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ENPB

A systematic approach to energy efficiency retrofit solutions for existing office buildings

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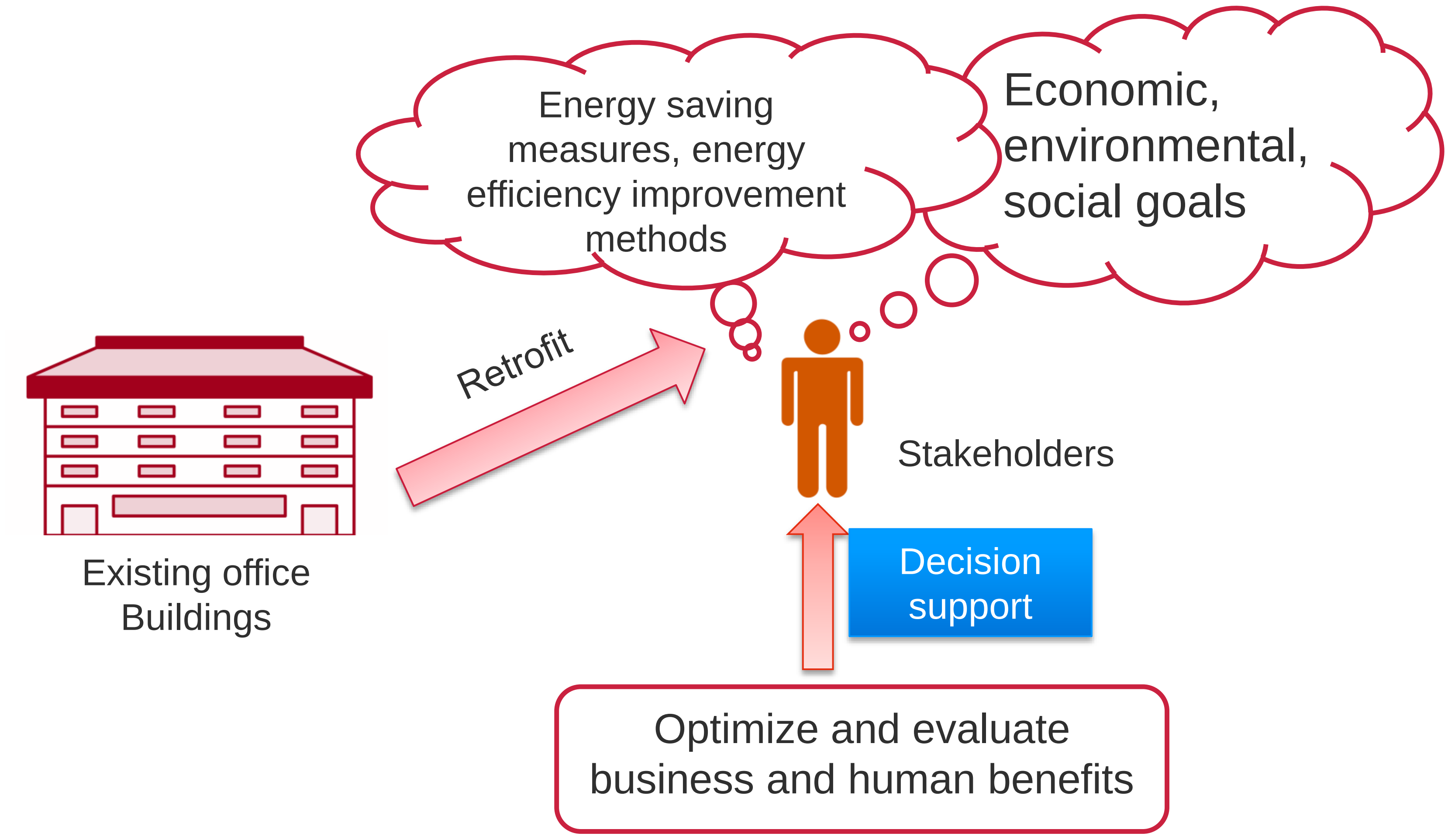
Problem Statement



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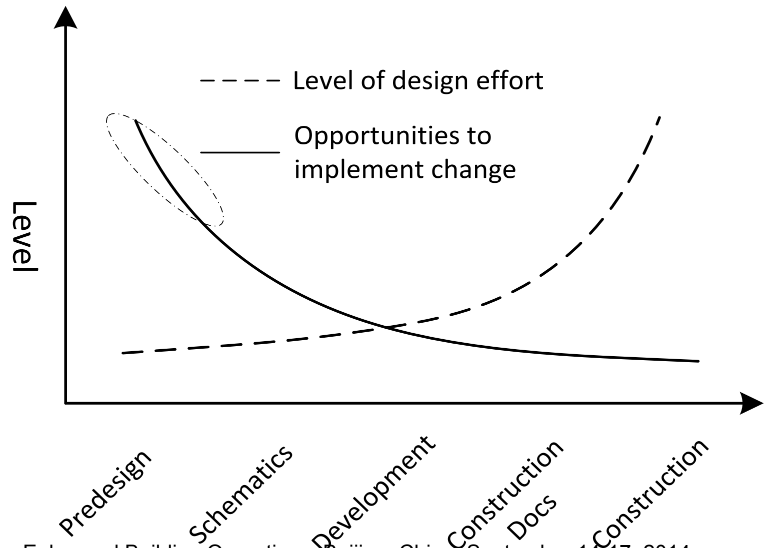
Problem Statement

- Highly intuitive selection: approximately 80% of all energy efficiency measures are selected without considering alternatives.
  - The knowledge and the expertise remain essential, but the help of proper design management tools that will assist the expert in addressing the problem in its full extent is certainly significant.
- The biggest impact for building performance and the best opportunities are determined by the decisions made in the early design phase.
  - But detailed information on building performance rarely gets back to design and development teams.



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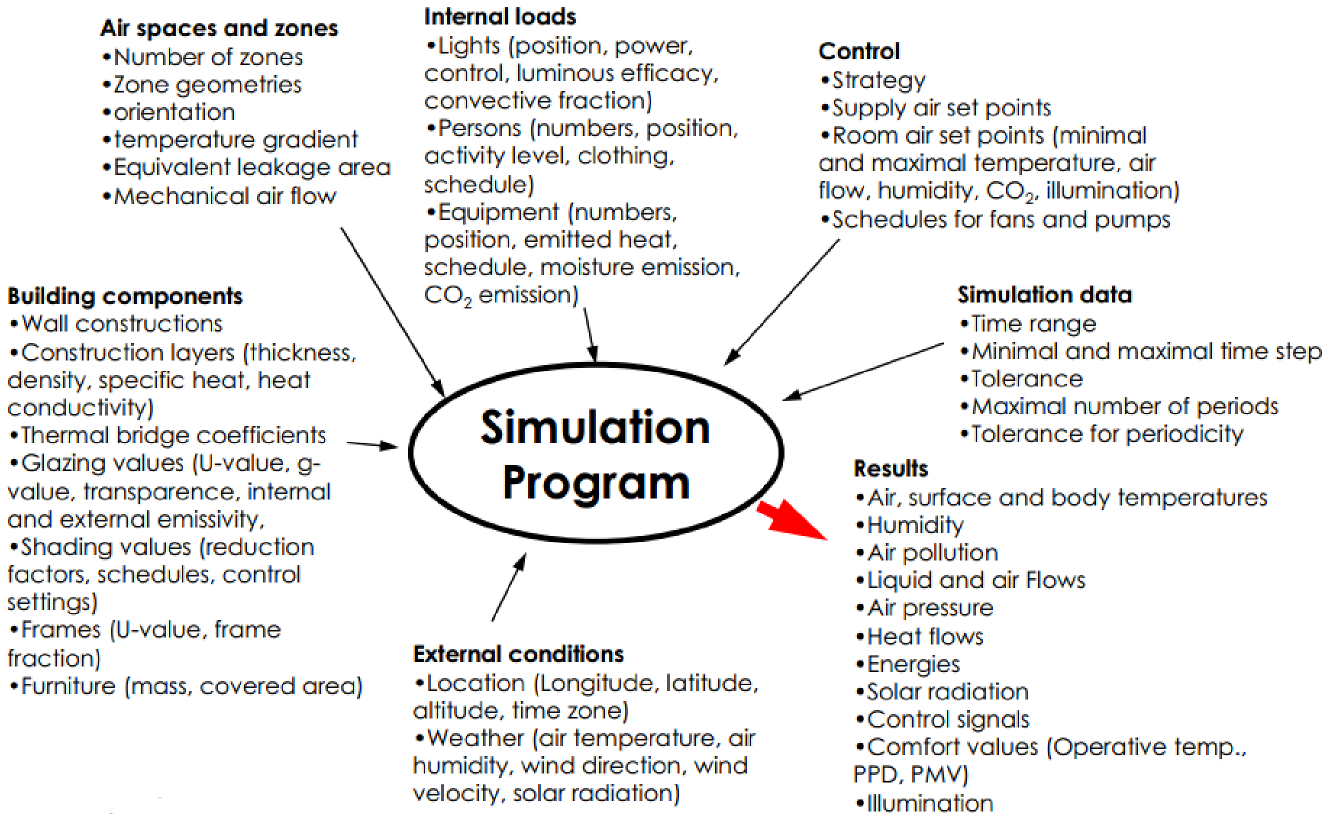
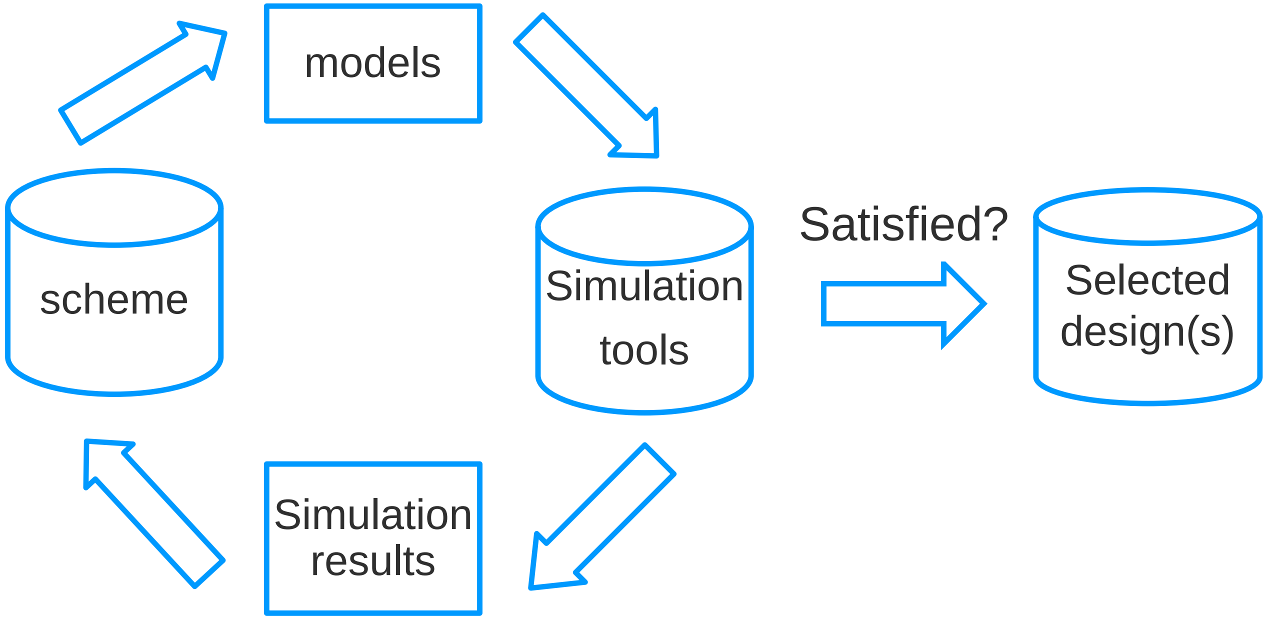
Building and Systems Simulation



Simulation allows architects and engineers to test out new designs before proceeding to construction and installation.

Reprint from “Multi-Objective Optimisation for the Design of Net-Zero Energy Buildings”, Ala Hasan

Solving the design problem? Past studies – Simulation based approach



Designers often do "trial and error" work in traditional design of building retrofits

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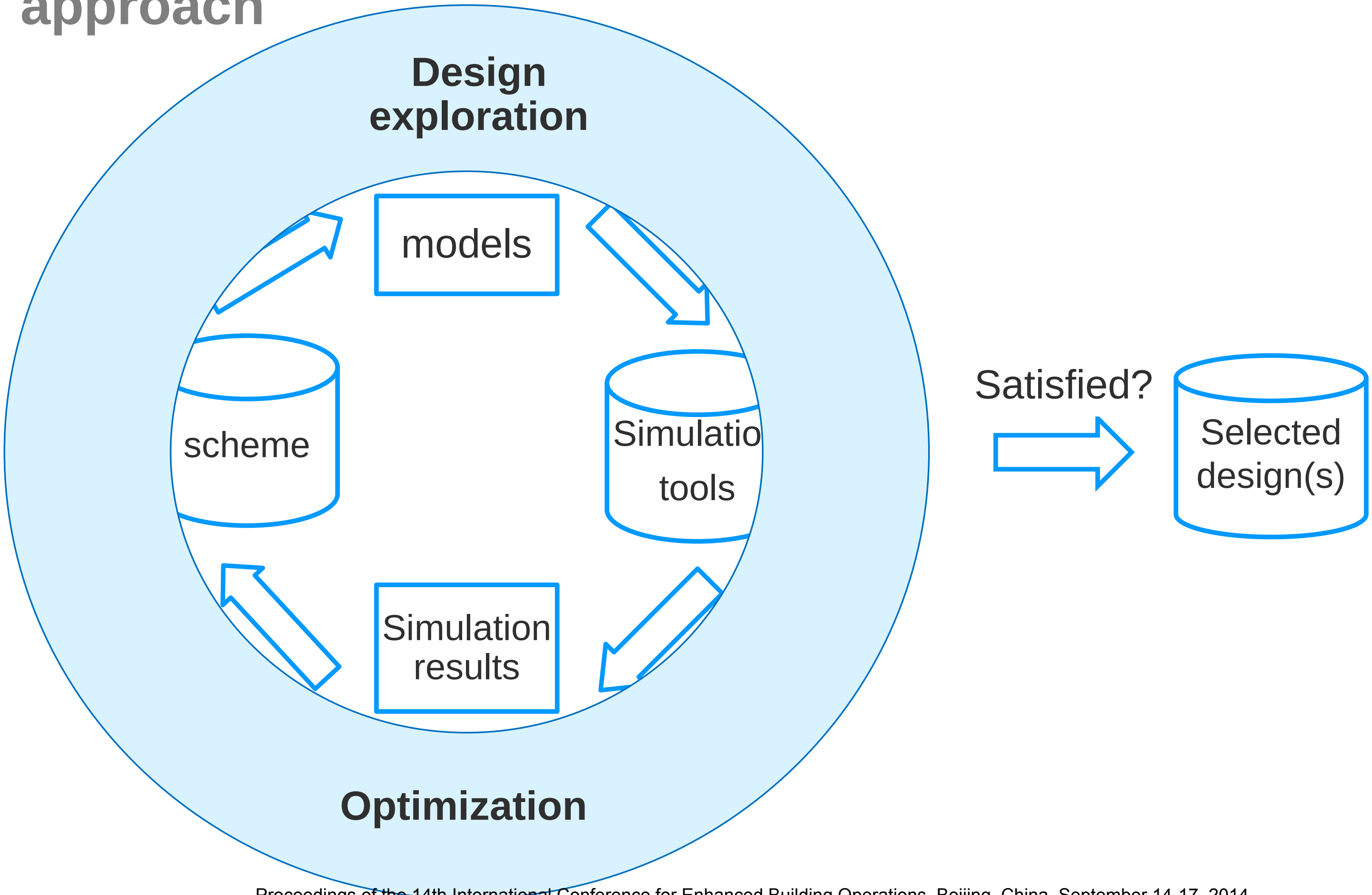
Past studies - Combined simulation and optimization approach



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General remarks

- Each building's energy retrofit is unique: it has its own characteristics and stakeholders which are generally different from others. Success of an energy retrofit project is tied with the assessment and selection of energy efficiency measures that can satisfy stakeholders' diverse, and often conflicting requirements.

- There is a need to integrate requirement analysis in making informed multi-criteria decisions for energy-efficiency solutions at the early design stage.

You cannot find the right answer if your are asking the wrong question – To find the right answer, we must ask the right question!

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Is there a better approach for better retrofit solutions?

Naturally.

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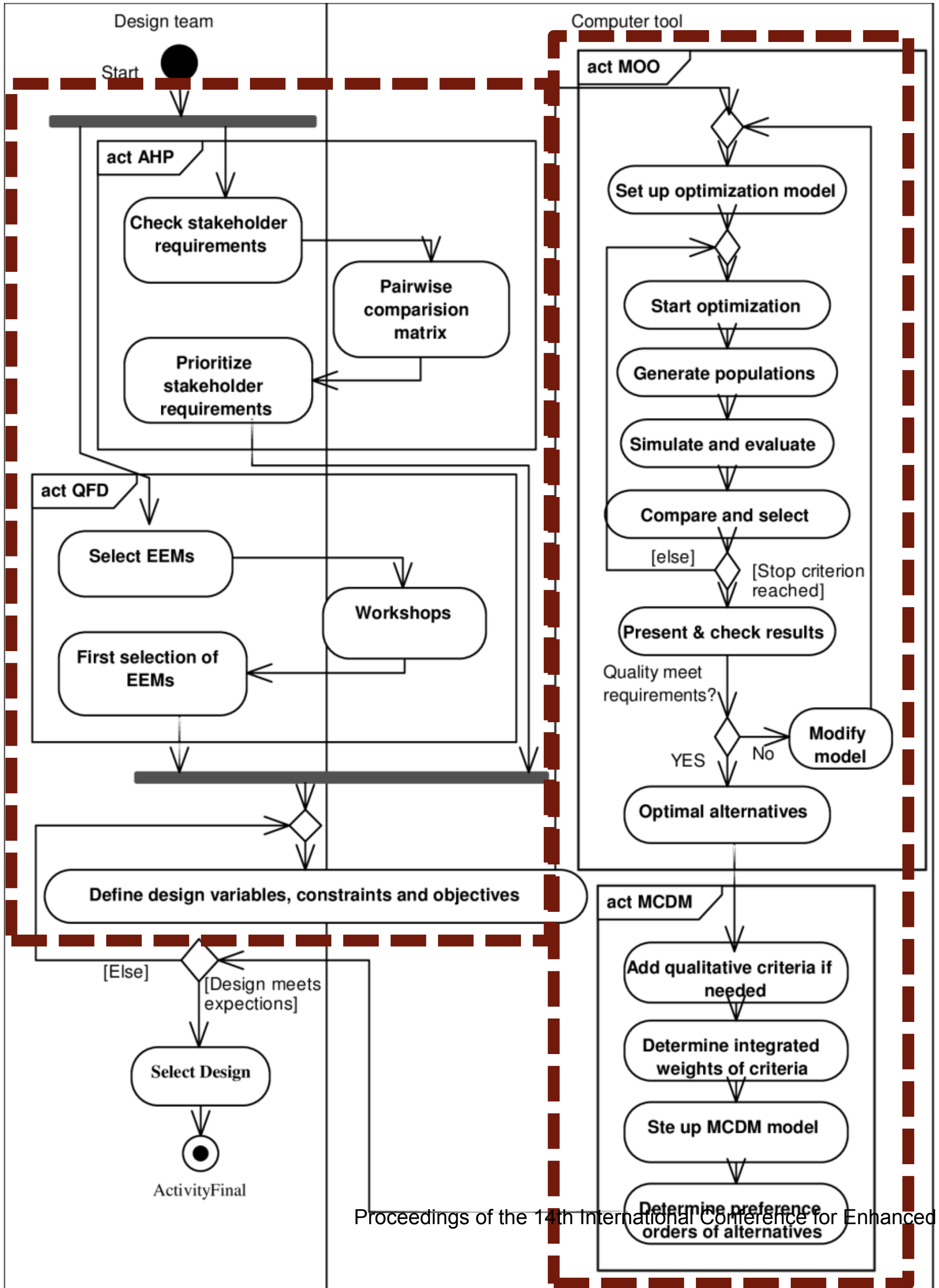
The activity diagram of design process and optimization



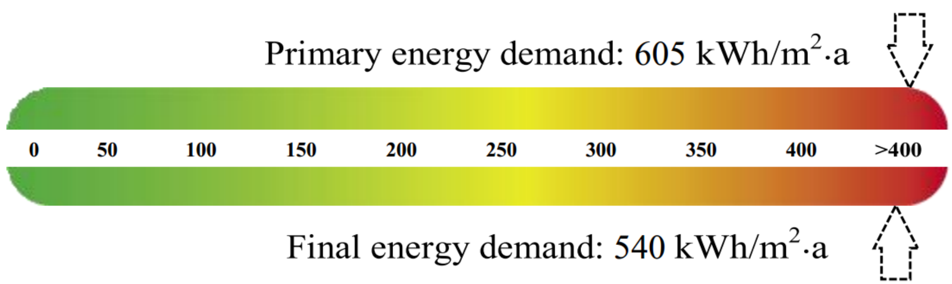
Integration of an analysis procedure carried out by a design team and a numerical optimization procedure by computer.

Specify design variables, objectives, and constraints.

Explore the design space for optimal solutions.

The study provides a basis for embedding requirement analysis and multi-objective optimization into the decision making on energy efficiency retrofit solutions, which considers the important role of the design team by carrying out the analysis procedure.

Example problem



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Requirement analysis

Potential improvements

- Insulate external walls
- Insulate basement ceilings
- Insulate roofs / attics
- Replace glazing systems
- Improve building tightness
- Replace heating system

Objective

- Reduce annual operational energy consumption
- Reduce investment cost
- Reduce annual GWP emissions

Constraints

- Energy consumption limits
- Indoor air quality limits
- Indoor temperature limits

EnEV 2009

DIN V 18599

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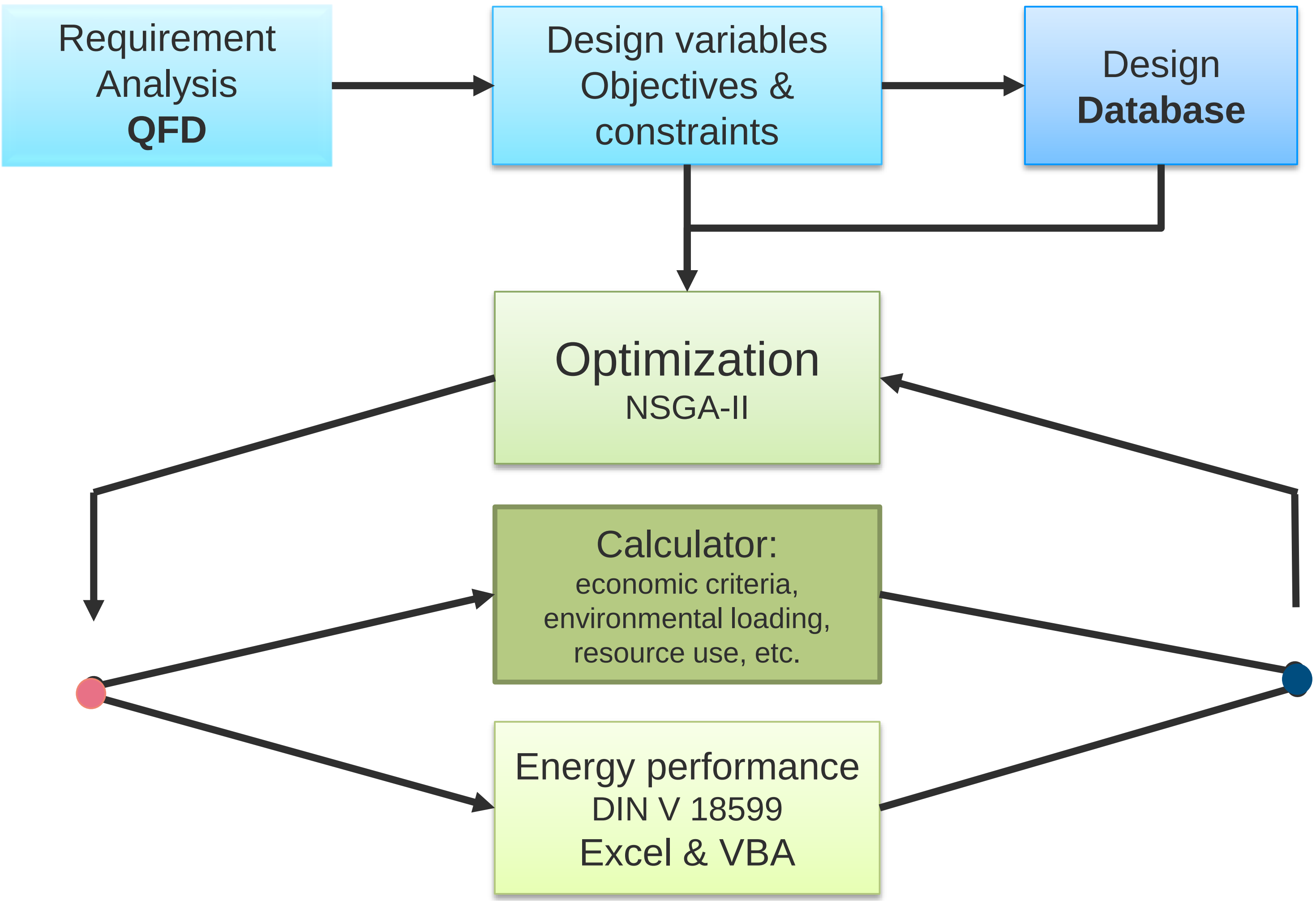
Multi-objective Optimization Development



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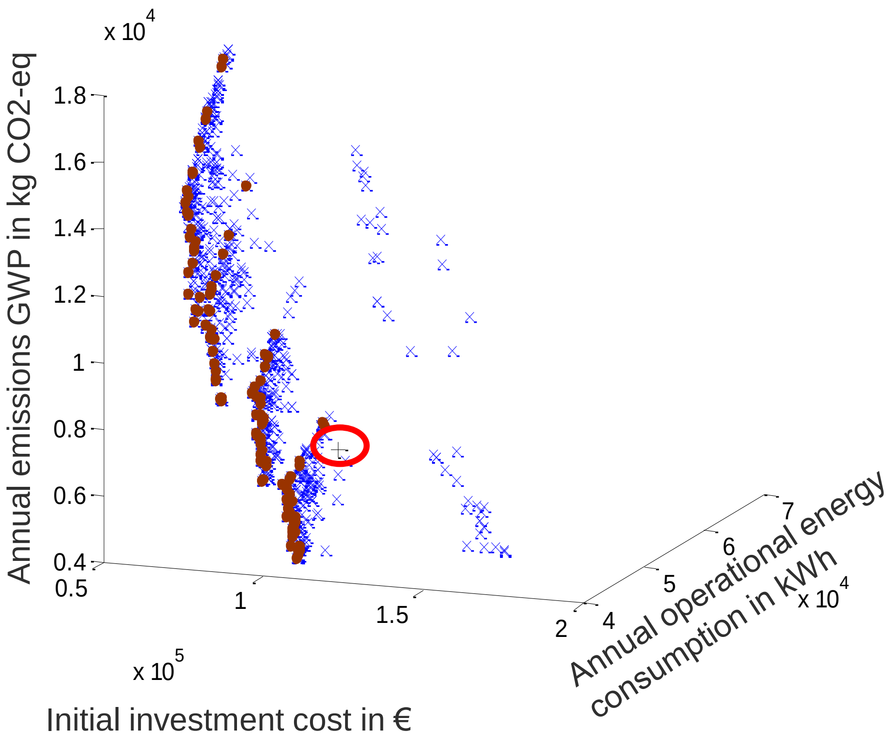
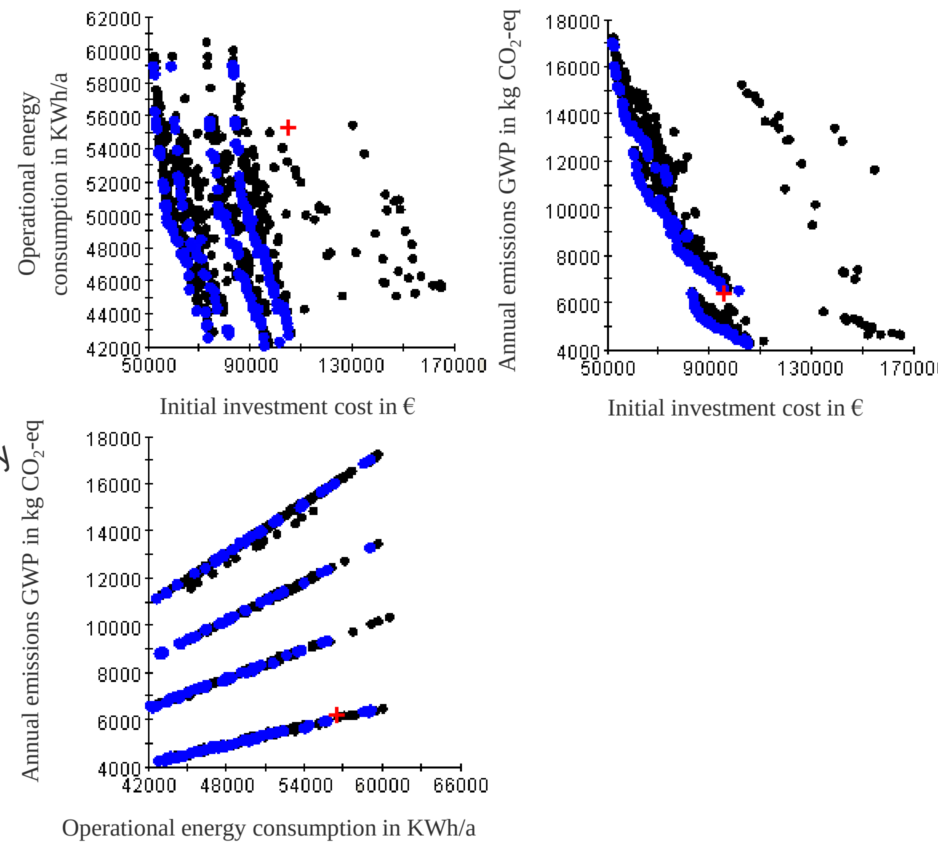
Optimization results



The Pareto front solutions and the candidate solutions of the case study



The 2D projections of Pareto optimal solutions (blue dots)

A solution is Pareto optimal if there exists no feasible solution for which an improvement in one objective does not lead to a simultaneous degradation in one (or more) of the other objectives.

Solution analysis: multiple criteria decision making (MCDM)

- The multi-objective optimization (MOO) process enables the generation of a set of Pareto optimal solutions.

- Usually only a single or a few solutions has to be chosen for further inspection and development. The final result will be a compromise, where human judgment and decision-making is involved.

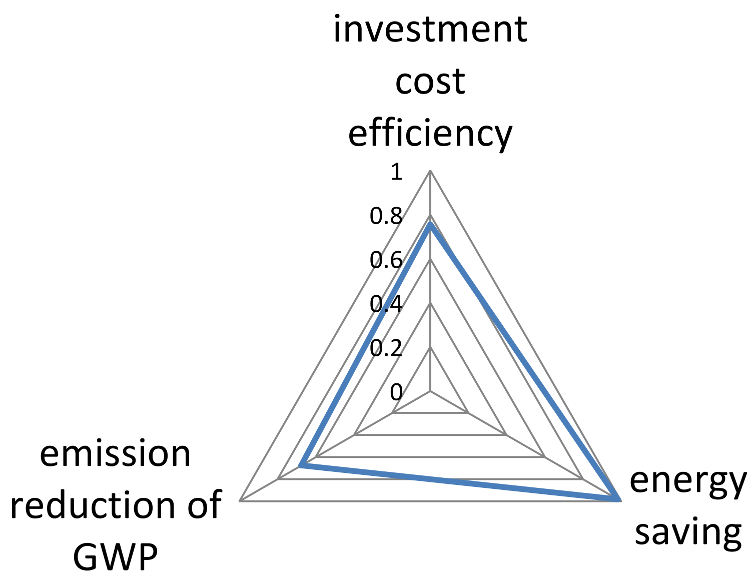
- How? Multiple Criteria Decision Making
  - concerned with structuring and solving decision and planning problems involving multiple criteria.

Solution analysis: multiple criteria decision making (MCDM)

1	76	0.770	31	14	0.709	61	63	0.660	91	102	0.609
2	107	0.766	32	17	0.706	62	2	0.659	92	45	0.609
3	26	0.760	33	69	0.704	63	57	0.657	93	32	0.609
4	21	0.757	34	24	0.704	64	80	0.657	94	13	0.609
5	113	0.757	35	115	0.700	65	94	0.656	95	42	0.608
6	36	0.755	36	74	0.690	66	60	0.653	96	8	0.607
7	79	0.755	37	95	0.687	67	38	0.650	97	118	0.605
8	55	0.754	38	112	0.686	68	10	0.648	98	62	0.605
9	56	0.754	39	15	0.685	69	18	0.640	99	98	0.604
10	91	0.750	40	97	0.685	70	39	0.634	100	3	0.604
11	46	0.750	41	12	0.683	71	68	0.632	101	61	0.601
12	89	0.749	42	44	0.677	72	93	0.632	102	6	0.600
13	59	0.748	43	88	0.677	73	119	0.631	103	66	0.594
14	114	0.746	44	50	0.675	74	41	0.631	104	82	0.578
15	7	0.745	45	40	0.674	75	5	0.630	105	70	0.576
16	51	0.745	46	92	0.673	76	64	0.628	106	103	0.574
17	72	0.742	47	48	0.673	77	22	0.627	107	67	0.574
18	96	0.742	48	105	0.673	78	19	0.624	108	117	0.573
19	75	0.741	49	30	0.673	79	84	0.623	109	100	0.572
20	101	0.739	50	78	0.670	80	77	0.618	110	54	0.571
21	49	0.733	51	104	0.670	81	33	0.617	111	31	0.569
22	99	0.731	52	4	0.670	82	28	0.615	112	43	0.565
23	81	0.730	53	106	0.669	83	34	0.613	113	29	0.565
24	58	0.730	54	23	0.669	84	65	0.612	114	52	0.561
25	71	0.726	55	86	0.667	85	87	0.611	115	47	0.544
26	120	0.720	56	20	0.667	86	16	0.610	116	37	0.486
27	90	0.717	57	9	0.666	87	116	0.610	117	25	0.449
28	11	0.717	58	108	0.665	88	1	0.610	118	53	0.446
29	109	0.715	59	27	0.662	89	83	0.609	119	73	0.437
30	85	0.710	60	110	0.661	90	35	0.609	120	111	0.420

An example of the MCDM application

Solution analysis: multiple criteria decision making (MCDM)



The radar chart of the Rank 1 solution (No. 76).

Rank 1 solution (No. 76)

- 180 mm Expanded Polystyrene (EPS) insulation on the external walls
- 160 mm EPS insulation on the roof
- 160 mm EPS insulation on the basement ceiling,
- high insulation glazing
- improvement of the air tightness to N50=1 1/h
- low-temperature boiler for gas combustion.

- ❑ Initial investment cost €73200
- ❑ Annual operational energy 42600 kWh
- ❑ Annual GWP 11200 kg CO_2-eq.

Conclusions

- A platform has been developed to integrate requirement analysis and optimization for a thorough exploration of the design space of retrofit solutions.
- Building retrofits can be explored in an integrative way so as to overcome the fragments of the planning process in the early phase.
- Outcome: **better** design(s) within a **reasonable** time frame!

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