



HAL
open science

Development of the Integrated Approach on the impact of the Climate Adaptive Building Shells, on the Performance and Energy Efficiency of Building

Liliia Isyk

► **To cite this version:**

Liliia Isyk. Development of the Integrated Approach on the impact of the Climate Adaptive Building Shells, on the Performance and Energy Efficiency of Building. Proceedings of the 4th International Congress on Ambiances, Alloaesthesia: Senses, Inventions, Worlds, Réseau International Ambiances, Dec 2020, e-conference, France. pp. 256-261, 10.48537/hal-03220304 . hal-03220304

HAL Id: hal-03220304

<https://hal.science/hal-03220304>

Submitted on 11 May 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Development of the Integrated Approach on the impact of the Climate Adaptive Building Shells

on the Performance and Energy Efficiency of Building

Lilija ISYK¹

***Abstract.** The consolidation of environment, and technology represents an ample conjunction of developed and innovative elements to serve the landscape. Construction performance depends not only on the operation of individual elements in the building but also on how they behave as integrated approach to satisfy the user demands. In architecture, projects are contained of different phases of architecture process, and several factors need to be considered among this cycle, such as climate, building shape, comfort levels, materials and systems, occupant health and security. Climate Adaptive Building Shells are important, as they are starting point of energy efficiency measures, the main determinant of the amount of energy required for heating, cooling and ventilation.*

***Keywords.** Climate Adaptive Building Shells, Energy Efficiency, Building and Environment, Sustainable Architecture, Facade Design*

Objectives

The objective of our research is to generate an integrated approach on the performance and energy efficiency of buildings. Discovering potential of CABS, by establishing the connection between optimization techniques and adaptive, rather than static building shells. The focus is not on the eccentricities of individual cases, but the problem is approached from a general perspective.

In our investigation we use the following definition:

A climate adaptive building shell has the ability to repeatedly and reversibly change some of its functions, features or behavior over time in response to changing performance requirements and variable boundary conditions, and does this with the aim of improving overall building performance.

Research project will contain of the investigation of the changing of CABS in the performance and variable boundary conditions. To do this, we will create a research model and after, we will develop a strategy to proceed with making a simulation, in according to the certain criteria. All the simulations will be focused mainly to measure the density, surface absorptance, thermal capacity, thermal conductivity, window to wall ratio, in the two positions of the research model: long-term adaptation and short-term adaptation. After the simulations all the data will be collected, organized and structured into the tables, and diagrams to be able to analyze the new knowledge on the performance and energy efficiency of buildings. Based on the results and outcomes of our investigation, we will determine and create an integrated approach.

¹ Ph.D. student, and young researcher, Lusofona University of Humanities and Technologies, Lisbon, Portugal, isyk.lilija@gmail.com

State of Art

Improvements in design and construction of building shells plays an important role in recent efforts that aim to connect the gap from current practice towards meeting our future energy saving targets. Notwithstanding the fact that good progress has been made, these attempts usually do not get around the status quo that building shells are typically designed as static elements in a dynamic environmental context. By being static or fixed, the conventional building shell has no means of responding to the changes in weather conditions throughout the day and throughout the year, and the variable nature of occupants' preferences. In contrast, climate adaptive building shells (CABS) do offer the ability of actively moderating the exchange of energy across a building's enclosure over time. By doing this in a sensible way, in response to prevailing meteorological conditions and comfort needs, it introduces good energy saving opportunities. A growing interest in CABS therefore speculates on an added value on top of passive design solutions, and considers the concept as one of possible ways to accomplish the shift towards net zero energy buildings. The concept of CABS is referred to by a multitude of ambiguous terms, including: active, intelligent, dynamic, interactive, smart etc.

Current progress in the field of CABS is characterized by fragmented developments; either driven by specific advances in material science (e.g. switchable glazing, adaptable thermal mass and variable insulation), or originating from creative processes in design teams. Literature on CABS in relation to building performance simulation (BPS) shows the same degree of fragmentation, as it mainly deals with performance evaluations of specific case-studies such as: dynamic thermal insulation, and smart windows. Despite these efforts, it remains unclear what type of building envelope behavior, actually results in the best building performance.

Within research settings, it has been demonstrated recurrently that the application of optimization techniques as a design aid, can move building performance beyond the level of "trial-and-error" designs. Initially, these developments led to the specification of generic design rules, derived on the basis of simplified building models. The advent of more efficient optimization algorithms, and the continuing trend of increasing computational power, now also enables optimization studies to be performed at a higher level of detail.

First results of the Research Project

Figure 1 shows the results of the whole-year simulation. In this graph, each dot represents a single building shell design. A solution is said to be Pareto optimal if, and only if it is not dominated in one or two directions by any other solution, in the decision variable space (Wang et al., 2005). In Figure 1 these Pareto designs are indicated in red.

From Figure 1, we observe a rather sparse cloud, and thus a relatively quick convergence towards optimal solutions. In addition, the plot shows a smooth trade-off curve. This means that many compromise points are feasible, and that it is up to the design team to make a rational decision, by taking their preferences into account.

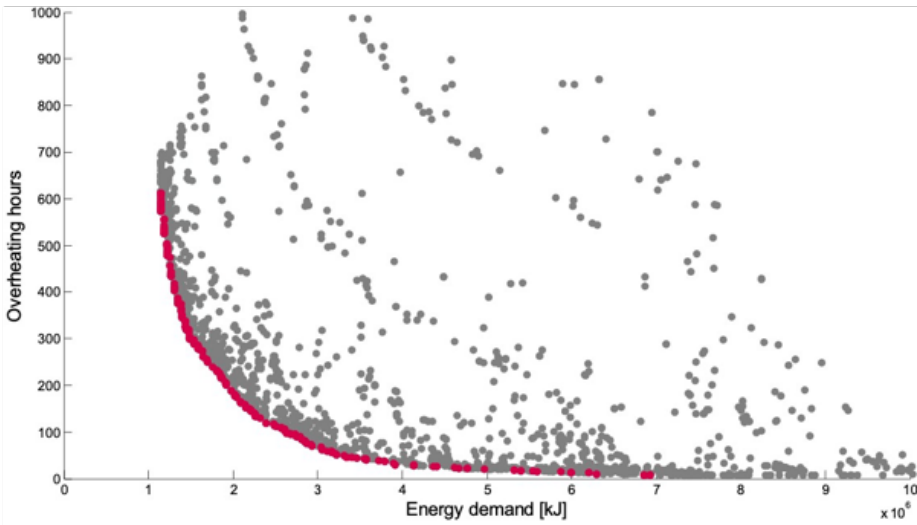


Figure 1. Scatter plot - Results of optimization for static building shell design

Whereas the scatter plot provides a clear overview of performance aspects, it gives no insights in terms of the design space. Figure 2 shows results for the same optimization run, but this time in a plot with parallel coordinates. In this figure, each line represents a single building design. The five left-most axes in the graph show the design parameters under evaluation. The two right-most axes show the performance that is associated with each of these input sets. By using the technique of ‘brushing’ (Martin and Ward, 1995), a sub-selection of the multi-dimensional space can be visualized. This type of analysis proved to be useful in facilitating more insights in the mapping from input parameters to performance space.

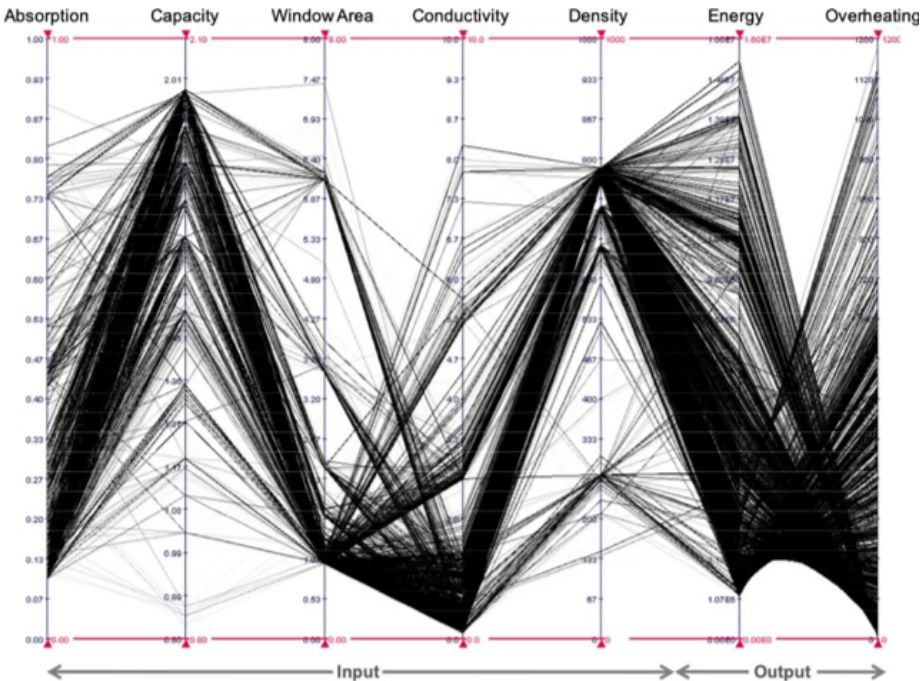


Figure 2. Parallel coordinates - Results of optimization for static building shell design

By contrasting the results with lowest energy demand to those with lowest number of overheating hours, Figure 3 and Figure 4 respectively, show that the designs with high levels of comfort tend not to coincide with those that result in low energy consumption. This result indicates the existence of conflicting goals, and the inability to meet them simultaneously. Likewise, complementary analysis also revealed that there exists a disparity between designs with low heating and low cooling energy demand. Decision-makers looking for well-balanced annual trade-offs will likely find their solution of preference located in the knee-point area of the Pareto set. This outcome indicates that performance of static building shells is at best only a good compromise for the whole year. In turn, it gives rise to the hypothesis that even the best static building shells can be outperformed by CABS.

Figure 3. Results with lowest energy demand

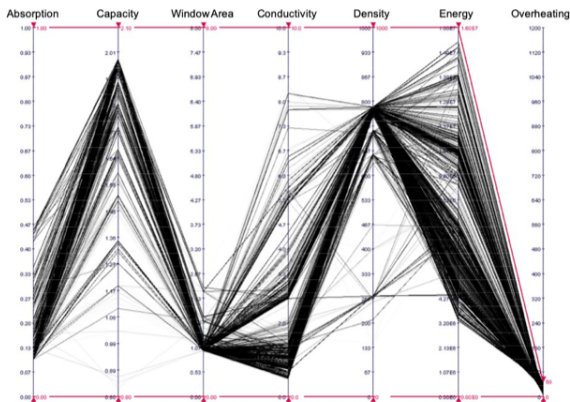
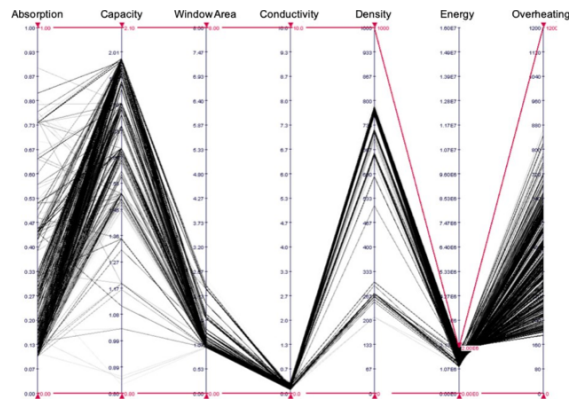


Figure 4. Results with least overheating hours

Observations

Based on the optimization study for the best performing static building shell design, the following observations can be made: The results of optimization tend to end up in the limits of the option space. Careful specification of possible parameter ranges is thus of primary importance.

The best performing building shell needs to make compromises in order to satisfy performance requirements throughout the whole year. This signals clear opportunities for the use of CABS. In the next section, the performance of the best static building shells will be compared to the performance of a CABS that is able to adjust its behavior at relatively long time-scales.

References

- Bosman P, La Poutré H (2007) Learning and Anticipation in Online Dynamic Optimisation with Evolutionary Algorithms: The Stochastic Case In Proceedings of Genetic and Evolutionary Computation Conference - GECCO-2007 London, UK, p. 1165-1172.
- Burdajewicz F, Korjenic A, Bednar T (2011) Bewertung und Optimierung von dynamischen Dämmsystemen unter Berücksichtigung des Wiener Klimas. *Bauphysik* 33:49-58
- Chantrelle F, Lahmidi H, Keilholz W, El Mankibi M, Michel P (2011) Development of a multi-criteria tool for optimizing the renovation of buildings. *Applied Energy* 88:1386-1394
- Clarke J, Cockroft J, Conner S, Hand J, Kelly N, Moore R, O'Brien T, Strachan P (2002) Simulation-assisted control in building energy management systems. *Energy and buildings* 34:933-940
- Coffey B, Haghighat F, Morofsky E, Kutrowski E (2010) A software framework for model predictive control with GenOpt. *Energy and Buildings* 42:1084-1092
- Crawley D, Hand J, Kummert M, Griffith B (2008) Contrasting the capabilities of building energy performance simulation programs. *Building and Environment* 43:661-673
- Deb K, Pratap A, Agarwal S, Meyarivan T (2002) A fast and elitist multi-objective genetic algorithm: NSGA-II. *IEEE Transactions on Evolutionary Computation* 6:182-197
- Esteco (2011) modeFRONTIER - the multi-objective optimisation and design environment. Available at: http://www.esteco.com/home/mode_frontier/mode_frontier.html [Accessed May 2011].
- Gero J, D'cruz N, Radford A (1983) Energy in context: A multi-criteria model for building design. *Building and Environment* 18:99-107
- Gyalistras D, Gwerder M, Oldewurtel F, Jones C, Morari M, Lehmann B, Wirth K, Stauch V (2010) Analysis of energy savings potentials for integrated room automation In Proceedings of 10th REHVA World Congress Clima
- Hoes P, Trcka M, Hensen JLM, Hoekstra Bonnema B (2011)(a) Investigating the potential of a novel low-energy house concept with hybrid adaptable thermal storage. *Energy Conversion and Management* 52:2442-2447
- Hoes P, Trcka M, Hensen JLM, Hoekstra Bonnema B (2011)(b) Optimising building designs using a robustness indicator with respect to user behaviour In Proceedings of Building Simulation 2011 Sydney, Australia.
- Hopfe CJ (2009) Uncertainty and sensitivity analysis in building performance simulation for decision support and design optimisation. Ph.D. Thesis. Eindhoven University of Technology.
- Loonen RCGM (2010) Overview of 100 climate adaptive building shells - MSc Thesis Report.
- Loonen RCGM, Trka M, Cóstola D, Hensen JLM (2010) Performance simulation of climate adaptive building shells - Smart Energy Glass as a case study In Proceedings of SSB 2010: 8th international conference on system simulation in buildings Liège.
- Manzan M, Pinto F (2009) Genetic optimisation of external shading devices In Proceedings of Building Simulation 2009 Glasgow, p. 180-187.
- Martin AR, Ward MO (1995) High dimensional brushing for interactive exploration of

multivariate data In Proceedings of the 6th Conference on Visualization'95 IEEE Computer Society, p. 271.

Rosen R (1985) Anticipatory systems. New York: Pergamon.

Ross A, Rhodes D (2008) Using Natural Value- centric Time Scales for Conceptualising System Timelines through Epoch-Era Analysis In Proceedings of INCOSE International Symposium 2008 Utrecht, The Netherlands.

Ross AM (2009) Combining Pareto Trace with Filtered Outdegree as a Metric for Identifying Valuably Flexible Systems In Proceedings of the 7th Annual Conference on Systems Engineering Research

Trcka M, Loonen RCGM, Hensen JLM, Houben JVF (2011) Computational building performance simulation for product and integrated design development and optimisation In Proceedings of Building Simulation 2011 Sydney, Australia.

Wang W, Zmeureanu R, Rivard H (2005) Applying multi-objective genetic algorithms in green building design optimisation. Building and Environment 40:1512-1525

Wright J, Mourshed M (2009) Geometric optimisation of fenestration In Proceedings of Building Simulation 2009 Glasgow, p. 920-927.

Zavala V, Constantinescu E, Krause T, Anitescu M (2009) On-line economic optimisation of energy systems using weather forecast information. Journal of Process Control 19:1725-1736