Long-term office space reallocation : A case study

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1 Introduction

The main building of Université Paris Dauphine-PSL will undergo massive construction and renovation over the next five years, which has a number of consequences on its operations. In particular, it affects availability of office space for all university personnel. More than 90 % of the office space will be renovated, and unavailable for one or more phases of the renovation (six phases total). The general renovation plan specifies which of the offices will be available or under construction/renovation at every phase, and it also affects individuals to office space at the end of the renovation process. It is expected that a given individual will have to move twice on average.

We have been commissioned to investigate the proposed moving plan and study its optimality with respect to several criteria tying to equity among various entities within the university personnel (central services, teaching departments, research institutes).

2 Optimization model

We have defined two models of the moving plan, based on allocating offices to individuals (microscopic model) or to entities (macroscopic model). Our motivation for the latter is both computational, in that it results in a smaller optimization problem, and conceptual, in that it provides a moving plan that is easier to adapt to changes in personnel.

The data defining our problem consists in the renovation phases and their duration, the offices and their capacities in terms of individuals, the set of offices available at every phase, as well as the initial and final occupation plan for the office space. For the macroscopic model, we reason in terms of entities, and thus we know which offices belong to a given entity at the initial and final stages. For the microscopic model, we have additional information in terms of individuals that constitute these entities. Finally, we constructed a graph of the university building with all the distances between offices.

We formulate our problem as an integer linear program. Our main variables are exclusively binary, and express whether a given office is affected to a given entity at a given phase. Other variables are used to model moves from one office to another. Linear constraints encode both general requirements, such as the fact that one individual is affected to a single office at every phase, and specific restrictions, such as the limited number of offices that can host the infirmary.

Our objective function aggregates three criteria that are evaluated over all entities, under the form of a weighted sum to be minimized. These criteria represent three significant criteria that should be balanced between entities.

Number of moves by entity If an office at phase p is unavailable at phase $p+1$, its occupants will have to move. A natural criterion to minimize while planning the allocation consists in the number of moves, which both benefits the entities and reduces the moving costs. Rather than measuring the total number of moves, we evaluate a weighted sum of the moves per entity, where the weighs correspond to the sizes of the entities.

Compression rate During the renovation, the available office space will shrink, and thus the number of offices per entity will be below that of the final and/or initial allocation. We define the compression rate for an entity e at a given phase p as the ratio

$$\frac{\text{number of offices at final phase for entity } e}{\text{number of offices at phase } p \text{ for entity } e}.$$

Dispersion rate The moving plan may result in entities that are spread out throughout the university building. To mitigate this effect, we seek to minimize the distance between offices of the same entity. The distance can be measured at several levels of precision. A first approximation consists in minimizing the number of neighborhing offices that do not belong to the same entity. A more precise criterion uses the graph of the offices, and evaluates either the maximum distance between pairs of offices belonging to the same entity or the sum of all distances between offices of the same entity.

3 Implementation and results

An important part of our work has consisted in cleaning the data through multiple interactions with the university committee in charge of the renovation plan. We then used that data to define our linear programming model using Gurobi, to be solved using our institute's computing server. The problem proved to be extremely challenging due to the large number of variables and constraints, particularly those encoding dispersion. Removing the dispersion criterion improving the running time significantly (hours rather than days), but it led to a worse model compared to the solution computed by hand. Indeed, even though the solver converged to an optimal solution, it generated significant dispersion among the entities, and in that sense was deemed significantly worse that the solution designed by hand by the renovation committee.

While using the number of neighbors with different entities as a metric for dispersion, the solver produced a near-optimal solution in a few days. Using distances increased the running time significantly, and the solver took about 36 hours to find a feasible point. The resulting solutions are approximately optimal, and we compared them with that proposed by the renovation committee.

We will discuss two key challenges in improving our work. The first one is related to the dispersion criterion, which we will seek to improve for the sake of scalability. The second challenge will consist in changing our pure utilitarianist aggregation (minimizing the sum of the costs of entities) into a more egalitarianist one such as minimizing the sum of squares or costs, or maximizing the Nash product after expressing costs as positive utilities. The latter two criteria are considered reasonable trade-offs between efficiency and fairness in discrete resource allocation.

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