RTKL's performance driven design: Lessons learned from the commercial practice

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ABSTRACT: Performance-Driven Design[SM] (PDD) is a branded initiative that strives to improve the value of the built environment. It applies the greatest available intelligence to create compelling design with measurable benefits. This paper describes the implementation of Performance Driven Design in RTKL's commercial practice of the Los Angeles office. Because the commercial practice is very fast paced, and developer and market driven, there are more obstacles to implementing sustainable design in projects. The practice group has developed different techniques to facilitate the implementation of sustainable design in these different environments and scales.

KEYWORDS: Performance Driven Design, Simulation Tools

INTRODUCTION

To reduce anthropogenic emissions and have any real impact on climate change, it is necessary to improve building performance, reducing GHG emissions, energy and water consumption, and waste production. This paper discusses a general process that includes strategies, workflows and tools used in the commercial practice of RTKL's Los Angeles office to implement Performance Driven Design. Furthermore, the process is flexible and adaptable and can be adjusted to different scales and requirements.

PDD has been implemented in the commercial practice in multiple scales. Most of our projects are quite large, many times including multiple buildings. Ideally the process should flow from the urban scale to the building form, façade design, and then the fabric. However this does not always occur in all projects and sometimes the work is in neighborhoods, buildings, and interiors of buildings. The approach has always been to optimize the performance through the implementation of design strategies in at least several specific areas.

This paper introduces the firm wide initiative and briefly discusses two areas in which the author has participated, outdoor comfort and envelope design. Additional strategies have been implemented by the author and many design teams in other RTKL offices.

1.0 RTKL's PERFORMANCE DRIVEN DESIGN

By drawing on ample evidence about the economic, environmental, and social impacts of design, Performance-Driven Design (PDD) seeks to apply the greatest available intelligence to create uplifting places with measurable benefits to people, place, and planet. RTKL's PDD is a branded initiative that promises not just to improve the quality of the work but also to create a new standard for design excellence. Starting with each project's goals and continuing through its strategies and results, PDD can be adapted to the unique circumstances of any project and support the needs of project teams and clients. The goal is to encourage experimentation and freedom around a shared vision and set of values that unite all of RTKL's work.

Over these past years, RTKL has developed several resources to implement PDD. These provide support in the upfront development of the goals (The Smart Start), strategies to pursue these goals (the Dart) and mechanisms to document these results (the Dash). The Smart Start provides an online collaborative platform for design teams to meet and discuss goals and generate a vision that responds to client requirements. Users can collaborate online in many ways such as research and charrettes. The DART is an interactive tool that guides designers towards PDD and has three steps: first, the variables are identified, then the strategies are selected and finally an approach is proposed. Variables are selected and organized interactively in a website. The beta version of the DASH permits to record real building performance data in one location.

2.0 PERFORMANCE DRIVEN DESIGN PROCESS IN THE COMMERCIAL PRACTICE

Projects in the commercial practice move very quickly, driven by the developer and market forces, making it more challenging to implement sustainable design strategies in projects. To achieve positive results the commercial practice enhances RTKL's Performance Driven Design methods with several strategies, implemented using multiple tools in different scales and phases. These activities are directed to optimizing specific areas of the project, such as massing and form, shading, window to wall ratios, skylight design, outdoor comfort etc. This has allowed the design team and the client to understand impacts of specific quantifiable benefits of implementation of the strategies, opening the door to the implementation of a stronger PDD in all areas: social, economic and environmental.

The activities in the process can be organized as a set of strategies that improve performance. Figure 1 describes the activities and the strategies in this process and how they are linked with the phases in the design process. The vertical columns indicate the phases: Conceptual Design, CnD, Schematic Design SD, Design Development DD, Construction Documents CD, Construction Administration CA, and Operation and Maintenance O&M. The horizontal bands are common PDD topics that designers deal with during the design process: site, envelope, light and energy. Rectangles in the intersection of these two are the strategies and processes that can be implemented in each area. These strategies and processes can take many forms and combine different analogue and digital tools most of them for simulation. It is thus possible to delve deeper into each of these “boxes” or combinations of boxes and develop very detailed workflows that include tools and activities.

Figure 1: Design Process with Strategies

3.0 SIMULATION TOOLS

The architectural design process is an iterative problem solving process in which sequences of sub problems that are not well defined are solved. During this process the documents to generate a building, which must satisfy many different criteria, are produced. Rittel proposed the existence of an alternating generation and reduction cycle, which repeats itself continuously improving design quality in each cycle (Rittel 1970) (Fig 2). This iterative process is key to correctly implementing Performance Driven Design, and for simulation tools to be well integrated in this process. Simulation tools are more commonly used as evaluation tools, but can also be used as generative tools to produce forms based on factors that optimize performance.

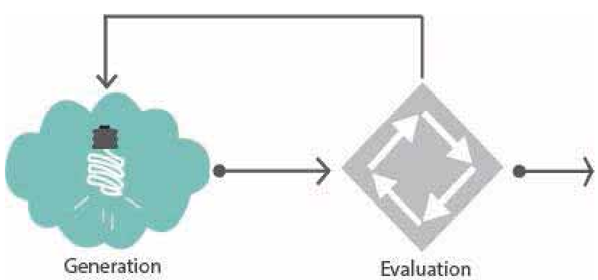

Figure 2: Generation/Evaluation of Ideas in Design Process (Source: Carbon Neutral Architectural Design, La Roche)

of Very Simple Design Tools (VSD Tools) that would be easy and simple to use, so that more designers could use them affecting more buildings (La Roche and Liggett 2003). Simulation tools are also CAD tools in the broad sense because they improve the quality of the final product through digital simulations. They are an important part of our performance driven design process and when used in the evaluation portion of the generation-evaluation cycle they help to quantify the effect of different design decisions, providing valuable feedback to project teams. They should be implemented as early as possible in the process and implementation should continue during all design phases.

Typically when we describe simulations we refer to them as simulations for design performance and simulations for code compliance. Simulations for design performance are done to quantify several parameters, some of which might not be required by code. In addition to energy, simulation modelling includes the measurement of many other variables which also provide useful information and facilitate design decisions. Some of the most common in our practice are insolation analysis on building and ground surfaces, illuminance and luminance levels in interior spaces, airflow in outdoor spaces, and energy consumption. Results of these simulations affect glazing to wall ratios, window design, shading systems, etc. The goal of simulation for design performance is to enhance the design by integrating performance attributes in the design, enhancing it. Modelling for code compliance is typically done for energy consumption, and due to the complicated nature of our projects in our practice is usually done by consultants. It compares the calculated energy use of the designed building with a reference baseline building to demonstrate that it complies with minimum performance criteria.

We like to initiate simulations as soon as possible in the design process. Feedback is less useful when simulations occur late in the process. However, we believe that it is never too late and it is always possible to implement design strategies that will improve project performance. Clear and visual communication of the results is also crucial to provide adequate understanding to the rest of the project team and the client. Finally, simulations must be useful. Analysis for the sake of analysis should not be done, there must be a possibility to respond to the analysis results and some time for after processing. Simulations should only be done if they will inform design decisions or if they are needed to demonstrate compliance.

4.0 OUTDOOR COMFORT

4.1. IOI Palm City, Xiamen

Xiamen is a Chinese port city with a monsoonal humid subtropical climate (Köppen Cfa), characterized by long, hot and humid summers, but moderate compared to much of the rest of the province, and short, mild and dry winters. A detailed climate analysis was performed to determine the effect of the key parameters that affect energy consumption and thermal comfort: Dry Bulb Temperature, Relative Humidity, solar radiation and wind speed and direction, in addition to the activity level and clothing. Figure 3 shows two of these, DBT and RH on a yearly basis.

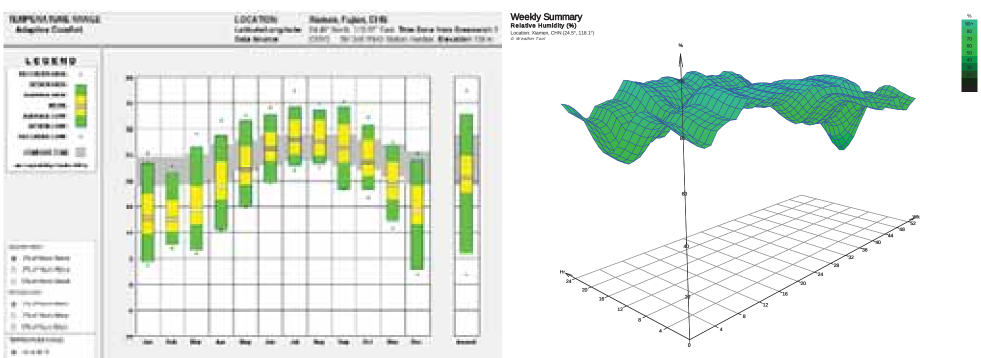

Figure 3: Annual Temperature and Relative Humidity in Xiamen

There are several indicators that can be used to determine thermal comfort. One of them is the Predicted Mean Vote, PMV, which considers human and environmental variables: Activity (met), Clothing (clo), Air temp. (°C), Mean radiant temp, affected by long wave, diffuse and direct solar radiation (°C), Air speed (m/s), and relative humidity (%). The comfort model using PMV works well in buildings with HVAC systems, but occupants in naturally ventilated buildings are tolerant of a significantly wider range of temperatures. This is explained by a combination of both behavioral adjustments and physiological adaptations. These effects are incorporated in a revision to ASHRAE standard 55 in 2000 and is valid only when the monthly mean outdoor temperature is between 10 °C (50 °F) and 33.5 °C (92.3 °F). Thus, standard 55 which was originally solely based on the PMV model now has an optional method for determining acceptable thermal conditions in naturally conditioned spaces. The standard states that occupants' thermal responses in naturally conditioned spaces depend in part on the outdoor climate and may differ from thermal responses in buildings with centralized air conditioning systems. This is due to the differences thermal experiences, changes in clothing, availability of control options and shifts in occupant expectations. The neutrality temperature in this model can be calculated using the following correlation:

Tn = 18.9+ 0.255 ATout

Where:
ATout: Outdoor average effective temperature
Tn: Neutrality Temperature

Even though adaptive comfort has been developed for indoor comfort, it can also be used to a certain extent, for outdoor comfort. Assuming there is shade and air movement, comfort can still be achieved during 61% of the period from June to September between 10 AM and 10 PM, (80% acceptability limits) (Fig 4).

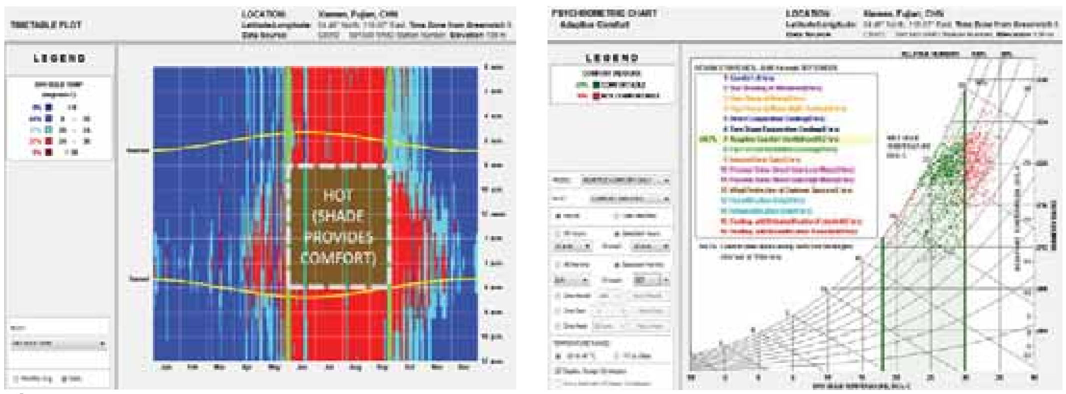

Figure 4: Analysis Period in the Timetable plot and Adaptive Comfort from June-September, 10 AM to 10 PM.

The recommended outdoor comfort strategies in the summer are to provide air movement to promote evaporative cooling in the skin and shade to reduce effects of longer wave radiation. An important outdoor feature in the project is a curved south facing outdoor plaza with dining terraces. These terraces will be shaded with canopies thus reducing solar radiation to the body. To determine the effect of wind a 3d wind tunnel analysis with Vasari, using the smallest possible grid, was performed using predominant wind directions to determine if there was enough air flow at the level of the human body. Multiple slices were analyzed and results indicate that there is not enough air velocity at the terrace levels (Fig 5).


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igure 5: Summer simulation at section terrace. Wind from south, 5 m/sec (18 km/hr)

To increase the airflow in this outdoor area, the exterior wall of the entrance towards the center is converted into a solar chimney by adding a double skin façade towards the front (Fig 6 left). This idea was tested by CTL-E Corp using a CFD program. Site wind speed was set at 2 m/sec and wind from the south. Results indicate that the double skin provides improvement compared to the entrance with no double skin, increasing wind at lower level from about 0.2 m/s to 0.3 m/s. This option will perform even better if the solar chimney is widened to double the size increasing to 0.45 m/s (Fig 6 right) or at least doubled in size at the bottom (image not shown). This means that if air movement is increased and shade is provided through the canopies (not shown), comfort will increase.

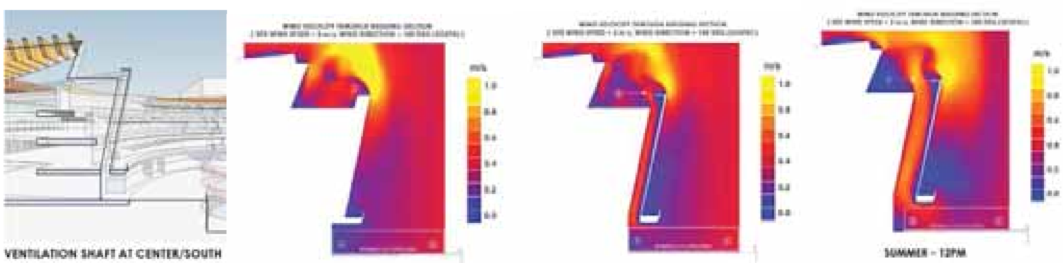

Figure 6: Ventilation shaft at center of south terrace. CFD simulation with no double skin

4.2. Case study Eden City project

This is a mixed use project that includes many themed activities in outdoor settings. PDD was integrated in the master plan phase. The fact that the client wanted to develop an outdoor mall in a location with a cold climate provide a challenge and the priority was to provide maximum outdoor comfort during the different seasons, especially during the cold winter in central China.

Figure 7 is a workflow diagram that illustrates the outdoor comfort analysis process in this project. Overheated and under heated periods are determined with climate analysis, and different tools help to generate guidelines that subsequently inform the project. These design concepts were evaluated with simulation tools and thermal stress calculations to determine problem areas. Finally solutions were proposed to address them. This process of generation and evaluation of solar and wind ideas was repeated as the project was developed during the the master plan phase.

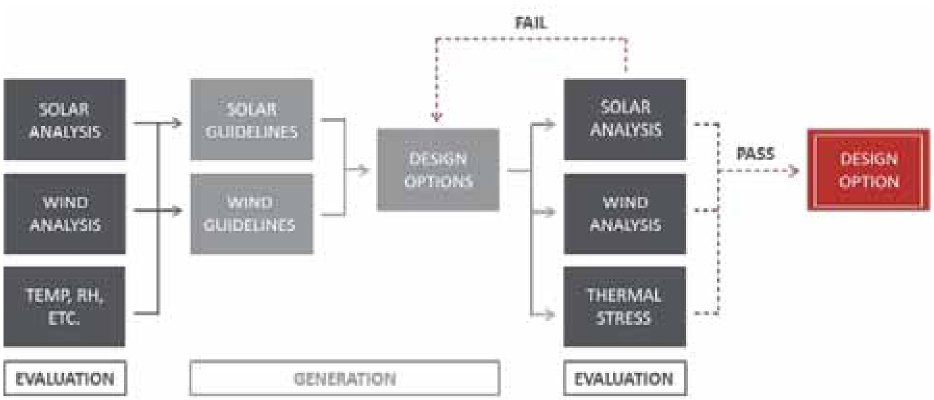

Figure 7: PDD process for outdoor comfort

Solar and wind recommendations effectively guided the design team in this process. To achieve comfort during the cooler period (October to March) solar radiation had to be promoted in outdoor spaces to increase Mean Radiant Temperature while cool winds had to be blocked. Four orientations were studied: north-south, and rotated 15, 30 and 45 degrees (Fig. 8). Glazed atrium spaces are also proposed as part of an outdoor network in which pedestrians can enter at different points to find places of refuge and warmth A distance to height ratio of 1.8 was proposed to ensure sufficient solar radiation in outdoor spaces with lower altitude winter sun (Fig 9).


Figure 8: Outdoor solar analysis: four orientations in Eden City Mall

Figure 9: Solar guidelines from analysis

The Universal Thermal Climate Index, UTCI, developed by the European Union is a thermal stress index for outdoor spaces. According to the developers, after accessible models of human thermoregulation were evaluated, the advanced multi-node ‘Fiala’ thermoregulation model was selected, extensively validated, and extended for purposes of the project. In the next step a state-of-the-art adaptive clothing model was developed and integrated. This model considers (i) the behavioural adaptation of clothing insulation observed for the general urban population in relation to the actual environmental temperature, (ii) the distribution of the clothing over different body parts providing local insulation values for the different model segments, and (iii) the reduction of thermal and evaporative clothing resistances caused by wind and the movement of the wearer, who was assumed walking 4 km/h on the level (Journal of Thermal Biology 2003).

Research has found agreement with this standard and the use of outdoor spaces in China, further strengthening the reasoning to implement this indicator in China (Lai et al 2014). Preferences in solar radiation, wind speed, and relative humidity were related to air temperature. The higher the air temperature was, the higher the wind speed and the lower the solar radiation and relative humidity desired by the occupants, and vice versa. The data were also used to evaluate three indices. The Universal Thermal Climate Index (UTCI) satisfactorily predicted outdoor thermal comfort, while the Predicted Mean Vote (PMV) overestimated it. The neutral Physiological Equivalent Temperature (PET) range found in this study was 11-24 C, which was lower than the ranges in Europe and Taiwan. The neutral physiological equivalent temperature (PET) range found in this study was 11–24 °C, which was lower than the ranges in Europe and Taiwan. That study indicated that residents of Tianjin were more adapted to cold environment.

Thermal stress was calculated in this project using UTCI at 3 PM in January, March and April. Consistently there was less thermal stress with more solar radiation and less air movement during this period, demonstrating that a reduced outdoor thermal stress could be achieved in the winter by increasing solar radiation and reducing air velocity.

Table 1: Thermal Stress at 3 PM during three dates and under different conditions.

Date	*condition* *Sun & no wind*	*Sun & low wind*	*Sun & wind*	*Shade& low wind*	*Shade & wind*
January	12.3 No thermal stress	7.9 Slight cold stress	-4.4 Moderate cold stress	0.3 Slight cold stress	-13.1 strong cold stress
March	18 No Thermal stress	15.3 No thermal stress	6.4 Slight Cold Stress	10 No Thermal Stress	1.4 Moderate Cold Stress
April	21.3 No Thermal Stress	19.3 No Thermal Stress	12 No Thermal Stress	14.3 No Thermal Stress	7.2 Slight Cold Stress

5.0 BUILDING ENVELOPE

Integrated analysis of the envelope includes the analysis of components as a function of solar gains during peak cooling loads, summer and winter, daylight (luminance and illuminance) and energy consumption. This integrated analysis process can be used to study different envelope components, for example window and shading options to select the best overall solution.

A typical workflow for envelope analysis is indicated in Fig 10. The first step is also to calculate the effect of the environmental variables in the determination of overheated and under heated periods. There are several options to determine these periods, degree days, upper and lower comfort ranges or using a simple energy model. Appropriate climate responsive design strategies are also selected using multiple resources such as Climate Consultant and the 2030 Palette. A façade insolation study permits to quickly determine critical orientations (Fig 11) and determine vertical and horizontal shadow angles for them and generate shading options (La Roche, 2011). These options are then tested using different simulation tools for insolation (Fig 11), daylight levels, glare and energy use such as Ecotect, IESve, COMFEN. These can be further refined and then re-evaluated. Alternatively, the designer must go back one or more steps to the design of the shading options or the calculation of the system.

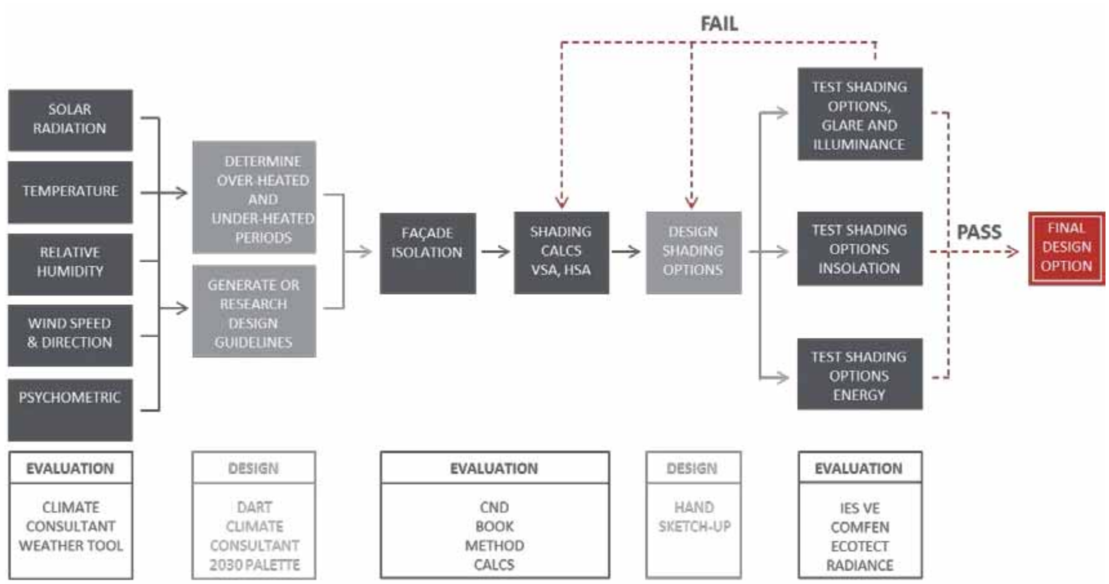

Figure 10: Envelope/shading workflow

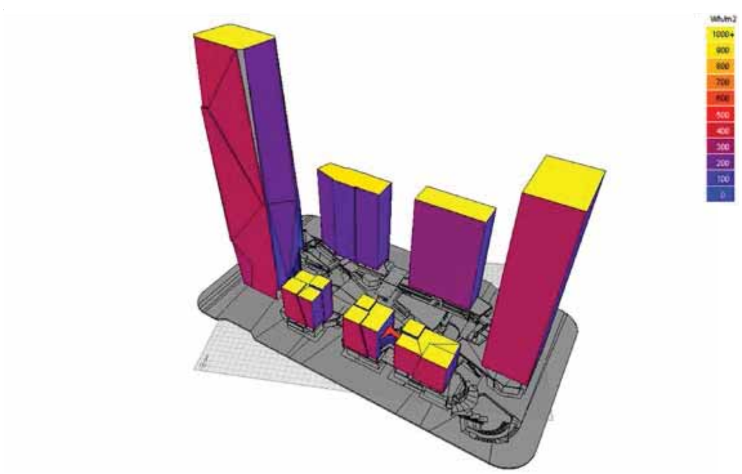

Figure 11: Envelope Insolation, Guangzhou poly mixed use project

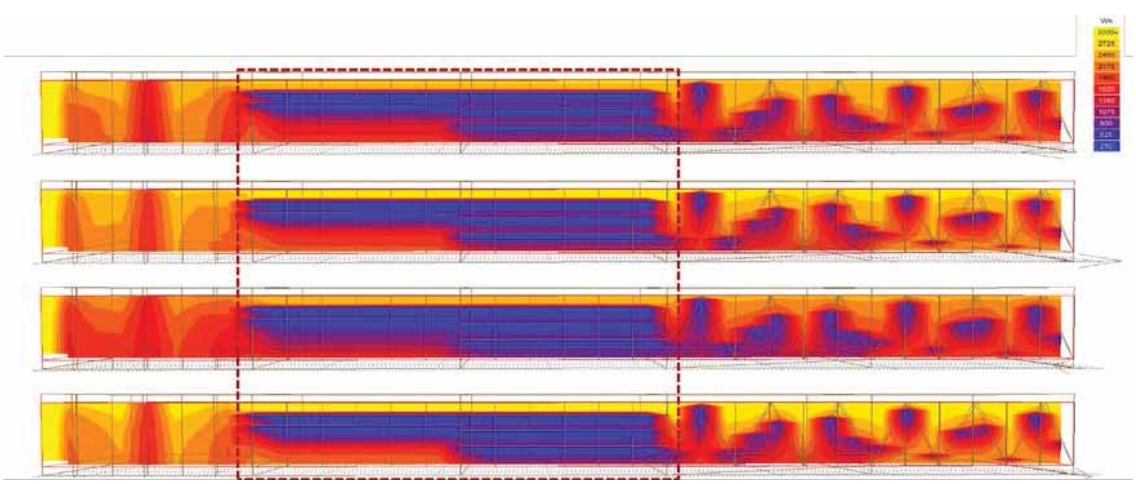

Figure 12: Insolation evaluation of several shading alternatives. Mega Kuningan mixed use project

Figure 13: Insolation and programmatic evaluation of West Façade Wetherly Residences

For the Wetherly residences in Beverly Hills, an insolation analysis of the west façade during the cooling season (April 1 to October 31) divided it in three areas that receive different quantities of solar radiation (Fig 13 left). Even though this shading effect from neighbors cannot be considered in energy modelling calculations, it can be used to differentiate this facade in three areas that require maximum, medium and reduced solar control. Various options were tested to analyze the effect of the angle and the levels of solar radiation in the western façade and optimize the inclination of the fins to reduce solar radiation while maximizing the view and privacy. All of them were above a minimum value. A shading matrix was developed that spatially referenced the program facing the façade (Fig.13 right) with the insolation level. Specific solutions were proposed for each of these combinations.

CONCLUSION

Commercial developers will typically implement environmental strategies that have economic payoff. By focusing PDD on improving building performance in key areas and quantifying this performance it has been possible to implement PDD in the commercial practice and impact specific areas of multiple projects in a short time. It has not yet been possible to develop a project in which there are significant quantifiable benefits in all PDD areas: social, economic and environmental. Ultimately, buildings should have a reduced environmental impact measured by how they affect climate change and resource consumption; promote human health and quality of life, and benefit society while providing added value to the community. Building performance is measurable using appropriate metrics for each of these areas.

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