Exploration of "What-If” Scenarios: A Prototype for Research Buildings at Stanford's School of Medicine

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1 Analysis of the Problem

1.1 Context

The Spatial Planning Project for a prototypical research building at Stanford University School of Medicine was created to address a real and urgent need for a dynamic tool which objectivizes the sequence of relocation of functional spaces from existing, aging facilities into new buildings, over time.

1.2 Statement of the Problem

Our team was tasked to address the 18 departments located in the 4 wings of the Stone complex out of the 45 total departments located throughout the Stanford University Campus. These departments were slated for demolition and phased moves with a hierarchy of priorities and commitments. In addition there were functional relationship constraints, commitments associated with Principal Investigators (PIs) recruitment, planning requirements and further influences from the unpredictability of funding which may radically change priorities for relocation into the new building.

The traditional process is characterized by a linear and sequential approach. The solution is defined early on, without full context, and details are developed incrementally in each phase without the ability to revisit previous decisions.

Currently, complex, campus-wide planning processes tend to produce static documents in spite of rapidly changing academic environments. Over time, the design options’ appraisal process is often perceived to be biased and poorly documented relative to complex interdependent design driving factors. The inherent changes which occur over the life of a complex planning process are often made within the confines of specific building projects and appear to lack the benefit of being informed by the original inter-twined driving design forces.

Furthermore, the volume of options that can be produced using that traditional process during complex projects such as this (characterized by dynamic interdependencies), can become overwhelming as well as confusing to stakeholders, to the design team and to other external parties.

1.3 Summary Statement of the Solution

The Aditazz approach represents a radical development in spatial thinking. Our methodology proposes a departure from a linear, sequential process to one in which “no decision is final until all decisions are final” i.e. a framework which permits the simulation and storing of multiple possible strategies which address complex and evolving requirements.

Our rational rule-based methodology exploits large-scale computation which results in a legible and logical output that can be easily understood. The Aditazz methodology tracks and records all design decisions, allowing retrospective reviews and auditing. We enable a rapid and clear understanding of the selection process and with an objective, rule based method of planning.

2 The Project: Redefining Spatial Thinking in the Planning Process

2.1 Challenges

We understood the project challenges to be as follows:

A. Maximize the space utilization of the prototypical research building and allow for the exploration of "what-if" scenarios based on possible aggregations of potential candidates and committed departments.

B. Identify solutions which can be optimized for a certain set of quantifiable performance metrics as defined by Stanford School of Medicine.

C. Define a planning methodology and software "engine" which can respond to functional requirements which evolve over time given the changing nature of research, funding, new requirements, construction staging, etc.

To address these challenges, we assembled a cross-disciplinary team, including the Aditazz spatial modeling team, room library and user interface designers, computer analysts as well as building architects with experience in campus-wide master planning and the design of research facilities.

2.2 Approach

Our methodology determined that the need is initially a lot larger than the available new space and hence the relocation would have to occur as a multi-phased planning process, while recognizing the complex constraints and multiple inter-dependencies within which the functional spaces must operate.

We mapped the complexity of the programmatic scenarios to a custom designed computer program, which can generate aggregation scenarios for all 45 departmental "candidates", each defined by various parameters such as previously made commitments, priority of relocation, net area, programmatic drivers (space ratios), etc. The software allowed the user to explore and compare various options by changing the constraints and the user-defined parameters.

The software and space planning thinking and methodology were developed based on the material provided to us by the Stanford School of Medicine, including:

A. Project data for 45 departmental "candidates" for relocation from their current location into the first prototypical research building at the Stanford School of Medicine.

B. The list and details of those departments already "committed" for relocation i.e. five departments for which there was already a commitment to be re-located in the prototypical research building.

C. The shape, overall building size, exterior form (building envelope), the number of floors (4 above, 2 below-grade) and floor heights of the prototypical research building per the feasibility study approved by the city of Palo Alto.

This building envelope formed the "baseline" for the application of the Aditazz software and space planning methodology (with minor modifications to allow for daylight penetration to Floor 0).

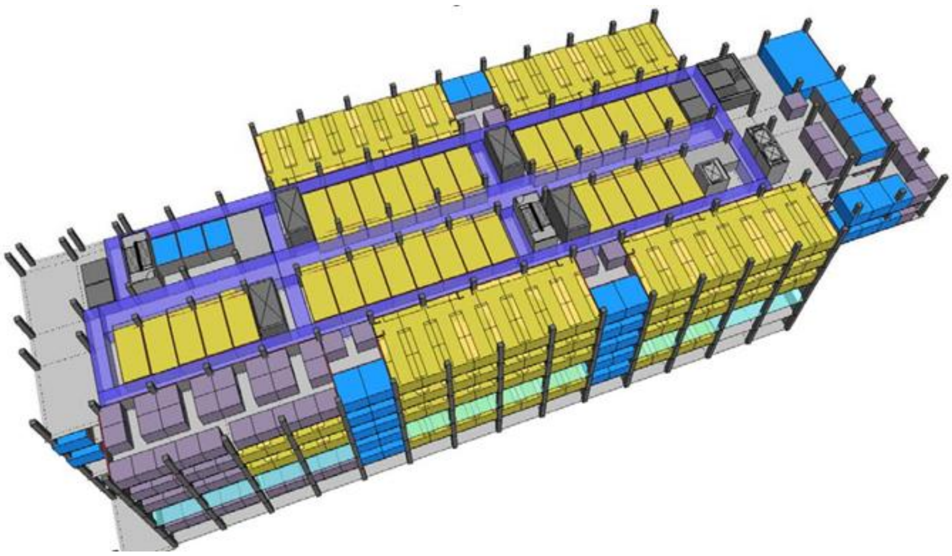

Fig. 1. Prototypical Research Building Baseline Option 1 with skylights on Floor 1.

D. Programmatic drivers, i.e. the ratios between the various functional space typologies (between the number of principal investigators and corresponding number of research benches); the areas of lab support; the number of offices and number of work stations for each department.

E. Intrinsic to our approach is the context of interdisciplinary collaboration. A number of disciplines coalesced on this project and their contributions may be defined as:

Architects: Orchestrated the inter-disciplinary team effort as well as the development of design solutions including design strategies for day-lighting, lab planning strategies to improve lab and building efficiency and space utilization, building section studies and performance evaluation framework for the of scenarios' appraisal.

The Software Engineers: Formulated the problem as a genetic algorithm optimization problem and developed and prototyped the methodology for software to perform space planning, including, but not limited to:

- Development of mathematical and data models describing space allocation in lab research buildings.
- Formalize space assignment optimization tasks and implement the optimal assignment algorithm.
- Assure extension of the developed methodology and prototype to SoM master space planning process.

The User Interface Designer: Prototype user interface allowing the software user to view, evaluate, modify, and perform space allocation, as well as control automatic optimal space assignment;

The Planners: Problem formulation, program analyses, flow diagrams, library of planning modules, library of plan options.

2.3 Solutions

The Aditazz spatial modeling methodology allowed for both manual and automatic placement of departments within the prototypical research building given massing (shell) and according to constraints identified by users. These options were visualized both as floor plans (as shown below) and as section diagrams generated by the software program for each aggregation.

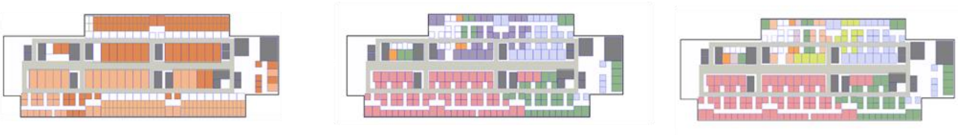

Fig. 2. Shows (left side floor plan) 1A No Overrides; (center floor plan) 2A No Overrides; (right side floor plan) 2B No Overrides. The Aditazz team demonstrated the functionality of the Facilities Planning Software, using two predefined scenario models:

Scenario 1: All floors are planned with a combination of labs, lab support, faculty offices and non-faculty workstation modules. This shall allow any department, irrespective of whether it has a need for benches, or only a need for computational space, to be located on any floor the lab building.

Scenario 2: Floors 0 to 3 have a combination of labs, lab support, faculty offices and non-faculty workstation modules. Floor 4 is planned with only faculty offices and non-faculty workstation modules. This is to allow the consolidation of departments that do not have a need for benches onto one floor.

For each of the two scenarios, two options were generated. The following describes the constraints set in each generated option.

Scenario 1A (the floor plan on the left):

- No floor assignment to any department
- No overrides to the space program

Scenario 1B:

- Genetics Department committed to relocate assigned to Floor 2 and Neurology Department committed to relocate assigned to Floor 1.
- Overrides set per the client's request.

Scenario 2A (the center floor plan):

- Genetics Department committed to relocate assigned to Floor 2 and Neurology Department committed to relocate assigned to Floor 1.

Scenario 2B (the floor plan on the right):

- Genetics Department committed to relocate assigned to Floor 2 and Neurology Department committed to relocate assigned to Floor 0.
- Overrides set per the client's request.
- Priorities for shell changed.

For the automatic placement of the candidate departments into the prototypical research building, we took our Spatial Layout Genetic Algorithm Engine (patent pending) as a basis.

We took our inspiration for the algorithms from genetics in the belief that excellent design can take the patterns and formulas of nature as a template. This inspiration was augmented with a number of principles within our approach.

- Focus on the experience of all people involved (as opposed to the things involved).
- Focus on the integration in the habitat (as opposed to be a self sufficient silo).
- Realize itself through a massive exploration of options (as opposed to be the result of a series of assumed perfect decisions).
- System that is dynamic and adapts to location and time (as opposed to rigid templates).

- Composition by a large number of simple elements from a minimum but sufficient set (as opposed to all full custom pieces) put together according to a rigorous set of rules that ensure quality without sacrificing creativity.

The setting was substantially different however. The original algorithm places department blocks, while optimizing rich adjacency constraints, minimizing overlaps and satisfying area and window allocation requirements.

Input to the optimization engine for the prototypical research building consisted of the predefined floor plans and the space program containing the number of lab benches, faculty offices and workstation modules per each candidate department.

The result of optimization is the selection of the best subset of the candidate departments and their locations in the building that optimally utilize building resources. Each possible assignment of selected departments to their positions in the building is called chromosome.

The quality of results for each chromosome is characterized by fitness function. The fitness function takes into account the area utilization, department priorities and adjacency constraints including restricting department placement to a subset of the building floors.

$$\text{Fitness} = \sum \text{constraint costs} + \sum \text{violation costs} + \sum \text{excess capacity costs} + \sum \text{department priority costs}$$

Genetic algorithms utilize a number of methods to optimize fitness functions that are specific to each particular problem at hand. These methods include:

- Population generation
- Candidate selection
- Crossover
- Mutation functions

All of these functions had to be designed and implemented anew. As a result we have a flexible, extendable and customizable setup for the category of problems similar to the one in this project.

3 Conclusion

We believe that our demonstration of the Aditazz spatial planning software's capabilities and the overarching planning methodology developed specifically for this project by using the Aditazz Realization Platform will help the Stanford School of Medicine codify and quickly test and rank many scenario sets, change the priorities for relocation among all the departmental "candidates" as needed, and characterize with qualitative and quantitative attributes, multiple scenarios in order to create viable options for further development.

Although our approach and software are illustrated using only one building (the prototypical research building), the above methodology is designed to have the capacity to scale to handle multiple buildings, complex constraints and the ever-expanding needs of a phased planning process.

The spatial thinking which formed the basis of our methodology successfully spans several disciplines and perspectives, including mathematicians, the computer software modeling team, room library and user interface designers, computer analysts as well as building architects acting as translators between traditional architectural design and lab planning logic and computer language and coding.