Optimised Parametric Model of a Modular Multifunctional Climate Adaptive Façade for Shopping Centres Retrofitting

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Abstract

A modular multifunctional façade for the retrofit of shopping malls, capable of adapting to different climates and to the existing building features both by the presence of movable components and by proper sizing of the fixed ones, is under development within the European FP7 project CommONEnergy. In particular, this curtain-wall façade is equipped with a fixed shading system, a photovoltaic panel with a battery feeding the automated openings for natural ventilation. The aim of this work is to define a reliable parametric model for a multi-functional façade system, to support designers with a set of useful data for the holistic design of the façade configuration depending on climate, orientation and building use. Firstly, a reference zone model for the façade was devised; this had to be both representative of reality and smartly defined for simulation software implementation. Besides the definition of the façade model parameters, all unknown design parameters were identified with their minimum and maximum values, depending on different possible applications and environmental conditions in which the façade could be applied. The inputs for the model were defined in a parametric matrix and included: facade module size, façade orientation, climate, window typology (thermal transmittance and g-value), distance between the shading lamellas, tilt angle, and openable window size. The simulation engine was decoupled: visual comfort and artificial lighting use were assessed with Radiance, while the façade thermal behaviour was evaluated by means of building energy simulations in TRNSYS, taking into consideration the daylight assessment results. For each simulated configuration, a set of relevant outputs fields for Indoor Air Quality, thermal and visual comfort, and energy performance were derived. The main considered performance indicators were the long-term percentage of people dissatisfied, the number of hours when CO_2 concentration was within the recommended values for each of the categories defined by EN 15251:2007, the illuminance provided by daylight, the energy consumption due to lighting, ventilation, heating and cooling, and the energy generated by the PV panel. Moreover, all outputs were collected in a pre-design support tool comprised of a database accessible through a filtering system to gather the desired performances. This work highlights the role of thermal and daylighting simulation in the design of an adaptive multifunctional façade through the definition of a methodology for the support at the pre-design phase.

Keywords

Façade, Multifunctional, Parameterization, CommONEnergy, TRNSYS

DOI 10.7480/jfde.2017.1.1421

1 INTRODUCTION

"Shopping malls are sometimes perceived as 'icons of a consumerist society', because of their high energy demand, high CO_2 emissions and waste, despite the increasing, mostly individual, 'green' initiatives in the field. The Com- mONEnergy project seeks to transform shopping malls into lighthouses of energy efficient architecture and systems." (Commonenergyproject.eu, 2016). Wholesale and retail buildings represent 28% of the EU non-residential building stock and present the highest specific energy demand (BPIE, 2011). Therefore, existing shopping centres offer a great retrofit opportunity for the reduction of their energy consumption. The EU FP7 project CommONEnergy (Commonenergyproject.eu, 2016) aims to re-conceptualize shopping malls through deep retrofitting, developing a systemic approach comprised of technologies and solution sets, as well as methods and tools, to realise their implementation. Modern shopping centres tend to include glazed envelopes in their design ensuring good day-lighting and offering a more seamless connection between the indoor shopping space and the outdoor environment. However, glazed envelope features need to be carefully evaluated in order to limit the energy consumption for air conditioning. Within the CommONEnergy project, among other retrofitting solutions for shopping centres, research and industry partners (Acciona, Bartenbach, EURAC, Sunplugged) are developing a modular multifunctional climate adaptive façade system. The newly developed modular climate adaptive façade concept outlined by (Attia, Favoino, Loonen, Petrovski, & Monge-Barrio, 2015), is based on an optimally designed natural ventilation and daylight control, lightweight substructure, enriched by rapid assembly possibilities. Thanks to its flexibility and modularity, this façade system is suited for retrofit applications offering the opportunity to adjust the façade design according to climate and building features. The high number of design possibilities raises the need for a tool that enables designers to make informed decisions about façade configuration, glazing materials and shading geometry depending on the building design constraints, such as climate, façade orientation, facade module size and indoor space usage. The aim of this work is to define a parametric simulation model to evaluate the performance of a variety of configurations of the modular multifunctional climate adaptive façade from both an energy and indoor environment quality perspective. Moreover, a preliminary design tool, based on a user-defined filtering process, has been developed in order to inform designers towards the optimal façade configurations depending on the design requirements and targets.

The first section of the paper describes the façade concept. Then, the methodology applied for the parametric model set up is reported: the input settings, the parametric matrix and the key performance indicators. Finally, an example application of the design tool is presented.

1.1 THE MODULAR MULTIFUNCTIONAL CLIMATE ADAPTIVE FACADE

The modular multifunctional climate adaptive façade system is a general replicable concept, adjustable for different applications and designed to be used in modular construction methods aiming for a high level of prefabrication (Treberspurg & Djalili, 2010). The facade modularity and its light weight substructure allows its application as envelope retrofit solution for most existing retail buildings, while its multifunctionality gives the opportunity to adjust the system to the particular local climate conditions and indoor space usage.

The façade system was developed to respond to the following functions, listed in order of design priority:

- to protect against overheating through solar gain control by combining a glazing system with a shading element;
- to provide fresh air and to cool indoor space by natural ventilation by means of automated façade openings;
- to supply energy for window automation with integrated PV modules;
- to maintain transparency between indoor and outdoor while providing daylighting and attract customers.

The façade system consists of a modular frame made of mullions and transom with flexibility in their position, enabling easy integration of possible technologies such as: shading systems, automated openable windows and photovoltaic panels. In principle, the anchorage system allows double screen installation, and may be easily adapted to multiple designs, creating different geometric, aesthetic and energy solutions.

In the model discussed in this work, the concept of multi-functionality is ensured by the presence of automated openings located in the lower and upper part of the façade, enhancing single-sided stack ventilation (see Figure 1). Glazed façades are commonly used in retrofitting for aesthetics and communicative reasons but a problem due to energy performances arises, due to the transparent nature of the glass that critically characterizes the thermal performances of the enclosure. So, the proposed façade has been carefully designed for the appropriate selection of glass characteristics, considering climates and façade orientation needs, taking into account also shading system effects of a fixed lamellas system. A thin-film PV panel was integrated into the façade to generate the electricity needed for automatic window actuation. The thin-film photovoltaic panel included in the module was the same length as the façade and is 0.3 meters high. The energy provided by the PV supplies the power needed for automated windows; moreover, in order to store power when not directly needed by the actuators, a battery is integrated in the façade module, behind the PV panel.

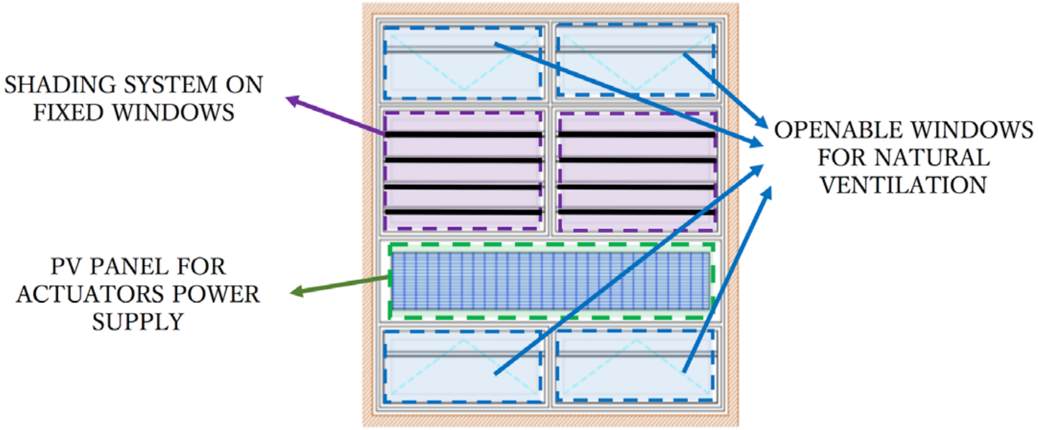


FIG. 1 Main components in the façade designed by Acciona.

2 METHODOLOGY

The model parameterization consists of running the selected model “n” times, changing the “m” values of “p” parameters, with n=m*p. This process allowed a set of outputs for each simulation to be gathered so that the façade performances for each desired configuration could be determined.

The parametric simulation model was based on a single-zone model, intended to be representative of typical shopping mall environments. The reference zone was 15-meters deep with adiabatic boundary conditions on all the walls, except for the one that incorporated the multifunctional façade. The depth of the reference room was selected to consider the effects of ventilation rates on a representative volume of typical malls environments. The multifunctional façade module covers the entire external wall of the reference zone model. As far as the façade module is concerned, it was drawn considering a distinction between the fixed mullion and transom and the assigned frame’s percentage of windows installed in the module. As proof of concept, three volumes of zone were considered in the study: 60 m^3, 90 m^3 and 270 m^3 for the façade module dimensions of 2[m]x2[m], 2[m]x3[m] and 3[m]x6[m], respectively. The fixed glazed part of the window was provided with a fixed lamella shading system. Thermal transmittance of façade elements, such as mullions and window frames, were set in accordance to data provided by the façade designer (U-value ‘frame & mullion’=3.59 W/m2K). The first part of the process that led to the model definition was setting the reference zone parameters and the application of the following building physics reference points:

- set point temperature values for the heating and cooling system are the ones recommended by the EN 15251-2007;
- the natural ventilation rate has been assessed using the single-sided, two vents, buoyancy driven model (CIBSE,2005)
- the infiltration rates depend on indoor-outdoor temperature difference and wind speed according to Coblenz & Achenbach, (1963);
- internal gains due to people, appliances and artificial lighting system have been provided by an Italian shopping malls design company.
- Secondly, the input data were defined in order to include all the possible simulation choices for the desired conditions in each considered configuration and were divided into three categories:
- climatic conditions and façade orientation;
- application, depending on the indoor space usage;
- façade module size and the characteristics of the glazing system and shadings configuration.

Finally, the simulation results were post-processed in order to represent Indoor Air Quality, thermal and visual comfort and energy performance of the reference zone. The main considered performance indicators were the long- term percentage of people dissatisfied (LPD) (Carlucci, 2013), the number of hours in each IAQ category, the energy consumption due to lighting, ventilation, heating and cooling demand and, the energy generation from the PV panel.
The developed tool produced simulation results in different plots guiding users towards the optimal selection of facade configuration.

2.1 BUILDING ENERGY SIMULATION MODEL

The first step of the work concerned the implementation of the façade model in the TRNSYS simulation environment. TRNSYS was chosen for its flexibility as energy simulation software through its compatibility with other software used during this study. Within the type 56 model, different possible algorithms were available for the modelling of the heat transfer and solar radiation exchange between the façade and the indoor and outdoor environment.

The model geometry was drawn with SketchUp using a Trnsys3D plug-in and then imported into the TRNSYS simulation environment (Klein et al, 2010); in particular, the thermal behaviour of the reference zone was modelled by Type 56.

Given the high number of simulations for the parametric analysis, a trade-off between computation time and model accuracy had to be considered. Thus, two geometry modelling approaches (standard and detailed model geometry) and two radiation calculation modes (detailed (Gebhart, 1971) or 'standard' (Seem, 1987) were analysed and compared in order to quantify the influence of the different model approaches on simulation results, in particular concerning windows and frame geometry inputs. The deviation in output trends showed the need to use a detailed model geometry that considered the geometrical distinction between the frame of the windows and the mullions and transoms of the module. Furthermore, the standard radiation model led to a reduction in the computational time of the simulation (71.93 seconds down to 29 seconds) compared to the detailed radiation model, without affecting the results in any critical way (Pinotti, 2016). Therefore, the standard radiation model (Seem, 1987) of TRNSYS was used through the simulation process.

The PV power production was evaluated using the TRNSYS Type 94 model (Klein et al, 2010). This component allowed the electrical performance of a photovoltaic array to be modelled in a detailed way, knowing all the parameters of the PV module. It was chosen in the simulation because of its easy implementation in the whole model and thanks to the possible interaction with other components, such as batteries or regulators.

2.2 INPUTS DEFINITION

Table 1 reports the facade configurations used in the parametric analysis. Façade module size and configuration resulted in different proportions between openable windows and fixed ones, with a consequent change in the percentage of frame in each window. Different module sizes, assumed to be representative of a real possible application case for a shopping centre façade module, were investigated because the different percentage of frame area over the whole façade module influenced significantly the thermal performance of the envelope. The dimension of the openings and louver was calculated in order to ensure three levels of pre-defined air change rates (4, 6 and 8 ACH) when the outside temperature is 25°C and there is 1 K difference between indoor and outdoor temperature (CIBSE, 2005).

FAÇADE WIDTH	FAÇADE HEIGHT	ZONE DEPTH	FRAME % OPEN-ABLE WINDOW	FRAME % FIXED WINDOW	OPEN-ABLE WINDOW WIDTH	OPEN-ABLE WINDOW HEIGHT	OPEN-ABLE WINDOW AREA	FIXED WINDOW AREA	PV AREA
[M]	[M]	[M]	[-]	[-]	[M]	[M]	[M2]	[M2]	[M2]
3	6	15	22%	9%	1.5	0.60	0.90	6.40	0.9
3	6	15	17%	9%	1.5	0.90	1.35	5.97	0.9
3	6	15	14%	9%	1.5	1.20	1.80	5.54	0.9
2	3	15	31%	15%	1	0.42	0.42	1.74	0.6
2	3	15	24%	16%	1	0.63	0.63	1.54	0.6
2	3	15	21%	17%	1	0.85	0.85	1.33	0.6
2	2	15	36%	21%	1	0.35	0.35	0.85	0.6
2	2	15	27%	23%	1	0.52	0.52	0.69	0.6
2	2	15	23%	27%	1	0.69	0.69	0.53	0.6

TABLE 1 Possible configuration of the facade module

Three different typologies of building use have been considered in the parameterization: 'Shops' (SHP), 'Common Area' (CMA) and 'Restaurant' (RST); different building use implies different lighting, appliances and occupancy density and profiles, and, therefore different internal gains. It must be noted that, in the case of 'Shop', no shading system were applied on the façade because each façade module was supposed to be a shop window. All orientations (North, South, East and West) for each configuration of the reference zone were simulated but for north-oriented façades no shading system was applied on the façade.

A review of minimum requirements for national regulations and standards set by energy efficient building certification schemes (see references in Table 2) as well as on available products on the market was carried out to define the most likely ranges of U-values and g-values for glazed components in several European countries. The result of this part of study gave realistic thermal transmittance and their respective solar gain values, representing the state of the art in the field of windows and glazing technologies that complied with the current regulatory framework. Upper limits for U-values referred to the minimum requirements for national regulations. The lower limit referred to the minimum U-value recommended by the standards set by energy efficient buildings certification schemes. Feasible ranges of g-values were assigned to each U-value, taking into account the state of the art of the glazing industry (agc-glass.eu, 2016). Window glazing system models were developed using the WINDOW 7.4 database (Lawrence Berkeley National Laboratory, 2011). Table 2 reports the glazing U-value and g-value ranges for several locations.

Country	Reference city	Heating Degree Days (HDD)	Uw-value [W/m² K] (max)	g-value (max)	g-value (min)	Uw-value [W/m² K] (min)	g-value (max)	g-value (min)
Norway	Trondheim	5211	1.20[1]	0.67	0.20	0.80[2]	0.63	0.25
UK	London	2800	1.80[4]	0.52	0.29	0.85[3]	0.63	0.25
Austria	Wien	2844	1.90[5]	0.73	0.25	0.85[3]	0.63	0.25
Italy	Modena	2529	2.20[7]	0.52	0.29	1.30[8]	0.67	0.22
Italy	Palermo	585	3.00[7]	0.77	0.40	1.30[8]	0.67	0.22
Spain	Seville	1460	4.20[6]	0.61	0.37	1.25[3]	0.67	0.20

1 (Kommunal- og moderniseringsdepartementet, 2010)
2 (Norsk Standard, 2012)
3 (Passivhaus Institut, 2016)
4 (British Department for Comunities and Local Government, 2013)
5 (Austrian Institute for Building Technology, 2007)
6 (Ministerio de Fomento, 2013)
7 (Dipartimento di Energia del Ministero per lo Sviluppo dell'Economia, 2013)
8 (CasaClima, 2014)

TABLE 2 Glazing U-values and g-values ranges.

In order to prevent direct sunlight from entering the zone, a fixed shading system was evaluated for all the large central windows in the façade modules, except for the 'shop' application and for north-oriented cases. Among the parameterization variables the tilt angle and spacing of the lamella were also considered. In order to evaluate the effect due to the shading system, a dedicated model, and the related parameterization (in Figure 2 all the combinations of in- puts for the shading system parameterization are presented), were undertaken using Ladybug+Honybee (Sadeghipour Roudsari & Pak, 2013) plug-in for Grasshopper (McNeel, Rutten, & Associates, 2007). Ladybug+Honybee allows for the use of well validated Radiance software (Ward, 1989), within a parametric environment such as Grasshopper, to predict the reduction of solar radiation entering the zone and the daylight availability within the zone.

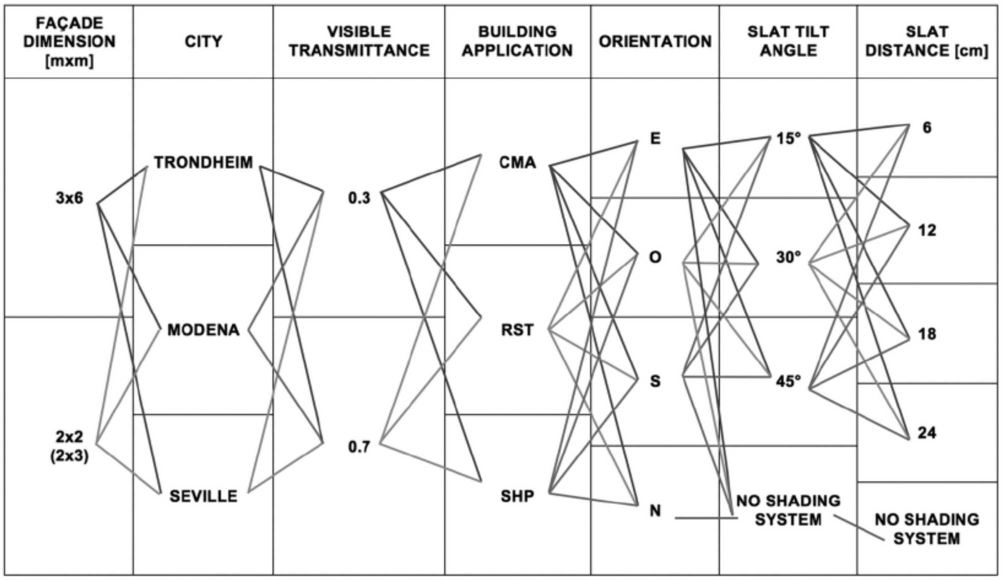
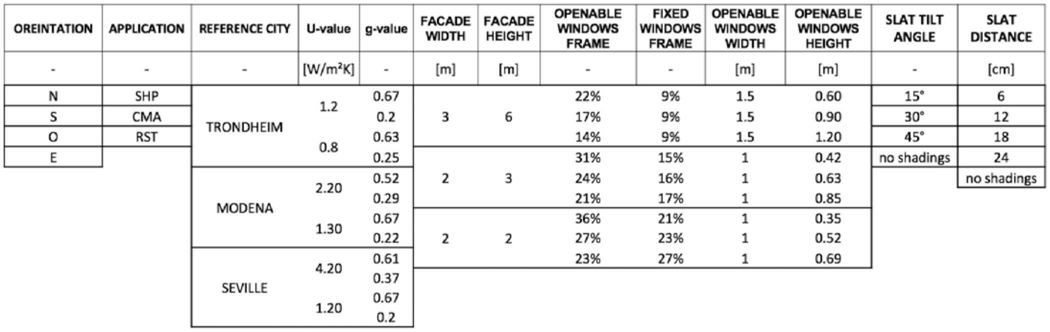


FIG. 2 All combinations for the shading system parameterization – lines link the available inputs for the configurations (Trondheim, Modena and Sevilla cases)

Essentially, the hourly shading effect induced by the fixed lamella has been translated in the TRNSYS model as reduction of direct and diffuse solar radiation entering the zone. Moreover, the hourly level of internal illuminance predicted by the daylighting simulation has been used within TRNSYS to control artificial lighting dimming.

The parametric analysis was run through the JE+ software (Zhang & Korolija, 2010) in full-factorial mode. JE+ soft- ware allowed parameterization simulations on the TRNSYS input file. Therefore, for each available combination of inputs, one simulation had to be run. The parametric analysis led 8424 façade configurations, or simulation runs (Figure 3), 2808 for each climate.



OREINTATION	APPLICATION	REFERENCE CITY	U-value	g-value	FACADE WIDTH	FACADE HEIGHT	OPENABLE WINDOWS FRAME	FIXED WINDOWS FRAME	OPENABLE WINDOWS WIDTH	OPENABLE WINDOWS HEIGHT	SLAT TILT ANGLE	SLAT DISTANCE
-	-	-	[W/m²K]	-	[m]	[m]	-	-	[m]	[m]	-	[cm]
N	SHP	TRONDHEIM	1.2	0.67	3	6	22%	9%	1.5	0.60	15°	6
S	CMA			0.2			17%	9%	1.5	0.90	30°	12
O	RST		0.8	0.63			14%	9%	1.5	1.20	45°	18
E				0.25	2	3	31%	15%	1	0.42	no shadings	24
		MODENA	2.20	0.52			24%	16%	1	0.63		no shadings
				0.29			21%	17%	1	0.85		
			1.30	0.67	2	2	36%	21%	1	0.35		
				0.22			27%	23%	1	0.52		
		SEVILLE	4.20	0.61			23%	27%	1	0.69		
				0.37								
			1.20	0.67								
				0.2								

FIG. 3 Summary of parametric analysis variables (Trondheim, Modena and Seville climate)

2.3 OUTPUTS DEFINITION

Table 3 reports the key performance indicators from the simulation results post-processing. These outputs were chosen arbitrarily in order to allow considerations both for the indoor environment quality (indoor air quality, thermal comfort, daylighting) and on the energy consumption of the reference room.

All the outputs and their trends were analysed using Matlab-based filtering methods. Starting from the huge amount of available combinations of inputs, each leading to different outcomes, a series of significant graphical layouts were predefined within Matlab, in order to have a general view of all the simulated configurations and to map their outputs; then, keeping the layout of these general graphs, the need for more specific selection through the available configurations arose, in order to easily display on those graphs only the desired ranges of outputs, while excluding the unwanted cases. So, a series of filters on the input and output parameters were implemented and users could select their own preferences excluding undesired ranges for specific variables, thus obtaining the optimal facade configuration for any given boundary conditions. Users could define the optimisation parameter, depending on their design targets. For instance, designers may decide to give priority to the comfort of occupants over energy consumption. By filtering their selection, users can set their order of priorities. This simple design tool to support façade designers, based on filtered graphs, is meant to be the foundation for a more user-friendly and accessible tool, that will be developed in the future. Table 4 summarizes two different filtering selection procedures available in the tool. So, following one of the two filtering procedures, designers can go through all the available configurations for the façade and end up with just a few cases, whose characteristics depend on the filters applied.

The graph for the LPD filtering relates the percentage of hours with an IAQ in categories 1 or 2 (y-axis) with the percentage of LPD (x-axis); moreover, the colour of the indicator gives information on the characteristics of the type of glazing used in each facade configuration (U-value, g-value and visible transmittance).

As far as the LIGHT CONSUMPTION filter is concerned, it was decided to use data on artificial lighting consumption as indirect indicators of the value of available daylighting inside the zone. Obviously, the lower the artificial lighting consumption results, the higher the daylighting is. The second filter was used to ensure good levels of daylight. By applying this filter, the light consumption (y-axis) was related to the configuration of the shading system: distance between lamella (x- axis) and lamella angle degree (colour of the indicator).

OUTPUT	UNIT	DESCRIPTION	REFERENCE
SPECIFIC HEATING DEMAND	kWh/m^2	-	
SPECIFIC COOLING DEMAND	kWh/m^2	-	
LONG-TERM PERCENTAGE OF DISSATISFIED	-	The necessity of using such an indicator instead of the most known PPD is due to the will of having an output for each simulated configuration, summarizing the result of all the considered periods.	(Carlucci, 2013)
LIGHT CONSUMPTION	kWh	Calculation of the lighting consumption has been possible thanks to combined parameterizations regarding the shading system, giving as result the overall luminous flux entering the zone from daylight and considering a designed enlightenment value.	
MECHANICAL VENTILATION CONSUMPTION	kWh	The electric energy required by fans for providing airflows required to keep an acceptable IAQ, considering a specific fan power of $0.75\ Wh/m^3$.	
N° HOURS WITH NATURAL VENTILATION	h	Number of hours over the occupied period when natural ventilation can be activated.	
N° HOURS WITH EFFECTIVE NATURAL VENTILATION	h	Number of hours over the occupied period when natural ventilation can be activated and provides same or higher airflows than mechanical ventilation	
N° HOURS IAQ CATEGORY 1	h	CO2 concentration in the air has been calculated and Indoor Air Quality categories have been assigned to the environment	(EN 15251,2007)
N° HOURS IAQ CATEGORY 2			
N° HOURS IAQ CATEGORY 3			
N° HOURS IAQ CATEGORY 4			
N° HOURS THERMAL CATEGORY 1	h	Thermal categories have been assigned to the room environment after having compared the running outdoor mean temperature with the operative temperature inside the room	(EN 15251,2007)
N° HOURS THERMAL CATEGORY 2			
N° HOURS THERMAL CATEGORY 3			
OVERHEATING HOURS	h	Overheating and overcooling number of hours exceeding thermal categories limits	(EN 15251,2007)
OVERCOOLING HOURS			
OVERHEATING DEGREE	°C	Estimation of the severity of overheating and overcooling	(EN 15251,2007)
OVERCOOLING DEGREE			
PV POWER GENERATED	kWh	PV power generated by the façade PV module	
PV POWER DIRECTLY TO LOAD	kWh	Power generated by the PV being directly used by the actuators of windows	
POWER SUPPLY FROM GRID	kWh	Electric energy supplied from the grid to accomplish window automation demand when battery is not charged and no energy is generated by PV	

TABLE 3 Output from the simulation

Remaining configurations were filtered on the base of total consumption available, choosing cases with the lowest energy demand: heating system, cooling system, mechanical ventilation, light consumptions were considered; moreover, power demand from the grid was taken into account in the total amount of energy consumption. Therefore, in the TOTAL CONSUMPTION filter's graph, the total energy consumption (x-axis) was related to the percentage of hours with an IAQ in categories 1 or 2 (y-axis) and LPD value being identified using the colour scale.

COMFORT PRIORITY	LOW CONSUMPTION PRIORITY
1. LPD filter	1. TOTAL CONSUMPTIO+POWER FROM GRID filter
2. LIGHT CONSUMPTION filter	2. LIGHT CONSUMPTION filter
3. TOTAL CONSUMPTIO+POWER FROM GRID filter	3. LPD filter
4. FINAL DESIGN CHOICE	4. FINAL DESIGN CHOICE

TABLE 4 Different filtering procedures depending on the design priority of the designer

Finally, a few cases remain, all with very similar comfort and consumption characteristics; therefore, the ultimate selection is related to designer's preferences on shading configurations (slat orientation angle and distance), proportions of the façade module and type of the glazing to be used.

3 RESULTS

3.1 DESIGN TOOL METHODOLOGY

Given the parametric model and its output database, a methodology has been set up to support the choices of designers under a performance based approach. A filtering method has been chosen in order to pass from all the database configurations to the target ones. The process is based on preferences of designers; in the tool, these preferences were represented by filters applied to the displayed results. By doing this, the configurations with undesired values for a certain input or output could be excluded from the filtering procedure. By the end of the process, only combinations with similar designed performances remain and the user may visualise the results of their preferences applied on all the possible configurations, facilitating their final choice.

3.2 EXAMPLE APPLICATION OF THE DESIGN TOOL

One applied example of the façade configuration selection process is shown below: it was used to design a 3m x 6m south-oriented façade in a 'restaurant' building application in Seville. The priority in the choice of allowed ranges was given to the occupants' comfort level.

Step 1: LPD filtering

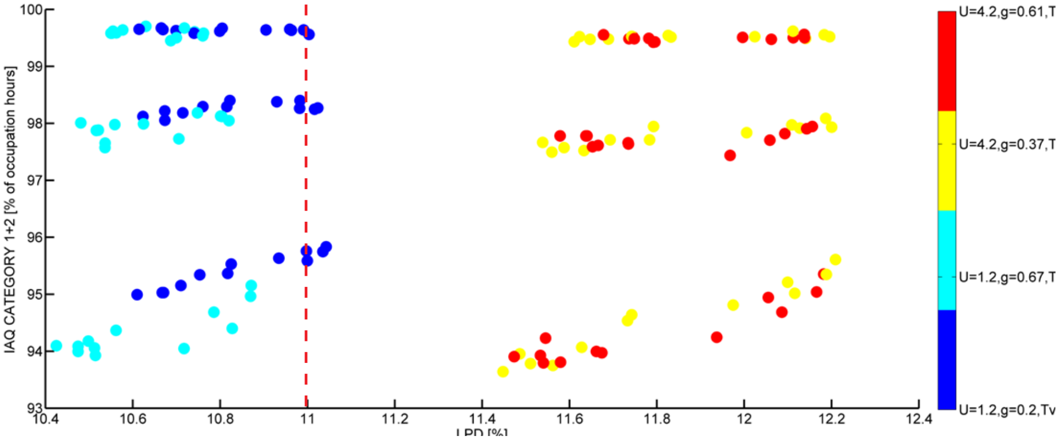


FIG. 4 LPD % - Seville_3x6_RST_S

The first filter selected was the one regarding thermal comfort (LPD). So, after evaluating the available range for the LPD in this specific case while trying to keep lowest values (PPD<10% as recommended by ANSI/ASHRAE Standard 55-2013), filters on LPD were applied. In Figure 4, all the configurations for 'restaurant' 3x6 south-oriented Seville facade were reported and a filter on **LPD<11** was selected.

Step 2: Light consumption filtering

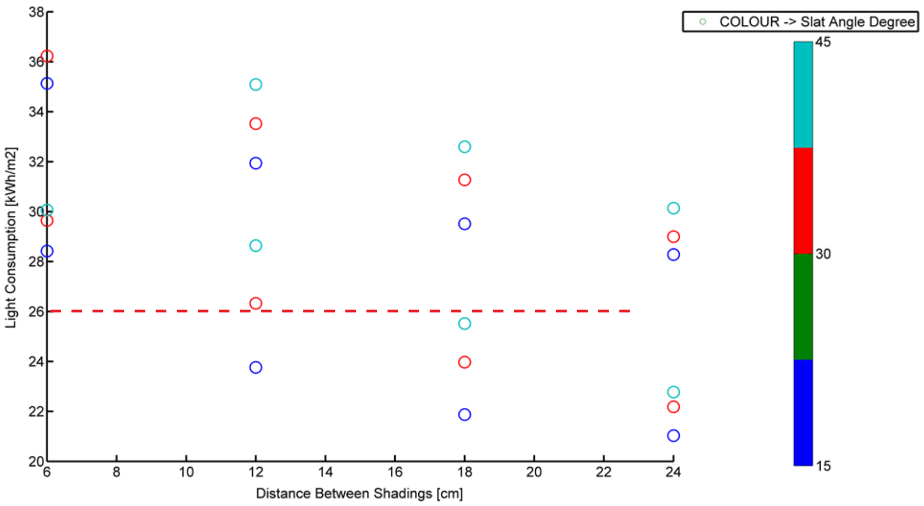


FIG. 5 Light consumption and shading configuration - Seville_3x6_RST_S

Among the façade configurations with higher thermal comfort, a filter on artificial lighting consumption was applied setting a threshold of **26 kWh/m**^{2} (Figure 5); this value left many cases for the final choice, while simultaneously reducing available configurations.

Step 3: Consumption filtering

In this example, on the base of consumption range showed in Figure 6, total energy consumption filter will be set to 147 kWh/m2 as maximum value. The remaining configurations are reported in Figure 7.

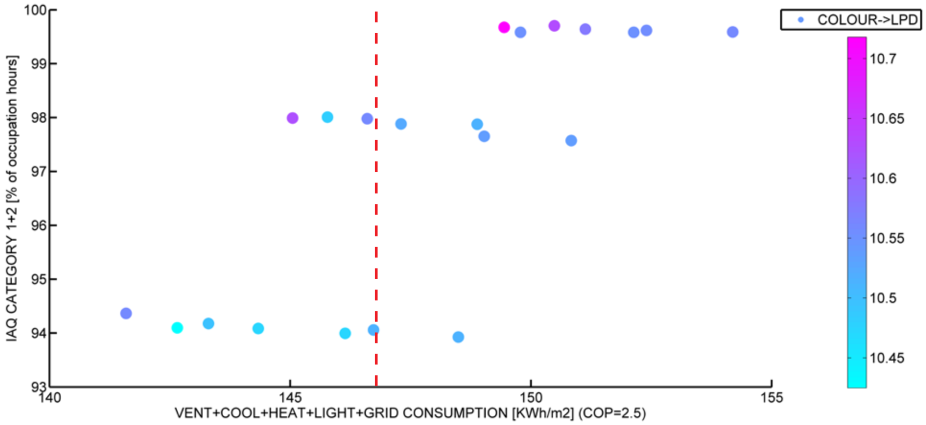


FIG. 6 Total consumption related to IAQ and LPD - Seville_3x6_RST_S

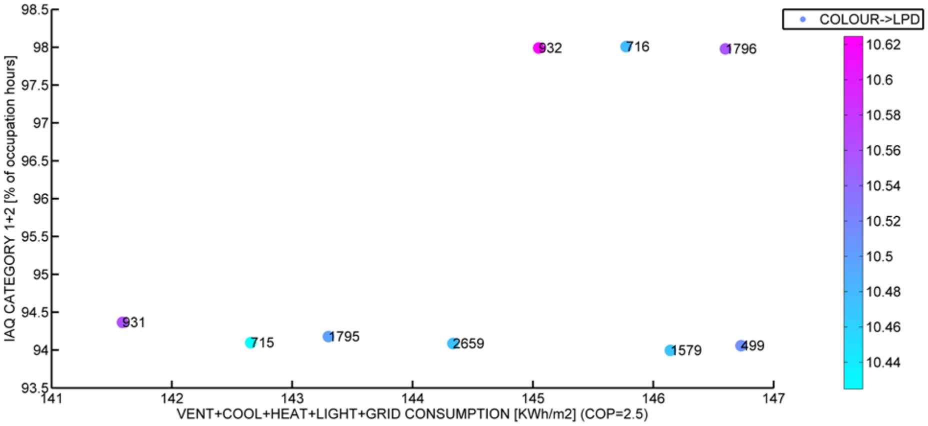


FIG. 7 Remaining cases after filtering on consumptions, ID simulation displayed - Seville_3x6_RST_S

Step 4: Design choice

Table 5 summarizes the filtering process for the applied example described and lists the resulting optimal façade configurations among which the designer could choose.

STARTING CONDITION	SEVILLE 3X6 MODULE "RST" APPLICATION SOUTH-ORIENTED				
DESIGN PRIORITY	**COMFORT**				
FILTER	LPD	< 11%			
FILTER	LIGHT CONSUMPTION	< 26 kWh/m^2			
FILTER	TOTAL CONSUMPTION	< 14 kWh/m^2			
FINAL DESIGN CHOICES	SHADING CONFIGURATION AND FACADE PROPORTIONS	ID SIMULATION	SLAT ANGLE DEGREE	DISTANCE BETWEEN SHADINGS [cm]	AREA OPENABLE WINDOW [m^2]
		499	15°	12	SMALL
		715	15°	18	SMALL
		716	15°	18	MEDIUM
		931	15°	24	SMALL
		932	15°	24	MEDIUM
		1579	30°	18	SMALL
		1795	30°	24	SMALL
		1796	30°	24	MEDIUM
		2659	45°	24	SMALL

TABLE 5 Table 5: Summary of the filters applied in the example described and available configurations

4 CONCLUSIONS

This paper presents a parametric design tool, suited to support the design process of a modular multifunctional façade allowing the façade itself the possibility of being climate-adaptive. The tool is based on a filtering procedure, generating graphs and driving the user to identify the most optimal façade configuration(s). The available configurations of the façade module – i.e. façade orientation, façade proportions and dimensions and glazing characteristics - were firstly modelled in TRNSYS and secondly simulated through a fully-factorial parameterization. Therefore, a smart graphical organization of data has been fundamental in order to manage the high number of results. The choice of the optimally performing configuration for a specific condition depends on the priority of the designer that was assumed to be low-energy consumption or high-thermal comfort oriented. Although the tool is at an early and prototypical stage (the knowledge of the adopted Matlab code is required), it has the potential to support the designer in the process of defining the most appropriate façade module for a particular climate condition; the tool becomes very useful when filtering the huge amount of configurations given by the parameterization, selecting the most relevant cases depending on the designer's preferences. Further improvements should be undertaken to develop the filtering design tool, enriching it with an intuitive interface, making it more user-friendly.

Acknowledgements

The research leading to these results has received funding from the European Community Seventh Framework Programme (FP7/2007-2013) under grant agreement n. 608678.

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