MULTI-DISCIPLINARY OPTIMIZATION IN THE EARLY STAGES OF DESIGN

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ABSTRACT

Architects are master jugglers. This is most apparent in the early stages of design when they are balancing many major issues including client requirements, preliminary costs, aesthetics, community concerns, structures, environmental impacts, etc. Decisions made then have a huge impact on the performance of the building. With increased awareness of the importance of sustainable design, architects are looking for tools that evaluate analytical design choices and inform knowledgeable decisions. Simulation software has existed for decades. More recently, multi-disciplinary optimization algorithms offer potential solutions for well-defined questions, for example, what is a good trade-off between increasing window size for day-lighting that does not increase loads disproportionately? New processes that incorporate their benefits need to be developed.

This paper explains about parametric and multidisciplinary optimization techniques and then outlines a design approach to utilize them in the preliminary design stage of a case study building.

1. INTRODUCTION

Decisions made during early stage of design process have a critical impact on overall performance of buildings. However, often this is the least explored design alternative phase. This is mainly due to limited funds allocated to this early design, lack of awareness of the energy saving potential of this phase, and limited knowledge about optimization software and parametric analysis.This paper tries to emphasize the importance of utilizing parametric design and multi-disciplinary design optimization techniques at the schematic level for exploring different energy efficient design configurations and demonstrates one process to achieve that goal.

Currently, simulation tools are being used to validate the intuitions of architects and give them a basis to proceed with design or modify designs based on the outcome of simulation results. Simulation tools are incredible in making energy efficient design calculations, but studying several different design options is time consuming and often difficult as the critical ranges of variables might not be known. Parametric design possibilities and optimization techniques can make the process quicker and provides result from much larger pool of options.

2. PERFORMANCE BASED DESIGN TECHNIQUES

In addition to the traditional types of analytical modeling where a digital model is constructed and then performance simulations are run, there are software programs available that help in "optimizing" the design for specific criteria.

Optimization at the building and operations level has potential to be an important contributor to the performance of the overall designed space. There are a number of optimization objectives that a designer can focus on - like minimizing the following: energy demand (lighting, heating, cooling, auxiliary), primary energy consumption, embodied energy, operational carbon emissions, operational cost, construction cost. Or objectives might include maximizing indoor environmental qualities like daylight, air quality, and thermal comfort.

Several methods are available for doing optimization: parametric analysis, genetics algorithms, and the Pareto Front are discussed below in the context of software programs that use them. In addition, one might claim that an experienced architect “intuitively” tries to optimize multi-objectives passively, for example, previous experience from other buiding projects might have shown that a specific low-e glazing saves energy at a reasonable cost, and therefore the architect might choose that combination again. This type of “passive optimization” is mentioned further in the case study.

2.1 Parametric Analysis

Parametric analysis is a well-established technique to find design with most favorable characteristics (e.g. low loads, less energy consumption, most comfortable etc.) by systematically adjusting variables, usually only a few of them at a time.

Parametric analysis can be performed with just one variable. It can be as simple as having a spreadsheet where the user methodically changes one value until another value reaches a high or low value. The example in figure 1 shows a computerized algorithm where the length of the shading element is increased until the solar radiation on a window no longer decreased, thus optimizing the shade length. Often, when one parameter is being optimized it can also just be solved for mathematically rather than using a brute force method like this.

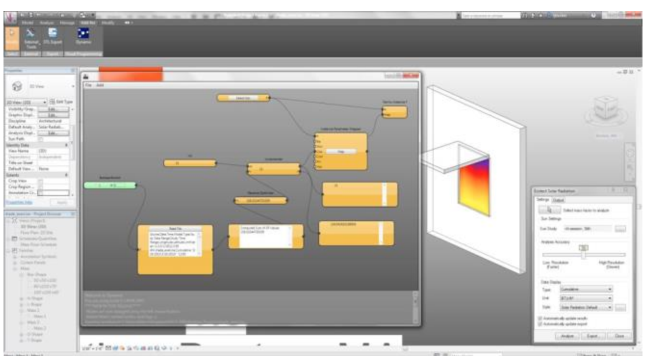


Fig. 1: Use of Revit Architecture and Dynamo to optimize the depth of the window shade. (image courtesy of Tyler Tucker)

Figure 2 is another example of parametric analysis with two variables. The designer is trying to lessen energy consumption by changing two variables. These variables are different façade scenarios (window-wall ratio WWR) and types of glazing. These results displayed in the form of series of parametric design curves are calculated using EnergyPlus engine and DesignBuilder interface. These design curves gives options for designer up front to analyze and choose a WWR coupled with glazing types based on both aesthetics and performance. Note that the designer is not being coerced into chosen a single solution, but is learning what the consequences of different choices are.

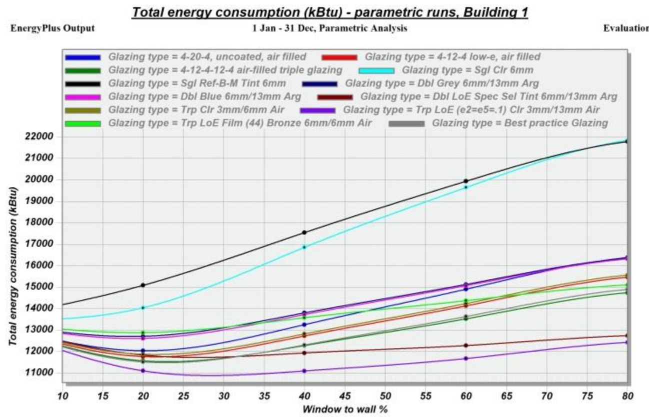


Fig. 2: Parametric design curves illustrating effect of different WWR and glazing combinations on total energy consumption

These types of design curves are very useful at early design phase of projects to understand the effect of different variables on building performance. This gives the designer a sense about sensitivity of the variables and establishes the key elements that effect performance parameters like thermal comfort and energy consumption. Sensitivity analysis is a potential extra benefit; through parametric iterations the designer can also learn which variables have the most impact. Once that is established, designer can make minimal changes with maximum impact on performance. Moreover, these parametric illustrations helps designer to communicate better with clients and make them understand the design decisions that followed.

In spite of all advantages discussed above, there are some limitations in finding optimal solutions using parametric analysis, for example, the number of variables that can be practically explored with single optimization objective (e.g. best comfort, low energy consumption etc.) (1).

2.2 Genetic Optimization

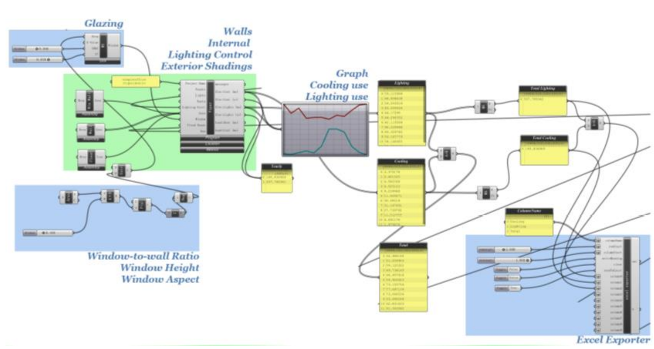
Another form of optimizing techniques uses genetic or evolutionary optimization algorithms to explore locally optimal design solutions (2). This can be a more efficient way to find optimal designs depending on the problem and can solve for multiple conflicting objectives, for example, minimizing energy consumption while maximizing comfort levels or minimizing loads while also minimizing life-cycle costs. This is also called multiple objective optimizations.

The research and development on finding an optimized design is not only limited to a building scale but also includes larger elements like a site and smaller components.

One example of optimization at the site level can be performed using SITEOPS. It provides rapid site evaluations, cost optimization, and value engineering. This tool is driven by parametric design elements, which allow objects to look and interact with each other. The designer can see the cost-based conceptual grading plan based on quick site layout. The project is submitted to SITEOPS server and optimization carried out online to find the best possible way to grade and do piping layout for this site in order to minimize cost implications. (www.siteops.com)

The other end of size spectrum deals with component level optimization. This includes optimizing external shades, light shelves, window tilt, etc. An example of this would be studying the depth of overhangs used with different glazing types with the objective of enhancing that performance of a space by minimizing loads and maximizing good daylight levels or some compromise of those variables.

Many examples have been created using genetic algorithms. An example done in Rhino 3d with DIVA optimized window size. . DIVA-for-Grasshopper is a plug-in for environmental analysis that runs thermal, daylight, solar radiation, and glare simulations.It balanced the benefits of daylighting to save electrical energy (that would be used for artificial lighting) and the increased use of air-conditioning in the summer because of increased heat gain through a larger window (Fig. 3) (3).



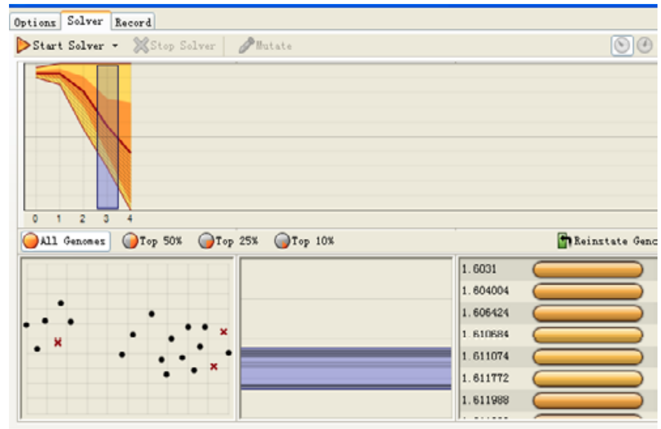


Fig. 3: DIVA for Grasshopper definition. Galapagos component. (images courtesy of Geman Wu).

Galapagos is a generic component for the application of evolutionary algorithms. Genetic algorithms and evolutionary systems provide a framework by which locally optimal solutions can be searched for within an infinite generative field of variation. Using these tools, the parametric system becomes the genome, the field of alternatives becomes the population, and the architect’s design goal becomes the fitness criteria (4). One can use evolutionary systems to look for design solutions that meet certain criteria.

This method does not necessarily find *the* optimal solution; it could find a local optimal solution instead.

2.3 Pareto Front

Building level optimization can be done in several software programs including DesignBuilder’s optimization module. The DesignBuilder optimization module is used for multiple objectives that are of interest to the designer, but may be in opposition to each other, for example, minimizing energy demand normally leads to increasing capital cost. The DesignBuilder optimization module addresses multiple objectives that are defined in the software and also deals with constraints to that optimization objective (e.g. minimum day-lighting criteria to meet, limited capital cost, discomfort hours allowed, etc).

The result for this kind of problem is not a single best solution but a “2d space” of optimum solutions. The result that meets the objectives and satisfies the constraints creates a feasible region. The set of points that bound the bottom of the feasible region is known as “Pareto Front” (5). The Pareto Front is a line that connects all optimal solutions for the defined objectives and constraints. These results in DesignBuilder interface is plotted on x-y graph with all optimized solutions marked in red. Figure 4 shows the feasible region of optimal solutions and the Pareto Front.

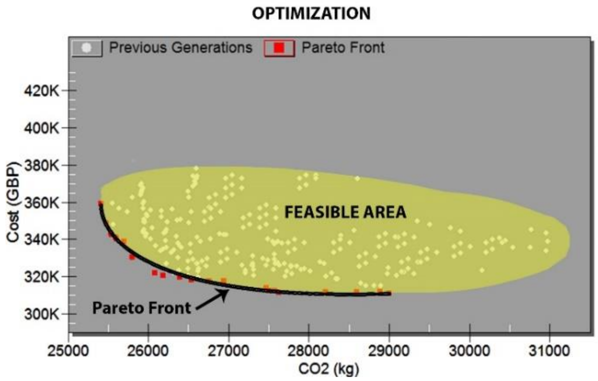


Fig. 4: Multi-objective optimization results and the Pareto Front where the more optimal solutions are located along

3. CASE STUDY

This case study was started as a competition proposal organized by the ADOPT research group, but latter became its own research project. The site constraints and parameters were adapted from the competition brief. The program required the following: 22,000 sf open office, 3,000 sf cellular office, 4,000 sf utility space, and circulation to form a 30,000 sf building. Functional criteria and specific sustainable targets were set that included minimizing operational carbon emissions, minimizing construction cost, satisfying comfort criteria based on ASHRAE 55, and achieving the minimum day-lighting requirement criteria set by the designer. The site was located in south London near Gatwick Airport.

As a design project, practicalities of design such as aesthetics, frontage, site constraints, and others under the umbrella of sustainable planning were considered. But smaller architectural details (for example, fittings, furniture, decorative materials, staircases, etc.) were ignored as they would not have much impact on the thermal, daylight, and cost performance of an early stage model. The major goal of the case study was to explore how multi-objective optimization algorithms can be incorporated into the design process.

The shape of the building was derived in response to the neighboring site conditions, solar insolation, and wind analysis. The process started with the use of Climate Consultant, Ecotect, and Vasari to understand the local London weather and site conditions. The following was deduced:

- London is primarily heating load dominated climate.
- During office hours in summer months in London, there are cold winds (32F-70F) blowing primarily from SW direction.
- There is a need of maximizing solar gain during dominant colder months and use natural ventilation as cooling strategy during hotter months.

The designer used “passive optimization,” knowledge about similar conditions and trade-offs, based on the data shown in the software programs. These included measures to reduce energy consumption of the building without actually dealing with building fabric or systems. These included the following:

- The building was sited to obtain as much direct solar gain as possible to passively heat the building during colder months and simultaneously make sure the neighboring buildings did not block cold winds during summer (Fig. 5). The building form itself was also specifically designed in order to maximize solar absorption from the east, south, and west sun and reduce heating load on active systems. This form catered to several criteria including meeting functional requirements, frontage to building, context relationship, maximizing solar gain, and using cool breezes during hot months

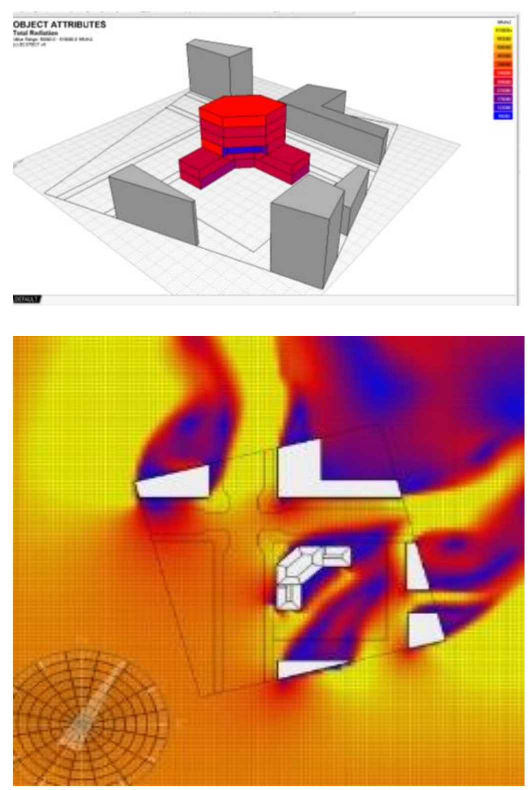


Fig. 5: Solar radiation (Ecotect) and wind tunnel analysis (Vasari)

- The footprint of building was placed on a less shaded area of the site (marked as red zone in Fig. 6). The building mass was set to multiple floors to capture more direct solar radiation during the coldest months when the ground level of site gets shaded as the low sun angle being blocked by neighboring buildings.

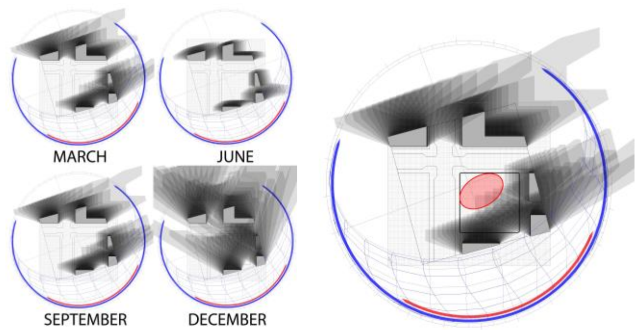


Fig. 6: Passive optimization – determining the least shaded area of the site for most solar heat gain

Once the basic 3d form was created, the Revit model was exported and imported into DesignBuilder using gbXML (Fig. 7). The basic default construction, glazing, opening, and HVAC templates for a typical office building were applied. Heating load, cooling load, annual energy consumption and tentative construction cost were noted for this baseline model. The Energy Use Intensity (EUI) for baseline model was 67 kbtu/sft-yr. The cost of construction was 32,30,000 GBP (British Pounds).

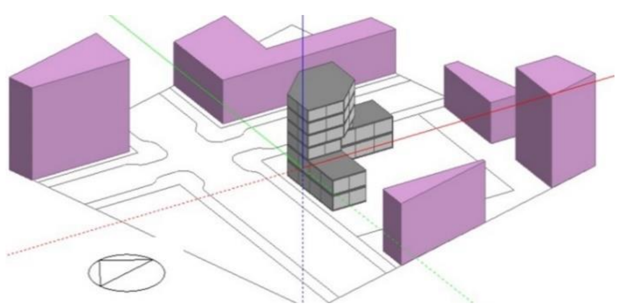


Fig. 7: DesignBuilder model

DesignBuilder was then used to optimize the façade, construction, HVAC systems, lighting and related controls of the building. In order to reduce simulation time of performing thousands of optimization simulation, only one typical floor (the 4th floor) was optimized, and changes were then applied to the whole building. Ideally, either the first or second floor plan should have been optimized separately as they don't come under 'typical' category. However, the designer in this case focused on only one floor to explore different options as majority of discovered strategies could be implemented on lower floor as well.

There were two objectives to be optimized: minimize construction cost (in British pounds) and lower operational cost (in terms of carbon dioxide - CO2 emissions). There were several parameters tested. These parameters were not all selected and optimized at once but in subsets. Earlier optimization focused on reducing external loads through envelope and construction. Later internal loads, HVAC system and controls were optimized. This helped maintain logical optimization while not preventing the software from crashing.

The first subset was the façade in which window wall ratio (WWR), glazing type, and shading type parameters were optimized. The range of WWR was given as 40-90%, eight different double glazing types, six different types of triple glazing, four types of louvers, and four types of overhang systems were selected for testing (Fig. 8).

Optimisation Analysis Settings Data

Objectives | Constraints | Design variables

Variable	Min Value	Max Value	Step	Options List	Target objects
Window to wall %	40.00	90.00	20.00	-	Building
Glazing type	0.00	0.00	0.00	14 options	Building
Local shading type	0.00	0.00	0.00	8 options	Building

Fig. 8: Parameter settings for façade optimization

The optimization was set with constraints on the number of uncomfortable hours (maximum 200) and minimum day-lighting criteria (Daylight Factor >= 2%) (Fig. 9). Uncomfortable hours are the hours when the combination of operative temperature and zone humidity ratio is not in the ASHRAE 55-2004 defined summer or winter clothes region. The lighting controls were also selected as a 3-stepped control system in the base building to include the savings due to better day-lighting. Stepped control allows the lighting system (or occupant) to switch lighting on/off according to the availability of natural daylight in three discrete steps.

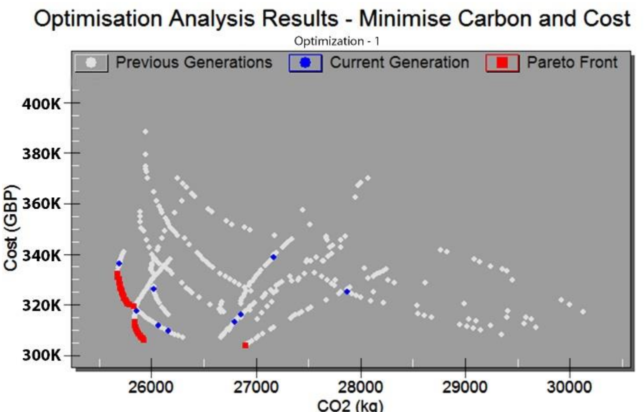
Optimisation Analysis Settings Data

Objectives | Constraints | Design variables

Name	Constraint KPI	Operator	Value	Units
Discomfort Hours	3-Discomfort hours	1-Less than	200.0000	Hours
Daylight Availability	4-Daylight availability	2-Greater than	2.0000	%

Fig. 9: Constraints for optimization (typical)

The DesignBuilder optimization module calculated solutions based on Pareto Front Evolutionary Algorithm. Optimal solutions in this case would be a WWR with the best suited glazing and shading type to reduce both construction and operational cost by minimizing cooling load, heating load, and maximizing daylight penetration. Figure 10 shows DesignBuilder optimization module output screen illustrating each simulation performed during optimization as a dot. These dots are spread all over the graph illustrating construction cost (y-axis) and CO2 emissions (x-axis) with different set of combinations. The dots in red form the Pareto Front and indicate the most optimal solutions based on objectives and constraints selected. The table underneath the graph shows the parameter combinations of optimized solutions that lie on Pareto Front.



Iteration	Generation	Pareto	Window to wall %	Glazing type	Local shading type	CO2	Cost
795	42	1	68.544	.Dbl, Air, Selective Tinted	SS 0.5m projection Louvre	56682.392	674618.698
200	10	1	44.301	.Dbl, Air, Selective Clear	S_0.5m Overhang	57052.260	636129.936
131	7	1	48.798	.Dbl, Air, Selective Clear	S_0.5m Overhang	56980.578	641898.887
22	1	1	42.884	.Dbl, Air, Selective Clear	S_0.5m Overhang	57102.274	633245.338
458	24	1	58.768	.Dbl, Air, Selective Tinted	S_1.0m Overhang	56958.030	659626.144
2189	117	1	65.024	.Dbl, Air, Selective Tinted	SS 1.0m projection Louvre	56718.918	670120.945
40	2	1	49.091	.Dbl, Air, Selective Clear	S_0.5m Overhang	56975.100	643341.115
296	15	1	51.681	.Dbl, Air, Selective Clear	SS 0.75m projection Louvre	56966.085	646225.583
1953	104	1	67.371	.Dbl, Air, Selective Tinted	SS 1.0m projection Louvre	56694.281	673119.481

Fig. 10: Façade optimization results

Over 2500 simulations were carried out to get a set of about 20 optimized solutions. Out of these, designers can select the options and combinations that suit their overall design goals. As an example: if designer have personal preference (maybe aesthetic reasons) to have WWR around 65% and minimize the operations cost as second criteria, then his closest best options would be to go with iteration 795, 2189 or 1953 as described in chart above in figure 9. However, if his objective is the most optimized solution in terms of minimum construction cost then iterations 200 and 22 would be better. In this case, the designer chose 68% WWR with double air tinted glazing, and a 1.5' louver considering aesthetic reasons and minimizing operational cost. These changes were updated in simulation model, and an annual simulation was run.

The next step was to dive deeper in the model for optimizing construction assemblies. Eleven different types of wall constructions, eight types of roof constructions, infiltration (range: 0.2 - 1.2), and four different types of floor constructions were used as testing parameters. WWR with a smaller range (40-70%) and three types of best performing glazing types from the previous optimization step were also included as parameters at this stage. (Fig. 11).

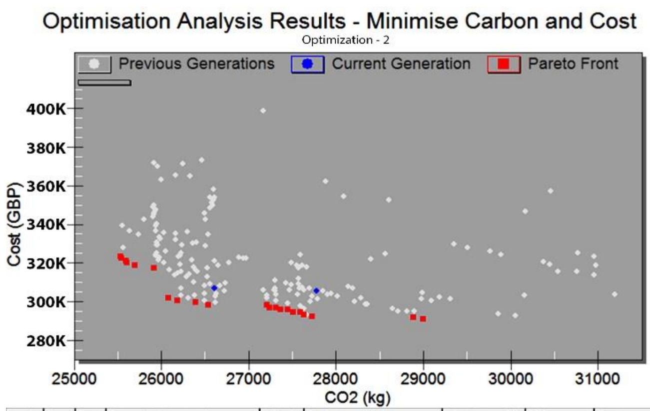
Optimisation Analysis Settings Data

Objectives | Constraints | Design variables

Variable	Min Value	Max Value	Step	Options List	Target objects
External wall construction	0.00	0.00	0.00	11 options	Building
Infiltration	0.00	1.00	0.20	-	Building
Flat roof construction	0.00	0.00	0.00	8 options	Building
Internal floor construction	0.00	0.00	0.00	4 options	Building
Window to wall %	40.00	70.00	20.00	-	Building
Glazing type	0.00	0.00	0.00	3 options	Building

Fig. 11: Parameter settings for construction optimization

Figure 12 shows the 1500 iterations with the 15 most optimized solutions for construction assembly that meet those objectives (minimize construction and operations cost) under the constraints (max. 200 uncomfortable hours and Daylight Factor >= 2%) defined by the designer. The red dots collectively form the Pareto Front, and the table below shows their combinations.



Iterati...	Gen...	Par...	External wall construction	Infiltrati...	Glazing type	Window to wall %	CO2	Cost
8	0		SS SIPS wall	0.516	SS, Triple, Air, LoE	82.131	58056.126	848608.836
7	0		SS SIPS wall	0.725	!Competition, Dbl, Argon, LoE	41.320	60919.560	697400.376
6	0		Uninsulated Wall, Medium weight	0.877	SS, Triple, Air, Selective Clear	63.851	57979.136	785056.507
5	0		SS SIPS wall	0.621	SS, Triple, Argon, LoE	51.535	59273.637	755359.658
4	0		Uninsulated Wall, Medium weight	0.267	SS, Triple, Air, Selective Clear	51.193	60886.386	747090.486
3	0		Best practice Wall, Medium weight	0.508	SS, Triple, Air, LoE	86.041	58346.611	866723.788
2	0		Uninsulated Wall, Medium weight	0.690	SS, Triple, Air, LoE	82.082	57671.349	849842.029
1	0		Uninsulated Wall, Medium weight	0.180	SS, Triple, Air, LoE	54.027	62972.026	759658.706
0	0		Best practice Wall, Medium weight	0.552	!Competition, Dbl, Air, LoE	81.398	58408.824	805885.382

Fig. 12: Construction optimization results

Due to current software limitations, optimizing more than one construction variable was giving an error. Considering an optimization of only the fourth floor and that the external wall being the dominant factor, the optimization was taken forward with external wall as construction parameter. Out of 15 most optimized solutions, the designer can pick and choose the option that best fits their overall design goals as discussed earlier. In this case, the designer gave more importance to reducing operations cost and chose the option that minimizes it keeping the WWR in range of 60 – 70%. SIPS wall with infiltration value of 0.5 along with double air tinted glazing and WWR as 65% was considered as the optimized solution to move forward with to next step.

Once parameters dealing with external loads were decided upon, the focus then shifted to internal loads, HVAC system, and controls. This first stage of this category included optimization of following: HVAC system, lighting type and related controls including external window openings, and heating and cooling set points. Several different types of HVAC systems were tested including VAV (Variable Air Volume) with terminal reheat, fan-coil units, VRF (Variable Refrigerant Flow) heating/cooling with DOAS (Dedicated Outside Air Systems) with heat recovery, passive chilled beams with displacement ventilation, ground source heat pump with floor heating, natural ventilation and air source heat pump with floor heating, and LTHW (Low Temperature Hot Water) radiators with natural ventilation. In addition many lighting systems were tested that involved different combinations of LEDs and fluorescent lamps (Fig. 13). This was an important step as HVAC and lighting typically forms majority of end use energy consumption.

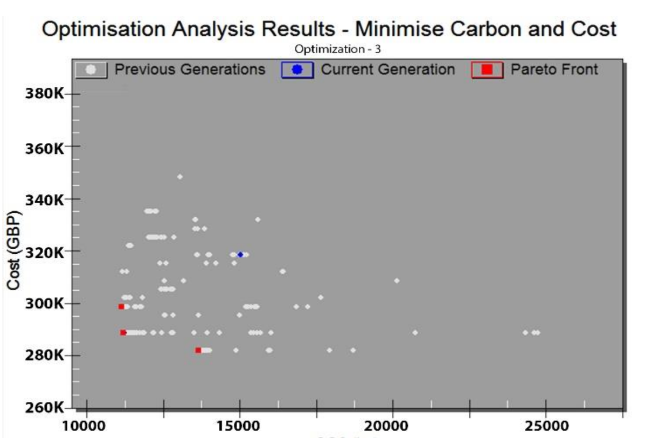
Optimisation Analysis Settings Data

Objectives | Constraints | Design variables

Variable	Min Value	Max Value	Step	Options List	Target objects
HVAC template	0.00	0.00	0.00	10 options	Building
Lighting template	0.00	0.00	0.00	15 options	Building
% External window opens	0.00	60.00	20.00	-	Building
Heating set-point temperature	18.00	24.00	2.00	-	Building
Cooling set-point temperature	22.00	28.00	2.00	-	Building

Fig. 13: Parameter settings for HVAC & light optimization

The constraints of thermal comfort criteria was important while choosing optimized HVAC system and setpoints. The constraint made sure that number of discomfort hours were below 200. In other words, unmet load hours as defined by ASHRAE were within the limit defined by designer. Figure 14 shows output results of this step. The designer chose LTHW radiators with natural ventilaiton as preferred HVAC strategy in addition to T5 fluorescent lamps with linear controls, heating setpoint as 68 F and cooling set point as 76 F. These were chosen keeping in mind the least operational cost.



Iteration	Gen...	Pareto	HVAC template	Lighting template	% External window...	Heating set-poin...	Cooling set-po...	CO2	Cost
8	0		SS_Fan-coil unit	LED (linear daylight control)	39.062	20.868	24.258	55977....	768117.364
7	0		Passive chilled beams, displacement v...	CFL no control	24.809	18.780	27.355	39770....	782710.643
6	0		SS_Fan-coil unit	T5 fluorescent (linear daylight control	18.006	20.616	22.921	57477....	746227.445
5	0		Ground source heat pump (heating onl...	LED no control	17.889	21.807	23.525	64507....	738930.806
4	0		SS_VAV with terminal reheat	LED (linear daylight control)	5.806	19.402	24.293	71420....	775414.003
3	0		LTHW radiator heating, nat vent	T5 fluorescent no control	5.806	18.246	27.777	32837....	680557.690
2	0		Air source heat pump (heating only), flo...	T5 fluorescent (linear daylight control	45.572	23.302	27.455	11137....	724337.527
1	0		LTHW radiator heating, nat vent	CFL no control	36.012	20.933	24.804	37645....	702447.608
0	0		SS_VAV with terminal reheat	LED no control	21.466	21.302	26.047	48917....	811897.201

Fig. 14: HVAC and lighting optimization results

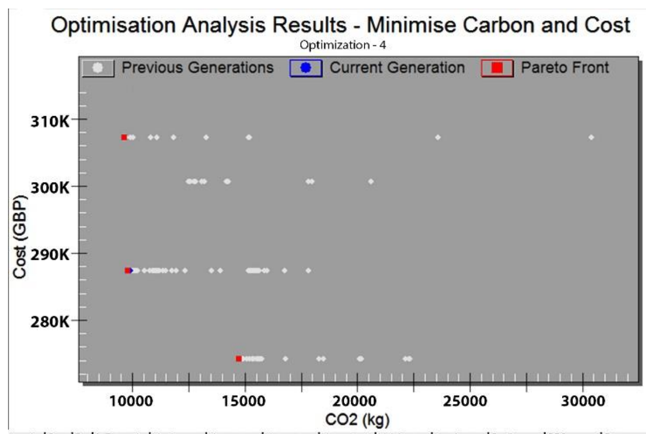
The final stage of the optimizing of the building was the fine-tuning of the control systems, which included the percentage of external window opening, natural ventilation set point temperature and max temperature difference, mechanical ventilation set point, cooling and heating set points (Fig.15). The final output results are shown in figure 16.

Optimisation Analysis Settings Data

Objectives | Constraints | Design variables

Variable	Min Value	Max Value	Step	Options List	Target objects
% External window opens	0.00	100.00	20.00	-	Building
Mech vent set-point temp	20.00	28.00	2.00	-	Building
Nat vent max temp. difference	-50.00	2.00	2.00	-	Building
Nat vent set-point temp.	10.00	30.00	5.00	-	Building
Natural ventilation rate	0.00	12.00	2.00	-	Building
Lighting template	0.00	0.00	0.00	4 options	Building
Heating set-point temperature	16.00	24.00	2.00	-	Building
Cooling set-point temperature	22.00	28.00	2.00	-	Building

Fig. 15: Parameter settings for control optimization



Iteration	Ge...	P...	% External...	Mech ven...	Nat vent ...	Nat vent s...	Natural ve...	Lighting te...	Heating s...	Cooling se...	CO2	Cost
151	15		66.764	23.386	-16.807	27.713	9.959	!Competiti...	16.594	27.232	31715.193	702447.608
150	15		58.260	23.386	-22.602	27.243	7.296	!Competiti...	16.368	22.012	32222.259	680557.690
149	15		66.373	23.386	-12.385	27.302	7.296	!Competiti...	16.469	27.232	32247.728	680557.690
148	15		66.764	23.112	-25.398	27.243	7.296	!Competiti...	16.594	27.232	31716.461	702447.608
147	15		66.764	23.386	-16.807	27.713	10.076	!Competiti...	16.587	27.232	54011.341	665964.411
146	15		66.471	23.386	-12.385	27.302	7.707	!Competiti...	16.469	26.522	32247.334	680557.690
145	14		66.764	23.112	-22.602	27.243	10.076	!Competiti...	16.587	26.522	54017.666	665964.411
144	14		66.764	23.112	-25.398	27.243	7.296	!Competiti...	16.594	27.232	31716.461	702447.608
143	14		66.471	23.488	-16.096	27.302	7.695	!Compet...	16.594	27.238	32276.5...	680557....

Fig. 16: Control optimization results

Controls is an important criteria in making sure that building works as conceptualized. The combination chosen for final tuning in terms of controls included linear lighting controls, heating set point as 68 F, cooling set point as 78 F, natural ventilation set point being 70 F, 40% of external window opening during summer conditions with modulating window opening areas reducing it to 5% when temperature difference between inside and outside temperature reaches 10 F.

All identified optimized strategies dealing with facades, construction, HVAC, lighting and controls on fourth floor were then replicated on all floors of the building, and an annual simulation was run. Table 1 shows summary of all parameters that were optimized.

TABLE 1: OPTIMIZED RESULTS

Type/Stage	Before Optimization	After Optimization
Façade	60% WWR No shading	65% WWR 1.5' louver
Construction	Stnd R-19 Timber Frame Wall	SIPS wall Double air tinted glazing Infiltration: 0.5
HVAC	VAV with Reheat	LTHW radiators with natural ventilaiton
Lighting	Suspended Fluorescent	T5 fluorescent lamps with linear controls
Controls	None	Heating SP 68F Cooling SP 78F Linear Lighting Controls External Window Opening: 40% Modulating Window Area: Till 5% of original opening

The orignal Energy Use Intensity (EUI) for the baseline model was 67 kbtu/sft-yr. The cost of construction was 32,30,000 GBP (British Pounds). The optimized building's EUI was reduced to 23.89 kbtu/sft-yr (63% reduction), and the construction cost was reduced by 3,87,600 GBP (12% reduction).

CONCLUSION

The design was optimized for minimizing construction and operations cost by fine tuning number of parameters such as glazing, shading, wall to window ratio, construction assembly, HVAC type and controls, natural ventilation set points, lighting controls and day-lighting criteria. This was done by optimizing one floor first and then replicating the optimized strategies to whole building.

In summary, the EUI was reduced to 23.89 kbtu/sft-yr (63% reduction), and the construction cost was reduced by 3,87,600 GBP (12% reduction). What is critical for designers is not only the amount of energy that was saved in this case study, but the integration of optimization process in the design process. The optimization process gives enough flexibility to the designer to choose what he considers as the optimal solution based on project constraints out of designs landing on the Pareto Front.

These optimization tools are constantly developing, improving their optimization capabilities, and becoming more user friendly for designers. However there were important limitations: optimization couldn't be done at specific parts of the building, and the constraints option is not properly integrated to optimization process leading to software crash or inefficiencies currently in DesignBuilder.

The design process is based on a series of digital and analogue tools that help architects simulate, manage, synthesize, and balance the huge amounts of information that they need to work with. Newer tools with optimization capabilities can help designers make informed choices. But it isn't just the architects. Consultants, engineers, contractors, facilities managers and others have to do the same thing, but with different concerns and software tools available. And the building after completion may be able to fine-tune itself.

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