Generative design for Hospital Pharmacy: optimizing spaces /flows with Dynamo/Refinery

Dominique Aupy & Oscar Mannarella

BIM Project Leader BIM Project Leader

AUTODESK. UNIVERSITY

Introduction

About the speaker

Dominique Aupy

French architect and engineer, Dominique is currently a project leader for Engie Axima, working on specific BIM services for hospitals and other innovative projects such as indoor air quality simulation. He joined the ENGIE group to develop BIM technology.

ENGIE Axima is a company of the ENGIE Group, a multinational company promoting affordable carbon-free energy transition as a service.

How it begun …

FLEXIBIM Concept

In spring 2018, ENGIE Axima won a public call for expression of interest for the future digital hospital.

BIM based solution in the hospital environment

FLEXIBIM Concept

CREATE AND VISUALIZE MODULAR SPACE AND ORGANIZATION CONFIGURATIONS

For new construction or rehabilitation works

Attention to Staff functional needs and patient wellness

EVALUATE PROPOSED SOLUTIONS

Technical impacts, air quality, consumption, lighting, process …

INVOLVE STAFF AND PATIENTS INTO THE DECISION-MAKING PROCESS THROUGH VR SOLUTIONS

CONDUCT PRE-FEASIBILITY STUDIES

Collaborative contract

ENGIE Axima initiated a partnership procedure with the biggest hospital organization in France, the Public Assistance of Paris Hospitals (referred as APHP in the following)

APHP represents 39 hospitals receiving 10 million patients per year.

It is the biggest employer in the Paris region and also an international influencer in the hospital environment.

Collaborative contract

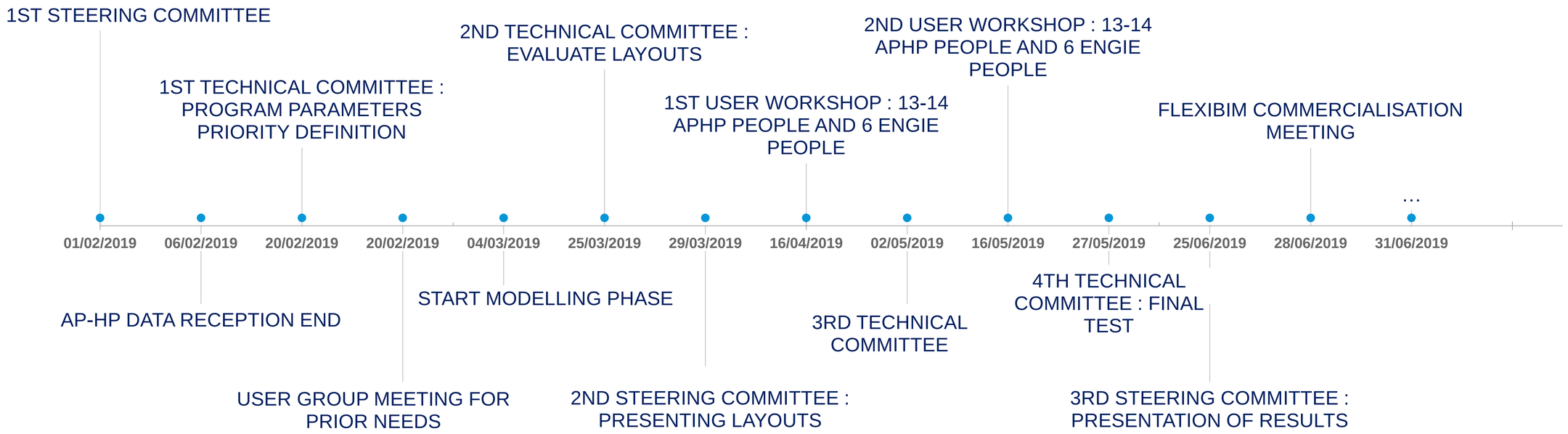
It was essential to involve our partner in the process both financially and technically in a Proof of Concept.

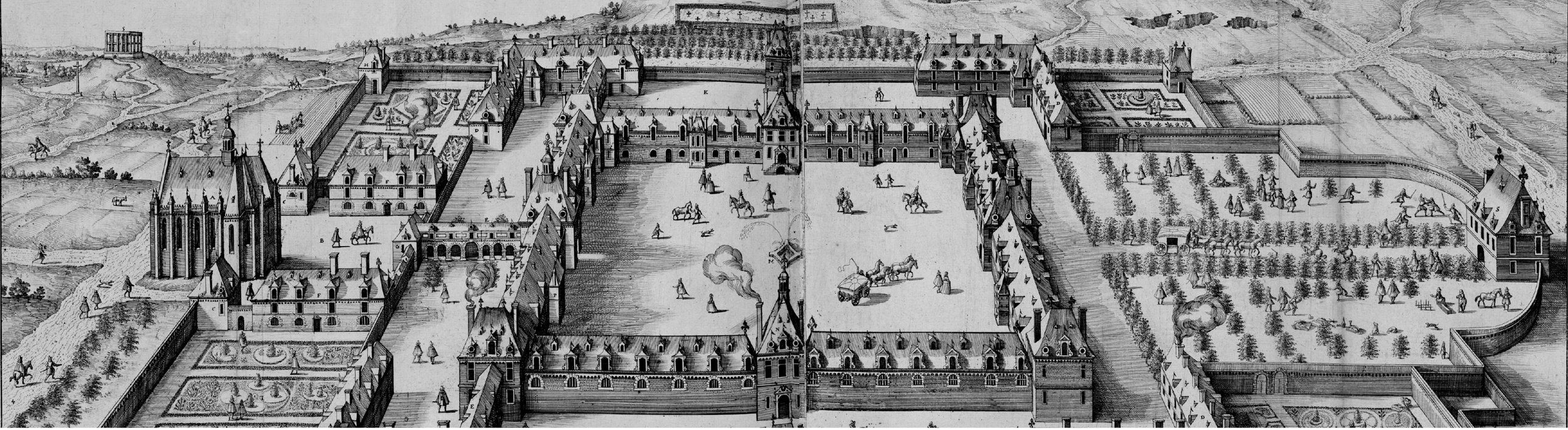
Organization:

- Financial participation was of 30% for our partner.
- Incentive agreement for APHP in case of further commercialization of the solution.
- It was established that each party will provide a team of people to work on the project paced by :
  - steering committees,
  - technical committees,
  - user group meetings.

Collaborative contract

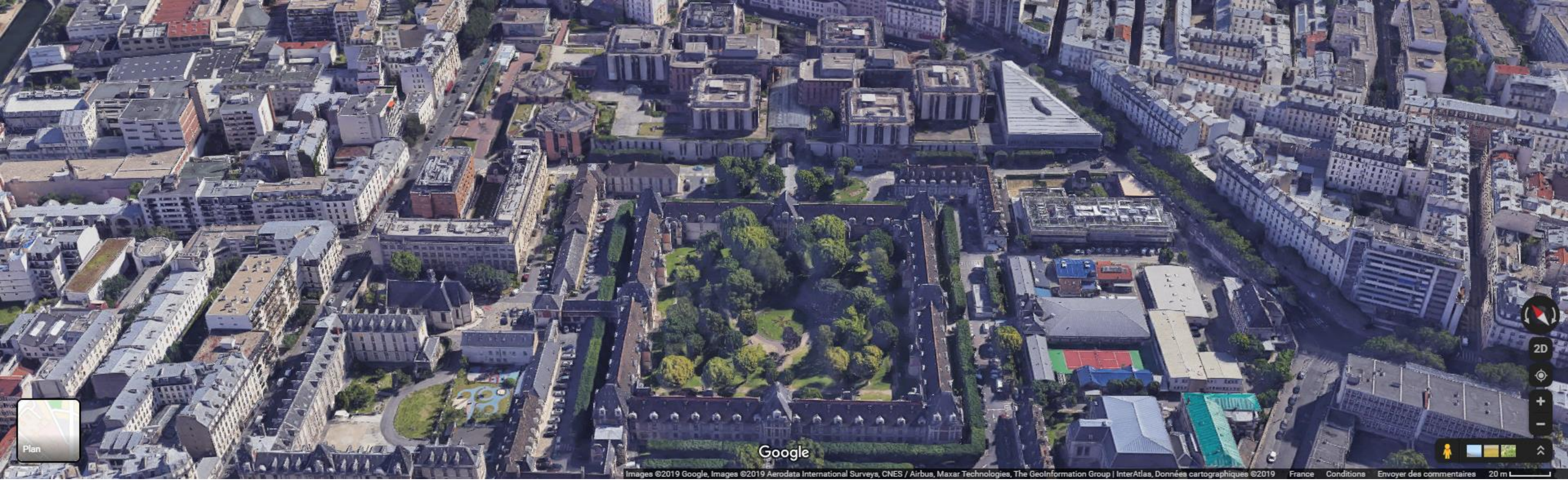
A strict 5-month planning.





Site: Hospital Saint-Louis in 1608 by Claude Chastillon

One of many very old hospitals in Paris



Site: Hospital Saint-Louis 2019

Today, the modern extension behind the hospital is hosting a big part of the medical equipment and the pharmacy. As it is an historical site, the battle for space is happening in the modern part already very dense.

APHP chose its inner pharmacy to test FLEXIBIM: 1300m² to reorganize and optimize with a material/people flow constraint at basement 1 level.

Deliveries

Deliveries can be daily or weekly.

Some goods require cooling.

Stock management in the pharmacy

This stock supplies the pharmacy. There are possibilities for improvement.

Stock management in the pharmacy

Here a robot stores medicines.

The operator feeds the robot when deliveries arrive and fills the containers according to the received order.

One can see inconvenient pipes.

The important part of this activity is to provide a container on time with the proper medicines and material, but logistics was not seen as a priority.

Stock management in the pharmacy

Here we see stocks in the circulation and again inconvenient pipes.

The volume of stock spread in the pharmacy.

Automated delivery of prepared container

Once the containers are ready, delivery is fully automated within the hospital.

https://autode.sk/2QcNrD7

Natural light source 1

On one end there is a classified waterfall installation without water.

Natural light source 2

On the other end, the warehouse has natural light on the delivery courtyard and its level is 1 meter lower than the pharmacy.

Offices and circulations

Corridors are narrow with low ceilings.

Offices are mostly small without natural light.

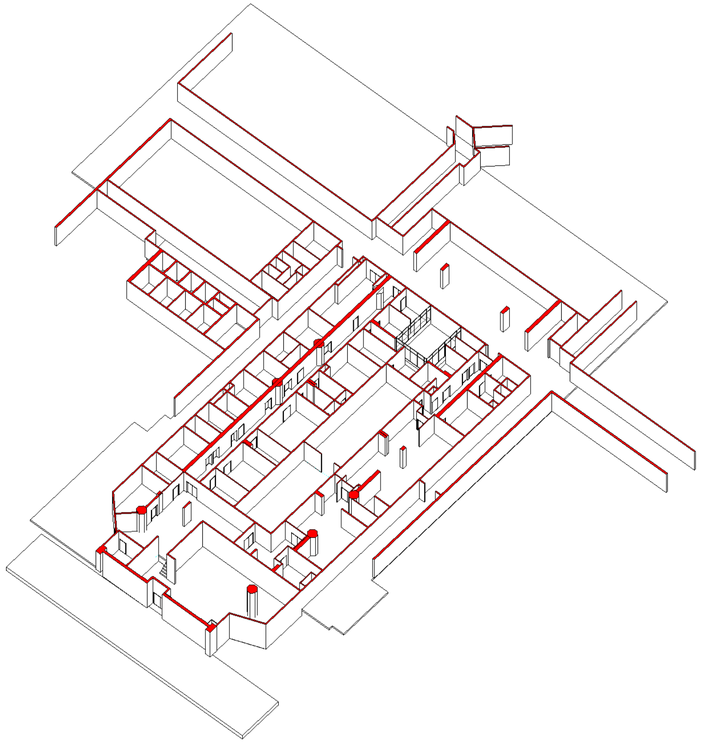
Data collection

To start with, we gathered information to build a BIM model of the existing situation and we conducted user group workshops to acquire the following data:

- Existing plans
- List of rooms
- List of furniture
- A proposal made by an architect in order to have the architectural program (no other sources available) and a room adjacency matrix
- Pictures and explanations about the Pharmacy
- List of flows (horizontal and vertical) for people and materials/medicines
- Stock volume

Existing layout

In order to analyze the flows, we made a model of the existing layout and organized user workshop to identify the flows.

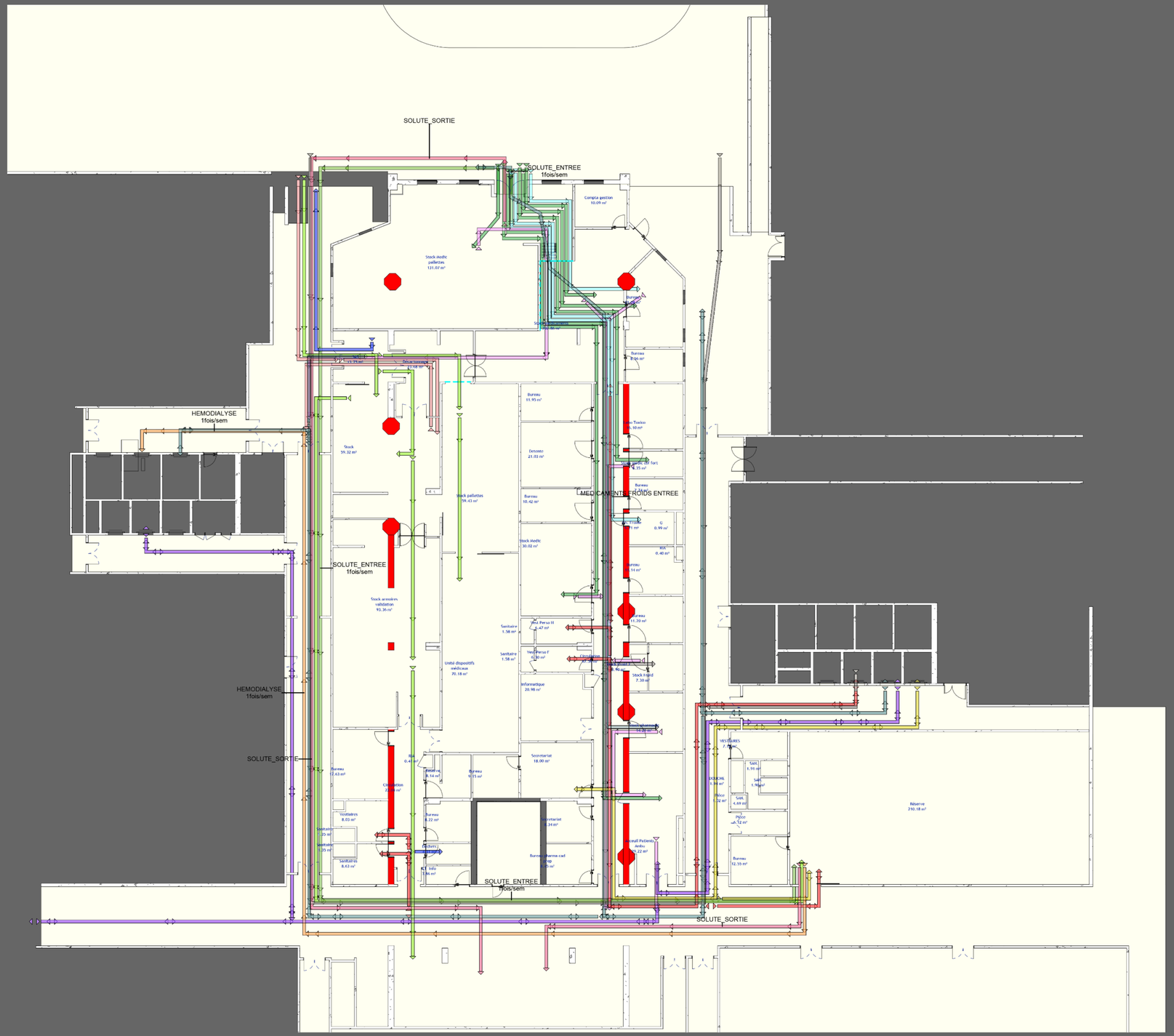


Structural constraints

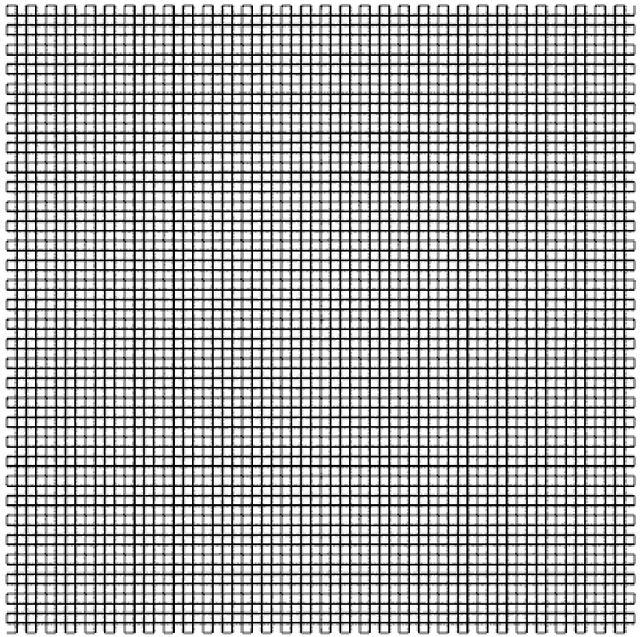
Here the structural constraints in red that unfortunately show a heavily constrained environment.

Flow analysis

For people, material and medicines

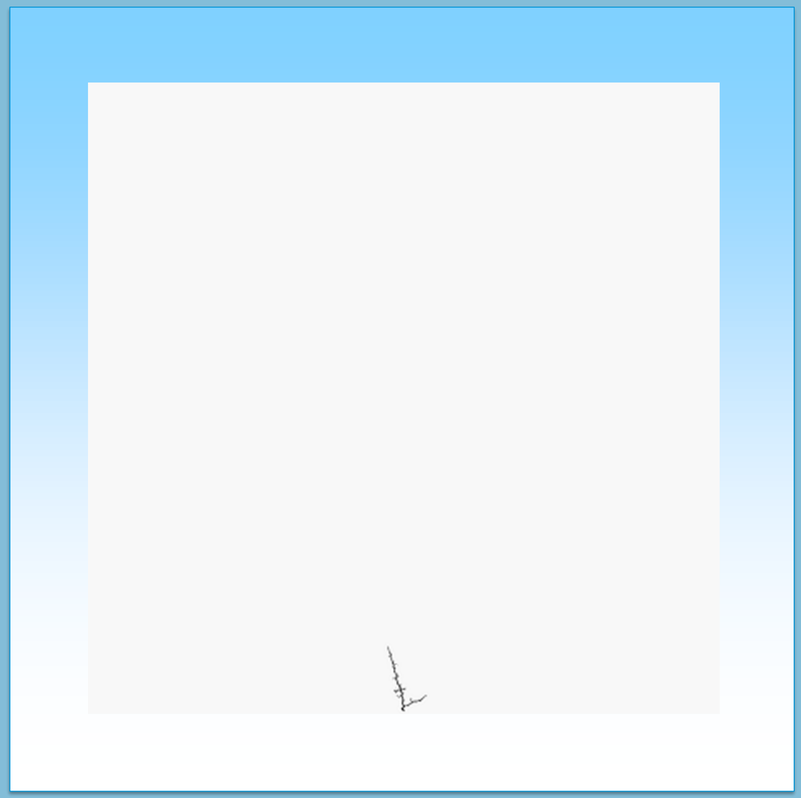


Imagining a space planning process



Subdivision

Consists in splitting an area to achieve room separation and get a layout after several iterations.



Tree development

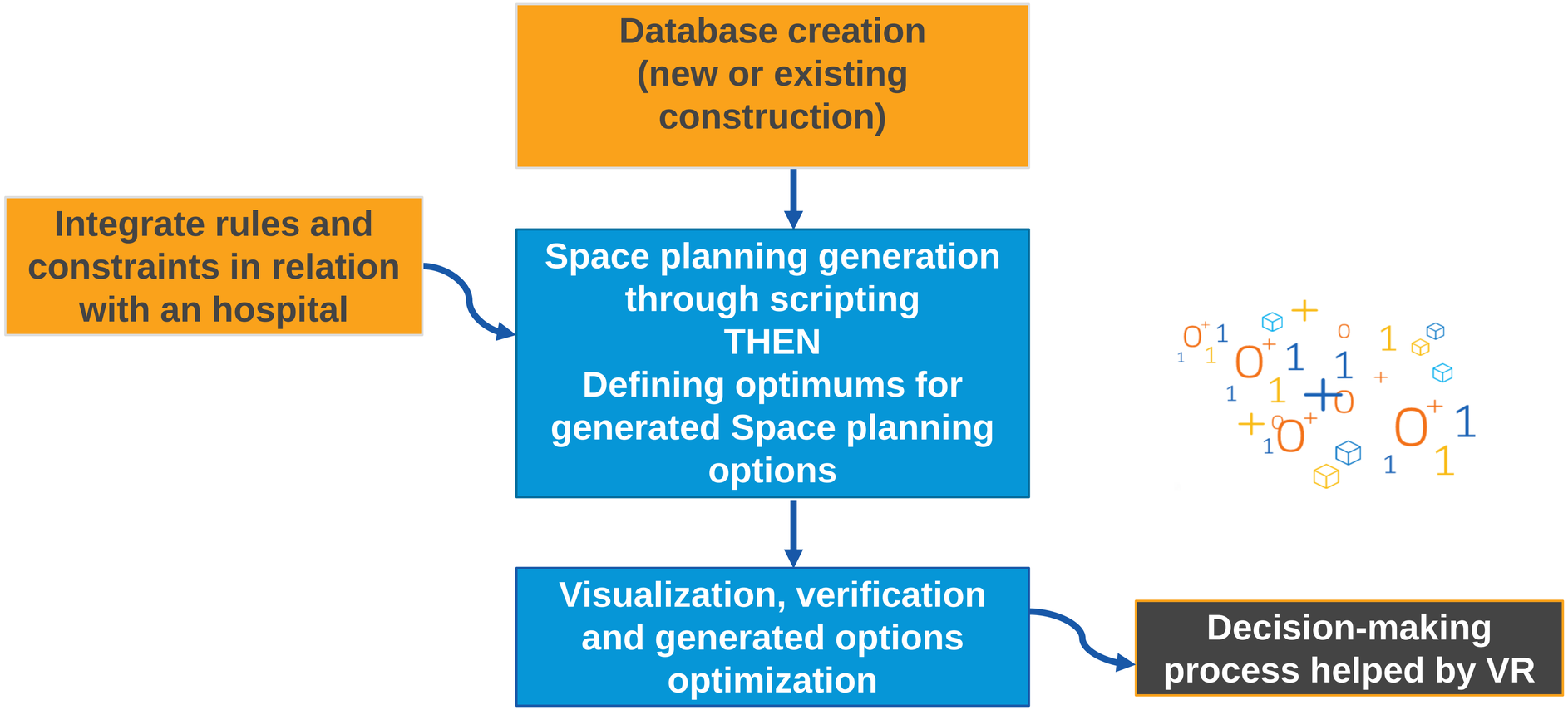
Area growth by addition limited by a boundary in our case.

WORKS BY VISUAL ARTIST RAVEN KWOK :

https://ravenkwok.tumblr.com/

Space Planning Process

The generative process was initiated according to this figure below.



Preparation

RULES AND CONSTRAINTS

- Minimize stock space (volume could convert to area with fixed height) and maximize workplace
- Reduce flow paths
- Optimize natural light in workplace
- Check flows on generated optimized space solutions in a second time

DATA CREATION

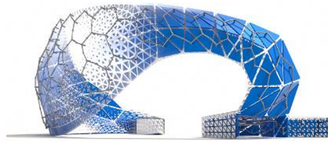
- Room Excel matrix by department
- .sat file of the overall area to load into Dynamo
- Adjacency factor using departments that would include their services.

Tools

Hereafter is the tool palette we have been using during the project.

AUTODESK REVIT 2020

DYNAMO STUDIO



REFINERY BETA TEST

3D STUDIO MAX

UNITY

POWERBI MICROSOFT

TWINMOTION

PYTHON

Space planning script

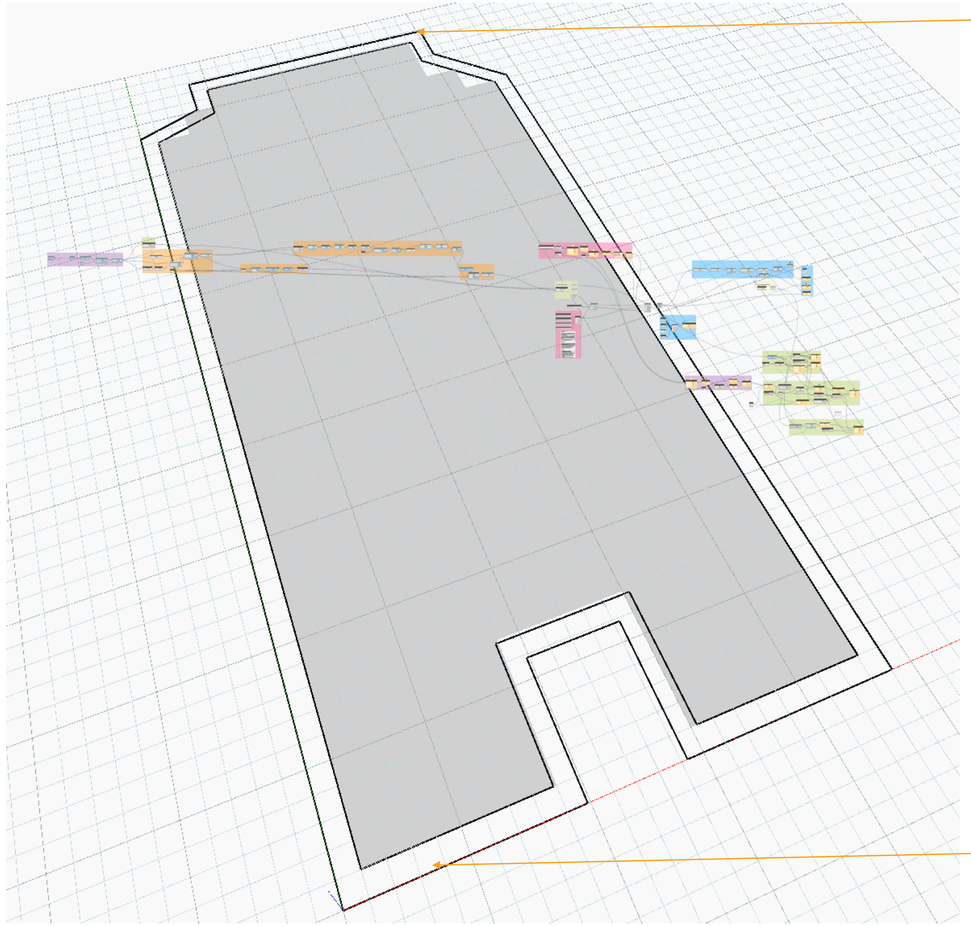
MACRO ZONING (DYNAMO+REFINERY)

It consisted of preparing a department Excel matrix from which the script would create a subdivision of the total area in macro zones that corresponded each to one department. Tolerance area parameters were included into the script.

The pharmacy was divided in 5 departments:

- Offices
- Services (toilets,…)
- Clinical research
- Stock
- Delivery/transformation zone

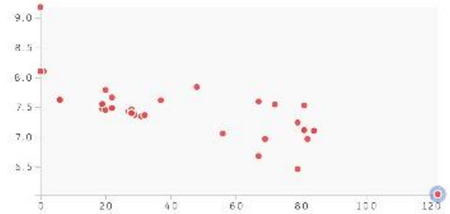
Natural light constraint with a parameter which value varied from 0 to 1; natural light was located at the ends of the “bottle” shape of the area, good natural light could be obtained if the parameter was close to 0 or 1.

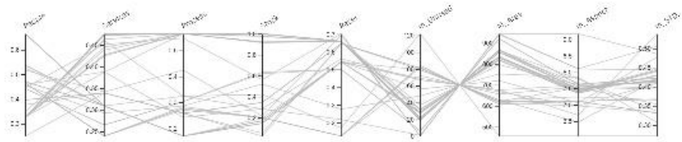


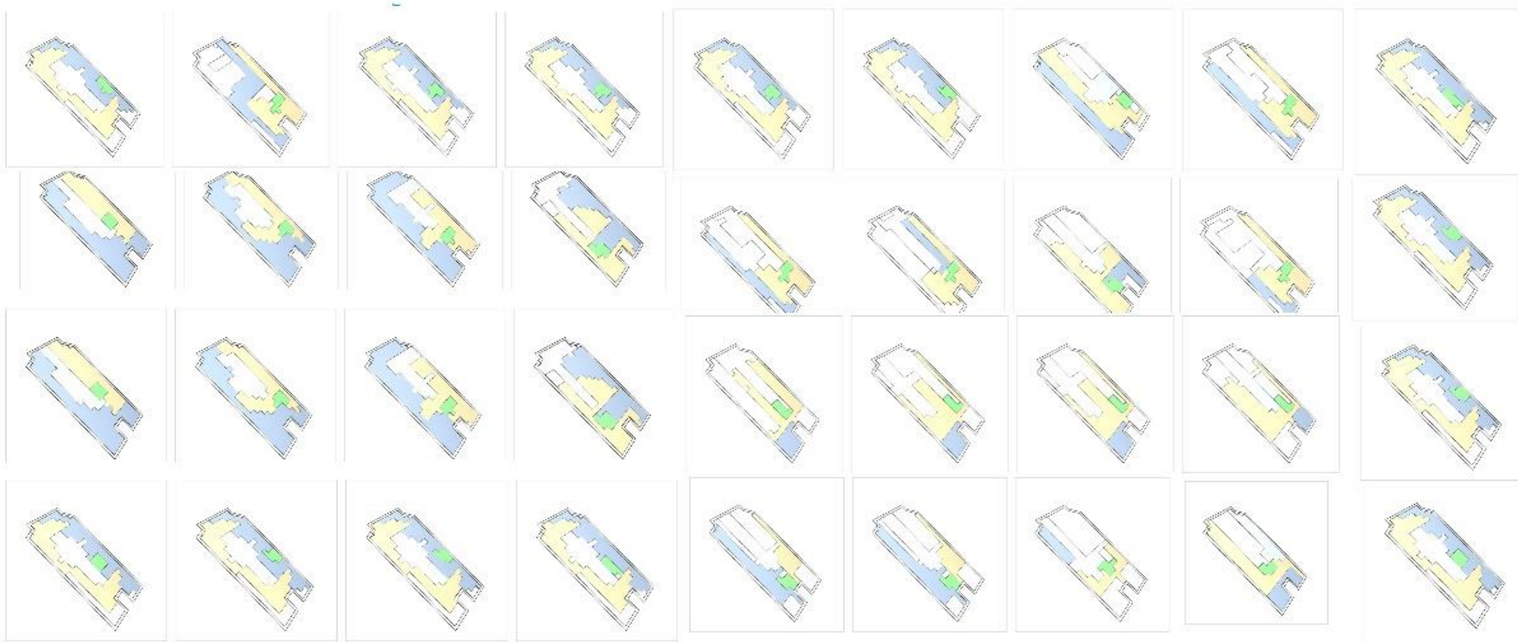
Space planning script

MACRO ZONING (DYNAMO+REFINERY)

The script developed with the aid of Autodesk Consulting also introduced the notion of “seed” that represents the physical beginning of the generative design calculation. Once the script was ready, we connected it to Refinery to generate optimized solutions in correspondence with the set priorities and we retained 3 solutions.





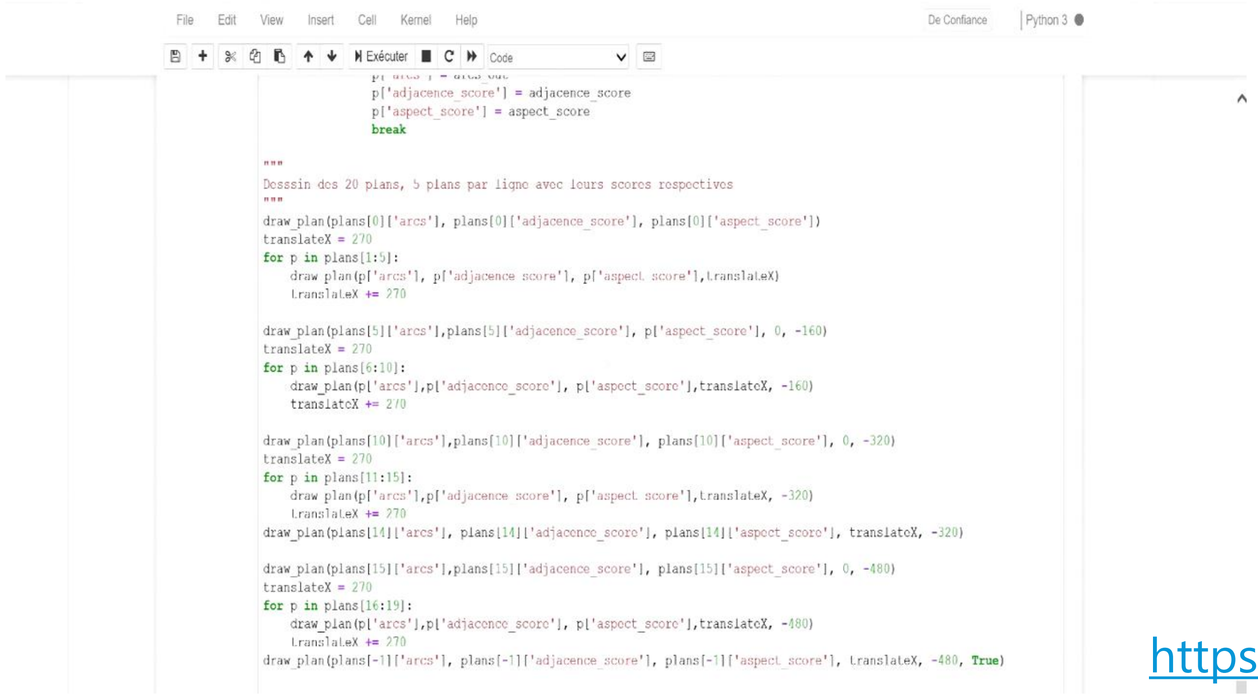


Space planning script

MICRO ZONING (DYNAMO+REFINERY+PYTHON)

Once the macrozones were configured, we built two experimental approaches to subdivide them.

Script 1 : From the Excel/JSON room matrix of a department, the script would further subdivide one macrozone (department) into microzones or rooms.

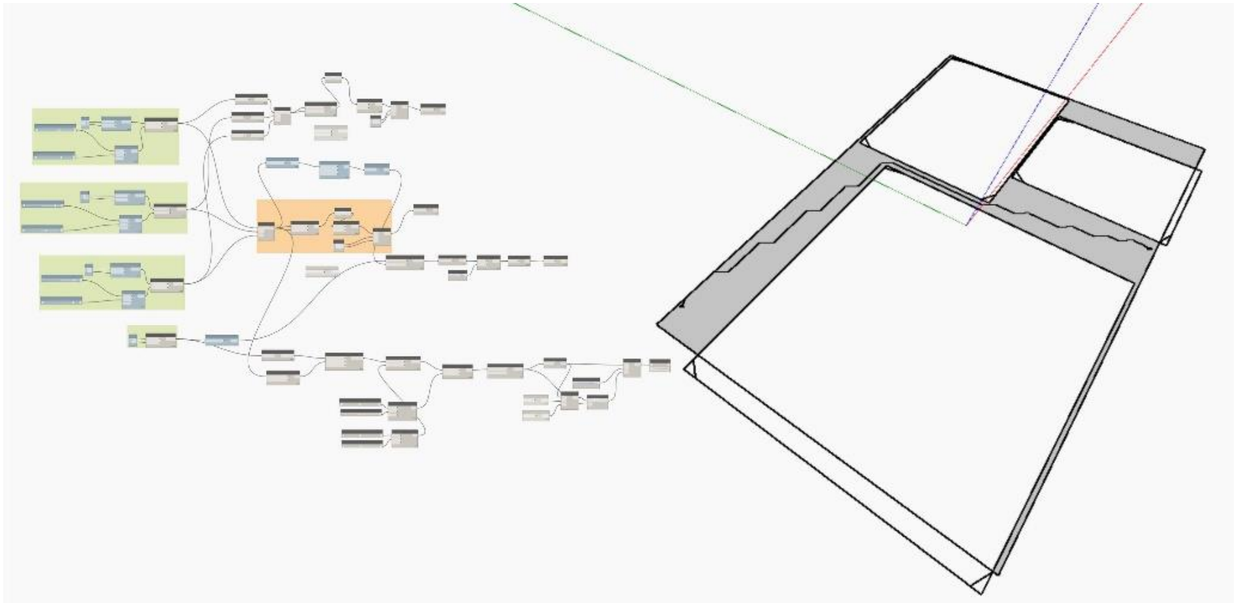


https://autode.sk/36ZXCkH

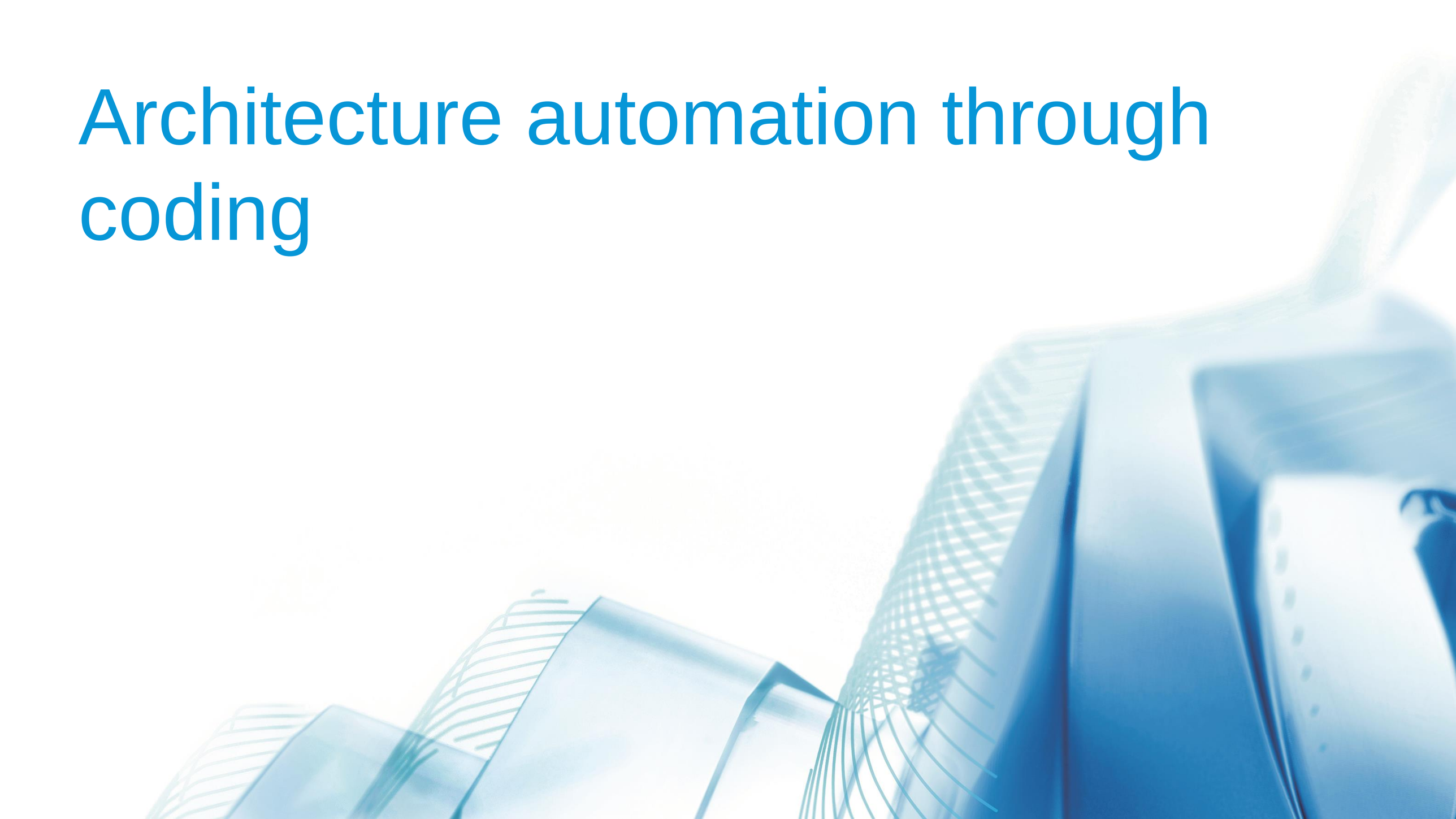
Space planning script

MICRO ZONING (DYNAMO+REFINERY+PYTHON)

Script 2 : From the Excel/JSON room matrix of a department, the script would further place microzones or rooms with Dynamo and optimize the path between two points in a department figuring an inner circulation path.

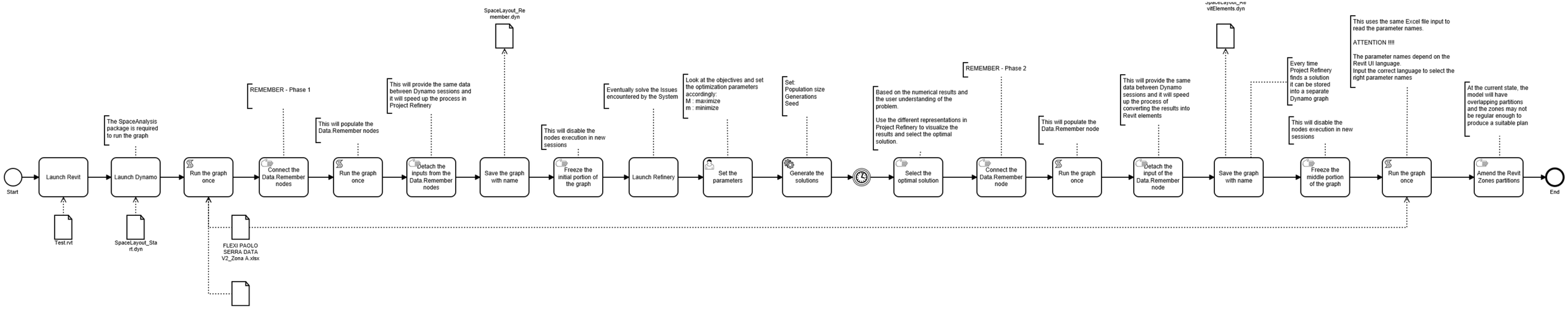


Architecture automation through coding



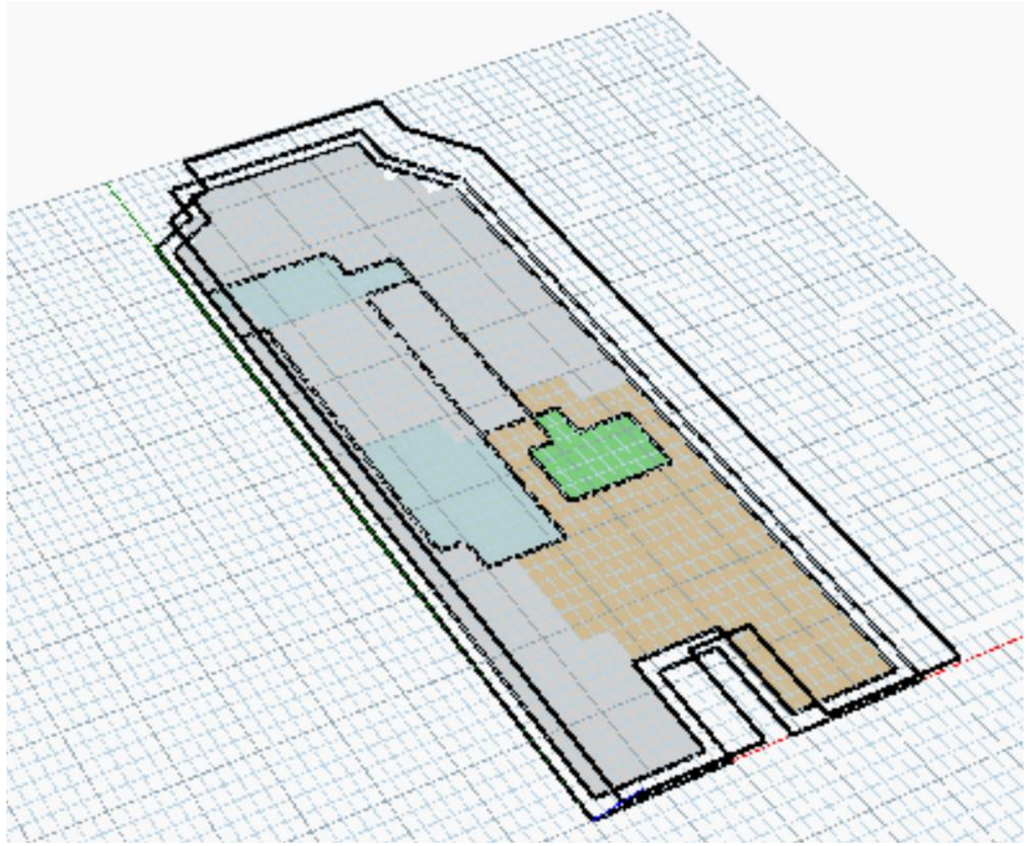
Scripting

Our script followed several steps shown hereafter.



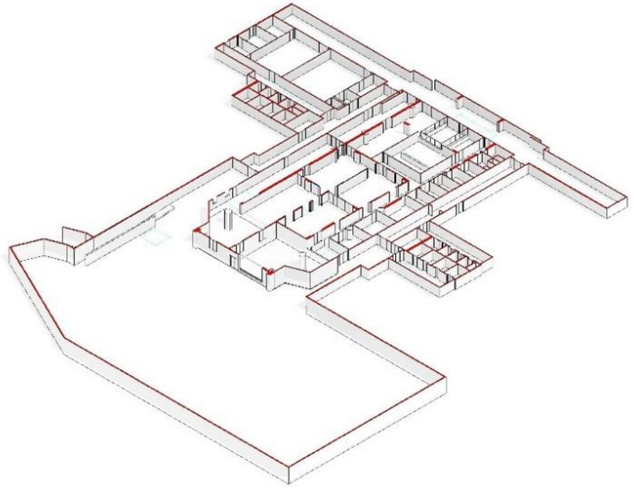
Wall creation automation

Once Refinery has done its operations, we could go through the results manually and generate automatically with Dynamo the walls of a selected solution in Revit as a base to an architectural project.



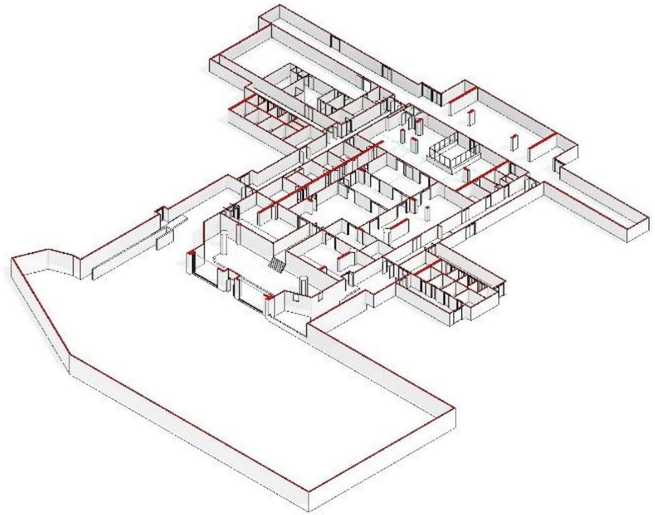
Wall creation automation

Amongst the 150 generated options, we selected three to be developed. For each, wall generation was accomplished in 10 seconds with Dynamo.



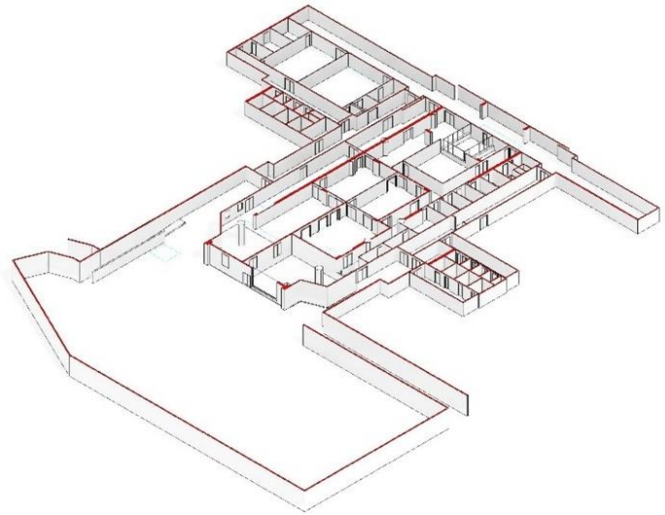
Model generation:10s

V1



Model generation:10s

V2



Model generation:10s

V3

Developing the generated versions

From the created bases, we finalized the microzoning manually and according to the known constraints. At that point, one must admit it was not the best case to start practicing generative design as the site was overconstrained.

V1

V2

V3

Analyzing the solutions

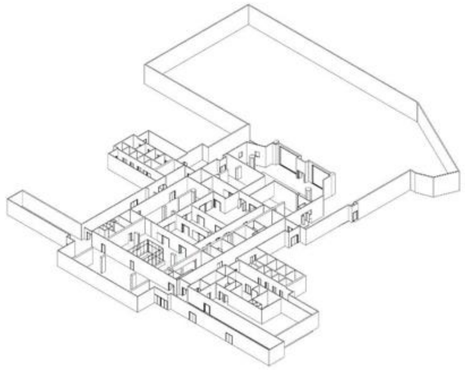
Once the generative process had produced three acceptable solutions, we had to present the results to the user group for validation and we prepared comparisons using Power BI and extractions from Revit showing:

- Working place area gains
- Stock spaces
- Walking length and new goods paths
- Natural light results
- Room areas compared to program

Nom	Surface
ACCUEIL PUBLIC	35,19
ARCHIVE	14,61
BUREAUX OPEN SPACE 10-15	28,95
BUREAUX OPEN SPACE 1-9	192,54
CIRCULATION	17,70
CIRCULATION 2	39,31
DECHETS	8,92
DIRECTION	11,20
DISPENSATION	18,32
ELEVATOR EST	11,97
ELEVATOR OUEST	5,29
ENTREE	9,58
Labo Toxico	25,00
Rèserve	150,11
Robot	13,86
Salle informatique	29,47
SAS	36,79
SECRETARIAT	15,15
STOCK	27,06
STOCK MEDIC	46,46
STOCK MEDIC COF FORT	43,29
STOCK MEDIC PALLETTES	87,99
STOCK PALLETTES	127,00
STOCK PHARMACIE	43,29
TOILETTES	7,25
TOILETTES FEMME	11,52
TOILETTES HOMME	11,59
UNIT. DISP. MEDICAUX	71,25

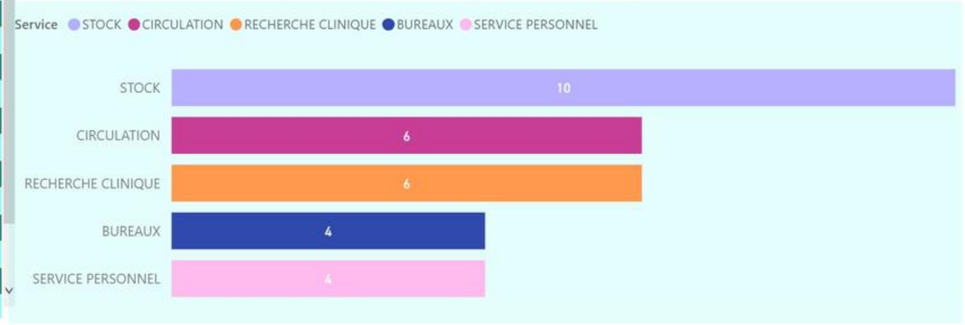
ZONES	Surface	Volume
BUREAUX	266,11	861,69
CIRCULATION	97,71	238,26
RECHERCHE CLINIQUE	123,36	259,43
SERVICE PERSONNEL	36,62	89,27
STOCK	630,37	1 815,00

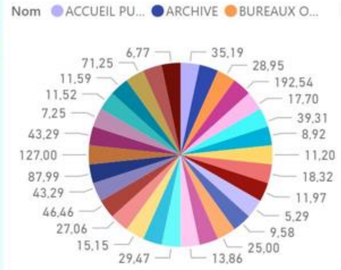
DONNEES MURS	SURF ET VOL
M3 VOLUME MURS A REALISER	754,10
SURFACE BRUTE	4 189,25
SURFACE FENÊTRES	49,92
SURFACE OUVERTUE PORTES	220,96
SURFACE REVETEMENT MURAL	3 875,23

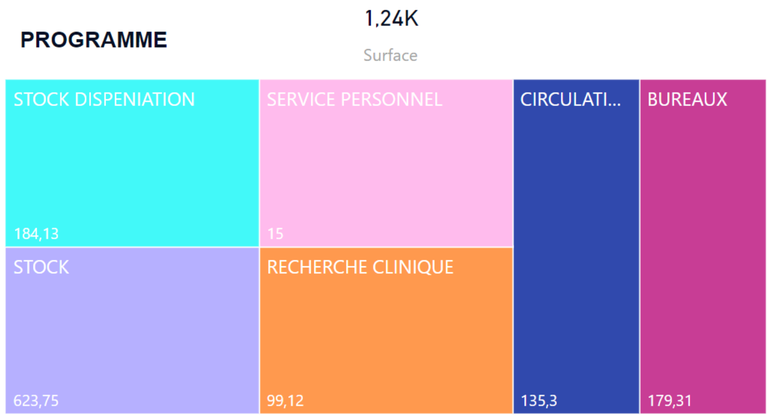


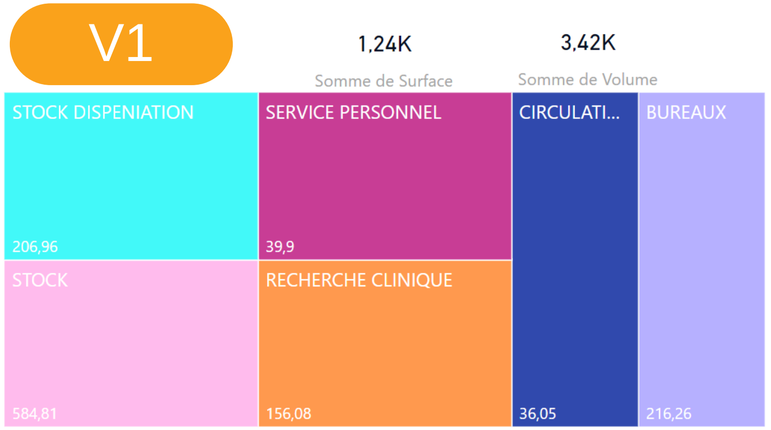
RESULTATS DES FLUX

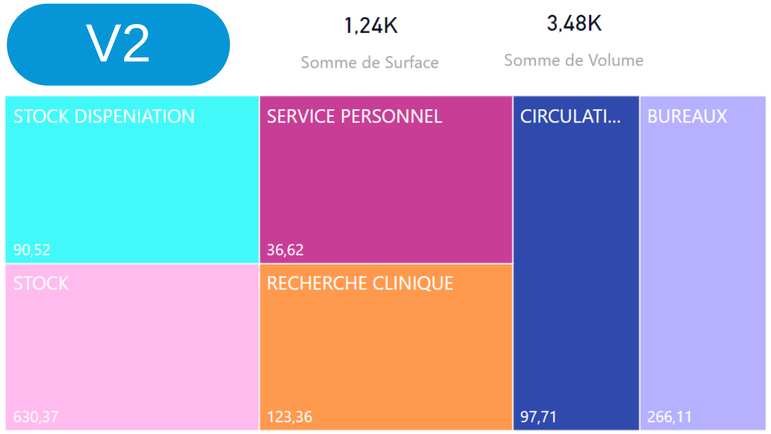
COMPARATIF DES FLUX

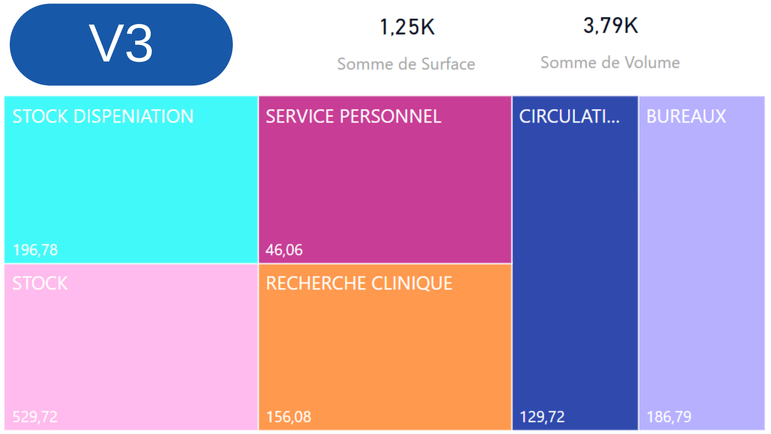






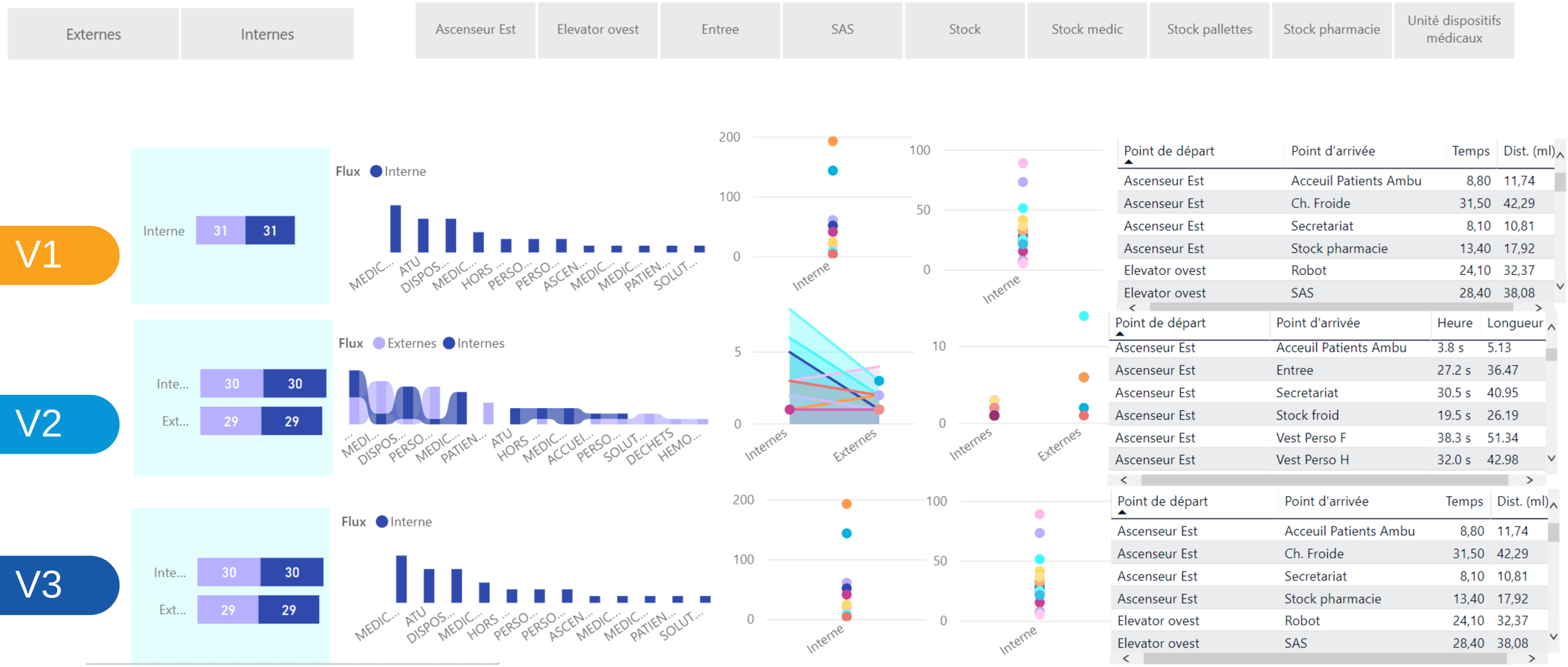






Analyzing the program results

Version 2 had better results as regards offices.



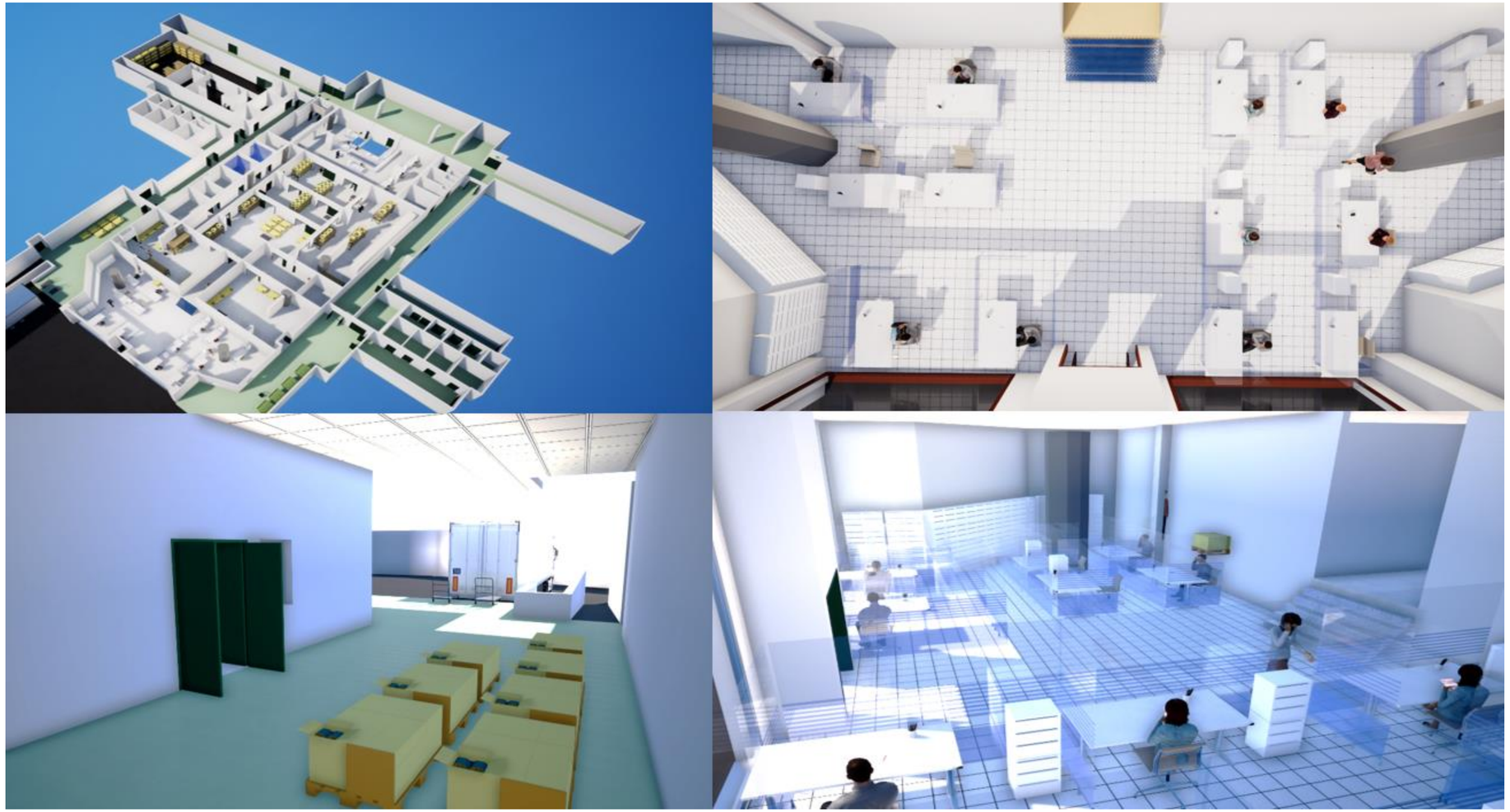
Analyzing the flows

Version 2 had better results as regards flows. We measured distances and travel times.

Refining the solution with VR and layout tool

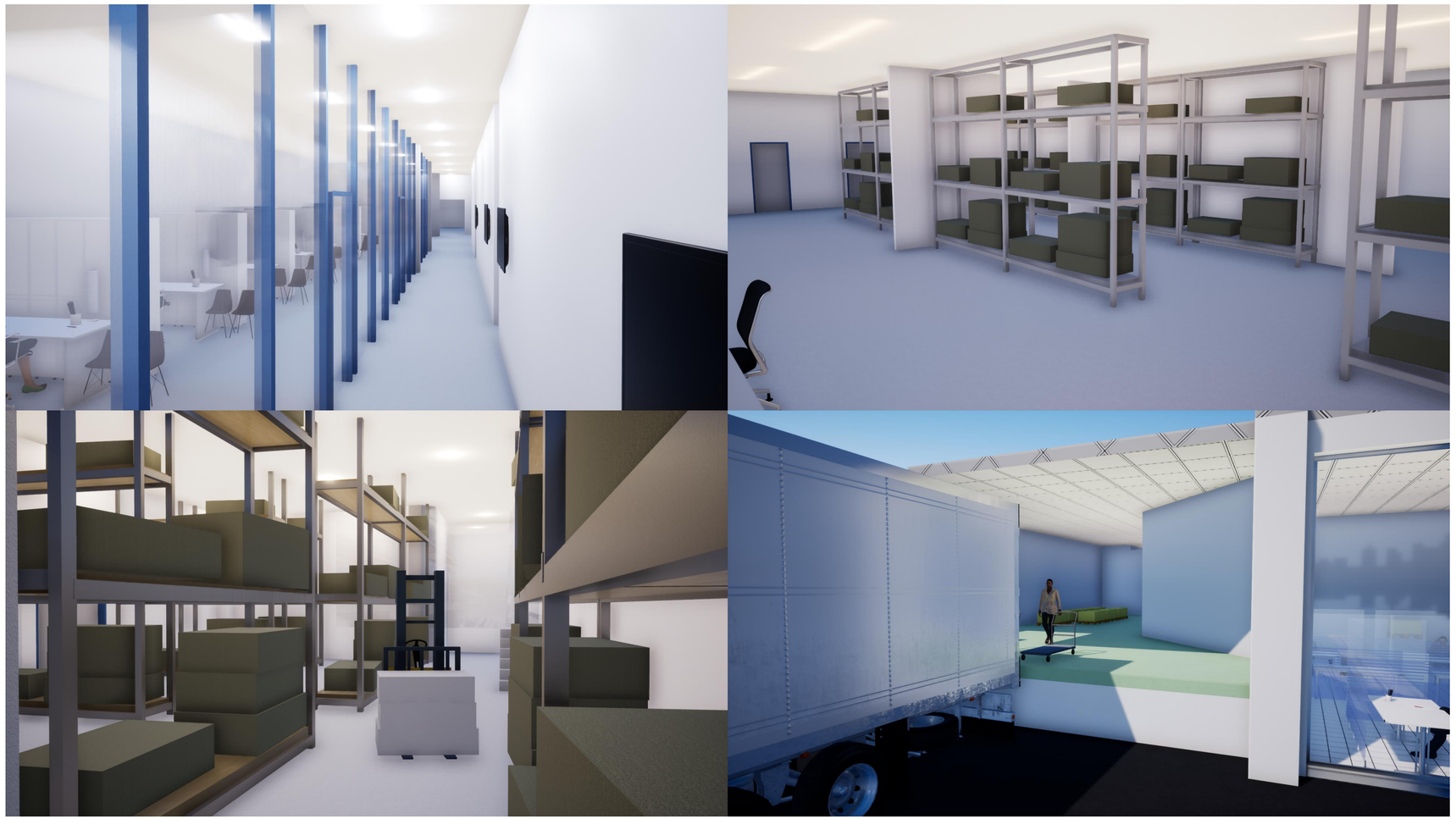
Twinmotion

With Twinmotion, we could texture the model and populate it with people and furniture. The user group had the opportunity to feel and test its new working place in VR.



Twinmotion

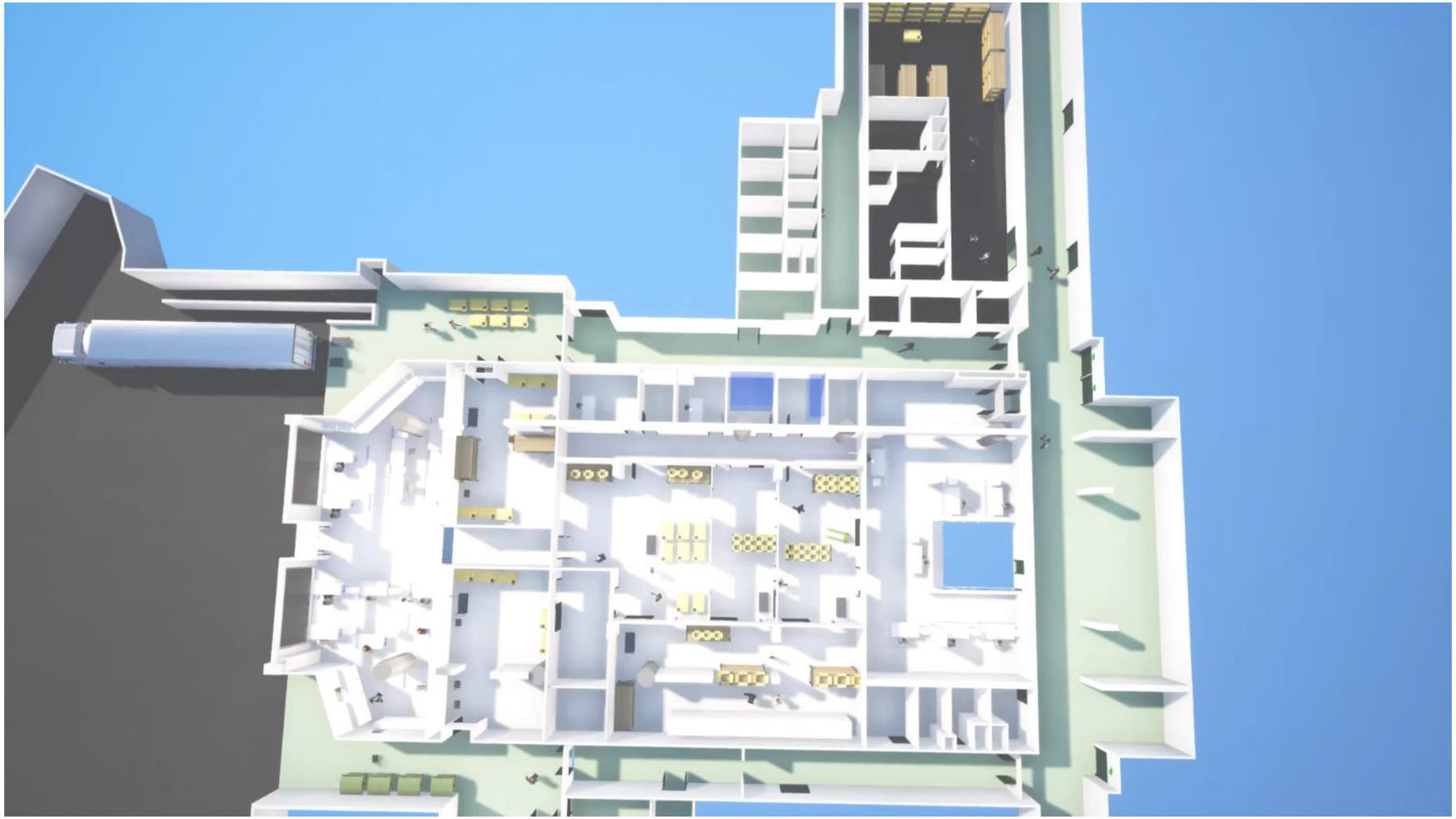
Circulation became clear. Stock was organized. Delivery used a logical shorter way.



Twinmotion

Visit the new pharmacy : https://autode.sk/2NHAccb

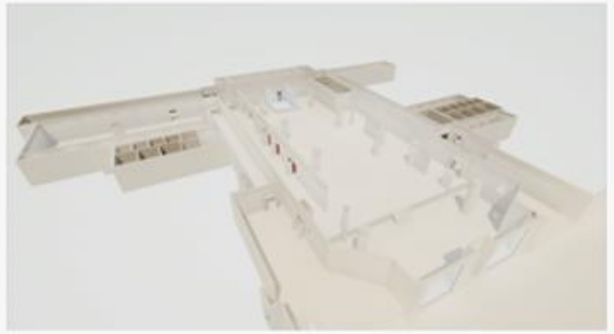
Twinmotion



Controlling the flows : https://autode.sk/2X4NQcq

Realiz3D

Through another partner, Realiz3D, we developed a web-based platform to make the model available to the user group so that they would be able to play with different space solutions themselves, modifying the layout or adding equipments/furniture.

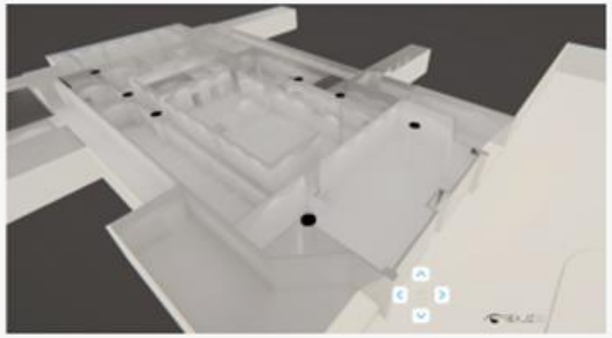


V0

Date Création : 17/06/2019 16:24

V3

Date Création : 17/06/2019 15:12



Espace Pharmacie

Date Création : 13/05/2019 18:10

Conclusions

Difficulties :

- site and implementation of generative design

Results :

- APHP satisfied with the result of the P.O.C. – other buildings to follow

New directions:

- Include to the generative design process a cost estimation of the works/energy consumption per solution
- Make a tool that could assess different architectural proposals
- Pursue this research involving Operational Research, Artificial Intelligence and Machine Learning.
- This process showcases that new ways of collaborating in the building industry exist in achieving common pre-conception between architects and professionals.

AUTODESK®

Make anything™