Department of the Built Environment/ Building Physics and Services/Building Performance

Performance assessment of shade screen with night time insulation considering higher complexity occupant behavior models

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1. Introduction

Energy problems and sustainability targets lead to the building sector to search for new approaches and technologies. While the building façade is the main parameter that influences the energy performance of buildings, seeking for innovative façade concepts becomes inevitable. Dynamic facade systems one of the most promising solution of such concepts which is more flexible than static facades. This systems have ability to respond or benefit from external climatic conditions to meet efficiently and more important effectively occupant comfort and well-being requirements.(Loonen, 2015) Additionally, dynamic facade technology can play an important role in balancing various aspects of indoor environmental quality (IEQ), such as, discomfort glare, view to outside, privacy, thermal comfort and air quality(Baker, 2014)

There are many challenges of the performance assessment of dynamic facade systems, one of most important ones is occupant behaviour which directly affect the assessment of adaptive facades. Different dynamic façade technologies have different interactions with the HVAC system, occupant comfort expectation and other building subsystems. (Loonen, 2015) User interaction and satisfaction are two primary factors that cannot be neglected in the development and operation of automated building system. (Baker, 2015)

Occupant behavior influence can cause large deviations between predicted and actual performance, ultimately leading to a failure in achieving the desired building performance. Occupant interacting components in BPS tools are currently represented in terms of static schedules. (Gunay,2015) This implies that occupants are passive recipients of the indoor climate. different design and control alternatives studied in BPS models should result in unique schedules. Because the static schedules fail to reflect these dynamic interactions between a building and its users, they do not necessarily promote better design alternatives. A main issue with the introduction of occupant behavior models in building performance simulation (BPS) is the choice of an appropriate modeling complexity for a specific case. (Gaetani, 2016) It becomes more important while the case building has dynamic facade systems which change the properties of itself or behave in different way.

The actual performance prediction of such systems is very critical due to more sensible comparisons with alternative façade solutions, make sure about efficiency of the technology. The real performance prediction is considered important by many stakeholders. Product developer could see the potential of the systems, decide an improvement direction of product , or a proper market strategies in terms of climate, building type etc. Building control companies are also interested with real performance for indicating proper control strategies. The comfort level and energy consumption of the system is taken into account by design teams . As actual performance prediction is undoubtedly relevant, some crucial questions arise:

"*How can the real performance be predicted?*

Can if/else-based façade control strategies and static schedules can present the real performance of dynamic facade screen?

For what use cases are simple OB models sufficient, and when are more complex OB models desirable?

The answers of above questions will be searched during project.

The main objective of project is proving the use of more complex occupant behavior models can lead to more realistic simulation results, to get more accurate representation of the actual performance of shading screen, to provide useful information for potential improvement of product and control strategies. This hypothesis will be tested with a dynamic facade element, shade screen with night insulation.

2. Shade screen with night time insulation

Shade screen with night time insulation is one of the dynamic facade element which is going to be examined in this project. It is a semi transparent low - E coating indoor shade screen, which is called Silver Screen by producer, has an extremely low emissivity with a comparison of other fabric blinds. Emissivity (or E) is the value on a scale from 0 (minimum) to 1 (maximum) that describes the ability of materials to radiate heat (infra-red radiation). Non metallised fabrics have a E value between 0.8 and 0.9, whereas SilverScreen has a value of 0.05.   A material hardly radiates heat and that the material can act as a barrier for the natural heat flow to colder areas thus it acts as an insulator. According to product developer, the insulative properties can provide up to 10% reduction of energy consumption. Further substantial decrease of insulation value (U-value) is the direct result and will contribute in lowering energy consumption, regardless the climate (warm or cold) it lowers heating and cooling costs. The metallised nano layer reflects the sunlight and prevents diffuse light passing through the fabric. The fabric allows for sufficient natural daylight whilst preventing glare. (Figure 1)

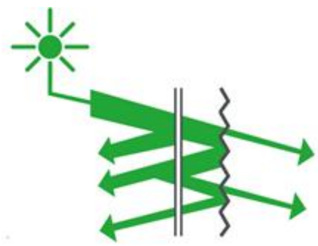
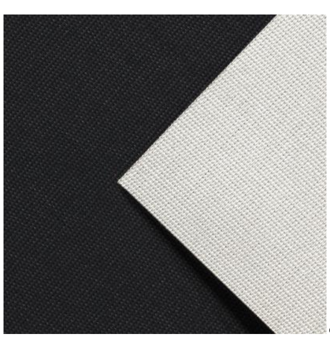
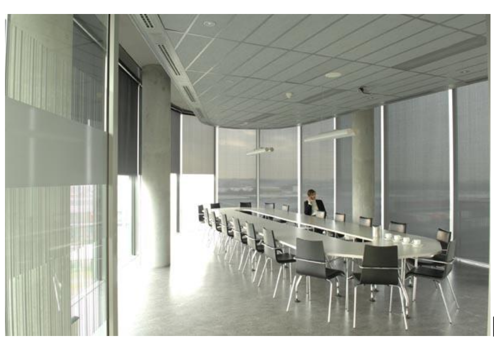


fig.1 reflection of the lights through shade screen

Solar radiation only turns into heat when the radiation is absorbed. The trick of this shade screen for overheating is to prevent incoming solar energy (light) being transformed into heat by absorption (short wave into long wave radiation). This highly reflective fabric with the nano-layer of aluminium reflects 83% of the solar radiation, preventing absorption and allowing the solar radiation to escape back through the window. This enhance shade screen's efficiency as indoor solar shading.



a



b

fig.2 material of shade screen(a), application at office (b)

The metallised fabrics reflect the light and prevent diffuse light. The characteristics of the weave (defining the view-through) are kept intact, creating excellent visual and thermal comfort.

3. Methodology

The research questions will be answered with the usage of building performance simulation tool. Different control strategies of solar shades will be simulated for a whole year and the impacts of shading on energy consumption in terms of heating, cooling& lighting and comfort will be analyzed. A single zone standard office is modeled for application of different control strategies.

3.1.Simulation Model

A model is developed in EnergyPlus v8.5. The simulation time step size is 5 minutes. The floor area of the model is 25 m² and the floor-to-floor height is taken as 3 m. (fig)The office have 15 m² of south-facing exterior envelope area, 8 m² of which is glazed (window-to-wall area ratio of 53%). Window's U-value is set as 2.7 W/m²K with a solar heat gain coefficient (SHGC) of 0.6, and a visible transmittance of 0.8. It assumed that the office located in the corner of building, the north and east interior walls of the office are treated as adiabatic, while the south and west face outside. The office is assumed to be used by one occupant and the heat gain is calculated in EnergyPlus by the Fanger thermal comfort model. The lights are assumed to consume 10 W/m² (with a radiant fraction of 0.5). The equipment power density is assumed as 125 W per occupant during the occupied hours.

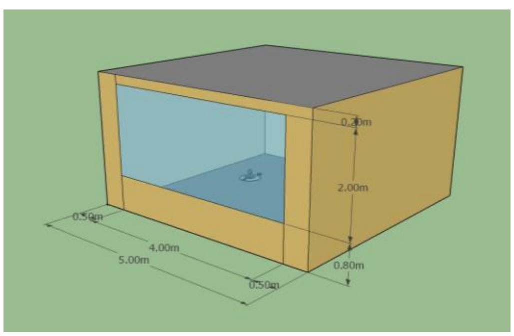


fig.3 simulation model

Table 1 Performance Criteria Simulated with EnergyPlus Type	Set-Point
Illuminance in reference point	500 lux
Discomfort Glare Index in reference point	22
Minimum Indoor Temperature	20°C
Maximum Indoor Temperature	24°C
Solar Irradiation	200 W/m2

An ideal air-based heating and cooling system is assumed with sensible heating and cooling capacities of 1.5 kW. The maximum heating and minimum cooling supply air temperature are kept at their default values, respectively 50°C and 13°C. On weekdays, the heating set point is 20°C between 6 h00 and 22 h00, and it is set back to 15.6°C otherwise. The cooling set point is 24° on weekdays and set back to 27°C. The infiltration rate is taken as 0.3 air changes per hour (ach).

Two locations which are heating load is much higher than cooling load are considered: Oslo, Norway, and Amsterdam, the Netherlands. Amsterdam has a seasonal average temperature of 3-5°C for winter and 17-19 °C for summer season , while it is 0-(-4) and 15-16, respectively, for Oslo. A reference point is set 1.5 m away from facade with work plane height (0.8m) to measure discomfort glare index and illuminance.

3.2.Control strategies

The efficiency of shade screen with night time insulation will be tested for indicated locations, and it is comparison will be done when blinds are closed during night time. Then, the complexity of shade screen control strategies will be increased step by step. Firstly, two extreme situations (no blinds and the blinds always closed) will be examined, to make a good comparison, in terms of the energy demand and visual comfort . This will give a range of values to compare all other results. These extreme situations cannot show the real performance of shade screen, more variables will be added subsequently.

One of the embedded Energy plus control strategies, High solar irradiance, is chosen as an further examinations. The control of solar gains through the window is very complicated but also crucial. It can cause overheating, but it can also be used when heating is necessary. Thus, the control of shade screen is done with solar irradiance. The shade screen gets closed when solar irradiance higher than 200 w/m2.

Energy Management System (EMS) is an advance features of energy plus, it provides high-level, supervisory control to override selected aspects of EnergyPlus Modeling. An EMS is able to access a wide variety of sensor data and use this data to direct various types of control actions. EMS sensors are used to get information from elsewhere in the model for use in control calculations. Within this frame some occupant behavior models are selected from literature, and predictions made by those models comparison with each other based on the simulations of an office. The way these predictions influenced the heating, cooling, and lighting load calculations of a BPS tool was demonstrated.

Selected occupant models and implementation of Ems will be explained in the following sections.

Selected occupant models (Gunay, 2015)

The work will be extended with two blind use and a presence occupant models from literature with EMS.

Reinhart(2004) blind use model ,indicated as a model A, suggests that occupants close their blinds, when the direct solar irradiance on the workplane (0.8 m above the floor level) exceeds 50 W/m2. In Newsham's(1994) blinds use model ,indicated as a model B, the blinds closing actions are predicted with the transmitted direct solar irradiance; the simulated occupants are assumed to close their blinds when it exceeds 233 W/m2. In both models, occupants are modelled to open their blinds only at arrival and blinds are modeled as binary components (fully open/closed). Blinds modeled as closed during night time(22:00-06:00h) in these blind use models.

In Reinhart's occupancy model, five different event times are predicted in the beginning of each workday. These events are: (1) arrival time at 8 h00 with a standard deviation of 15 min, (2) a coffee break at 10 h00 with a standard deviation of 15 min, (3) a lunch break at 12 h00 with a standard deviation of 15 min, (4) a coffee break at 15 h00 with a standard deviation of 15 min, and (5) departure at 18 h00 with a standard deviation of 15 min. In this model, the durations of coffee breaks and the lunch break are taken as 15 and 60 min, respectively.

Ems implementation

Figure 4 illustrates the implementation of occupant models in the EMS application of EnergyPlus. The communication between EnergyPlus (building and HVAC model) and EMS application (occupant model) was carried out through the so-called EMS sensors and EMS actuators.

In this study, EMS sensors can be pictured as the environmental variables that an occupant senses, whereas the EMS actuators can be portrayed as the building components that an occupant controls. These EMS sensors are transmitted direct solar irradiance and direct solar irradiance on the work plane (W/m2), and the daylight on the workplane (lux). The EMS actuators are occupant presence and blinds, and they link to the schedule values of the EnergyPlus objects for window shading control objects.

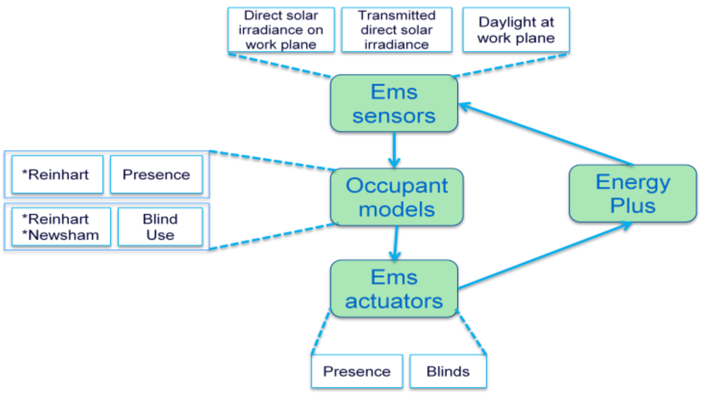


Figure.4 Implementation in EnergyPlus' energy management system (EMS) application a flow chart illustrating the data exchange between EnergyPlus and occupant models

The OB models are implemented in the building model by means of the EMS feature of EnergyPlus. The control strategies which going to be used during project are summarized in Table 2. The selected occupant models have been run an appropriate number of times to take their stochasticity into account.

table.2 control strategies

Energy plus embedded control strategies	**no blind**	**1**
	blinds always closed	2
	blinds nighttime closed	3
	blinds closed if solar radiation>200W/m2	4
EMS featured control strategies	Blind use model A	5
	Blind use model B	6
	Blind use model A with occupancy model	7
	Blind use model B with occupancy model	8

4. Results

First of all, night time insulation effect on energy load reduction is examined to show the effectiveness of shade screen. Three different locations' (Oslo, Amsterdam and Istanbul) heating load for a typical winter day is compared between shade screen and normal blind is done with EnergyPlus .(table 3) It found that in all locations this shade screen provide way better performance than a normal blind. it is proved that this shade screen could be beneficial for any location. However, it is also noted that it provides the same amount of energy demand reduction in all locations, even though the energy saving percentage varies a lot between locations due to the heating demand difference.

table.3 efficiency comparison of night time insulation shade screen in different locations

Heating load kW -27th January	Oslo	Amsterdam	Istanbul
no blind	16.9	12.6	5.1
normal blind nighttime closed	16.7	12.4	5.0
Shade screen with night time insulation	16.4	12.0	4.6
Energy savings	2.50%	4.20%	9.80%

After efficiency confirmation of shade screen , blind control strategies' simulations are run from simple through more complicated ones. The results will be presented separately in terms of basic EnergyPlus embedded control strategies and more complex EMS featured control strategies. Energy loads in terms of heating, cooling & lighting, discomfort glare hours percentage of occupied hours and blinds closed hours analyzed.

Figure 5,6,7 show energy load and comfort indicators results of Oslo, Amsterdam and Istanbul for EnergyPlus embedded control strategies. Starting from two extreme situations, no blind and blinds always closed, give the extreme results and the range.

A discomfort glare index of 22, as used as set-point in this study. For the control type blinds closed if solar irradiation higher than 200 W/m2 the % hours discomfort glare index higher than 22 is slightly different for locations, 13%, 18% and 20% , while it is 22%, 23%,27% without blind for Oslo, Amsterdam and Istanbul, respectively. Even though discomfort glare hours reduced with high solar irradiation control strategies, there are still need for protection against glare.

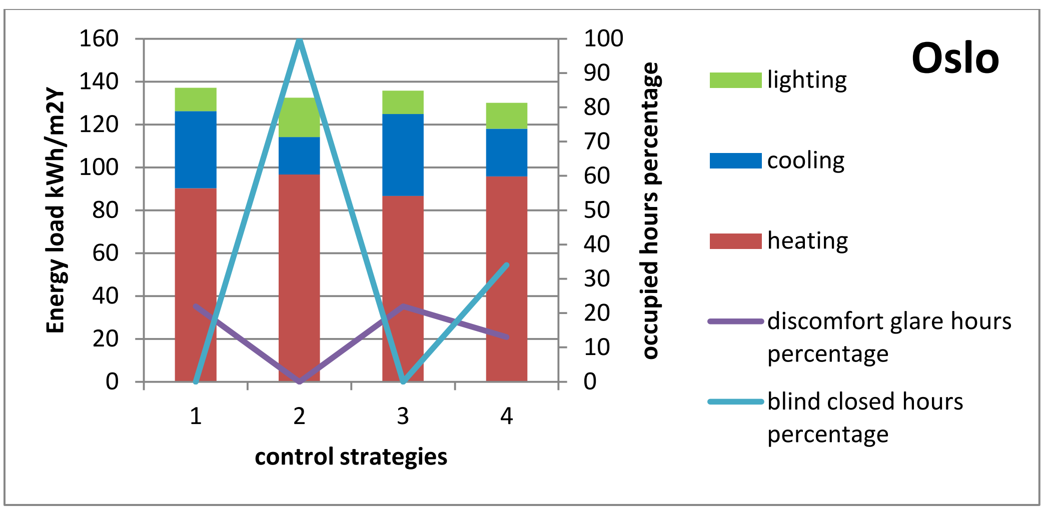


Figure.5 simulation results by employing different control strategies in Oslo

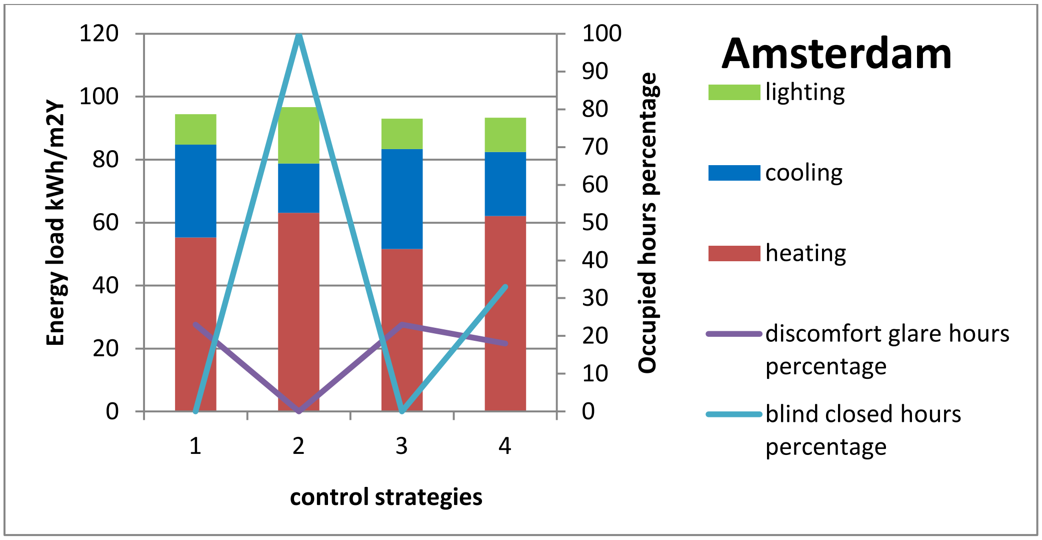


Figure. 6 simulation results by employing different control strategies in Amsterdam

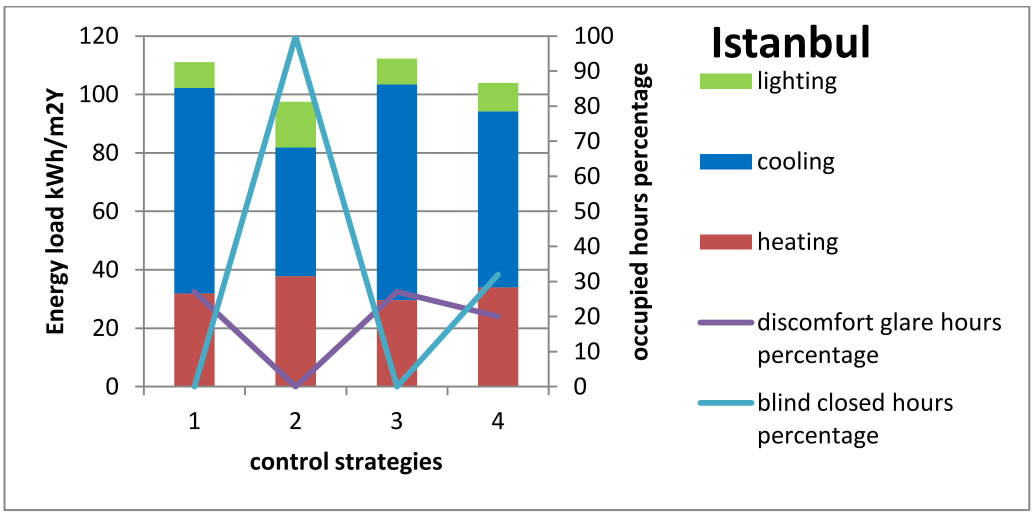


Figure.7 simulation results by employing different control strategies in Istanbul

While the shade screen decrease heating demand of the model for a typical winter day efficiently, the whole year simulation results do not present parallel output. The effect of night time insulation becomes invisible for whole year. the total energy load saving for whole year 1.6%, 1% , -1.1% for Oslo, Amsterdam and Istanbul respectively. (Figure 5,6,7) The night time insulation provide more energy saving for a typical winter day in warmer climates, but, in contrast, it increases the overall energy load for other seasons. Night time closed shade screen keep the room temperature inside as a insulator, increases cooling load of the model. Therefore, the relationship between climate and technology must be analyzed attentively with well matched control strategy. In this case, seasonal approach could be considered as a variable of control strategy, because it is obvious that it does not provide the same result as winter for other seasons.

Further examinations will continue with Oslo and Amsterdam, due the fact that Istanbul and the shade screen technology do not match well with simulation model for whole year.

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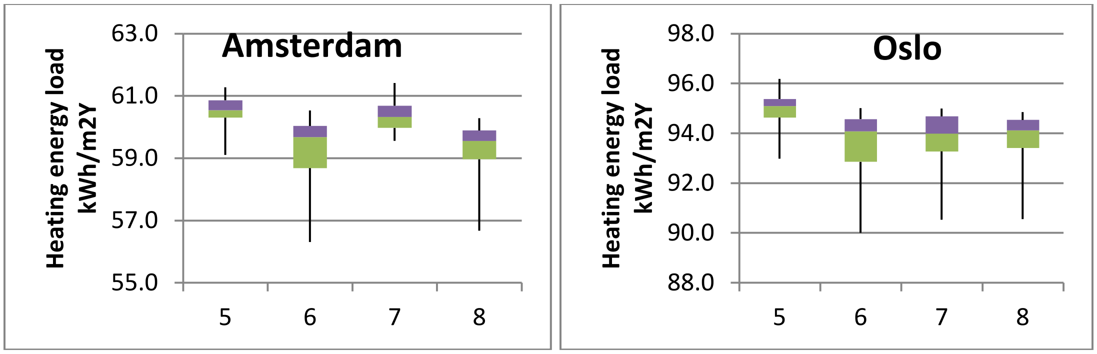

Figure.8 Heating load predictions by employing different occupant use models.

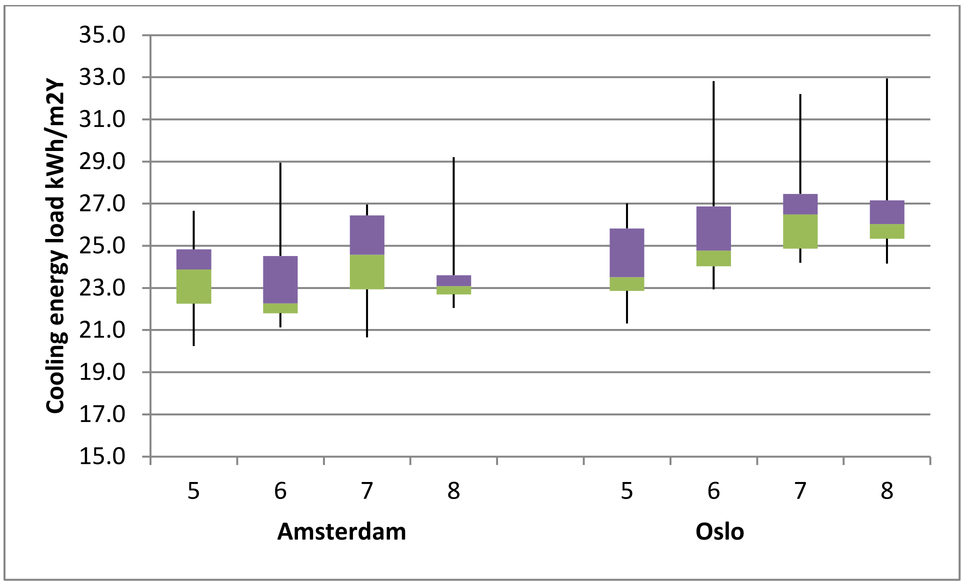

Figure. 9 Cooling load predictions by employing different occupant use models.

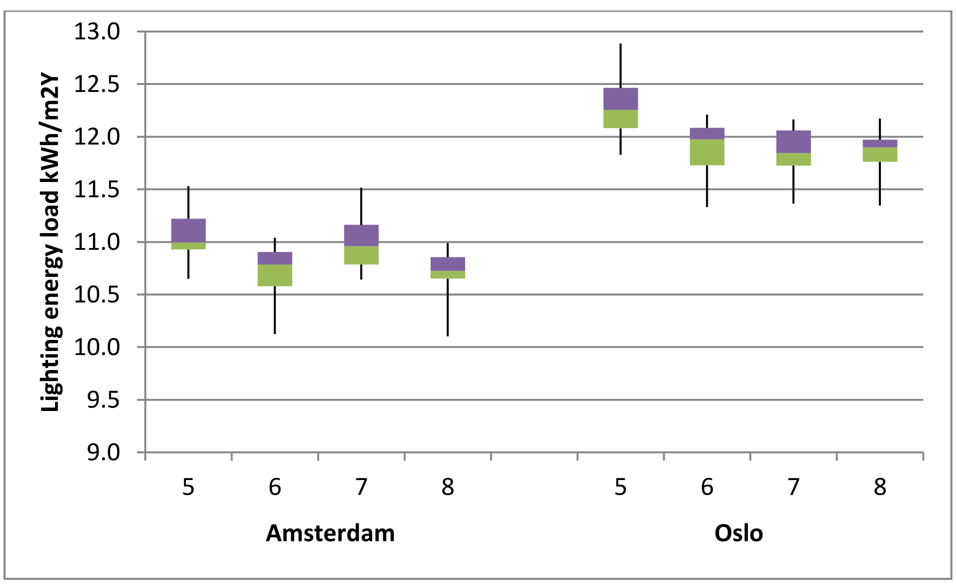

Figure. 10 Lighting load predictions by employing different occupant use models.

The more complex Blind use models(A&B) and their combination with occupant presence model are examined for Amsterdam and Oslo. The results (figure 8,9,10) shows that adding modelling complexity to the other considered aspects of OB does not leads to negligible differences .In this model, basic schedules would be enough for performance prediction.

5. Conclusion

This paper presented the results of building performance simulations case study setting, that aimed at clarifying the need of more complex occupant behavior model for real performance of dynamic facade systems . For this reason, different control strategies with various complexity level are used. Although different occupancy models and their combinations show slightly different energy performance in different locations, it would not be correct to say that more complex occupancy models show better accuracy for this project. These results show that — occupancy, blind use may be represented by simple schedules, for the considered building and performance indicators, as their effect on the energy performance is negligible. A higher level of complexity might be needed when representing other more influential parameters.

Moreover, selected blind use models are only allow to operate the blinds fully open or closed. Occupants cannot close to blinds partly which could be beneficial for having an outside view without the disadvantages of discomfort glare. Thus, this partly opening-closing action should be taken into account to achieve higher visual comfort and energy savings in future researches. It is also going to affect the actual performance. Furthermore, facade technology should be proper for the climate

Modeled shade screen's results in this project may not strongly support hypothesis , due to the fact that the dynamicity level or behavior may not be sufficient, or the model is not complex enough. However, It would not be correct to indicate that this project's hypothesis is completely rejected. Further examinations should be done with a real representative dynamic facade element with more realistic complex model.

6. References

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