Long-term office space reallocation: A case study

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Dauphine | PSL UNIVERSITÉ PARIS LAMSADE UMR 7243

A joint effort

The LAMSADE team

- Stéphane Airiau, Lucie Galand, Jérôme Lang, Sonia Toubaline (+ CR).
- Expertise: computational social choice, multicriteria decision aiding, optimization.

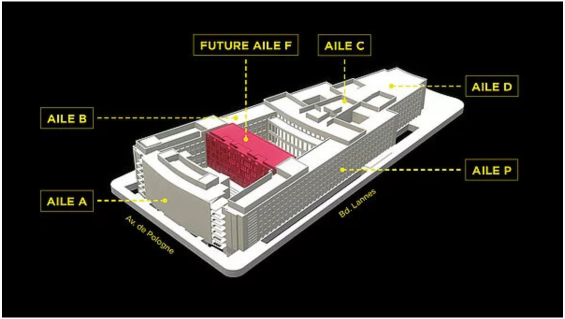
+ Our clients: V. Renaudin, P.-F. Guimont, Dauphine.

Outline

1. Reallocation plan
2. Mathematical model
3. Current and future work

Outline

The *Nouveau Campus* project



- New wing in construction $\Rightarrow$ 2024.
- Others renovated in order: B, P, C+D, A.
- Expected year of completion: 2027.

Our task

Main task

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- Shortage of offices in first two phases $\Rightarrow$ Compression.
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- Maximize global satisfaction of entities (departements, research centers, etc).

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Real-world challenges

- This is all happening once!
- Deadlines set by the university and the construction company.

$\Rightarrow$ We need something that works.

Problem data (1/2)

- $\mathcal{P}$: phases from 0 (initial) to 5 (final).
- $\mathcal{E}$: 22 entities (departments, research centers, services).
- $\mathcal{B}$: ≈ 1000 offices, with capacities $\{\kappa_b\}$ (either 2 or 3).
- $\mathcal{I}$: ≈ 1000 "individuals", with weights $\{\rho_i\}_{i \in \mathcal{I}}$ in $\{1, 2, 3\}$ and entities $\{e_i\} \in \mathcal{E}^{|\mathcal{I}|}$.

An Excel spreadsheet⇒Lots of data cleaning!

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Renovation phases

- 5 (remaining) phases of planned durations τ_p.
- For every phase p, $\mathcal{B}_p$: offices in renovation at phase p.
- $\mathcal{I}^c$: individuals that can share their office during renovation.

Problem data (2/2)

Dauphine's graph

- Built by hand (!)
- $|\mathcal{B}|$ vertices.
- Three edge types:
  - Next door offices (distance 1).
  - Change wing (distance 5).
  - Change floor (distance 10).

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Resulting graph

- Connected, easy to build once.
- Distances vary between 1 and 98 $\Rightarrow$ Problematic!

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Decision variables

Main boolean variables

- x_{bep}: Office b allocated to entity e at phase p.
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Distance-related variables

- v_{bep}: Number of neighbors of b at phase p that belong to a different entity (out-of-entity).
- t_{bdep}: Number of offices in entity e_b that are at distance d of b at phase p.

Constraints

- Offices allocated to at most one entity at every phase:

$$\sum_{e \in \mathcal{E}} x_{bep} \leq 1 \qquad \forall b \in \mathcal{B}, \forall p \in \mathcal{P}.$$

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- Final allocation set: $x_{be5} = x_{be}^5$.

Constraints ('ed)

Topological constraints

- Restriction of locations:
  Ex) PhD student offices
- Forbidden configurations:
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Many special cases

- Part of an entity moves out for one or more phase(s).
- Entities may change over the renovation period (Individual will).

Objective functions

For every entity e,

1. Number of moves (to be minimized)

$$M(e) = \sum_{p \in \mathcal{P}} n_{ep}, \quad n_{ep} = \max\left\{\sum_{b \in \mathcal{B}} (x_{be(p-1)} - r_{bep}), \sum_{b \in \mathcal{B}} (x_{bep} - r_{bep})\right\}$$

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2. Compression ratio (to be maximized)

$$C(e) = \sum_{p \in \mathcal{P}} \tau_p \frac{\sum_{b \in \mathcal{B}} x_{bep}}{\sum_{b \in \mathcal{B}} x^0_{be}}$$

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3. Dispersion measure $S(e)$ (to be minimized).

Several possible choices

- Take all possible distances into account:

$$S(e) = \sum_{p \in \mathcal{P}} \sum_{b \in \mathcal{B}} \sum_{d=1}^{98} d\, t_{bdep}.$$

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$$S(e) = \sum_{p \in \mathcal{P}} \sum_{b \in \mathcal{B}} \sum_{\ell=1}^{5} \ell \, g_{b\ell ep}.$$

where $g_{b\ell ep}$ corresponds to an interval of distances.

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- Use the number of **out-of-entity neighbors**:

$$S(e) = \sum_{p \in \mathcal{P}} \sum_{b \in \mathcal{B}} v_{bep}.$$

Criteria normalization and aggregation

Normalization

- Map criteria into $[0, 1]$.
- For entity e,

$$M(e) \leftarrow \frac{M(e)}{|\mathcal{P}| \sum_{b \in \mathcal{B}} x_{be}^{\mathbf{5}}}, \; C(e) \leftarrow 1 - \frac{C(e)}{\sum_{p \in \mathcal{P}} \tau_p}$$

- Normalization for $S(e)$ depends on maximum distance considered and/or maximum number of neighbors.

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Aggregation

$$\sum_{e \in \mathcal{E}} w_M M(e) + w_C C(e) + w_S S(e).$$

- Simple choice $w_M = w_C = w_S = 1$ (to be adjusted).
- We are thinking of something less utilitarian!

Implementation

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- Problem solved using Gurobi.
- Run on LAMSADE server.
- Orders: 10^6 variables/constraints.

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Tuning the function dispersion

- No dispersion metric⇒Very different solution from the current one.
- Use full distances⇒Struggle to find a feasible point.
- **Surrogates**
  - Use a smaller number of distance values ⇒ 2 days to find a feasible point!
  - Use the number of out-of-entity neighbors ⇒ 2 days to go beyond 10% optimality gap.

Our last results

- We optimize over all phases.
- The *Nouveau Campus* team computes the next phase by hand.

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Next phase comparison

- Hand-coded solution is better on all three criteria!
- Number of moves similar (206 vs 216).
- Many exchanges to refine ours without significant change in next phase.

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What now?

- Their solution has been adopted (time constraints).
- But the following phases will be obtained through our model.

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Weighting our objectives

Current objective

$$\sum_{e \in \mathcal{E}} f(e) = M(e) + C(e) + S(e)$$

- Sums the three terms equally.
- Our goal: Add (fixed) weights for every entity

$$\sum_{e \in \mathcal{E}} w_M^e M(e) + w_C^e C(e) + w_S^e S(e), \quad w_M^e + w_C^e + w_S^e = 1.$$

About the entities

- Different priorities!
- Compression/Dispersion do not have the same importance.

$\Rightarrow$ Entities will select their own weights.

Ongoing approach

- Based on ordered weighted averaging (Yager, '88)
- MILP model (Ogryczak & Olender, '12).

Current objective

$$\sum_{e \in \mathcal{E}} \omega(e, f) f(e)$$

- $\omega(e, f)$: Ordered weights from saddest to happiest entity (linearization)
- Our first test: $(5, 2, 1, \ldots, 1)$.
- Several others in the pipeline!

Other search directions

ROADEF-related

- **Constraint programming**: Finding a feasible solution.
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ROADEF-adjacent

- Continuous relaxation (given as a course project in M1 at Dauphine).
- Could use modern solvers for generalized linear programming (Summer internship).

Conclusion

What we have

- An MILP model that **can** be solved in reasonable time.
- A certificate that the next moving plan compares to the optimum.
- A flexible framework through OWA.

Moving forward

- Including entity preference data (poll).
- Explore alternate solving techniques (decomposition, continuous relaxations).
- We have limited time but appreciate all suggestions!

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Thank you for your attention!

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