Fraunhofer ISE

Assisted routing of facade-integrated ductwork

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AEGIR

Incremental Renovation Package

AEGIR DELIVERABLE D5.5 – VENTILATION DUCTS INTEGRATION SERVICE

Assisted routing of facade-integrated ductwork

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Agenda

1) AEGIR-PROJECT
2) PREVIOUS PROJECTS
3) METHODOLOGY
4) MANUAL DESIGN PROCESS
5) CONCEPT OF THE PROGRAM
6) RESULTS

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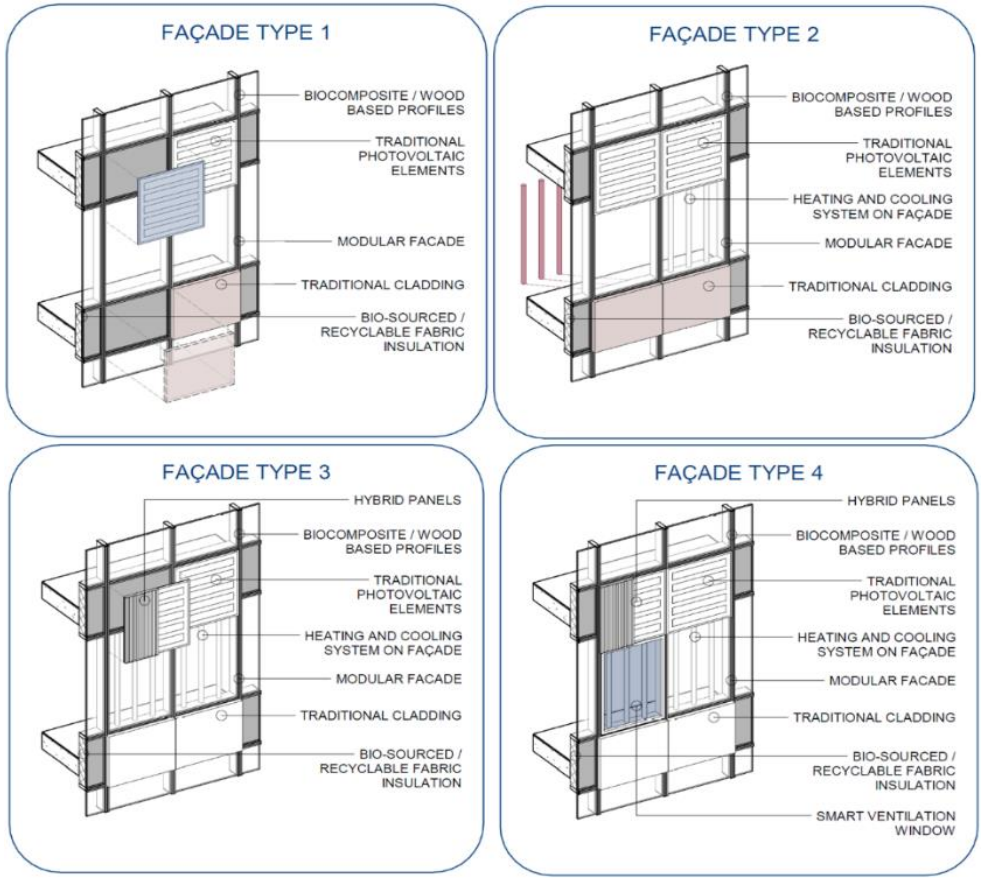
AEGIR-project



Interested? See More on:

1. Our Website: Home - AEGIR
2. Our promo video: YouTube - AEGIR

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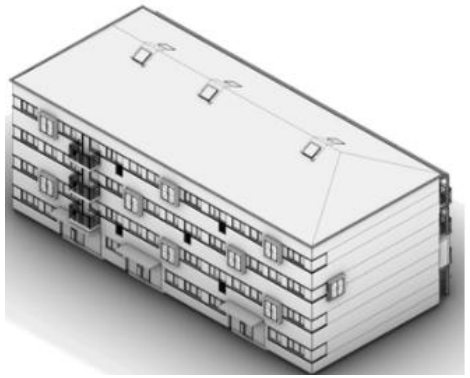
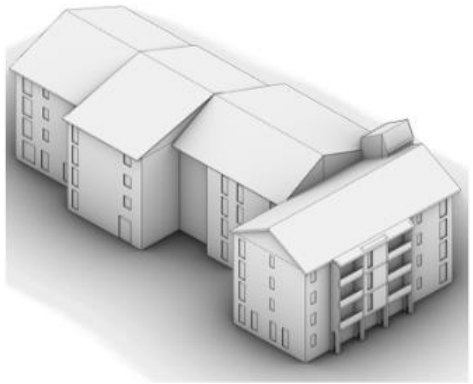
AEGIR-project: demonstration objects

Høje-Tåstrup in Denmark:
- Humid continental climate
- Residential multifamily block of "Gadehavegård"
- Floor area: 1,567 m²
- Occupancy: ~64 Pers



Boën Sur Lignon in France:
- Temperate oceanic climate
- Elderly care home "Residence Autonomie L'Astree"
- Floor area: 2,003.1 m²
- Occupancy: ~70 Pers



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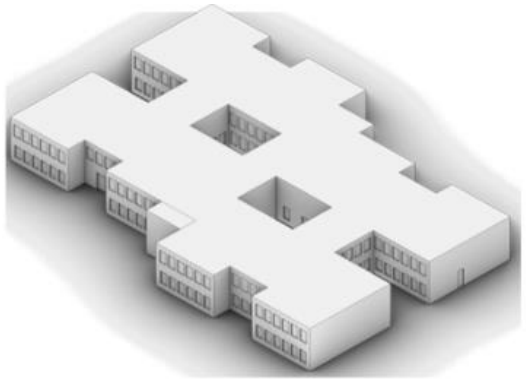
AEGIR-project: demonstration objects

Malgrat de Mar in Spain :
- Mediterranean climate
- School “Marià Cubí i Soler“
- Floor area: 1,669.3 m²
- Occupancy: ~700 Pers



Oradea in Romania:
- Continental climate
- 4 storey single family house
- Floor area: 232.8 m²
- Occupancy: ~4 Pers

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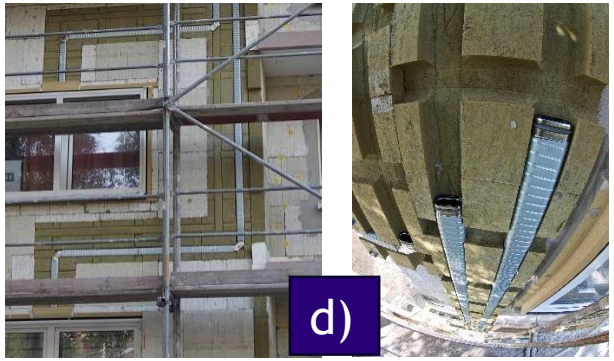
Previous ductwork integrations in facades

a) “LowEx – Existing Commercial Buildings” finished object on campus of Fraunhofer ISE

b) Plastic ductwork in expanded polystyrene insulation on Campus of Fraunhofer ISE

c) 3D-design of a section of the “RetroKit” demonstration object in Frankfurt a. M.

d) images of the metal ductwork integration in prefabricated mineral wool insulation of the “RetroKit” demonstrator



Challenge:

System needs to be designed and build at the interface between different construction trades.

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Methodology

Collect standards

- Technical standards for both ventilation ductwork and façade-components are relevant.

Manual design of the ductwork

- This step helps to understand, which challenges have to be tackled.

Summary of constraints

- Description of the design challenges to be translated into some programmable logic.

Development of the program

- Implementation of the pathfinding and optimization algorithms.
- Limitation of the search space by the constraints found in previous steps.

Redesign of the ductwork applying the tool

- Using the tool to find ductwork paths automatically.
- This is performed both for the same building as in the manual process but also for new building sections.

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Methodology – standards & regulation

Fire safety

- Based on GER (MOB, 2023) and FR (NF S 61-937, 1990)
- Standard apporach should be metall ducts with ≥ 20 mm of fire-resistant thermal insulation
- fire dampers between each utilisation unit

Airtightness - ductwork

- Based on EN 12599, EN 12237, EN 1507, EN 13180, EN 16798-5-1
- Minimum requirement airthighness class C (old) or ATC 3 (new)
- Preferable -> outside heated space class D (old) or ATC 2 (new)

Air Flow Rate

- Breating level: based on EN 16798-1 method 1 as default or national standards like DIN 1946-6
- At the air terminal devices assume mixed ventilation acc. DS 447 with a ventilation efficiency of 90% / air change efficieny of 45%

Thermal Insulation

- National heating load calculation
- Typical thicknesses: Germany -> 160 mm, Denmark -> 240 mm

Duct Sizing

- Based on DIN 1946-6 -> average flow velocity has been limited to ≤ 2.5 m/s

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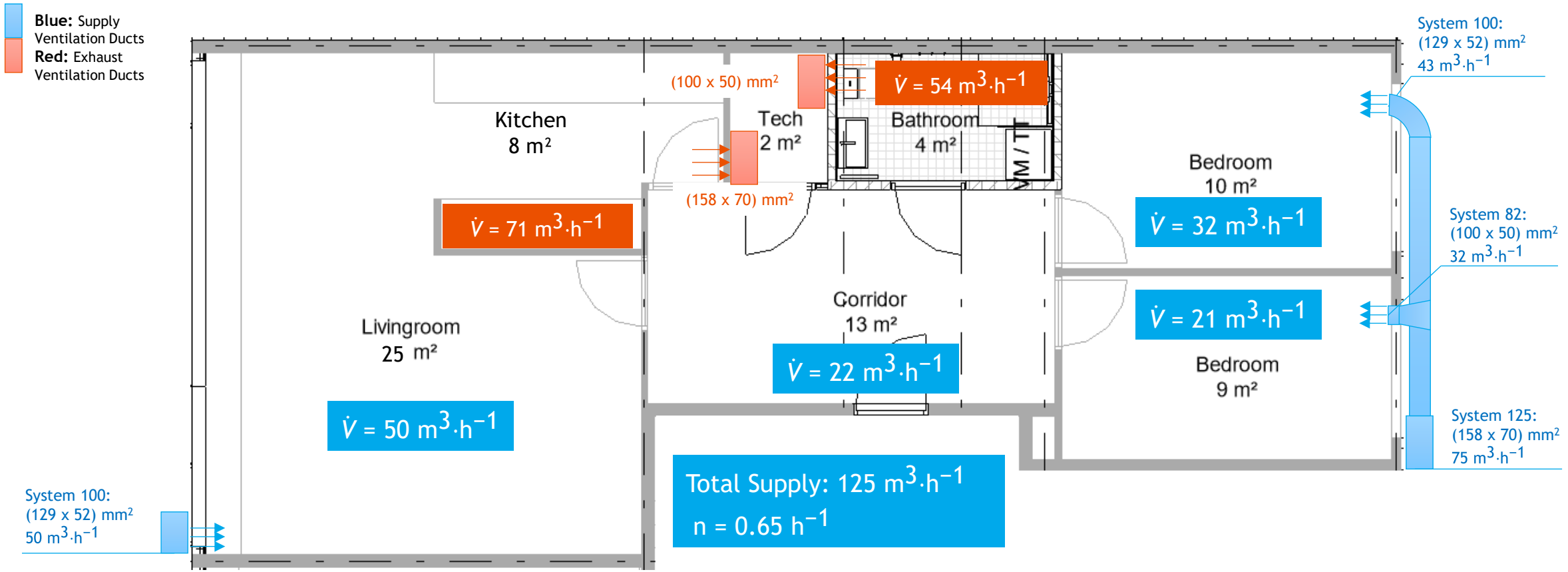
Methodology - manual design process 1

Flat type D in Denmark



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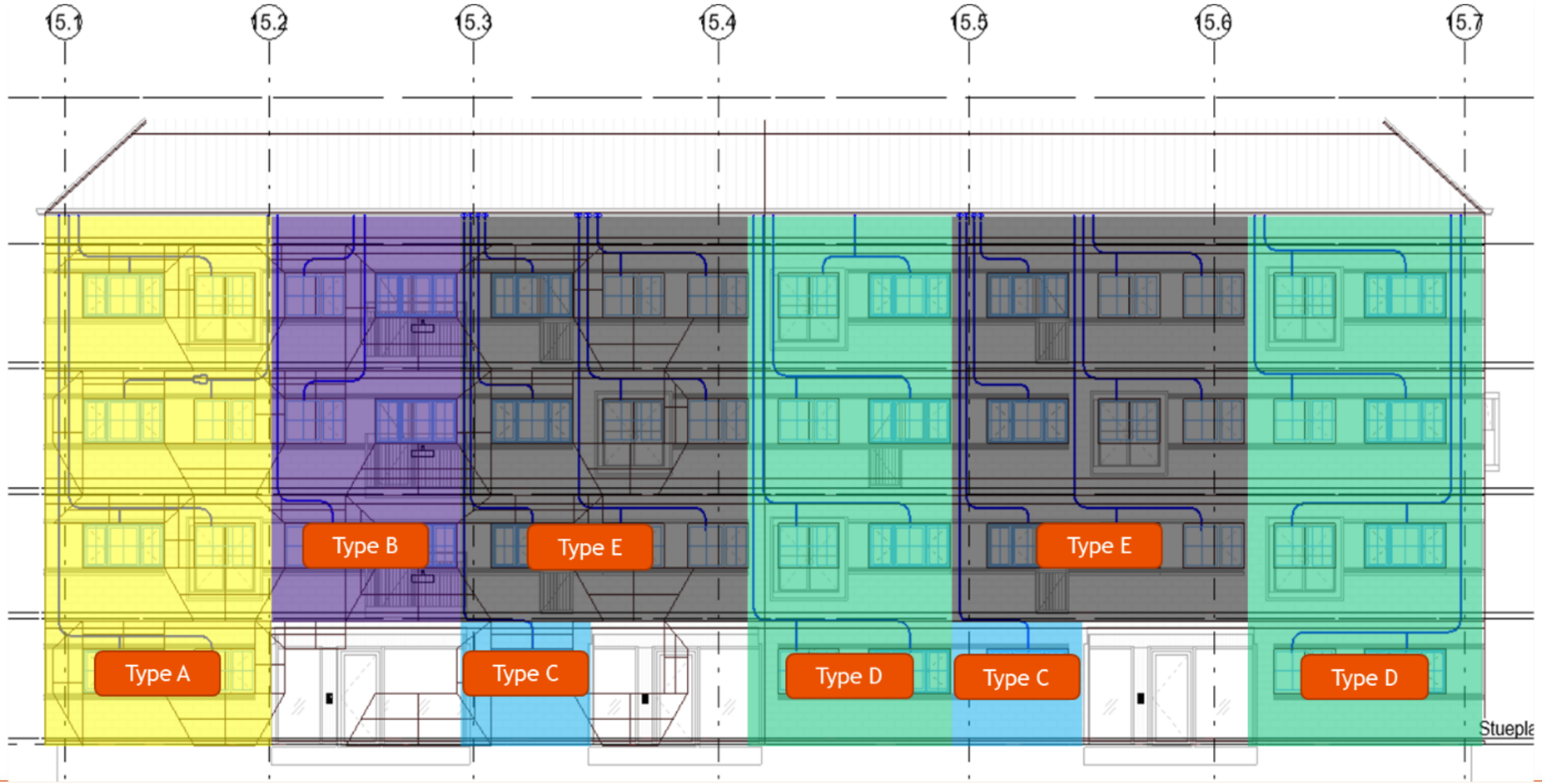
Methodology – manual design process 2



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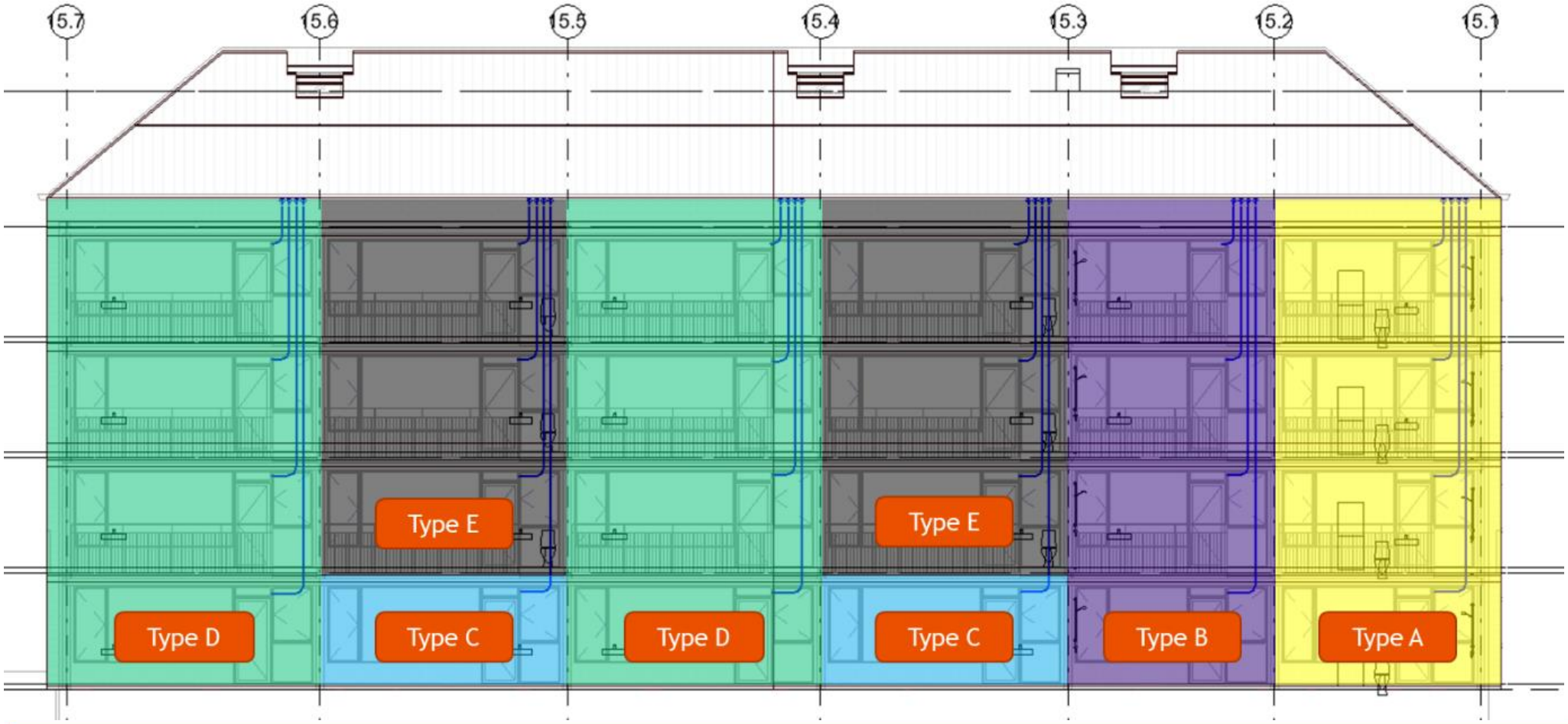
Methodology – manual design process 2



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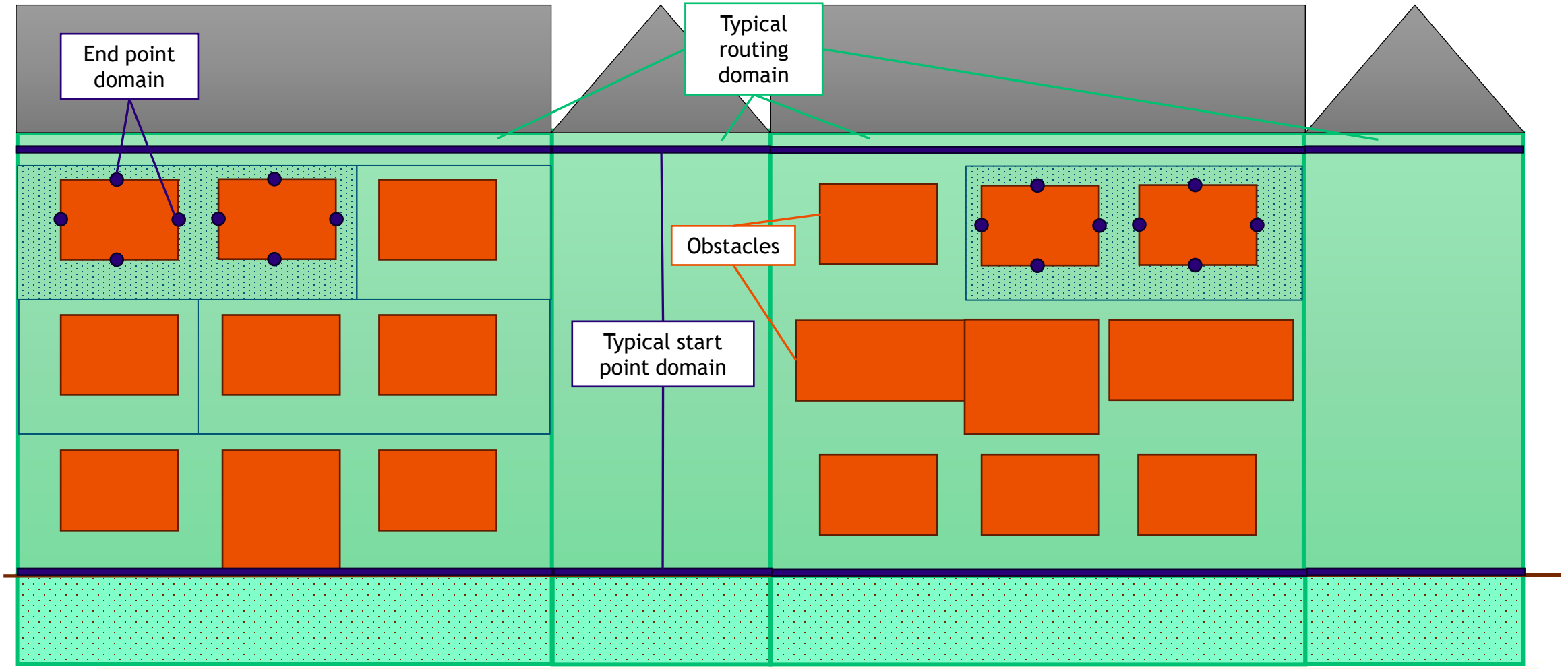
Domain definition & list of constraints



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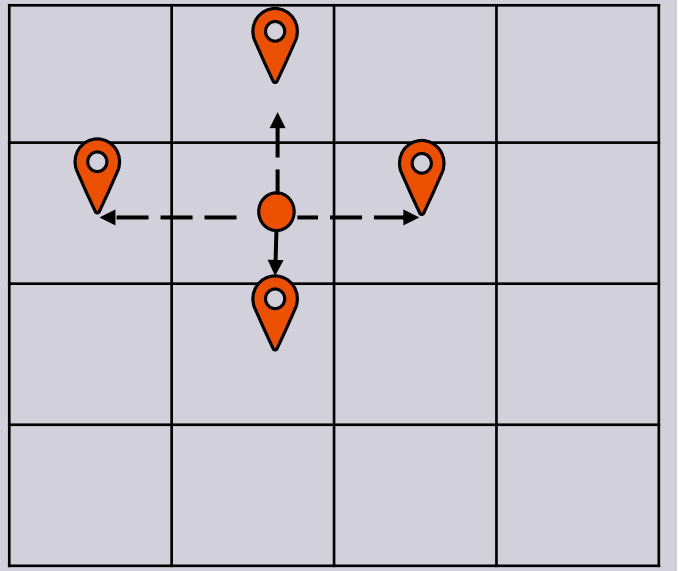
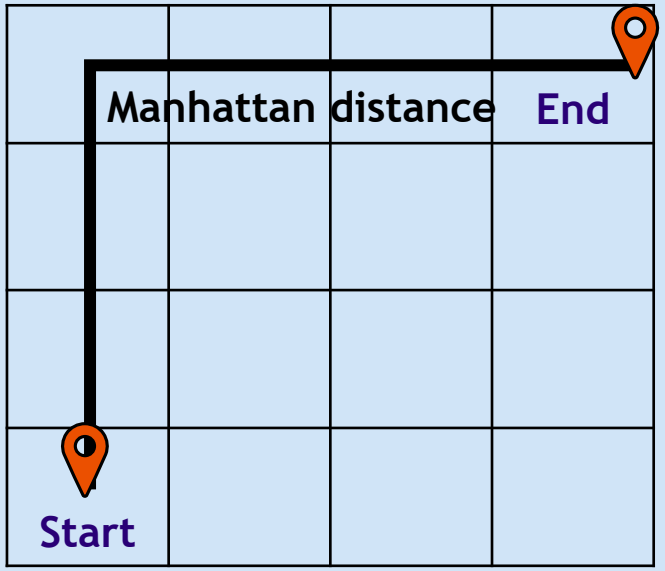
Concept of the program - A*-algorithm

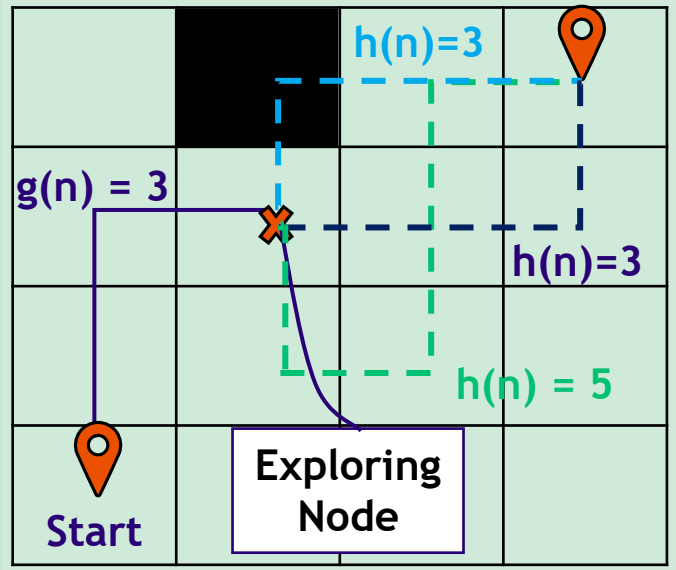
Allowed movements



Exemplary final path



Decision process of the A* - the black cell represents an obstacle



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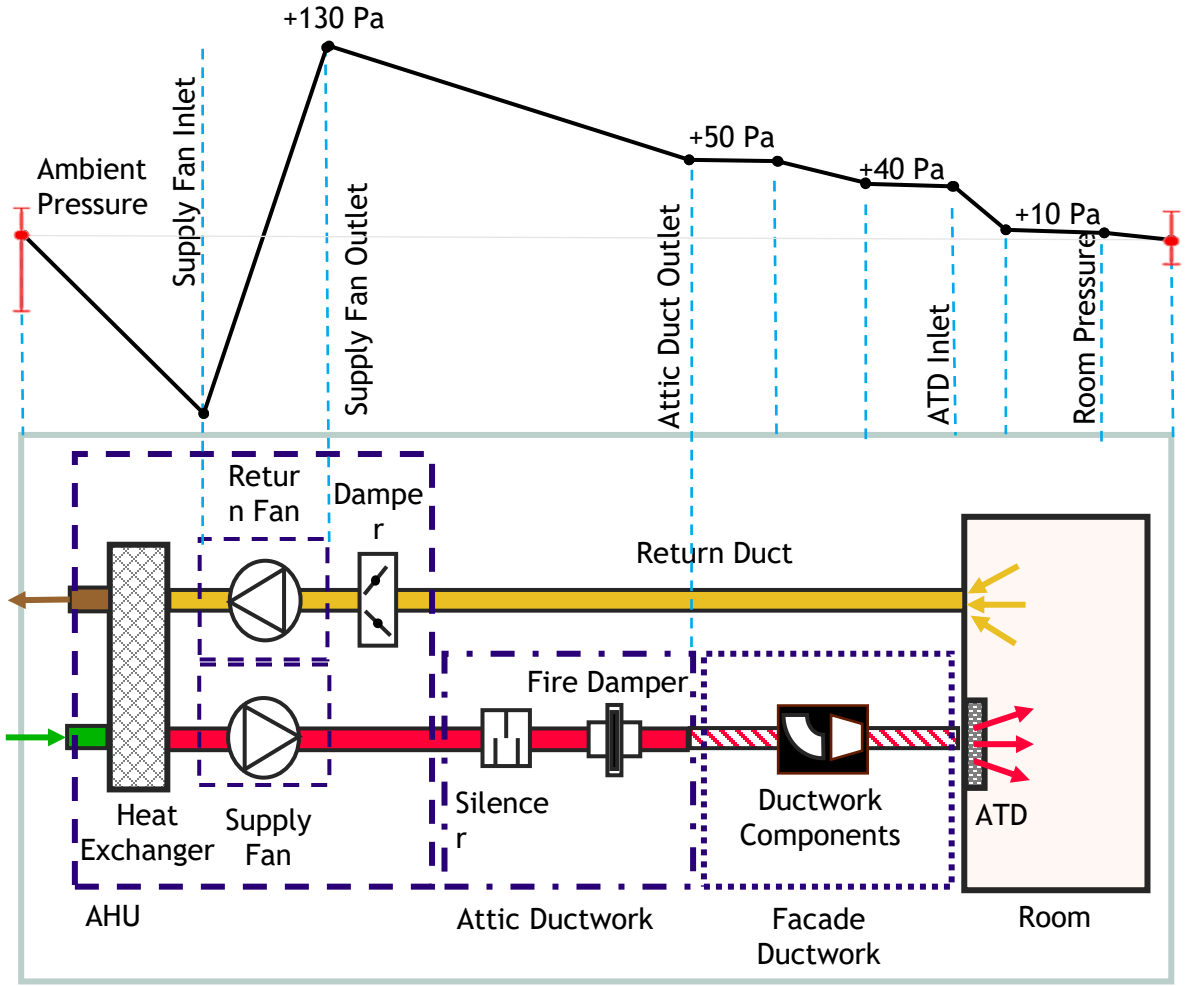
Optimization objective - pressure loss



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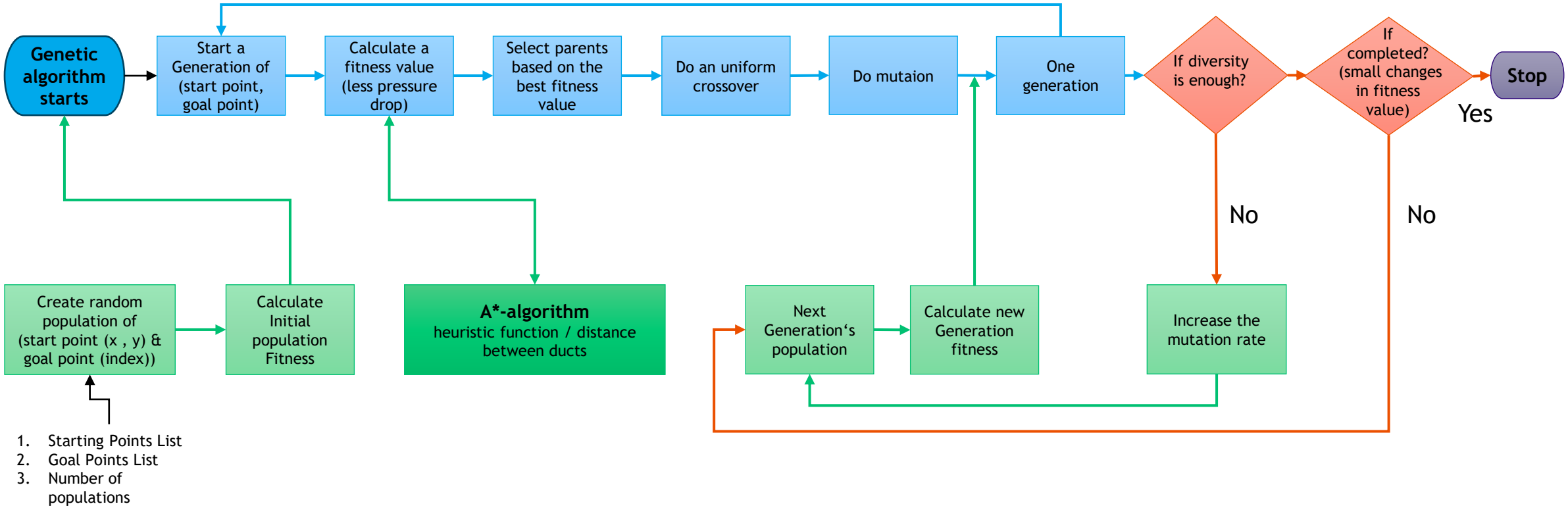
Genetic algorithm for domain reduction



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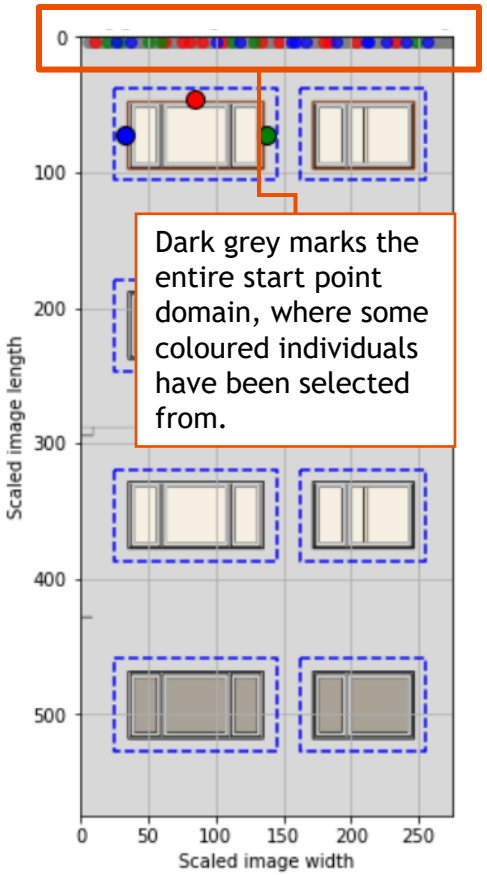
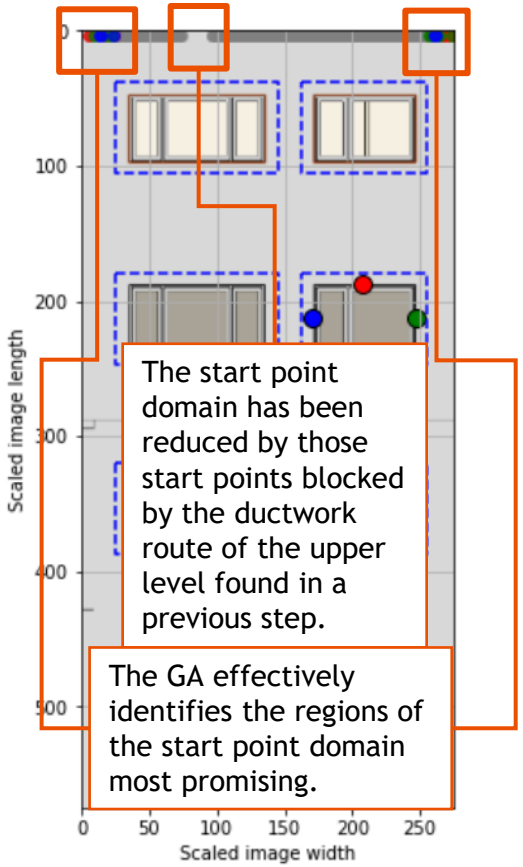
Intermediate steps of the program

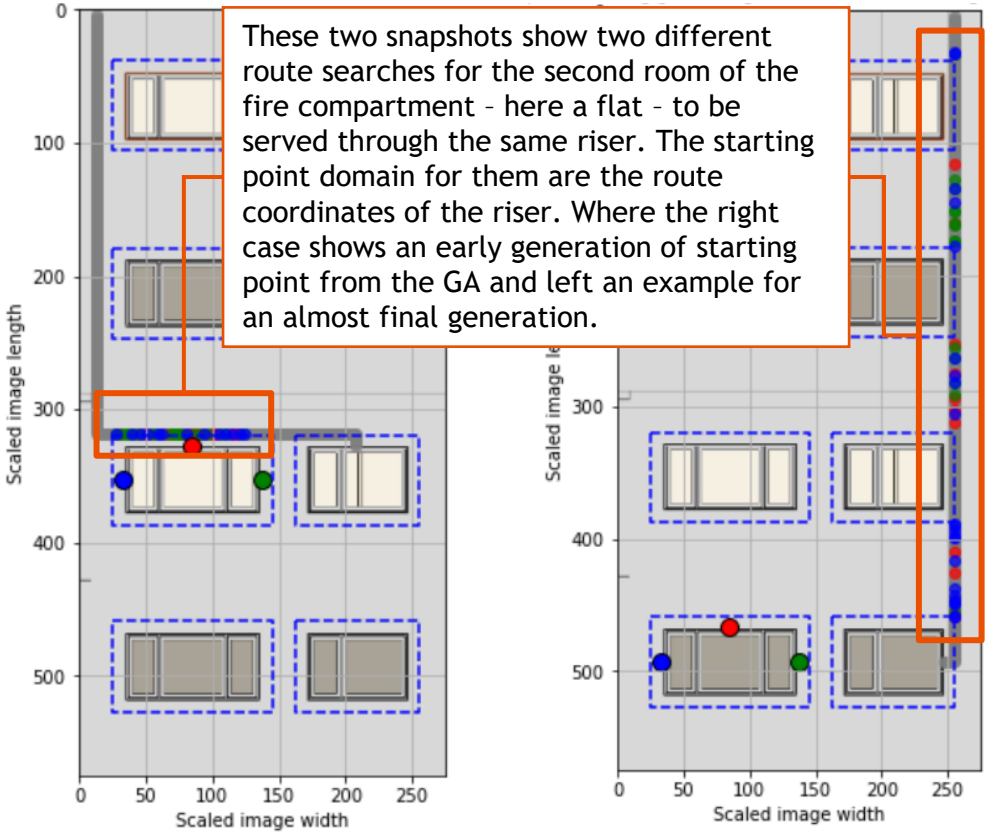


Dark grey marks the entire start point domain, where some coloured individuals have been selected from.



The start point domain has been reduced by those start points blocked by the ductwork route of the upper level found in a previous step.

The GA effectively identifies the regions of the start point domain most promising.



These two snapshots show two different route searches for the second room of the fire compartment – here a flat – to be served through the same riser. The starting point domain for them are the route coordinates of the riser. Where the right case shows an early generation of starting point from the GA and left an example for an almost final generation.

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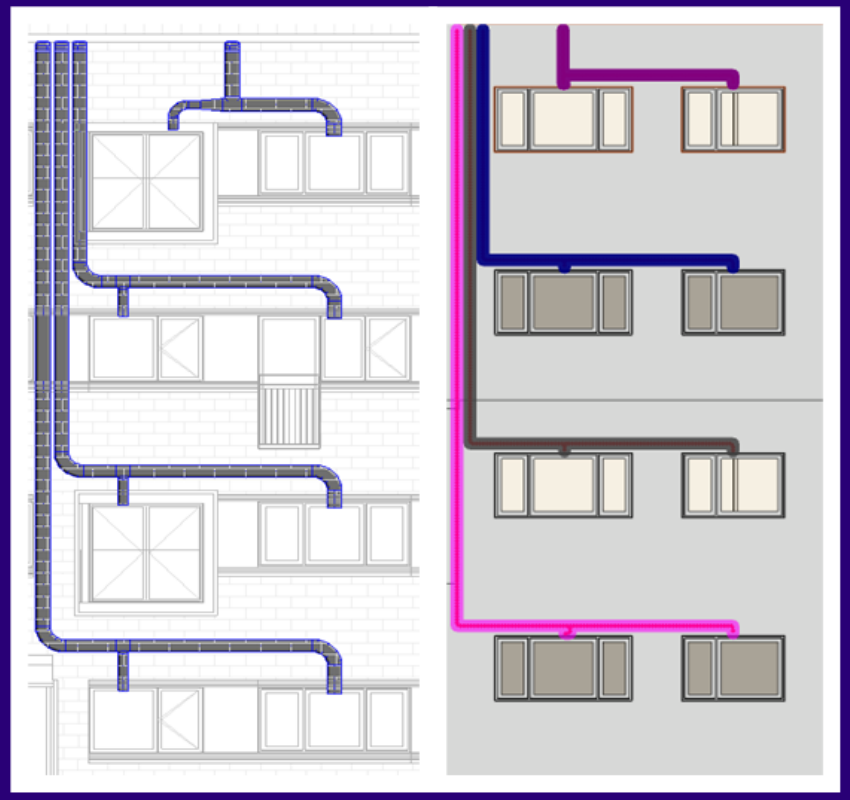
Results

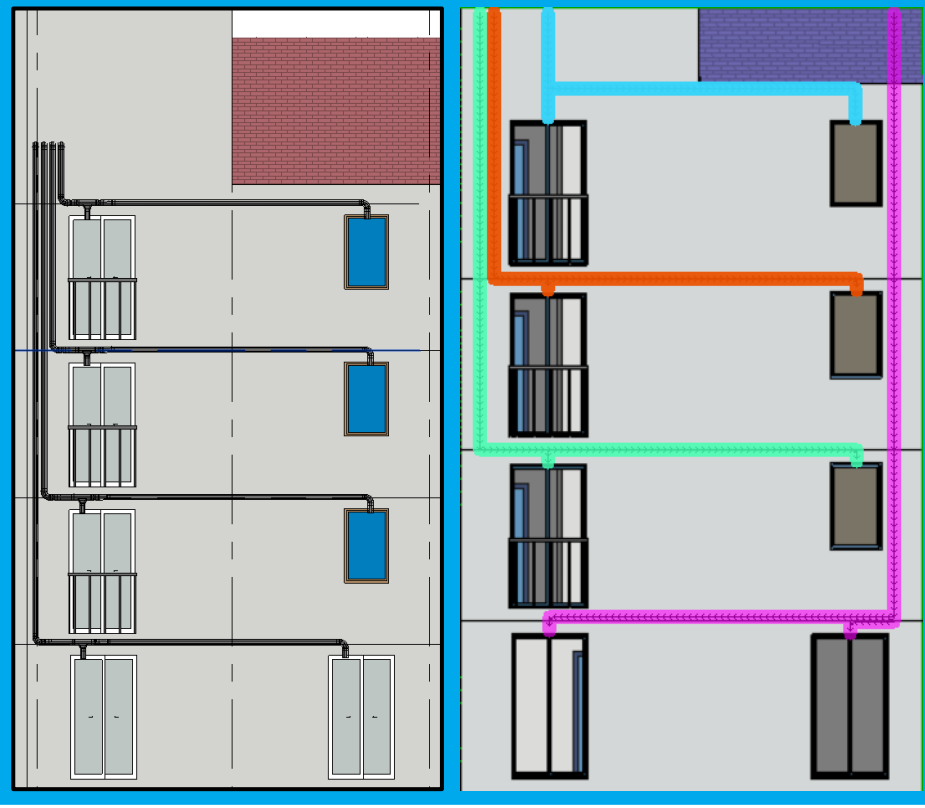
1st

Reference - Denmark



2nd

Validation - France



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Conclusion

Initial version of the program can reproduce the concept and has successfully been tested on another building with similar characteristics.

Future Tasks:

1. More buildings typologies should be analysed to extend the domain definition, and the constraints handled.
2. The objective function for the optimization should be extended, covering for example the heat losses as well.
3. The domain reduction through a genetic algorithm can lead to final solutions which are only local optima. This needs to be further analysed and refined, potentially by implementing alternative algorithms.

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A special “Thank-You” goes to our co-author Seyedehmaedeh Aghili who dedicated her Master's thesis to this topic and played a significant role in the realisation of this idea. We wish her all the best for her personal and professional future.

Thank You!

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