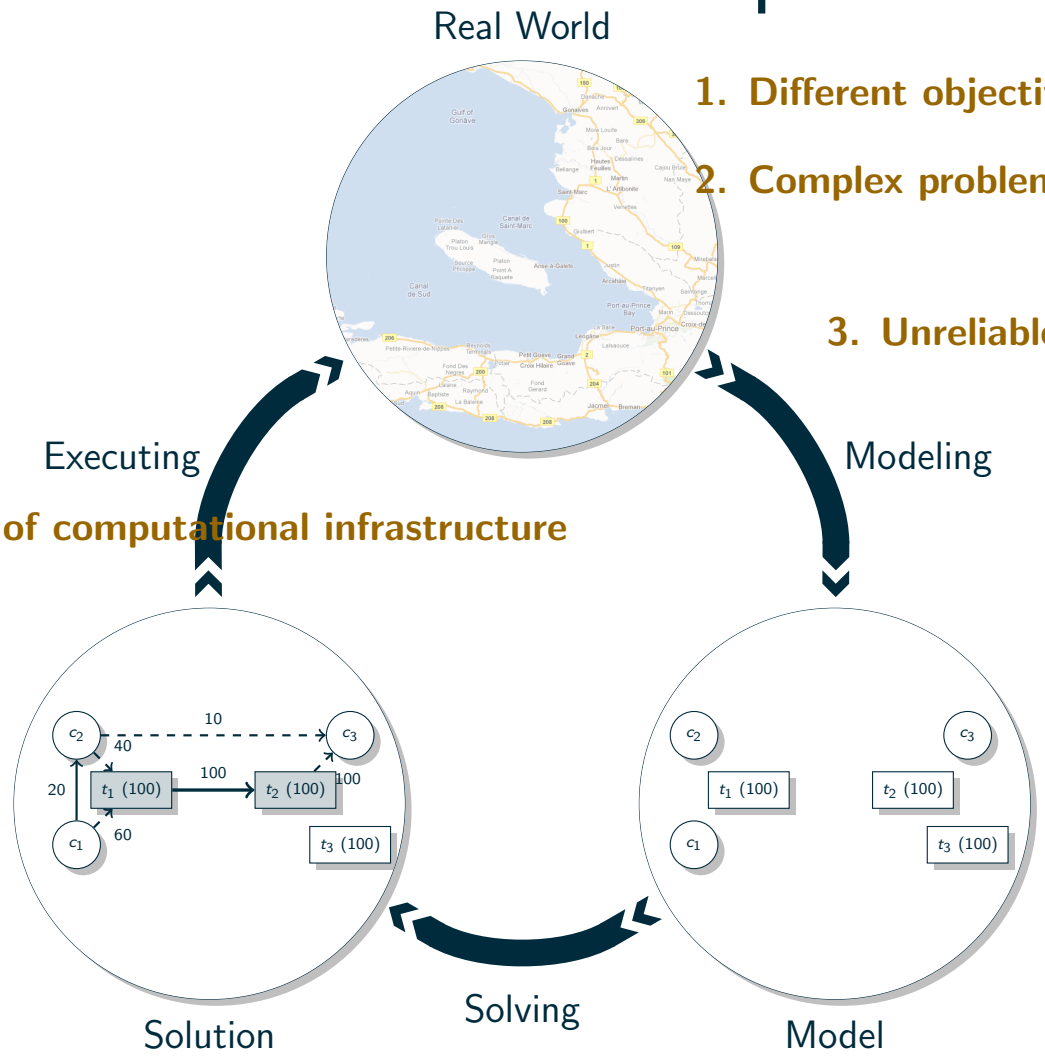
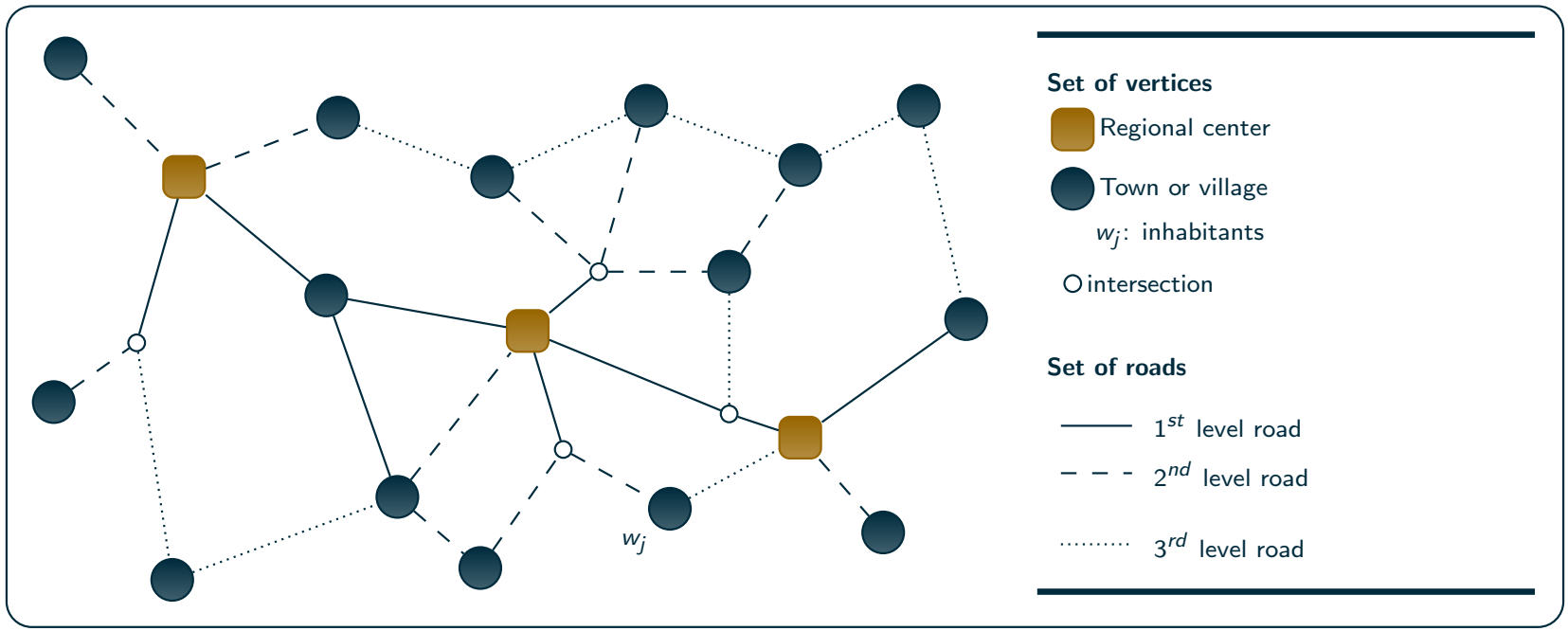


Challenges for OR

	Problem	Solution
1	Different objectives	Advanced modeling
2	Difficult problems	Advanced modeling
3	Unreliable data	Robust models, based on available data, pre-storing as much info as possible
4	Changing/unpredictable situations	Robust and flexible methods
5	Lack of computational infrastructure	Develop rules of thumb

The accessibility arc upgrading problem



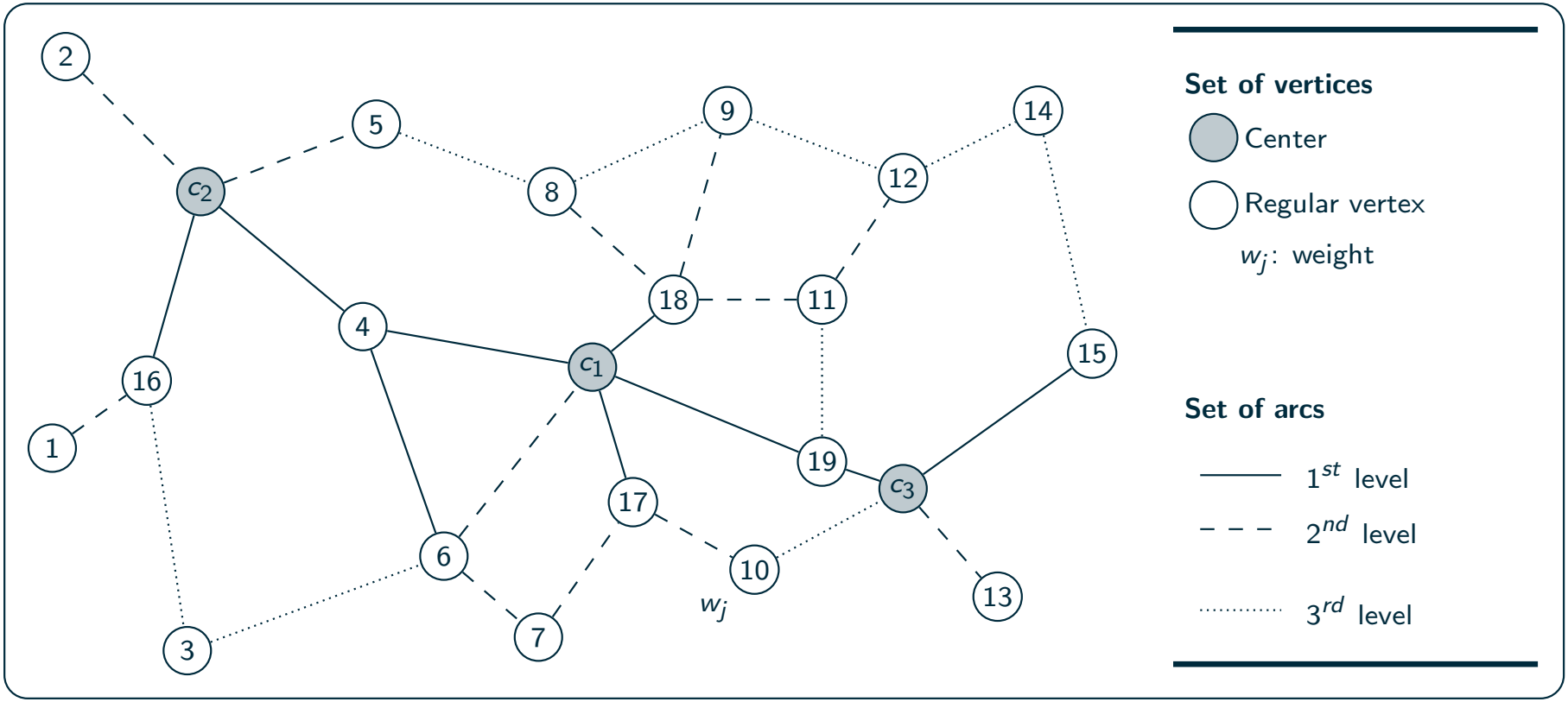
A-AUP Accessibility arc upgrading problem

Find an optimal arc upgrading strategy that maximises the accessibility

Notation

Notation	
$\mathcal{V}$	Set of vertices
	$\mathcal{V}_1$ Centres
	$\mathcal{V}_2$ regular vertices
$\mathcal{E}$	Set of arcs
w_j	Weight of vertex j
t_{el}	Time to traverse the arc e at level l
p_{el}	Cost of upgrading the arc e to level l
B	Financial budget

Problem definition



How is accessibility defined?

Definition

Accessibility is the degree of ease with which people or communities can access locations to satisfy their basic social and economic needs

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How do we measure accessibility?

Weighted sum of the time required to travel from each vertex j to its closest regional center

$$\sum_{j \in \mathcal{V}_2} \left\{ w_j \times \min_{i \in \mathcal{V}_1} \{SP_{ij}\} \right\}$$

A-AUP: Shortest path formulation

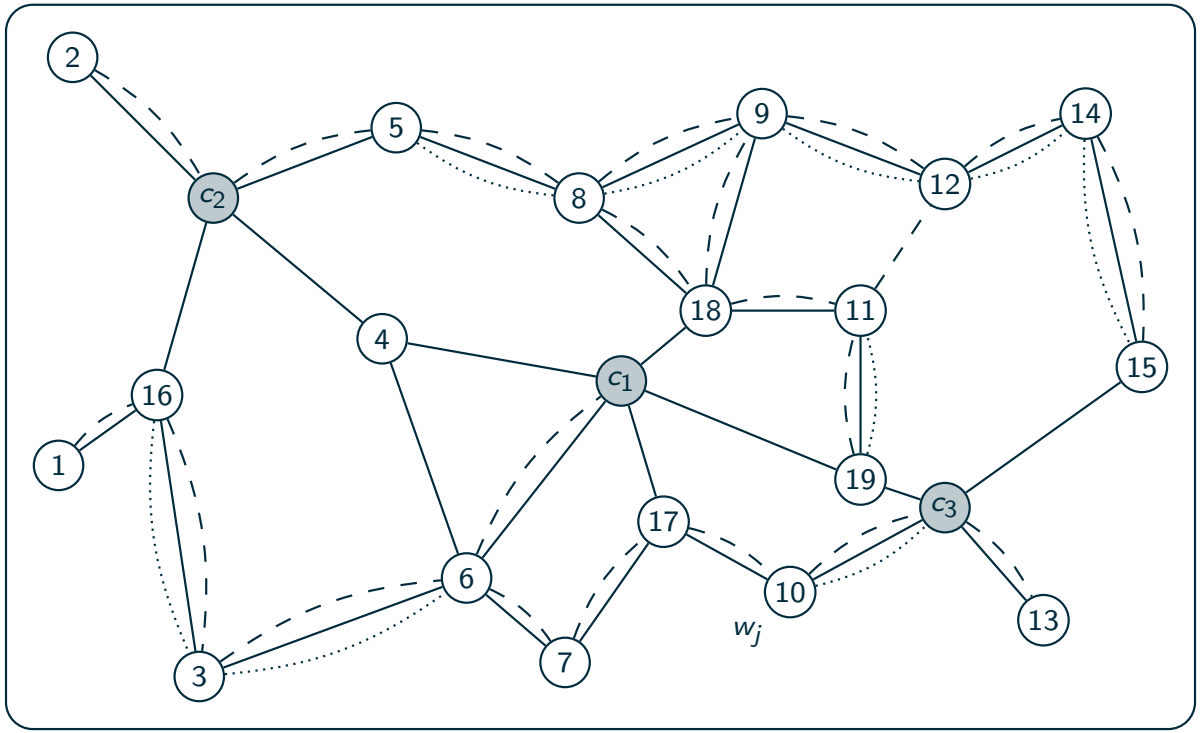
$$\min \sum_{j \in \mathcal{V}_2} \left(w_j \min_{i \in \mathcal{V}_1} \{ SP_{ij}(\mathbf{x}) \} \right)$$

$$\sum_{e \in \mathcal{E}} \sum_{l \in \mathcal{L}_e} p_{el} x_{el} \leq B$$

$$x_{el} \in \{0, 1\} \forall e \in \mathcal{E}, \quad \forall l \in \mathcal{L}_e$$

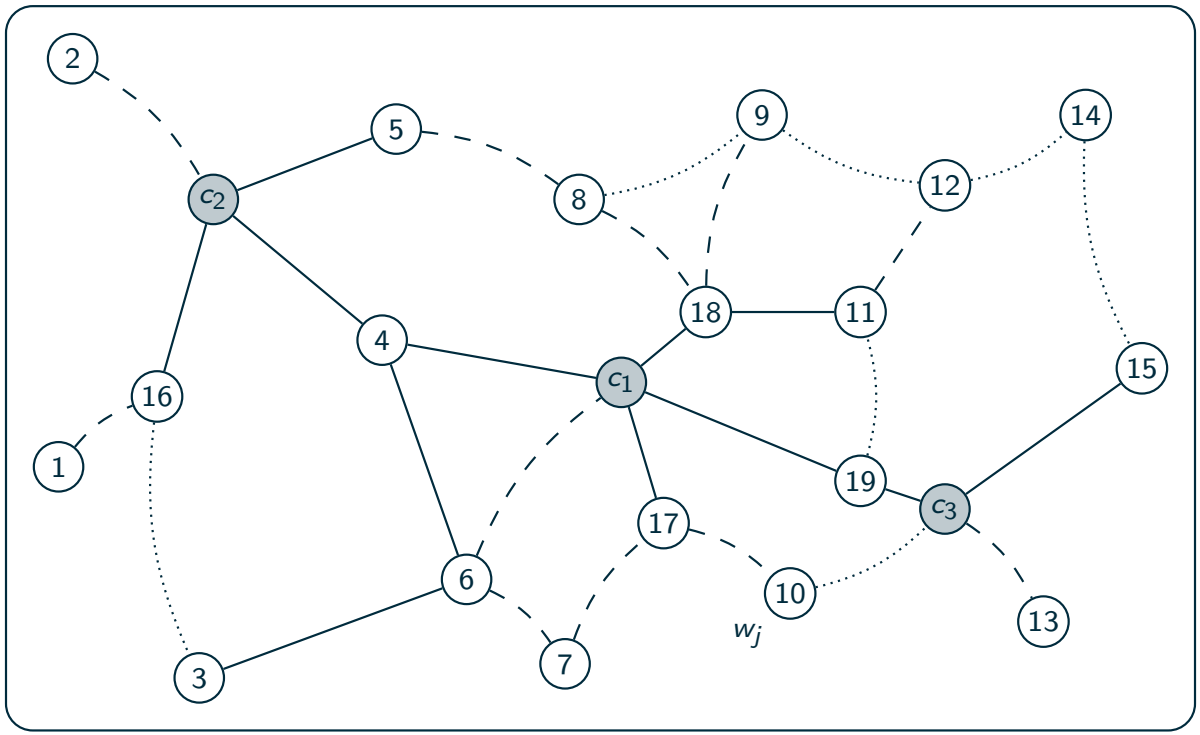
Two related decisions

1. Arcs to be upgraded
2. Paths to connect regular vertices to centres



Example 1

The solution of the shortest path problem depends on the upgrading decisions



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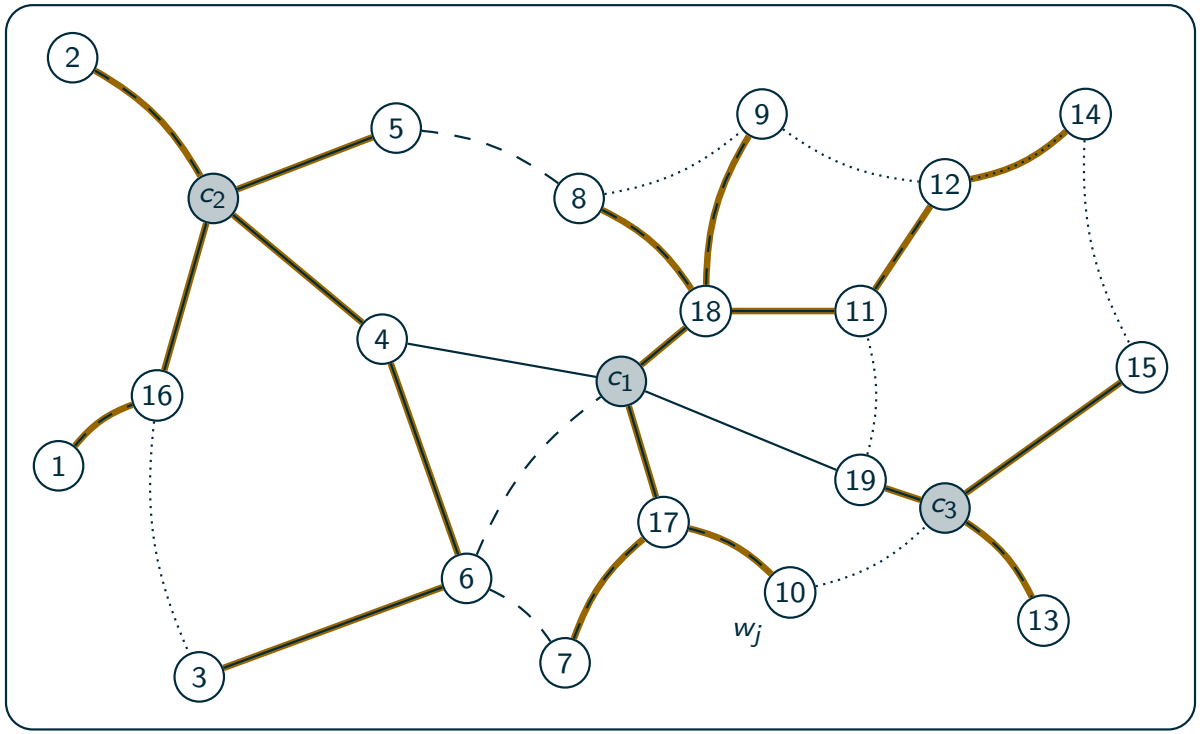

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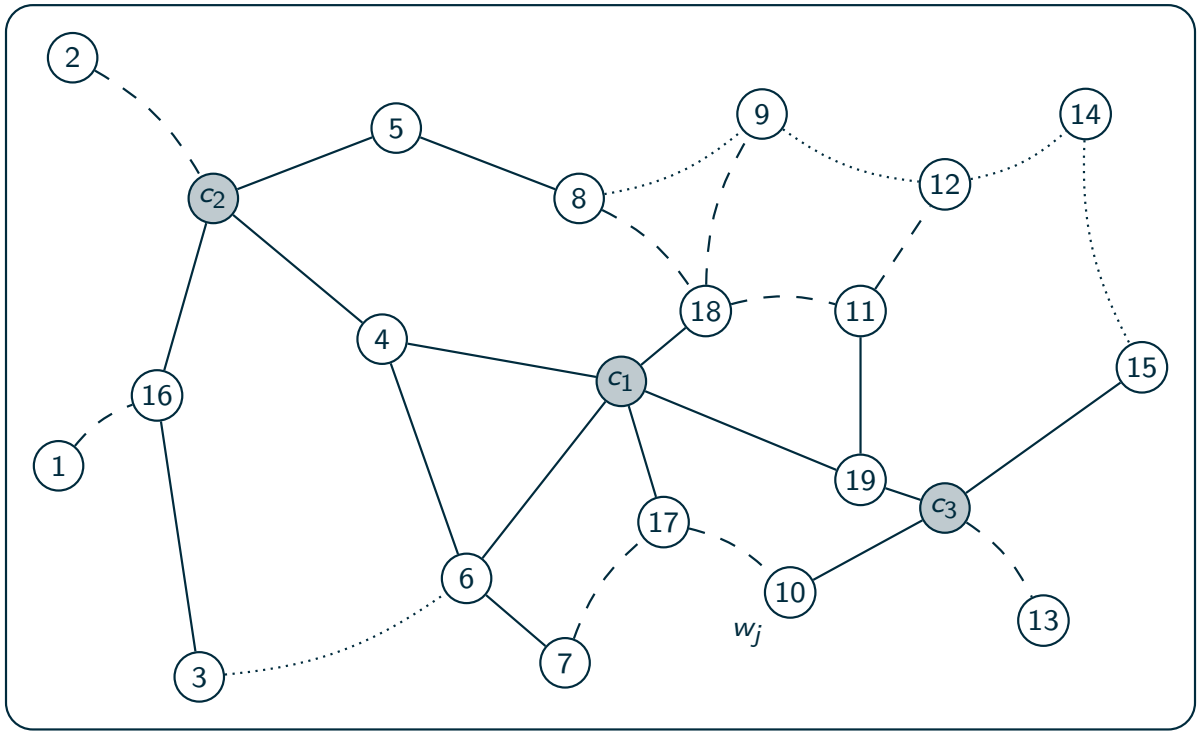

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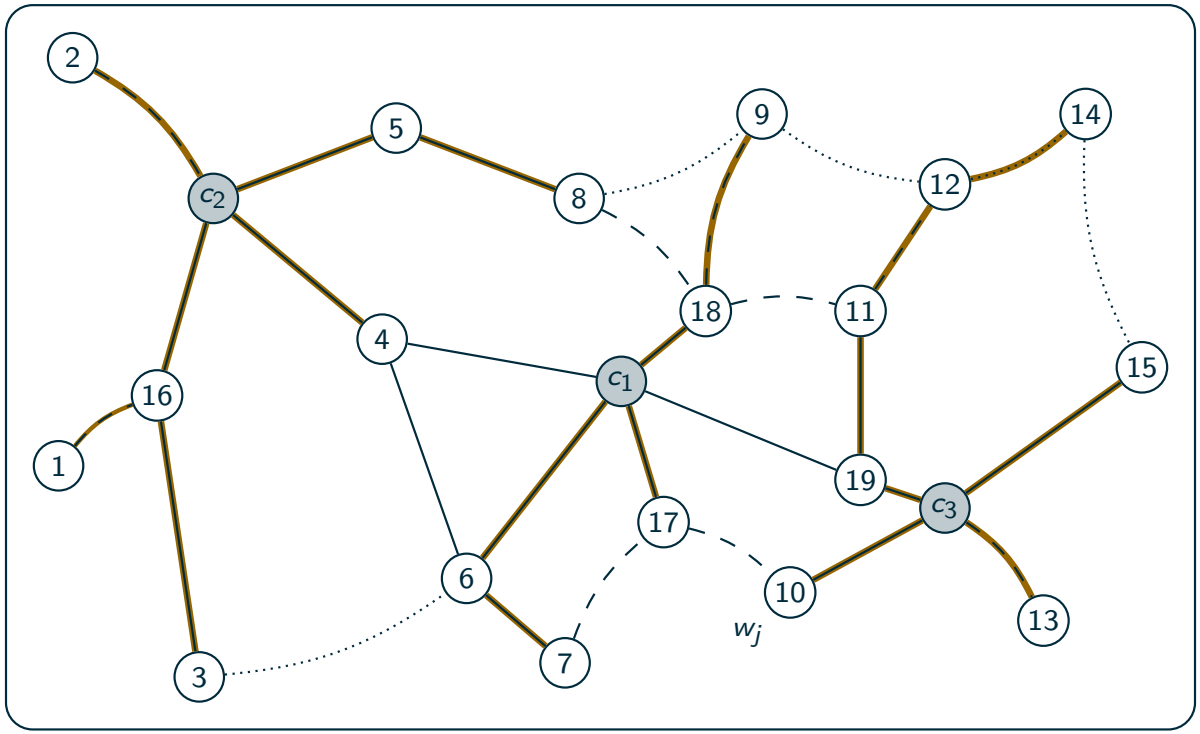
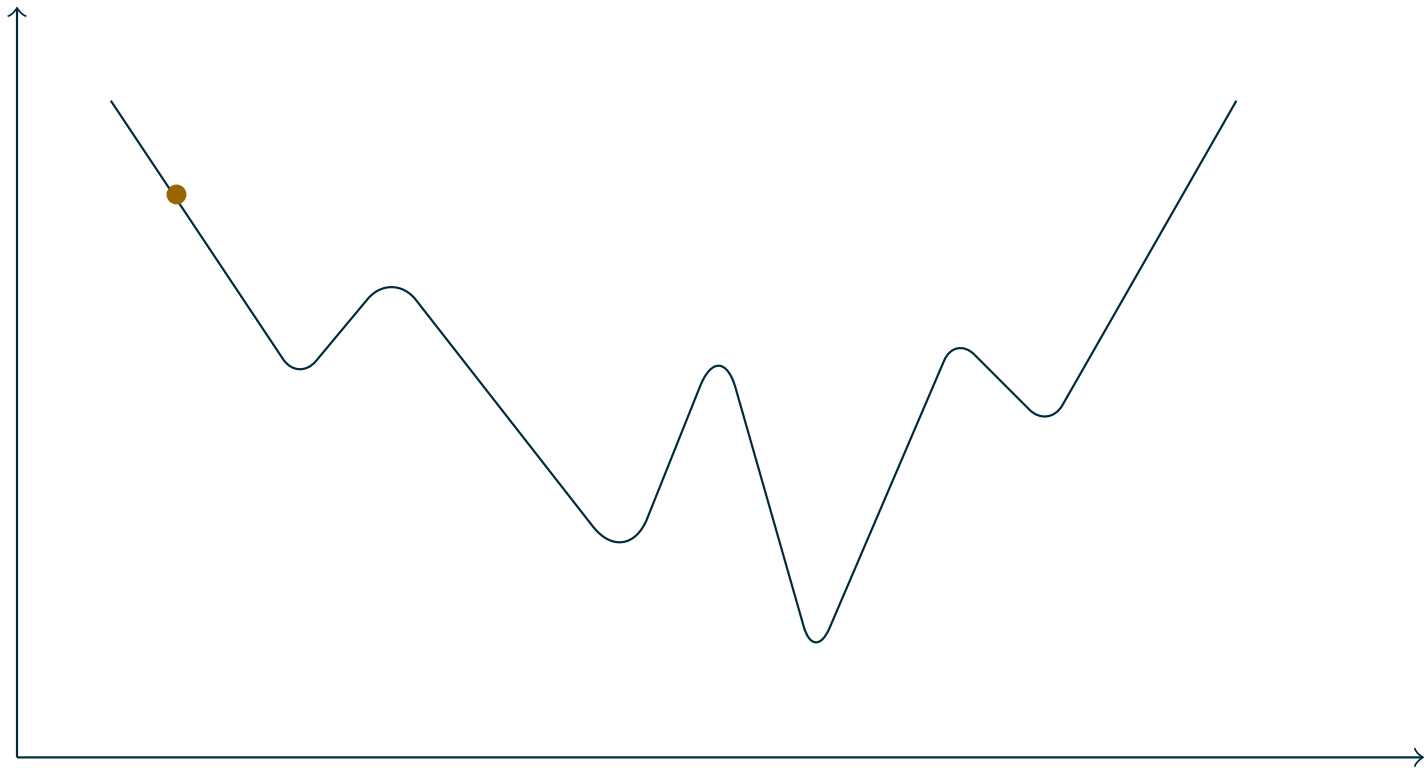


Variable neighbourhood search

- Three moves are considered
  1. Upgrade
  2. Downgrade
  3. Combined move (Upgrade + Downgrade)
- Two procedures to move the search away from local optima
  1. Strategic oscillation
  2. Shaking

Variable neighbourhood search

- Start from an initial feasible solution
- Iterate over the neighbourhoods



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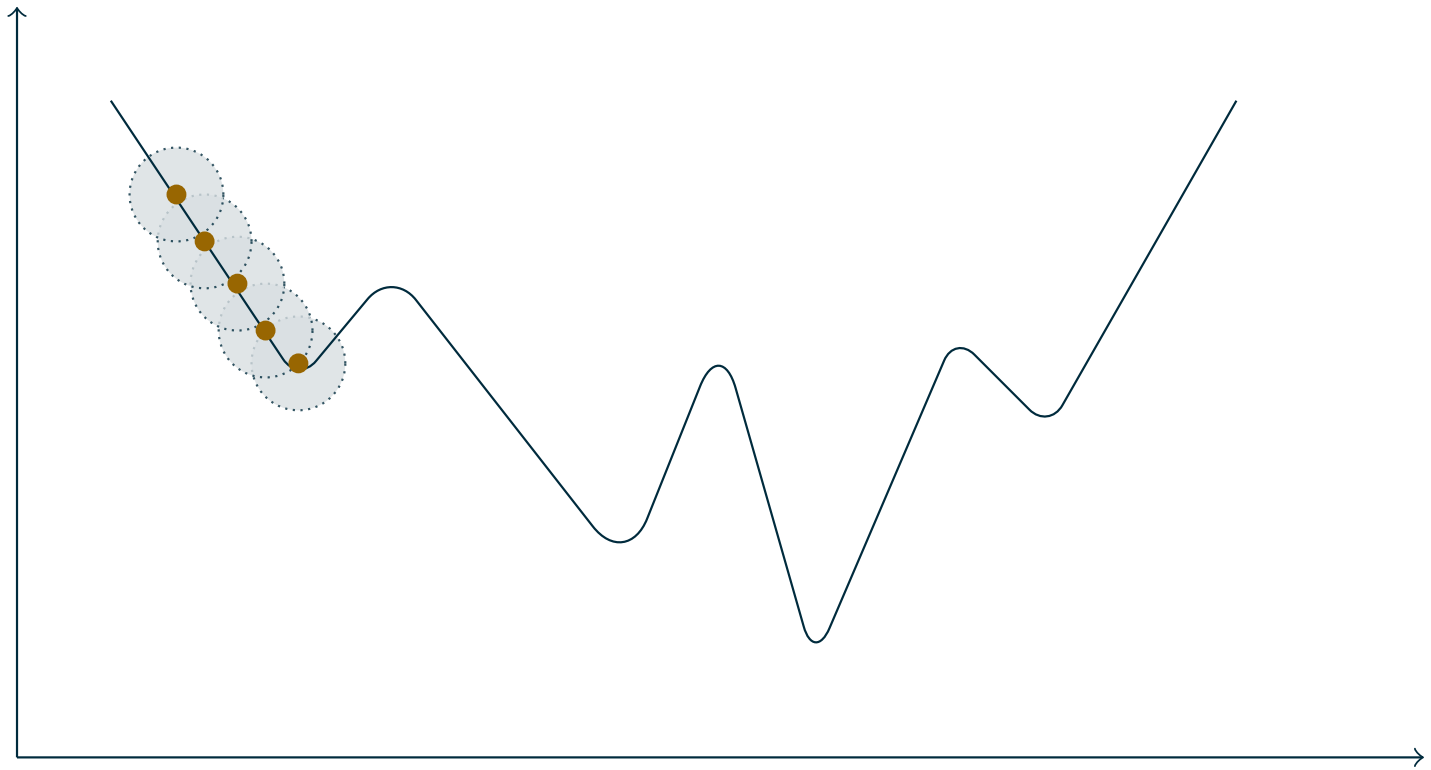

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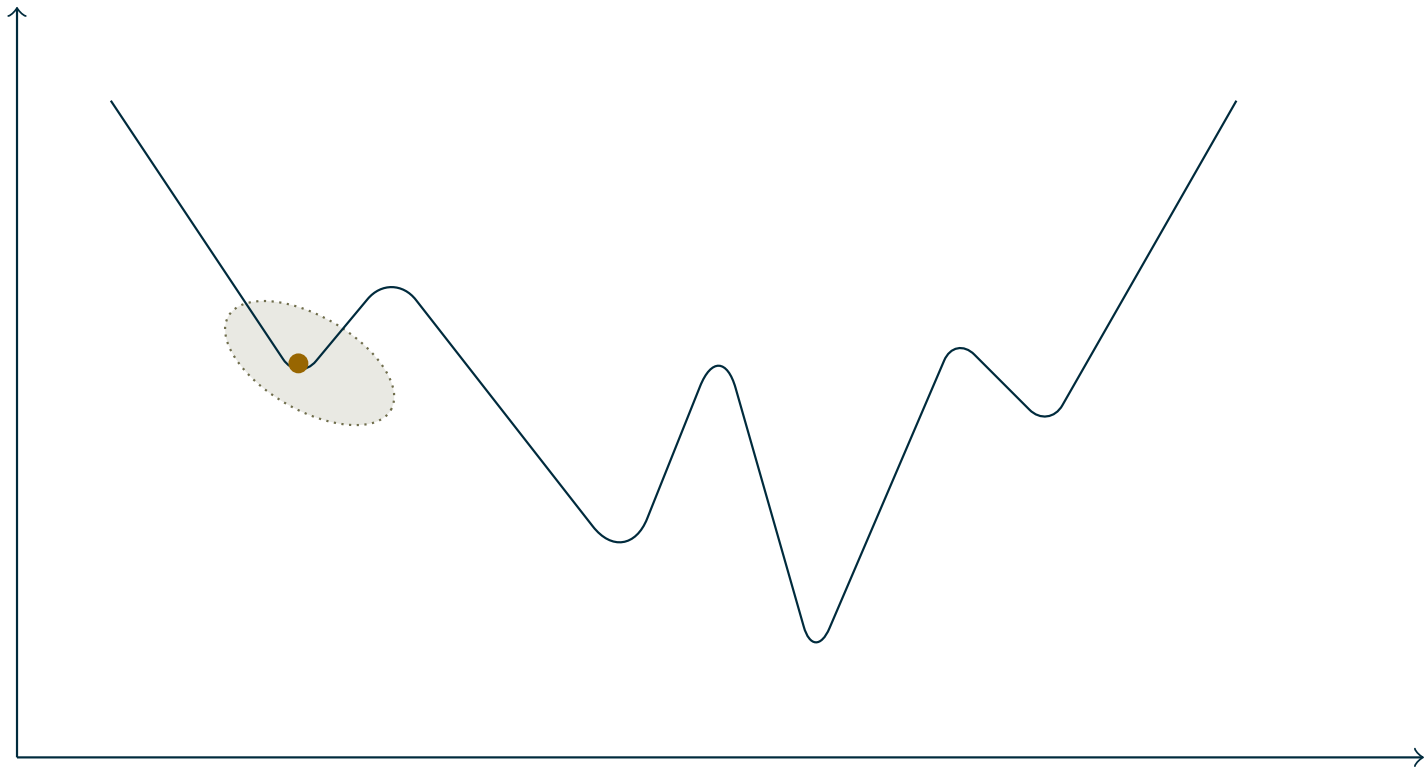

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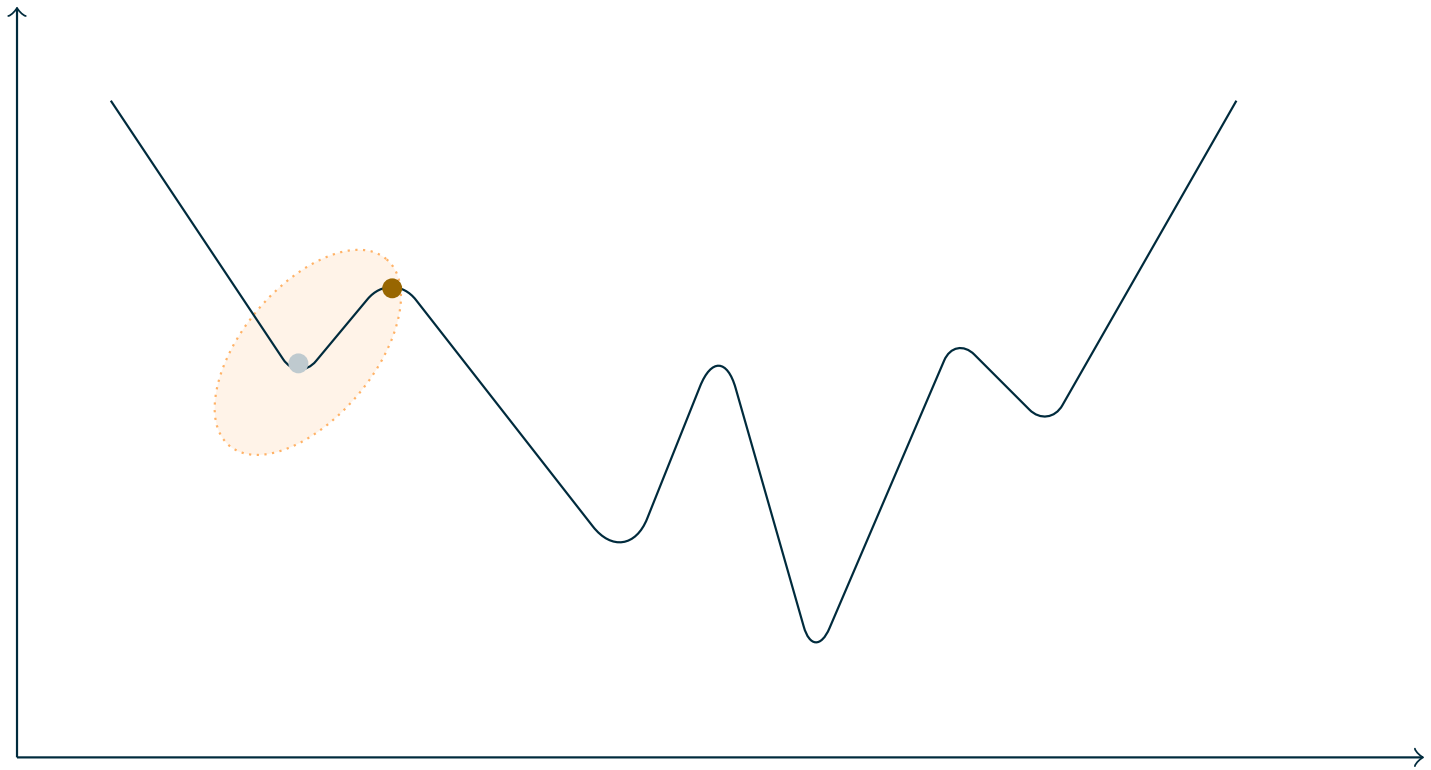

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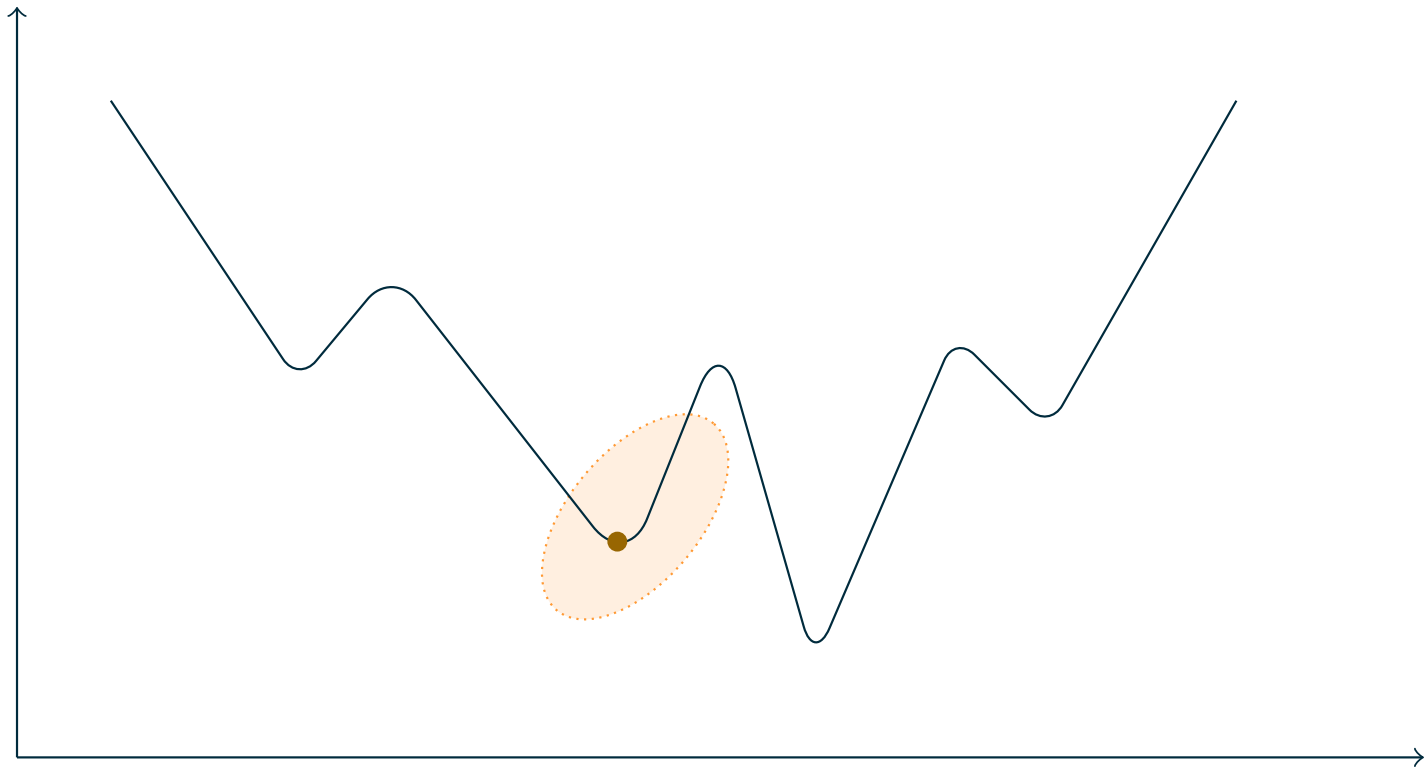
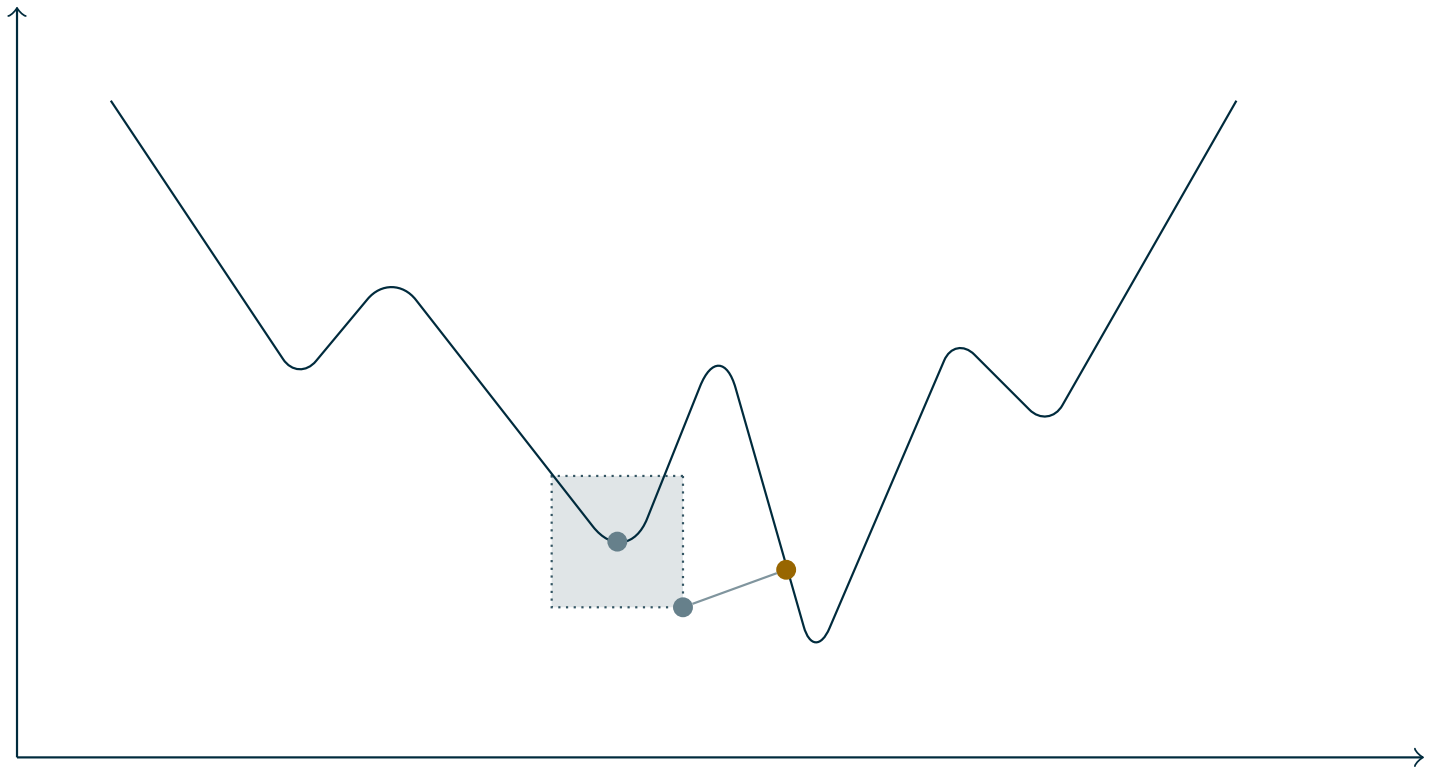


Variable neighbourhood search

- Strategic oscillation: Allow infeasible solutions
- Recover feasibility



Variable neighbourhood search

Special features of our VNS

- For a given upgrading strategy, the accessibility measure is computed by solving a MCFP
- Information from the MCFP is used to select the neighbouring solution
- As MCFPs are solved intensively, we have used re-optimisation techniques

VNS for the A-AUP

%budget	100	200	400
20	1.75	2.55	2.87
50	1.81	2.44	2.69
70	1.45	1.80	2.11
100	0.52	0.73	0.79

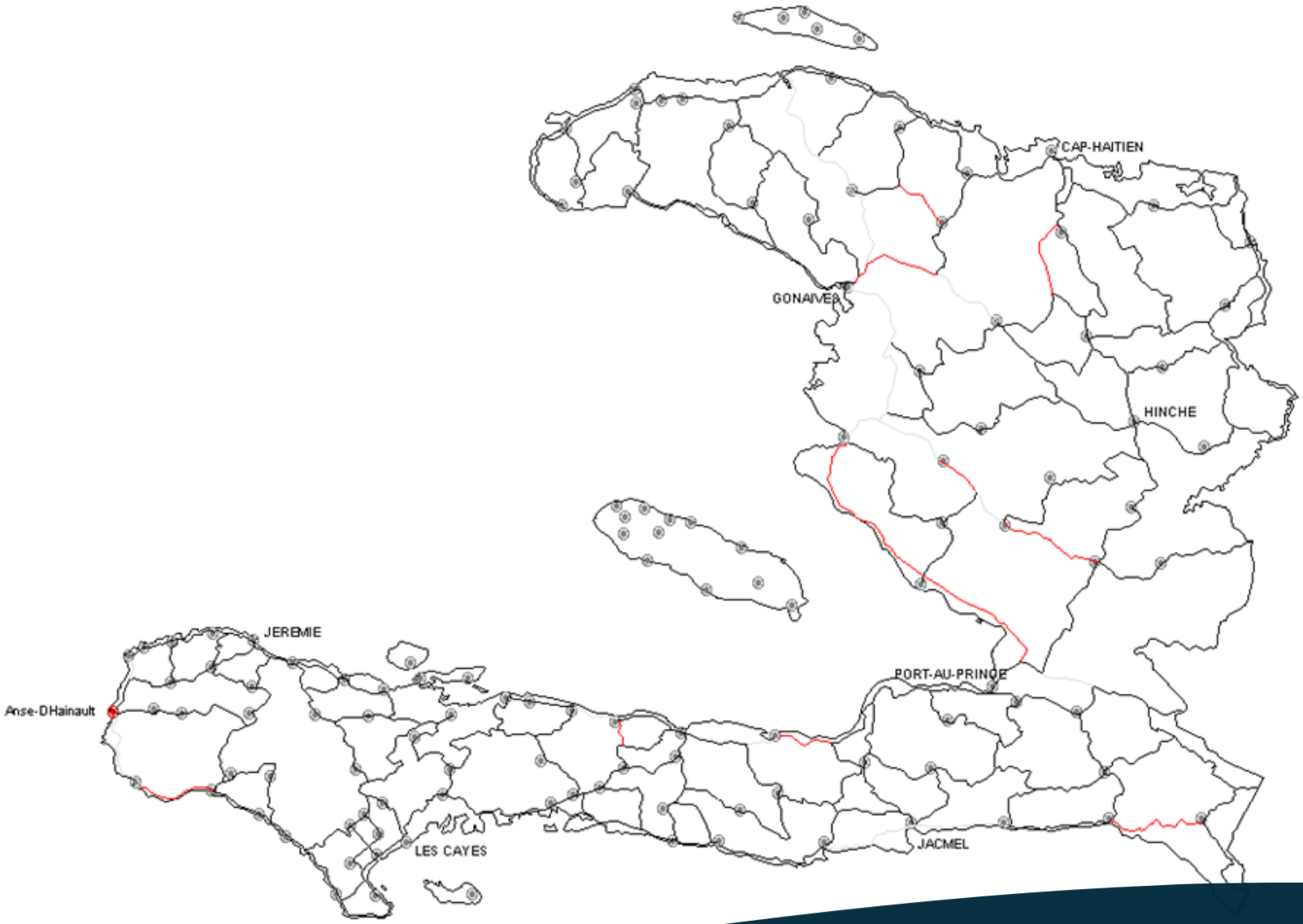
- The average gap to optimality is less than 3.0 %
- Instances with tight budget and large number of nodes have larger average gaps

Why is this study useful?

vertices	100		200		400	
%budget	Min.	Av.	Min.	Av.	Min.	Av.
20	46.39	65.21	51.85	67.85	54.25	68.87
50	67.20	88.02	79.12	89.05	78.98	89.70
70	78.26	94.50	87.28	94.87	87.43	95.43
100	90.83	98.65	94.11	98.66	94.64	98.92

- Large improvements in accessibility can be obtained by allocating the scarce resources properly
- On average around 89 % of the improvement target is obtained with a budget level of 50 % of the total amount required

Application to Haïti



Conclusions and future research

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- We develop and efficient VNS for it
  - The exact approach uses Cplex to solve a mathematical model
  - The VNS can be easily extended to consider additional constraints

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- We develop and efficient VNS for it
  - The exact approach uses Cplex to solve a mathematical model
  - The VNS can be easily extended to consider additional constraints
- How/who can we help?

General conclusions

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  (BUT we need to rethink the way we do things somewhat)