Academic year 2020 - 2021 #2 | July

MOLLIER

Study Association
Building Physics and Services

INSIDE INFORMATION

MOLLIER | UNIT BPS | STUDENTS | ACTIVITIES | MEMBERS

Lustrum Symposium recap

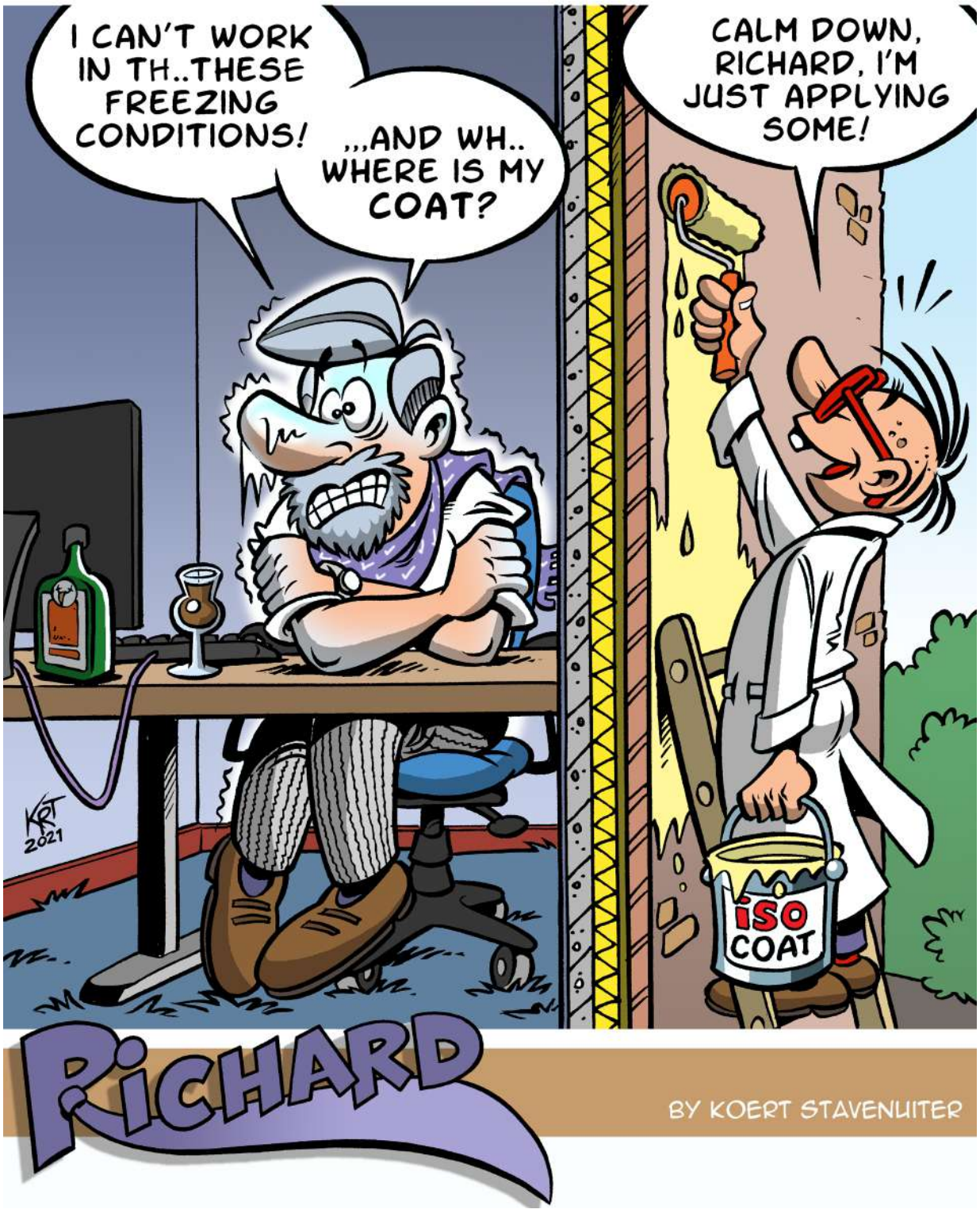
Comparison of two room acoustic parameter measurement methods

X. (Xueying) Guan, BSc

Context-aware shading strategies using machine learning

Ir. W. (Wesley) van der Sommen

BUILDING SKIN SOLUTIONS INCREASE THERMAL COMFORT IN OFFICE BUILDINGS...



Foreword

Laurens Castenmiller

Dear INSide Information reader,

We are already at the end of the academic year, which means that the second edition of the INSide Information lays in front of you.

As Mollier is celebrating its 25th anniversary this year, we wanted to jump back in time a little bit. In the beginning, Mollier existed of only a few members, but grew throughout the years to become the study association that it is today. The front and back cover of this edition of the INSide Information are characterized by some retro study trip photos to dive back into the history of s.v.b.p.s. Mollier. Maybe some of you still recognize these photos from the study trip to Chicago and Brazil. The study trip is one of our most popular annual events; we have been to some spectacular destinations in the past years.

To celebrate that s.v.b.p.s. Mollier turned 25, many festivities were organized by our lustrum committee. The opening of the lustrum took place during the Lustrum Symposium, streamed from the Blauwe Zaal. You can read all about it in the Lustrum Symposium Recap. The lustrum Party and Gala have been postponed to the new academic year. The Party will take place on the 9th of September in the fancy Café Thomas, located at Stratumseind. The Gala will be on the 19th of November, on a mystery location somewhere in Eindhoven. Make sure to not miss out! We can promise you that these will be nights to remember! Meanwhile, our webshop is always open, so find the Lustrum Merchandise via https://www.mollier.nl/lustrum-merchandise-available/.

Like always, graduation projects on topics like sun shading and comfort are included in this edition of the INSide Information. Read more about what our unit BPS is up to in the articles submitted by Afaq Butt on coating and performance, and Ruud van Herpen on the risks of having combustible items in escape routes. Also, some interesting company articles where submitted by our partners, Cauberg Huygen, ZRI, ABT, and LBP|SIGHT are included in this magazine. And in this edition, not just one but two new members have found the spotlight by writing an IceBreaker.

I wish you lots of fun reading those inspiring articles and hopefully see you at one of our (Lustrum) activities in the upcoming academic year!

Laurens Castenmiller

Editor in chief, INSide Information

INSide Committee
Laurens Castenmiller, Meghana Kulhalli, Nora Kuiper

COLOPHON

INSide Information
Volume 25 Issue 2,
July, 2021

The INSide Information is
published by s.v.b.p.s. Mollier

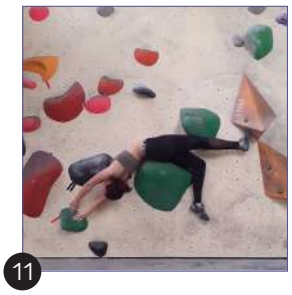
Front cover: Archieve
Cartoon: Koert Stavenuiter
Back cover: Archieve
Fotografie
Printing office:
Ledenblad.nl

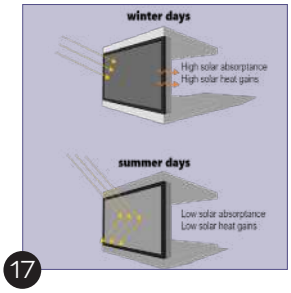
Visiting address
TU Eindhoven
Vertigo 2nd floor

Post address
Postbus 513
p/a Secretariaat BPS
5600 MB Eindhoven
Tel: (040) 247 4406

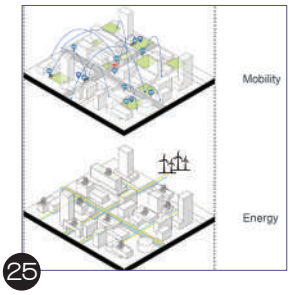
Email: inside@mollier.nl
Website : www.mollier.nl

This INSide


11



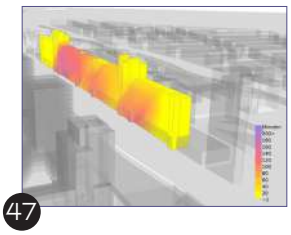
17



25


34


39


47

MOLLIER & MEMBERS

BUILDING PHYSICS & SERVICES

COMPANIES

unica

samen maken we de toekomst

Wij bieden je geen stage of een baan maar een carrière!

Wil jij samen met ons het verschil gaan maken in de toekomst? Wij zijn in ons vakgebied uniek van soort, daar wij met onze specialisme een totaal oplossing kunnen bieden aan onze klanten. Van projecten in data centers tot renovaties in de zorg en van onderhoud tot gebouwbeveiliging, van specialist in brandbeveiliging tot partner in ICT solutions; kortom een netwerk van bedrijven! Wist jij trouwens dat het nieuwe hoofdgebouw door Unica is ontworpen en gerealiseerd?

Binnen Unica is er genoeg ruimte voor persoonlijke ontwikkeling, waarbij het belangrijk is dat je kunt groeien. Als jij groeit, dan groeien wij met je mee! Wij willen je ook geen baan aanbieden maar een carrière. Er zijn inmiddels al heel wat TU/e voorgangers zoals Marc Scholman, Gert Jan Braun, Ricardo Poortvliet en Dennis Schuiling die een uitdaging hebben gevonden bij ons; wellicht kunnen zij jou wegwijs maken?

Wil je bij ons stage lopen, afstuderen of werken. Neem dan gerust contact op met onze recruiter James Smeets op **06 8320 6156**, één van de andere ex TU/ers of kijk op onze websites voor meer informatie; **unica.nl** en **werkenbijunica.nl.**

Mollier Activity Calendar

WEEKLY TEA TABLE

A break once in a while can do miracles when studying can be though at some times. The tea table originates from the gathering of members at 3 o'clock on Vertigos' floor 5 for a coffee break. During this break everyone was spilled with cookies and sweets not forgetting drinking tea or coffee meanwhile. This turned into online gatherings with small online games instead of some snacks. The most important is that it's laid back. Every week there is a new theme that brings a little twist to the table. This has been a study trip location reveal with local specialties to a birthday that has to be celebrated.

DINNER LECTURE YOUNG TVVL

Young TVVL, the network for young professionals in the technology sector, hosted the last lecture of the year on December 9th. Bart Kok and Kevin de Bont, old board members of Mollier, paved the way for a 'gezellige borrel'. They even did Jägermeister shots at the end of their lecture!

Bart and Kevin explained the possibilities that the network offers. TVVL connect, for example, is a really good place to call for (graduation) projects or internships. You can compare it to LinkedIn, but then specifically for the technology sector. Second, Young TVVL organizes various actions and events throughout the year to connect with their members. Make sure to sign up if you don't want to miss out!

PAINTING WORKSHOP

Who said that engineers lack the artistic gene? On December, 11th, Mollier engineers gathered for an online painting workshop and proved everyone wrong. They had received a watercolour set and were ready unleash their inner painter. Eugene, who hosted the workshop, picked out a landscape to paint and walked everyone through the steps. By the second hour, papers were flooded with paint and a number of distinct interpretations of the same landscape emerged. Take a look at the different paintings below!

MEET AND GREET

Looking for a master or graduation project, an internship or are you orientating for a job? Mollier's company market, the Meet & Greet, is always the right place to look for it! This years market was hosted online just before the Christmas holiday. Students had the opportunity to talk to 14 companies in different break-out rooms, which were distributed over four different rounds. At the start of each round, the companies shortly introduced themselves with a short pitch in the central call.

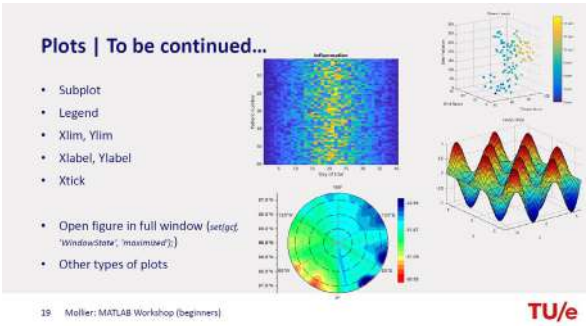
All students received a program booklet and a goodie bag with a cork notebook and a Mollier webcam cover, to match the online setting. The bag also contained some refreshments for the informal 'borrel' afterwards. The drink was a nice moment to check-up with the old and recently graduated Mollier members that had attended the market to represent their companies. We would like to thank all company representatives and students for joining!

MOLLIER PLAYS WORMS

On the 5th of February, Mollier travelled back in time to play an all-time favorite game of many: Worms Revolution. Mollier purchased the game in advance and sent it to the interested members for free. Everyone was very excited to play the game of their childhood. We all added each other as friends on the server, so the game could be played in a multiplayer mode. The participants were divided into randomized groups of 4 and the fun could begin! One round lasted for 30 minutes and then new groups were created. In the beginning, most of us needed to refresh our memories how to shoot and aim, or even how to move their worms. People were shouting and laughing at their own and/or other's mistakes. Since the event started at 20:00 and some people stayed in the meeting until around 01:00 in the morning proves that this was a successful and enjoyable activity.

MATLAB WORKSHOP

On February 11th a MATLAB workshop was held with a turn up in large numbers. The program MATLAB is used in BPS courses but proved relevant for a lot of students from other tracks and faculties. That afternoon the always enthusiastic post-doc (and old-member) Juliëtte van Duijnhoven from the Building Lighting group taught the basics. With quizzes and small exercises it was as interactive as possible even though it all was online. Running out of time was the only concern since there was a lot to tell and teach. In the end it proved to be a joyful and informative afternoon



BAKE TOGETHER - CARNAVAL EDITION

The carnaval was different this year compared to other year's. Due to the lack of festive events in and around Eindhoven Richard did organize a nice event to bake cinnamon rolls yourself. The ingredients that needs to be mixed are well explained so everyone could follow the instructions on his/her own pace. The cinnamon rolls needs some time in the stove as last step before we were able to taste the creations. During this waiting time nice conversations are shared, and those conversations continued when the cinnamon rolls are ready to taste, with the adjustment that we had something to snack next to the conversation!

MOLLIER PLAYS BOMBERMAN

Do you remember the game with the bombs and blowing up the crates? The game that you used to play when you were younger? Yes? Mollier definitely does! On the 5th of March, we had an online session of Bomberman which allowed for a nice catch up between the members. With this online game was that is was possible to play the game with 4, and even 6, people. When you are trapped with bombs off your opponent you are able to take revenge by throwing bombs from the sideline! After a few hours of playing we all did win some games, and enjoyed the game!

GENERAL MEETING OF MEMBERS #2

In March it was time for the Mollier board to give an update about the state of buisness to all the member. This general member meeting. This meeting was held online, hopefully for the last time. Generaly the members will have an oportunity to chat with each other after the GMM in the skybar of Vertigo, however this was not possible with the actual circumstances. For that reason the members who signed up for the GMM received 4 beers at their home address. At the beginning of the GMM there was an announcement that the lustrum banner was delivered, and there was promotion to join symposium (a recap is present at page 23 and 24). Halfway through there was a short coffee break to renew the energy level, if needed. After the break the updates of the finances and external relations are shared and the constitution of different committees was done. after the GMM there was some time to enjoy the beers and chat with the other members as well!

MOVIE NIGHT - ABSTRACT BIO ARCHITECTURE

As the cinemas were closed Mollier teamed up with other associations AnArchi (Architecture) and VIA (Urbanism) for a movie night. The evening revolved around the work of Neri Oxman which was captured in the Netflix series Abstract: The Art of Design. She combines architecture with material engineering on a biological level in environmental designs with complex shapes. A innovative and inspiring designer on the cutting edge of different subjects that gave enough input for a vivid discussion.

WINE TASTING

Richard Mollier was desperately searching for some good wines, and decided to oraganize a wine tasting with all members at the 16th of April. The members didn't disappoint him, even some 'new' members showed up to Help Richard by making a decision for the best wine. At the beginning of the evening everyone started tasting the dry white wine (Tarani Sauvignon Blanc, 2019) and did finish with the red wine (Zenato Ripassa Della Valpolicella Ripasso Superiore, 2017). Between the wines all members did answer some evaluation questions, and some quiz questions about wine. Also the wines where described with one sentence. Meghana gave the most original description of the sparkling wine, which was not tasted well by the mejority "Water trying to be wine. Jesus wasn't done working on this one quite yet". Kim was recognized as the wine expert. Both members did receive some personalized Mollier wine glasses.

BEER PONG VS KOERS

At the 6th of May the annual beer-pong battle with KOers took place. There was good hope that we were able to organize this battle offline, however the circumstances did not allow us to show our power offline and we had to impress KOers online. Everyone should have access to a laptop with the teams call and a webcam that captures the formation of the red cups! Everyone in the call was divided into different breakout rooms to play a match against to opponent at the other side of the screen. This year a special golden red cup (or actually gold cup) was created to honor the winners of this battle, and give them a change trophy. After a few rounds of beer-pong some beer was still left, and Mollier did show their beer-pong skills and prolongated the beer-pong title. With this win we also make sure the text on the poster was correct! (The poster said Beer pong vs. (K.O.)ers)

BACK TO CAMPUS DRINK

Last year all the drinks and activities were held online. In the beginning online drinks were doable, we could play an online game, and we saw new members to chat with. However having all the drinks online for more than one year is not prefered. On the 20th of May we are finally allowed to have a drink at the university! Richard did reserve several spots for the members. He was enourmous happy that he decided to be generous and did pay for most of the drinks of the members! It was pretty to see lots of members in real life, and not on the screen again.

PITCH AND PUTT

Two weeks after the back to campus drink another offline activity was organized. In Oirschot the members showed Richard their golf skills. The members were grouped and played the last tents of meters of a golf track and should cooperate to put the golf ball, as team, in the least strokes. The good weather and the joyful game resulted in lots of happy faces at the end of the game! Everyone did their best, and were treated with a drink after this activity.

Here at Van Hout/Ovvia we want to make an important contribution to accelerate the energy transition. Thanks to 90 years of expertise, we prove that making real estate integrally sustainable is good for the environment. That is our drive.

Ready to go green? See if the shoe fits...

A sustainable and green future will only be as smart as the people who work on it. So we are looking for bright people who want to contribute to creating a sustainable future. Students and master's graduates ready to wear green shoes, bursting with energy and are keen to continuously learn and develop.

Does this sound like you? Great! At Van Hout/Ovvia you'll meet likeminded people who appreciate team spirit and diversity. Because together we make bigger green steps towards energy transition!

Contact us and see how these green shoes fit you!

www.ovvia.nl / www.van-hout.com
info@van-hout.com

vanhout
adviseurs en installateurs

OVVIA

K+ ADVIESGROEP

Plezierig werken, aangenaam wonen, rustig studeren, recreëren of verzorgd worden, in ruimten en gebouwen die daarvoor geschikt zijn.

+ DOMUSDELA, EINDHOVEN

+ JACHTSLOT MOKERHEIDE, RESTAURATIE EN VERDUURZAMING

+ NIEUW HOOFDKANTOOR REV'IT, OSS

Al meer dan 25 jaar nemen wij, specialisten van K+ Adviesgroep onze verantwoordelijkheid in het adviseren van gebouweigenaren. Ons eerlijk advies op basis van kennis en ervaring is gericht op een veilige, gezonde én duurzame omgeving, nu en in de toekomst.

+ **Bouwfysica**
+ **Akoestiek**
+ **Brandveiligheid**
+ **Energiebeheer**
+ **Technische installaties**

www.k-plus.nl

Ice Breaker
Pam van Dijk

Hi! My name is Pam and I am 23 years old. I am finishing up the pre-master Building Physics and Services, and when that is all finalized, I might actually leave the Bollenstreek (Flower Bulb Region) and come live in Eindhoven. After high school, I studied Building Engineering at hogeschool InHolland Haarlem and moved there.

Figure 1. In my natural habitat, in a tree.

A little background on why I chose Building Physics and Services. I think it started with the idea of becoming an interior decorator at the age of 5 and developing a growing interest in 'pretty' buildings until I was 15. Around that time I thought I chose the wrong preliminary education to pursue architecture, because mathematics and physics were not something I particularly enjoyed, and chose to drop those classes. With some hard work, I managed to get in the bachelor of Building Engineering and within 2 months of classes, I was cured of wanting to become an architect. A teacher in the first year made me develop an interest in Building Physics, which eventually led to me doing an internship and graduating in Building Physics at the engineering consultancy firm DGMR.

I graduated on the topic of the WELL Building Standard, something I am still very much enthusiastic about. The focus of my research project was in which ways an existing school building could implement a healthier learning environment, through management changes, but more particularly through renovations of the building.

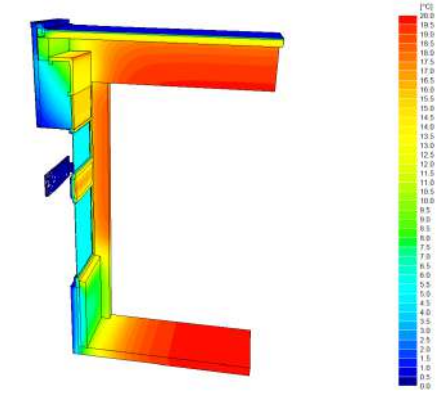


Figure 2. Visualization of a thermal bridge calculation in Trisco.

After reading about my previous education the reason I chose this pre-master might be obvious. It is because I am, by far, not an expert on building physics and want to learn more about the topic, while implementing this at the company I am working at, DGMR. At work I get the chance to make calculations on various topics, such as daylight, sound reductions, material performance of a building, insulation and of course healthy and sustainable buildings with BREEAM and the WELL Building Standard.

Figure 3. Sound measurements for my graduation project.

Besides working and studying I would like to think I am pretty active. I also work at a Squash club and sometimes play with some coworkers. I like to bike everywhere on my mountainbike and the sport taking up most of my time, at least before the COVID-19 outbreak, is bouldering. This is something I do about 3 to 4 times a week with some friends or alone (are you ever really alone with bouldering?), and when I finally move to Eindhoven I am planning to join ESAC! And last but not least, I have been active with my scouts group since 2008, where I meet up with friends every other week.

Figure 4. Bouldering sometimes requires some unique positions.

In the master's, I am planning on broadening my overall knowledge of Building Physics, but because I do not see my passion for healthy buildings disappearing any time soon, I think that will be my focus. For this reason, one of my biggest goals after the master's is to either become a WELL Accredited Professional, or a WELL Performance Testing Agent. But, you never know, so we will see what the future brings. For now, I am very excited to start the master and get to know everyone! ■

Context-Aware Shading Strategies Using Machine Learning

prof.dr.ir. J.L.M. (Jan) Henssen
Dr.ir. R.C.G.M (Roel) Loonen
Ir. S.B. (Samuel) de Vries

Author
Ir. W. (Wesley) van der Sommen

INTRODUCTION

Previous studies explored and confirmed that the energy performance of buildings is highly dependent on the design and size of the transparent façades in buildings [1]. Automatic solar shading systems have the ability to respond to various indoor and outdoor conditions and can significantly improve the performance of a building [2]. Effective use of daylight has an impact on energy usage, thermal and visual comfort [3]. In order to effectively control solar shading, the following must be considered: direct sunlight should be cut to reduce cooling load and discomfort glare, daylight should contribute to task illuminance to reduce electricity for lighting, and the outside view should be preserved as much as possible [4]. Effective building design considering shading from an urban context is fundamental to optimize energy performance [5]. Blind control strategies are often used for the specific location and orientation of the building it is designed for. However, studies have rarely considered urban context impacting the performance of solar shading systems [6]. Conventional methods for improving indoor daylight conditions and visual comfort often do not consider surrounding buildings.

Current automated solar shading systems using daylight linked control strategies are categorized as simple or state of the art. Simple systems use multiple sensors inside and outside the office space to assess and control daylighting. State of the art modeling systems use varying physics-based models to predict daylight conditions, often combined with a sensor to assess and control daylighting.

The main objective of this research is to improve the positive effects of shading control by extracting information about the surrounding environment. The proposed control algorithm aims to influence the behavior of the solar shading system based on knowledge of the built environment, leading to better building performance. Developing sensor strategies for advanced solar shading systems, which automatically adapts to the surroundings, minimizes the need for human interaction and allows for a simpler commissioning process. The proposed method aims to reduce glare and increase daylight in (office) spaces that experience hindrance in daylight quality caused by surrounding buildings. The approach aims to be scalable since it only requires commonly available data from a single photometer with no further need for human intervention.

METHODOLOGY

The research objective will be explored with multiple case studies using simulations. Glare and illuminance studies are simulated using Daysim with a 15-minute timestep. The obstruction detection potential starts with threshold calculations, which are carried out using confusion matrices. The potential of obstruction isolation and the application of multiple thresholds is then investigated. To automate the obstruction detection, and develop an unsupervised method, a workflow is proposed which uses machine learning to predict obstruction events.

The obstructions used to analyze the method are based on a common occurrence, a street canyon. Two situations have been considered, a full street canyon and an asymmetrical street canyon. To further analyze the rapid changes in solar exposure the model has to react to, a more extreme case with high-rise buildings is used. The high-rise case study uses a mix of low and high-rise buildings, with open areas in between as well. The case studies are illustrated in Figure 1.

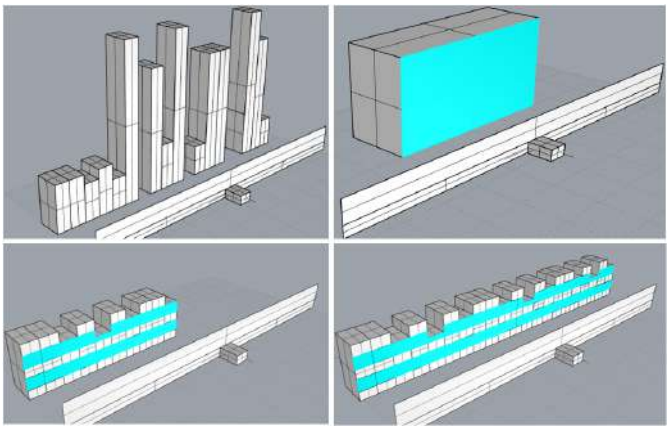


Figure 1. Case studies

Illuminance simulations using Daysim

The illuminance simulation with a 15-minute interval is run using Daysim with the Dynamic Daylighting Simulations method. This method is appropriate for cases where sensors experience rapid changes in solar exposure, for example in urban canyons [7]. Daysim is a simulation engine using Radiance and combines its daylight coefficient approach with the Perez sky model. The Radiance lighting simulation engine uses a hybrid approach of Monte Carlo and deterministic ray tracing to achieve a reasonably accurate result in a reasonable time. The Perez all-weather sky model is a mathematical model used to describe the relative luminance distribution of the sky. Daysim makes use of diffuse and direct raytracing, as well as a ground model for ground reflections. Daysim has fast calculation times since it uses the daylight coefficient method and is together with Radiance integrated into the simulation environment Honeybee/Ladybug[8]. The weather file used for the simulations is based on the hourly IWEC Amsterdam, The Netherlands (latitude = 52.30°, longitude = -4.77°) weather file, which is linearly interpolated to an interval of 15 minutes.

Threshold calculation

The goal of the threshold calculations is to find a control threshold that matches well with potential glare problems and daylight performance without too many wrong decisions. An example how indoor illuminance sensors can be used as input is shown in figure 2. Using a confusion matrix, the strategy can determine the threshold where the reference sensor can safely

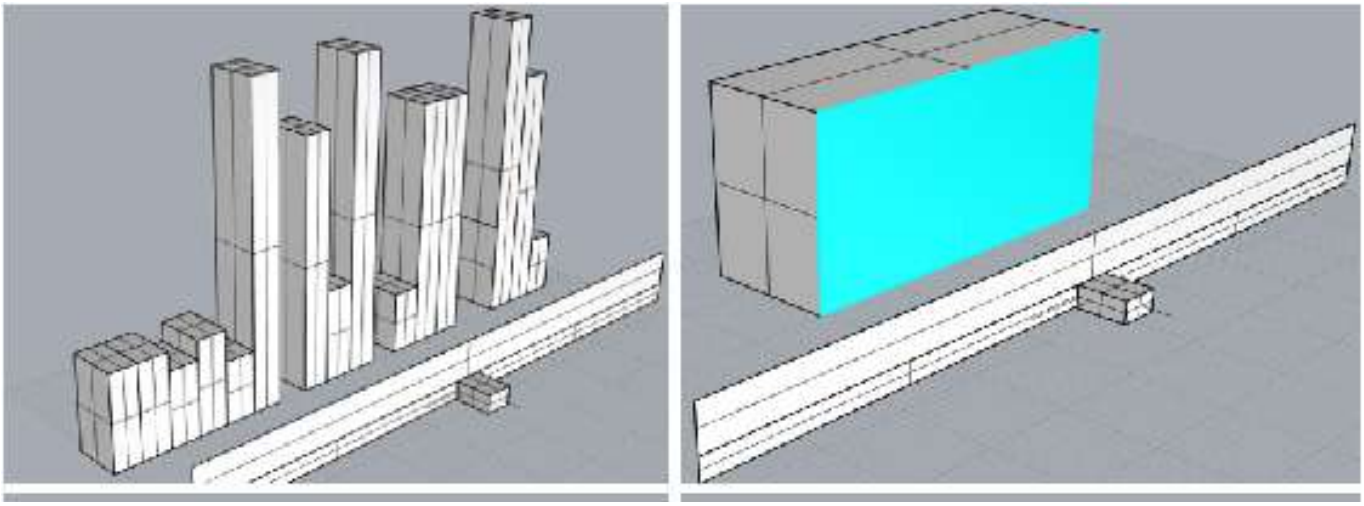


Figure 2. DGPs for two viewing position versus vertical illuminance sensor for a case facing south

assume the shading can be raised or closed without causing glare. The graph is based on the results from the illuminance simulation for a south orientation. It shows the simplified Daylight Glare Probability (DGPs) values for two viewing directions, plotted as a function of the reference sensor behind the window. For both the viewing position towards the wall and the viewing position towards the window, the maximum value of both positions is used. The graph shows the effectivity of a sensor threshold detecting the conditions where the risk of glare can occur. The limit where glare starts to be disturbing is above a DGPs of 0.4, indicated by a horizontal line in the graph. A threshold is then determined based on the data and visualized using a vertical line. An offset can be used to allow some glare, in favor of reducing the time the shading is down, admitting more daylight. Detecting a risk of glare is called 'positive' in this graph. The four quadrants of the confusion matrix are used to indicate the performance of the sensor threshold. True positives are moments where the chosen threshold correctly assumes there is a risk of glare, resulting in the solar shading going down. False positives are moments where the sensor threshold causing the solar shading to go down when there is no risk of glare, resulting in unnecessary loss of daylight. True Negatives are moments where the threshold rightly assumes there is no risk of glare and the solar shading can be raised. Finally, false negatives indicate moments where the threshold leads to a wrong decision where the solar shading is raised while there is a risk of glare, resulting in a situation where disturbing glare occurs.

The hypotheses stated that obstruction detection aids in the performance improvement of the office space. Since the majority of false decisions are located in the area of the obstructions, assigning a different threshold to that area can influence the number of wrong decisions during the year. When the sun is behind the obstruction the data point of that given time lies in the obstruction area.

Obstruction isolation

The results from the confusion matrix can be plotted in a sun chart map. A sun chart map can be used as a scatter plot with the solar azimuth and elevation in combination with a value for a certain moment. Figure 3 shows a Cartesian sun chart scatter plot with the results of the south orientated study with a street canyon as obstruction, for a viewing position facing a window at a 45 degrees angle. The plot uses a grid with the solar azimuth on the x-axis and the solar elevation on the y-axis. The grid represents the solar positions as seen from the reference illuminance sensor. It is filtered for a sun elevation greater than 0, meaning only moments when the sun is up. Furthermore, it is filtered for office hours from 08:00 until 17:00. The data points have been separated manually to assess the best-case scenario of isolating the obstruction area and assign a separate threshold to the moments the sun is behind an obstruction. Thresholds for both the obstruction points and free-view data points have been calculated using separate confusion matrices which can then be combined to calculate the results.

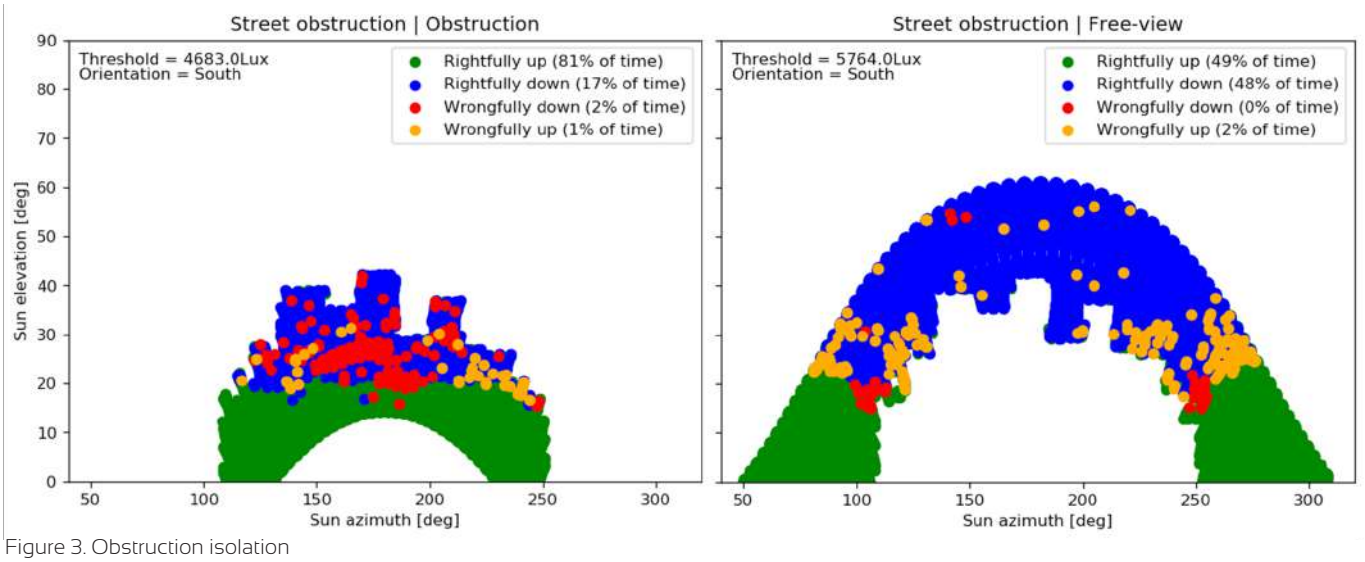


Figure 3. Obstruction isolation

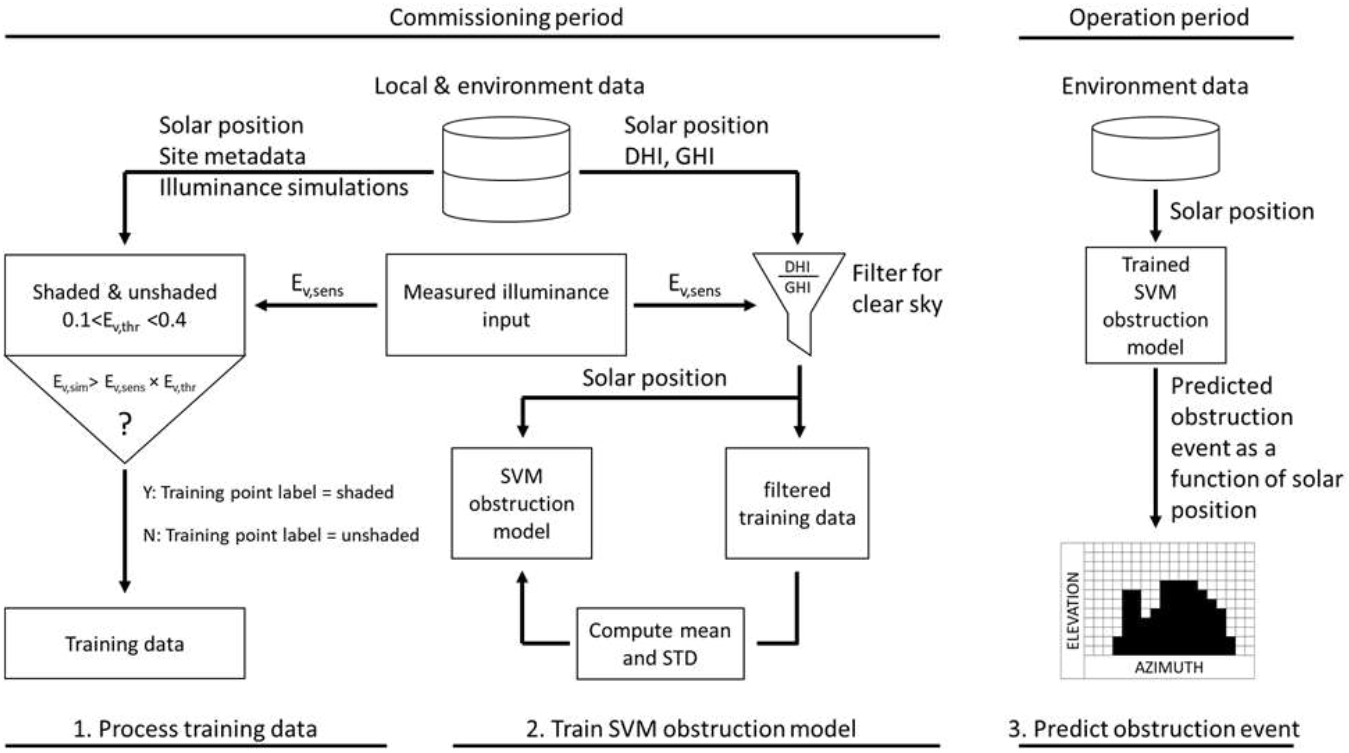


Figure 4. Support Vector Machine obstruction model flowchart

SVM OBSTRUCTION PREDICTION MODEL

In order for the sensor strategy to be unsupervised as projected in the research objective, the process of detecting the obstruction has to be automated. A method inspired by Bógnar et al. [9] is proposed to identify and predict local obstructions as seen from the user space by comparing the measured illuminance to their simulated equivalent and generalizing the results with the use of a machine learning. Illuminance data was gathered from the simulations and post-processed using Python. The obstruction detection model is written in Python and is using the Support Vector Machine (SVM) classification with the radial basis function (RBF) kernel. This is implemented using the Scikit-learn package. A step-wise procedure is shown in Figure 4, where the process is split into two general parts: the commissioning period and the operation period.

Commissioning period

To be able to differentiate obstructions from free-view, local and environmental data is used as input for an illuminance simulation which is then compared with measured illuminance representing operational sensor input. Using historical data allows the model to have a reference for the data to fit to. The data is filtered for the intent of only using moments where the sky is clear from clouds for the training purposes of the Support Vector Machine. If illuminance measured by the photosensor is lower than the in the simulated results on these moments, this is concluded to be caused by an obstruction. Clear sky days are categorized using a clear sky index (CSI), calculated by dividing the direct horizontal irradiance (DHI) by the global horizontal irradiance (GHI). During fully clouded moments, DHI and GHI values are equal. On fully clear sky days, the DHI values are typically between 10-20% of the GHI values. The diffuse fraction is obtained by dividing DHI by GHI. When the CSI is near 1, the sky is fully clouded, values near 0.2 represent a fully clear sky.

For this case, the dataset consists of two features, shaded (+) and unshaded (-) (Figure 5). These data points are used to train the SVM and construct a hyperplane dividing the datasets into two classes. The RBF kernel used to determine the shape of this hyperplane allows for a non-linear soft-margin classification using the *C* and γ parameter. The *C* value allows to disregarding misclassifications by simplifying the decision curve between the two classes. A low *C* results in a smooth decision curve whereas a high *C* aims to classify all training points correctly as shaded or unshaded. The γ value defines how far the influence of a single training data point reaches, with low values for γ meaning 'far' and high values for γ meaning 'low'. The classification takes place on a grid, in this case, a 2D grid using the solar azimuth on the x-axis and the solar elevation on the y-axis. The grid represents the solar positions as seen from the reference illuminance sensor on which the new data points are projected as obstructed (+) and not obstructed (-). Combining all the points classified as obstructed results in the obstruction detected and predicted by the SVM.

Operation period

Once training the SVM is complete, the decision curve can be extracted and used to classify new data points to the (+) or (-) class based on their features and position on the grid. From an evaluation of all parameters that influence the SVM results, the *C* and γ values have the biggest influence on the decision curve. These two parameters have been analyzed more carefully using a range of values applied to the street canyon case.

CONCLUSIONS

This study focused on improving the positive effects of shading control strategies by extracting and utilizing information about the surrounding environment. The results from the confusion matrix for the street canyon case study showed a majority of wrong shading positions in the area of the obstruction, implying obstruction detection has the potential of optimizing the decision making of automated solar shading systems. However, manual obstruction isolation was done to create a best-case scenario regarding obstruction detection. Assigning separate thresholds to the obstructed and non-obstructed data points has no substantial influence on the number of wrong decisions, resulting in a low potential to improve the performance of advanced solar shading systems.

To achieve unsupervised obstruction detection, a method is proposed to identify and predict local obstructions as seen from the sensor position by comparing the measured illuminance to their simulated equivalent and generalizing the results with the use of machine learning. The method consists of two steps: the commissioning period and the operation period. The approach aims to be scalable since it only requires commonly available data from a single photometer with no further need for human intervention. When complex obstructions containing

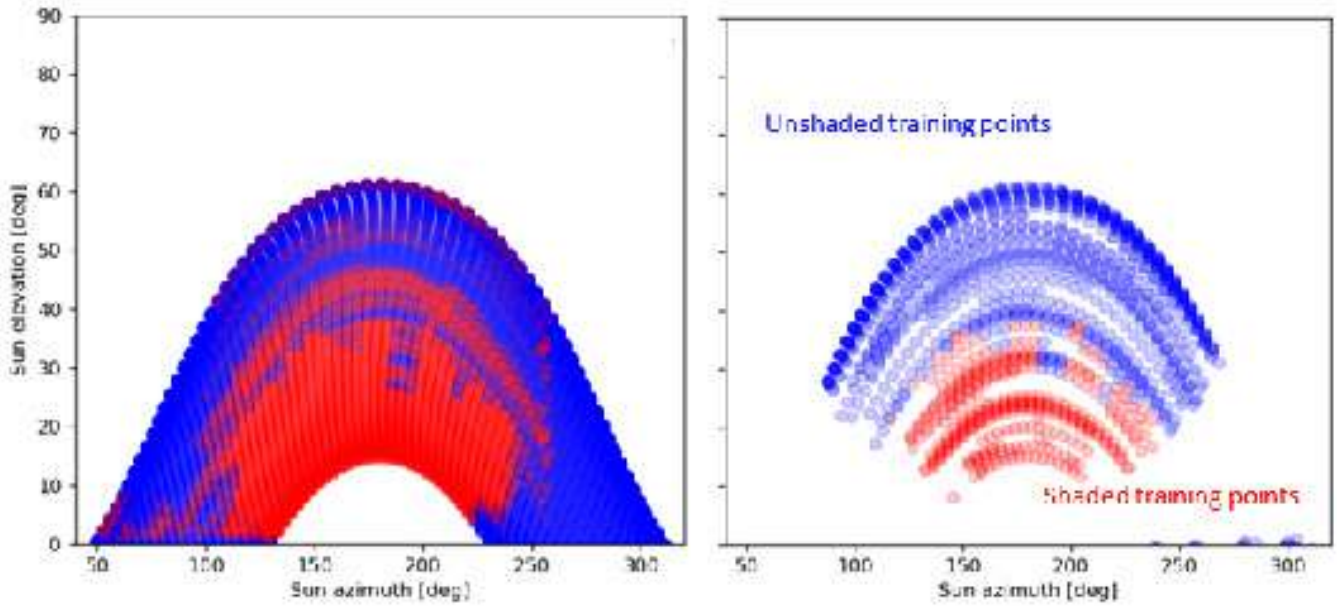


Figure 5. Training data for street canyon case, unfiltered (left) and filtered for clear sky (right)

gaps in between buildings are introduced, the model is unable to predict openings where sun exposure is only partially obstructed, like in the high-rise case study. The accuracy of the method is dependent on the length and start date of the commissioning period. As the prediction is dependent on solar positions, gathering sufficient training data can take up to a year. The obstruction detection model can then be used to assist in predicting obstruction events to aid automatic solar shading systems in their decision making regarding the effects from the urban context.

Using DGPs as a performance indicator for glare during this research has not been the best indicator for the research objective. DGPs has been proven to be a reliable indicator for glare in cases where the sun is not in the direct view of an occupant. This thesis included obstructions that cause rapid changes in solar exposure due to the sun partially being blocked. Sun position discretization in combination with the timestep used are responsible for wrong assumptions. Once the sun is not obstructed, direct sunlight is the main cause of glare, being in the direct view of an occupant. For these situations DGPs is not the best indicator for glare. Additionally, perception of glare can still occur due to direct sunlight being visible through a fabric roller shade, even when not indicated by sensors.

DISCUSSION

A critical look at the SVM obstruction prediction model shows several limitations. The dependency on solar position during clear sky periods makes the model less than ideal regarding commissioning time. The best fitting values for the C and γ have to be investigated for each sensor and case individually, requiring a lot of manual labor. This questions the unsupervised aspect of the research objective as the optimal values for the C and γ are sensitive to the density of training data. Using less data or a different timestep may result in a necessity to re-evaluate the parameter values. Small objects and cavities between buildings cannot be predicted by the SVM obstruction detection model proposed in this research, but are important regarding potential glare conditions. Therefore, an alternative method exploiting LiDAR data to identify smaller objects may be implemented to provide additional information about the surroundings impacting the performance of solar shading systems.

A potential use-case for the SVM obstruction prediction model could be to be a part of a model predictive control system. In a Model Predictive Control system, the model should have an idea of the surroundings. Employing the SVM obstruction model allows the urban context to be detected automatically. Certain sensors are expensive and generally installed once per building or façade, like pyranometers and High dynamic Range sky scanners. These central sensors are unable to predict effects from local shading on the room level. Employing cheap, local illuminance sensors combined with the SVM obstruction detection model, knowledge of central sensors can be combined to make predictions on floor or room level. ■

[1] M. Perino and V. Serra, "Switching from static to adaptable and dynamic building envelopes: A paradigm shift for the energy efficiency in buildings," J. Facade Des. Eng., vol. 3, pp. 143–163, 2015.

[2] S. Y. Koo, M. S. Yeo, and K. W. Kim, "Automated blind control to maximize the benefits of daylight in buildings," Build. Environ., vol. 45, no. 6, pp. 1508–1520, Jun. 2010.

[3] E. S. Lee et al., "A Post-Occupancy Monitored Evaluation of the Dimmable Lighting, Automated Shading, and Underfloor Air Distribution System in The New York Times Building," 2013.

[4] L. G. Bakker, E. C. M. Hoes-van Oeffelen, R. C. G. M. Loonen, and J. L. M. Hensen, "User satisfaction and interaction with automated dynamic facades: A pilot study," Build. Environ., vol. 78, pp. 44–52, Aug. 2014.

[5] I. G. Capeluto, "The influence of the urban environment on the availability of daylighting in office buildings in Israel," Build. Environ., vol. 38, no. 5, pp. 745–752, May 2003.

[6] W. J. Chung, C. Liu, and Y.-B. Seong, "Potential lighting and thermal demand reduction in office buildings using blind control considering surrounding buildings," J. Asian Archit. Build. Eng., vol. 18, no. 3, pp. 262–270, May 2019.

[7] D. Bourgeois, C. F. Reinhart, and G. Ward, "Standard daylight coefficient model for dynamic daylighting simulations," Build. Res. Inf., vol. 36, no. 1, pp. 68–82, Jan. 2008.

[8] M. S. Roudsari and M. Pak, "LADYBUG: A PARAMETRIC ENVIRONMENTAL PLUGIN FOR GRASSHOPPER TO HELP DESIGNERS CREATE AN ENVIRONMENTALLY-CONSCIOUS DESIGN."

[9] Bognár, R. C. G. M. Loonen, R. M. E. Valckenborg, and J. L. M. Hensen, "An unsupervised method for identifying local PV shading based on AC power and regional irradiance data," Sol. Energy, vol. 174, pp. 1068–1077, Nov. 2018.

heijmans

WIL JIJ BIJDRAGEN AAN DE GEBOUWDE OMGEVING VAN NEDERLAND?

Kom dan werken bij Heijmans en bouw mee aan toffe projecten, zoals woonwijken, kantoorpanden, universiteiten en ziekenhuizen. Dit doe je op gave locaties door heel Nederland. Benieuwd wat voor aandeel jij kan leveren aan de ruimtelijke contouren van morgen? Check dan snel **www.heijmans.nl** en volg onze social media-kanalen.

Sweegers en de Bruijn
is op zoek naar jong talent!
Ben jij die nieuw stagiair, afstudeerder, engineer, projectleider of adviseur?

Werk jij graag in technisch complexe projecten en zoek jij goede ontwikkelmogelijkheden passend bij jouw skills en competenties, dan komen wij graag met jou in contact!

- Gezondheidszorg
- Justitie
- Industrie & Laboratoria
- Onderwijs
- Sport / Cultuur / Recreatie
- Kantoren
- Duurzaamheid & Energie
- Exploitatie / Monitoring

INGENIEURS SWEEGERS EN DE BRUIJN

‘s-Hertogenbosch
Europalaan 12g - 5232 BC
Telefoon 088 030 7300
Internet www.swebru.nl

Adaptive building skin solutions

dr.ir. R.C.G.M. (Roel) Loonen
dr. E.J. (Jonathan) van den Ham

Author
ir. A.A. (Afaq) Butt

INTRODUCTION

Most of the mainstream energy retrofit solutions for residential buildings in the Netherlands focus on reducing heating energy demand through extensive use of thermal insulation in opaque building envelope constructions. Notwithstanding the effectiveness of such solutions, there are also several drawbacks associated with the application of thick insulation packages, especially related to materials impact, space considerations, invasiveness of the intervention, costs, and the increased risk for indoor overheating. In this context, the surface properties of opaque envelopes (e.g. coatings) have received little attention. Yet, these surfaces collectively represent a tremendous radiative heat transfer area that can act as both energy source and sink term in the building's energy balance.

Considering the advent and rapid development of advanced materials and coatings [1]–[3] that can dynamically vary solar absorptance and emissivity, it has become increasingly possible to actively manage the thermal interactions between the building its environment. Recent studies have shown the significant potential of various adaptive building envelope technologies in achieving the sustainability goals set for the built environment [4]–[7]. It is, therefore, worthwhile to investigate to what extent such smart building envelope technologies could become an integral part of renovation solutions that are thinner, faster to apply, and more cost-effective over the building's life cycle.

The optimal control of building envelope properties could potentially reduce annual heating and cooling demand. In winters, high solar absorptance and low emissivity would increase solar heat gains and reduce thermal heat losses, while in summers, low solar absorptance and high emissivity would reduce solar heat gains and increase thermal heat losses (illustrated in Figure 1).

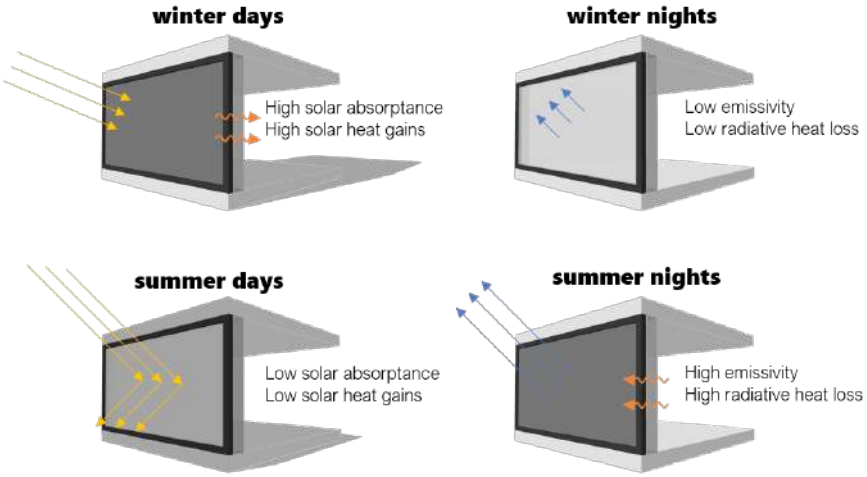


Figure 1. The desired impact of varying solar absorptance and emissivity over the year

However, the development and implementation of such adaptive technologies face numerous challenges. Product development is taxed with developing new products with properties and adaptive controls that guarantee energy reductions for target markets. On the other hand, building developers are confronted with the task of selecting appropriate technologies for application in various scenarios. A major factor contributing to the limited research into adaptive technologies is the complexity introduced by their dynamic nature. Ultimately, optimizing, comparing, and integrating adaptive technologies becomes computationally expensive [5].

METHODOLOGY AND RESULTS

In this PDEng project, we leveraged the advancements in building performance simulation (BPS) and computation to develop a simulation-based multi-objective optimization framework to optimize control strategies for theoretical and state-of-the-art (SOTA) building envelope properties and investigates their potential implementation in the renovation of the Dutch residential sector.

The first step was to develop a model predictive (MP) control of solar absorptance and emissivity varying between theoretical limits to understand the maximum potential of these properties. The annual simulation

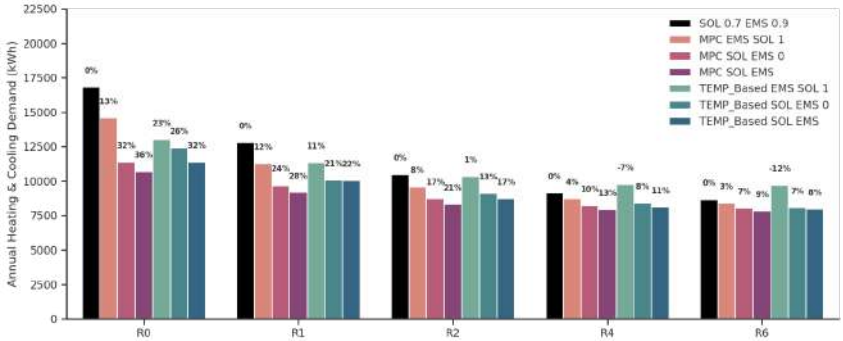


Figure 2. Annual heating and cooling demand for MPC and temperature-based (TEMP_Based) control of solar absorptance (SOL EMS 0), emissivity (EMS SOL 1), and combined coatings (SOL EMS), with percentage energy savings benchmarked against typical properties (SOL 0.7, EMS 0.9), with increasing insulation thickness

period was split into daily simulation horizons and genetic algorithms were used to generate populations of control strategies. The strategies are evaluated and ranked to select the control strategy resulting in the lowest objective cost for the simulation horizon before continuing to the next day. MP control of solar absorptance and emissivity results in a 21% to 36% reduction in heating and cooling demand of low insulated terraced houses (R2 and R0) eliminating the need for high insulation in building envelopes (Figure 2). The MP control was further used to develop an implementable rule-based control using outdoor air temperature as a switching trigger. The temperature-based control delivered 17% to 32% energy reduction for terraced houses (R2 and R0).

The second step involved screening adaptive materials for application in the renovation of Dutch houses. State-of-the-art (SOTA) electrochromic coatings change solar absorptance properties as a response to a variation in an electric field and have high switching ranges (80%), making them an ideal candidate for implementation, however, high initial costs have previously been a barrier against adoption [8]. Therefore, a techno-economic analysis was performed to compare electrochromic coatings with commonly chosen insulation upgrades to provide project developers with insights into implementing these technologies in the renovation of Dutch dwellings. A surface by surface investigation revealed that SOTA-electrochromic coatings obtain the highest energy saving per coating unit area when applied to the south façade due to the higher influence of solar irradiance on that surface.

The application of SOTA electrochromic coatings on the façade coupled with an Rc 1 insulation level results in scenarios with similar energy savings as a Rc 4 insulation level scenario. The temperature controlled SOTA electrochromic coatings on the south façade and R4 insulation on the north façade (S1) captures 95%, while, SOTA electrochromic coating on the south and north façade (S2) captures 86% of the heating savings of an R4 insulated façade with typical surface properties. The dynamic nature of SOTA electrochromic coatings further reduces the cooling demand by 12 to 13%, thereby significantly reducing the possibility of overheating in summer (Figure 3). Based on the net present value of the savings achieved from these scenarios in comparison to an R0 terraced house and the initial cost of upgrading the envelope of the terraced house from R0 to R4 a competitive coating cost per m2 was determined (Table 1). After further development, it is expected that SOTA electrochromic coatings can play a considerable role in the renovation packages aimed at the Dutch residential sector at competitive coating costs. Most notably, SOTA electrochromic coatings can reduce the requirements for insulation renovation in building facades.

CONCLUSION

The adaptive nature of SOTA electrochromic coatings reduces heating and cooling demand, thus reducing the risk of overheating in summer, resulting in a more robust construction capable of adapting to the changing environmental conditions in the future. The thin and modular structure of these SOTA electrochromic coatings could avoid the need for time and space-consuming deep façade renovations typically required in higher insulation interventions. ■

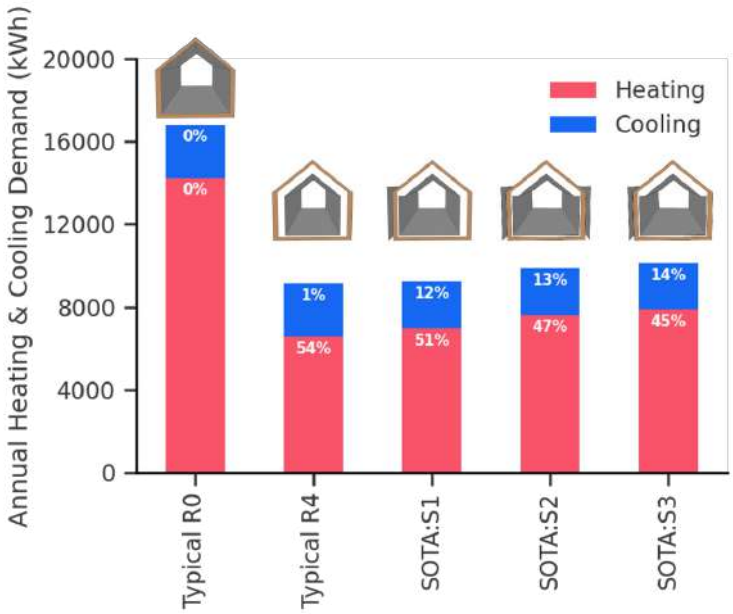


Figure 3. Heating and cooling savings from applying SOTA electrochromic coating (rule-based) on various façade of a terraced house

Table 1. Net present value (NPV) and predicted competitive coating cost (CC) €/m² for S1 and S2, ins: insulation level, Co: static/electrochromic coating, S/T switching temperature.

	South			North			Roof						
	Ins	Co	S/T	Ins	Co	S/T	Ins	Co	Heating demand (kWh)	Cooling Demand (kWh)	IC of ins (€)	NPV (€) i=2%	CC €/m²
T:R_4	R_4	Stat	-	R_4	Stat	-	R_4	Stat	6 549	2 572	10 000	26 977	
S_1	R_1	Elec	14	R_4	Stat	-	R_4	Stat	6 935	2 293	7 900	26 262	41
S_2	R_1	Elec	14	R_1	Elec	14	R_4	Stat	7 598	5 800	5 800	25 018	33

[1] J. Testa and M. Krarti, "A review of benefits and limitations of static and switchable cool roof systems," Renew. Sustain. Energy Rev., vol. 77, no. October 2016, pp. 451–460, 2017, doi: 10.1016/j.rser.2017.04.030.

[2] T. Karlessi, M. Santamouris, K. Apostolakis, A. Synnefa, and I. Livada, "Development and testing of thermochromic coatings for buildings and urban structures," Sol. Energy, vol. 83, no. 4, pp. 538–551, 2009, doi: 10.1016/j.solener.2008.10.005.

[3] H. Khandelwal, R. C. G. M. Loonen, J. L. M. Hensen, M. G. Debije, and A. P. H. J. Schenning, "Electrically switchable polymer stabilised broadband infrared reflectors and their potential as smart windows for energy saving in buildings," Sci. Rep., vol. 5, no. June, pp. 1–9, 2015, doi: 10.1038/srep11773.

[4] R. C. G. M. Loonen, S. Singaravel, M. Trčka, D. Cóstola, and J. L. M. Hensen, "Simulation-based support for product development of innovative building envelope components," Autom. Constr., vol. 45, pp. 86–95, 2014, doi: 10.1016/j.autcon.2014.05.008.

[5] F. Favoino, Q. Jin, and M. Overend, "Design and control optimisation of adaptive insulation systems for office buildings. Part 1: Adaptive technologies and simulation framework," Energy, vol. 127, pp. 301–309, 2017, doi: 10.1016/j.energy.2017.03.083.

[6] Q. Jin, F. Favoino, and M. Overend, "Design and control optimisation of adaptive insulation systems for office buildings. Part 2: A parametric study for a temperate climate," Energy, vol. 127, pp. 634–649, 2017, doi: 10.1016/j.energy.2017.03.096.

[7] R. Evins, "Multi-level optimization of building design, energy system sizing and operation," Energy, vol. 90, pp. 1775–1789, 2015, doi: 10.1016/j.energy.2015.07.007.

[8] D. M. Addington and D. L. Schodek, Smart Materials and New Technologies: For the Architecture and Design Professions. 2005.

Bouw
Ruimte
Milieu

LBP|SIGHT

Bouw | Ruimte | Milieu

ONZE EXPERTISES:

> Bouwakoestiek
> Bouwfysica
> Brandveiligheid
> Duurzaamheid
> Energie
> Gebiedsontwikkeling
> Geluid en trillingen
> Milieu
> Projectregie
> Rentmeesters
> Ruimtelijke ordening

We zijn een **ingenieurs- en adviesbureau** op het gebied van bouw, ruimte en milieu. Met ruim 100 medewerkers zijn we groots in professionaliteit én klein genoeg voor persoonlijk contact en hechte klantrelaties.

Onze cultuur? We werken in een informele setting en vinden het belangrijk dat je het bij ons naar je zin hebt. Dus: vrijheid, verantwoordelijkheid, **uitdagende projecten** met **volop doorgroeimogelijkheden** en aandacht voor de balans tussen werk en privé.

Ook fijn: ons kantoor ligt **op fietsafstand van Utrecht**. Wil je meer weten? Kijk dan op onze website.

STAGE LOPEN, AFSTUDEREN OF WERKEN?

Onze deur staat altijd open voor **stagiairs**, **afstudeerders**, **trainees** en **juniors**. Heb je interesse in een stage of afstudeeropdracht bij ons? Of zie jij jezelf bij ons carrière maken? Bekijk dan onze website voor de mogelijkheden en vacatures! En mail ons gerust: info@lbpsight.nl.

Volg ons en blijf op de hoogte van onze vacatures:

Kelvinbaan 40
3439 MT Nieuwegein
030 - 23 113 77
www.lbpsight.nl

Wij detacheren. We helpen jou bij het vinden van de baan waar jij blij van wordt en helpen onze opdrachtgevers aan de juiste mensen. Tijdens de detachering geven we jou de begeleiding die je helpt je verder te ontwikkelen. We bieden een vast contract, keuze uit elf talentprogramma's, coaching en zelfs een eigen Academy. Dus doe waar je blij van wordt en doe het vooral op jouw manier. Ontdek welke technische baan jouw hart sneller laat kloppen. Kijk op voort.com

info@voort.com | www.voort.com of volg ons op Facebook, Instagram of LinkedIn.

voort

Building a Brighter Future

LBP|SIGHT
www.lbpsight.nl

Author: Kristel van Oldenbeek - consultant at LBP|SIGHT

Not so long ago, sustainability was often hyped, seen as a costly necessity and given limited attention in the building design. Luckily, that mammoth tanker has turned. Nowadays, building equals sustainable construction. When designing and realizing a new building or reconstructing an existing building, attention is required for themes like energy-efficiency, climate proof, nature-inclusive and circular construction and a healthy indoor climate (building physics). These themes are preferably considered from the moment the first designing pen is put to paper until long after the ribbon is cut.

Figure 1: Ten building blocks

THE IMPORTANCE OF SUSTAINABILITY

Sustainable development means meeting the needs of the current generation without endangering the needs of future generations. With the current challenges we are facing, such as climate change, exponential population growth, loss of biodiversity and depletion of raw materials, sustainability has become more and more important over de course of the last decades. Consequently, it is now an essential theme in spatial development. Sustainable construction, in turn, is an indispensable link in the development of urban and industrial areas. This translates to constructing and using buildings in such a way that damage to people and the environment is limited as much as possible in all construction phases.

"Our goal for sustainable spatial development and construction is creating healthy, clean, safe and pleasant places to live, work and relax. For current and future generations. And doing so in a way that's affordable and preferably profitable." - Kristel van Oldenbeek, consultant at LBP|SIGHT

TEN BUILDING BLOCKS

The number of requirements and ambitions regarding sustainable development are growing each day, from government agencies, developers, building owners and from society as a whole. Moreover, there is an urgent call from stakeholders to include sustainability in an integral way from the very first idea or design. Each area and building is unique and requires a different approach when it comes to sustainability. Therefore, we created ten building blocks to make spatial development and building sustainable in a smart, innovative, affordable and integral way (Figure 1).


Figure 2: NPD-site Utrecht

NPD-SITE UTRECHT - REALIZING HIGH AMBITIONS

The NPD-site is a former business location of the Dutch Package Service in Utrecht. Here, a unique project 'DeBuurt' is being developed for healthy urban living, working and relaxing. An impression of this project can be found in Figure 2. LBP|SIGHT is involved in this project as a consultant on sustainable construction. The ambitions were high (for example EPC -0.02 and GPR 8.5) and we were closely involved in the process to realize these ambitions. Our advice comprised several of our building blocks and contributed to:

- Well-being (building physics): Healthy buildings with optimal sound insulation, external sun blinds and a high-quality ventilation system.
- Energy: The realization of a future-proof energy concept, including measures such as optimal insulation, aquifer thermal energy storage, solar panels & heat recovery from ventilation.
- Water & soil: A climate proof neighbourhood with green areas to reduce heat stress and minimal

paving to optimally make use of the infiltration capacity of the soil.

- Materials: A circular development in which the amount of needed material was minimized and materials with a low environmental impact were chosen for buildings and outdoor areas.
- Building: Flexible buildings that can be easily transformed for different functions, for example by realizing floors and roofs with high load-bearing capacity and by integrating movable walls.
- Biodiversity: A nature-inclusive neighbourhood with a diversity of plants and green facades.
- Mobility: A neighbourhood that stimulates sustainable modes of transport: with accessible indoor parking spaces for bikes and shared parking spaces for cars and car-sharing facilities.

"With the entire design team, we ensured that high ambitions on both sustainability and design have become reality. I am really proud of that!" - Michiel Hagenouw, senior consultant at LBP|SIGHT

NDSM-WHARF - ICONIC AREA WITH A UNIQUE HISTORY

The NDSM-wharf in the city of Amsterdam was one of largest and most modern shipyards in the world. The wharf is being transformed from a raw industrial site to a modern neighbourhood with possibilities for living, working and recreation. As a consultant on sustainable construction (including building physics) LPB|SIGHT is involved in several projects on the NDSM-wharf.

In the last century, mammoth tankers were constructed in the 270 meters long Kraanspoor building. An impression of this building is found in Figure 3. Today this historical landmark serves as a unique and award-winning office building: Kantoor Kraanspoor. Instead of tearing down the old building, we advised on a more circular approach: restoring the building, giving it a new office function and preserving as much of its historical value as possible. We suggested a lightweight steel construction for the building, with lots of glass and limited use of materials, thereby leaving the original crane track completely intact. Furthermore, to guarantee well-being of office workers, we opted for active cooling of floors and ceilings in order to maintain a healthy and pleasant indoor climate. This resulted in a heat pump with the water from the IJ as the source for thermal energy. The building now has infraplus floors, a glass facade and facade convectors. Pipes for cooling and heating are incorporated into the thin concrete shell of the floors.

Figure 3: Kraanspoor NDSM-wharf

"I love how the NDSM-wharf is transforming from an industrial site to a unique domestic area with attention for sustainability and the well-being of residents, without losing its raw and open character. It's great to be part of that!" - Sara van de Valk, Consultant at LBP|SIGHT.

LAURIERKWARTIER LEIDSCHE RIJN - HEALTHY AND CIRCULAR RESIDENTIAL BLOCK

Laurierkwartier (Figure 4) is a new residential block in Leidsche Rijn. It is a sturdy and robust building with a unique character and industrial look. LBP|SIGHT was involved in this project as a consultant on sustainable construction (including building physics). Our advice has contributed to the realization of:

- Biodiversity, Water & Environmental quality: A nature-inclusive and climate proof block. The beautiful green courtyard is an inviting place where residents can relax and interact with each other, work in the vegetable garden or exercise. The green courtyard also contributes to more biodiversity, reducing heatstress, waterbuffering and a better air quality.
- Well-being (building physics): Buildings with a healthy indoor climate, by integrated solar shading to reduce heat stress, both by architectural overhangs and screens.
- Materials: A circular residential block with shared facilities, thereby reducing material use. Furthermore, materials with a low environmental impact were chosen: wood as a renewable material for the building and recycled materials for the inner garden.
- Building: Flexible buildings, wherein the layout of the houses can be easily adjusted or extended to the wishes of the residents by using timber-frame-construction elements.
- Energy: The highest possible ambition regarding energy (EPC<0). For example by finding the right balance between daylight and architecture (preference: a lot of glass) and a minimizing the energy demand (preference: as little glass as possible). Furthermore solar panels were installed on the roof.

Figure 4: Laurierkwartier

"Our ambition is to develop a sustainable and pleasant living environment. This environment will be realized in a circular manner, with a green courtyard that promotes biodiversity and provides plenty of space for meeting, playing and relaxing." - Tijmen Hamerslag, AM (projectdeveloper).

SUSTAINABILITY: A DYNAMIC AND CHALLENGING PROCESS

Sustainability is a dynamic process which is characterized by a rapid succession of innovative solutions. A great challenge in which we enjoy playing our part with creativity and responsibility! Feel free to contact us if you want to build a brighter future together! ■

Alumni at Work
Marissa Vos

Hi, I was asked to give you some insight in my life after TU/e. So for those who don't know me, my name is Marissa Vos. I live, after spending 8 years in Eindhoven, in Utrecht nowadays, but grew up in the wonderful city of Grijpskerke. You probably never have heard of it as it is just a little place near Middelburg in Zeeland where people only go for a nice Dutch holiday. I studied at TU/e for 6 years of which I was active at s.v.b.p.s. Mollier for the last 3 years of my study. Currently I am 26 years old and living together with my girlfriend and two Russian cats in a nice neighborhood called 'Lombok'.

It actually took a while before I decided to start the bachelor 'Architecture, Building and Planning' on the TU/e. I have a very broad interest and combining design with technical features seemed the best combination after considering about 15 other studies. However, when I started I never wanted to become an Architect and liked the more technical side of building engineering. So eventually I chose the track for building physics and after 3 year of studying, I started my master Building Physics and Services.

21st Board of s.v.b.p.s. Mollier

Very happy Christmas picture of the 21st board

End Activity in Köln

At that moment I didn't even know that s.v.b.p.s. Mollier existed, as I knew only a few persons within the whole master track. Eventually this was exactly the reason why I signed myself up for the start activity after which I started to get involved with the nice atmosphere of our study association and ended up in the 21st board the year after. We were also known as the 21th board as we made that mistake quite some times, even once on the front page of the insight. I was the 'secretary' and 'commissioner of education' that year, which was truly the best decision of my master. We organized loads of nice activities, visited companies, drank a lot of beer and eventually went on a study trip to Seoul.

After that year I started to think about my graduation project. I had been triggered by wind nuisance and Computational Fluid Dynamics (CFD) in my bachelor studies and really liked the wind turbine project within the CFD master course. At that time I worked part-time within the building physics and energy department at the consultancy firm Deerns and was mostly interested in heat, air and moisture as well as in energy saving.

So, eventually I started my graduation project in the optimization of vertical axis wind turbines within CFD, which perfectly matched my interests at that moment. However, as I have quite a broad interest in different topics and constantly like to challenge myself, I didn't end up working in CFD.

Instead, I started working as a mechanical engineer at Royal HaskoningDHV. Here, I started at multinationals in Eindhoven where I worked on a lot of projects for industrial clients, ranging from breweries and cleanrooms to warehouses and office buildings. My main focus was on building services, utilities and energy saving for which I was responsible in large projects situated all over the world. I particularly did a lot of energy and concept studies and worked together with all disciplines in the built environment. The company really suited my needs after graduation as I was able to do the "post-hbo luchtbehandelingstechniek" and got a lot of chances to develop myself next to normal work. At young RHDHV I organized the international cross selling day, which is a large event for more than 300 international colleagues from over the world. During this event young professionals are able to network with each other and follow different workshops and innovations within the company. This really enabled me to build a network and was a nice way to continue developing myself after my study. Additionally, working at RHDHV was especially nice as I was constantly working together with old Mollier members which makes projects truly more fun.

Recently, I changed jobs and started to continue my career at ASML where I work as competence manager HVAC & Cleanroom Systems. My job entitles the optimization of the highly critical HVAC and Cleanroom Systems of ASML while managing all relevant risks and looking for opportunities to reduce energy consumption. Within this function I have a more strategic job in which I have to setup the master utility plans for both our local and global sites in the very dynamic semi-conductor industry. My focus is mostly on the performance, life cycle and sustainability of the systems, although I am also involved in quite some new built and renovation projects in Veldhoven. Within my current job I actually still do a lot of energy and concept studies, although the analysis is now based on actual data and the implementation has a direct result for the reliability and risks encountered in our assets. This entails a lot of new challenges and gives me the opportunity to get more insight in practical issues with regards to reliability, maintenance and risks.

International Cross Selling Day Committee at Royal HaskoningDHV

Currently I benefit a lot from studying Building Physics and Services. As I worked in both building physics and building services I especially experience the dependency of building physics on HVAC systems and vice versa. I apply a lot of the gained knowledge during my studies in my work, but mostly I apply the multidisciplinary thinking approach gained at university. Naturally, you have to learn all practical stuff related to both building services as building physics during your job. Sometimes, this might seem challenging, but it gives a lot of opportunities within your career as well.

That's enough about me for now. I hope you liked the story and if you want to connect or have any questions please feel free to send me a message. I am always in for a nice talk, a cup of coffee or a beer and as COVID-19 is slightly going to a better position you might even see me on one of the Mollier or Schoone Leij activities if they are back in place. ■

International Cross Selling Day Committee at Royal HaskoningDHV

23 FEBRUARY - 8 MARCH - 9 MARCH
11 MARCH - 14 MARCH

2022

BOUWKUNDE BEDRIJVEN DAGEN

fb.com/Bouwkunde.bedrijvendagen

@bouwkunde_bedrijvendagen

bouwkundebedrijvendagen.nl

info@bouwkundebedrijvendagen.nl

Would you like to work at PEUTZ

Peutz is an independent engineering company with an excellent reputation, thanks to the high quality of our work. New colleagues must have a solid theoretical knowledge. Because we have our own vision on many aspects of the fields of expertise, we will train you on the job to become a real Peutz employee. Would you like to work with the best people in your field of expertise? Please visit www.werkenbijpeutz.nl for our vacancies, internships and graduation projects in Eindhoven, Groningen, Mook and Zoetermeer.

acoustics
building physics
environmental technology
external safety
fire safety
flow technology
lighting design
machine learning
noise control
physics of the urban design
spatial planning
sustainability
vibrations control
working conditions






eindhoven – groningen – mook – zoetermeer – düsseldorf – nürnberg – dortmund – berlijn – leuven – parijs – lyon

Urban Layers: Towards an Integrated Urban Analysis and Design

Dr. Lorenzo E.M. Lignarolo
Building Physics specialist at ABT

While space in cities is becoming a scarce resource, the importance of the quality of the physical urban environment is more and more evident. Vibrant and inclusive districts have been associated with higher quality of living and innovation potential. Districts that promote outdoor activities with good outdoor comfort, air quality and green spaces can boost the health and productivity of the inhabitants. Areas where special attention is given to an efficient use of energy and water and to a reduction of urban heat island effect are proven to be more resilient and future-proof. However, given the extreme complexity of the urban system and its metabolism, all the above mentioned aspects are intertwined with each other, therefore an integrated approach is required. When it comes to process management, the communication with stakeholders plays a key role to achieve a high quality urban development and it has been always a challenge. Last but not least, sparse and often inconsistent norms and policies largely lack a holistic vision about the urban environment, not stimulating and often preventing urban innovation.

In early 2020, ABT elaborated the idea that having a tool able to quantify the quality of an urban project with facts and evidence, without complex engineering calculations could facilitate this process and the communication among stakeholders. Oosterhoff Group (the holding ABT is part of) started the project Urban Layers as part of the Quake innovation center. The aim of the project was to tackle the above-mentioned issues by developing a computational tool that will assist decision makers and design teams with an integrated analysis and evidence-based evaluation of the physical urban space. The tool was envisioned in the form of an online platform, where urban designers, engineers, developers, investors and municipalities will be able to generate virtual scenarios of districts and cities and to assess the quality of an urban project in different aspects and reveal a deeper correlation between different aspects or disciplines of the urban design.

Urban Layers was designed as multicriteria, modular and agile. *Multicriteria:* it addresses several technical aspects of the urban space at once, like energy networks, urban water management, connection with physical, environmental and anthropological context, comfort of outdoor spaces, mobility, costs and value of land, data strategies, etc.: these were mainly technical aspects (which can be based on science and evidence), but the idea was to keep Urban Layers open to be extended also to issues in the social realm. *Modular,* because composed by several independent calculation engines, each of which addresses one of the above-mentioned aspects (e.g. the energy module calculates the total energy consumption of a district, while the comfort module simulates the local microclimate). Each module has separate inputs and separate outputs from the others; however, some modules can be interconnected, i.e. the outputs of a module are the input of another. *Agile,* because Urban Layers provides analysis results in real time and is based on a light calculation method. Instead of deterministic calculations and simulation algorithms, it makes use of available data and machine learning.

In 2020, the project started with a goal to create the first module (the Energy Module for aggregated district energy calculation) and to integrate it into an online framework in which other modules would be integrated as well later on. However, both due to some technical difficulties and because of the urgent need to test the tool in the market, we shifted our strategy to working with prototypes of modules in different offline platforms (e.g. Power BI and Grasshopper) and test these in the market with workshops with clients and by applying them in commercial projects. The development of the integrated tool (including the GUI and a middleware to exchange data among modules and with the GUI) is reserved for later and will start no earlier than 2022 depending on the results of the module prototype implementation phase. Currently, the Urban Layers consists of the Energy module, the Site-Scan module, the Urban Comfort module, the Mobility module and the Water Management module. These modules are also schematically visualized in Figure 1.

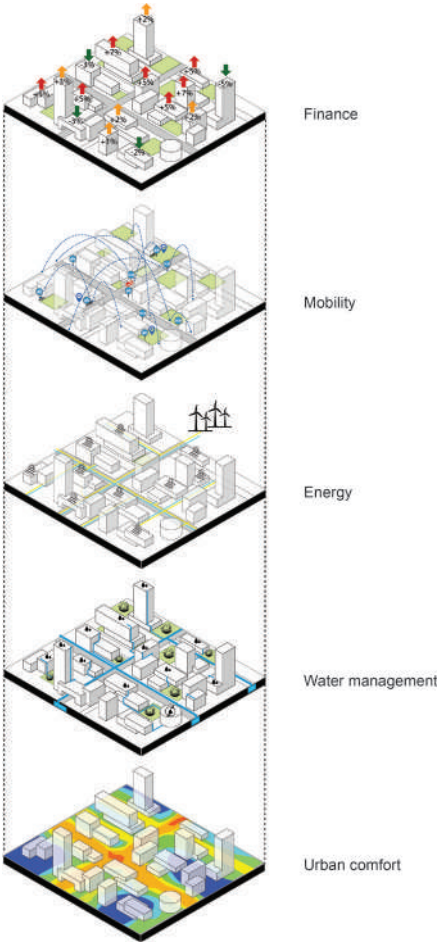


Figure 1: Schematics of some of the "layers" calculated in the software.

ENERGY MODULE

It can calculate the aggregated, hourly energy demand and consumption for a year of different groups of buildings (clusters) after defining the building functions (offices, retail, houses, etc.) and the energy systems (mixes of energy technologies like boilers, ATES, heat pumps, etc.). The tool shows results with several graphs in real time while the user changes the input. The Energy Module does not perform any simulation,

but is connected to a large database of average, normalized hourly energy profiles per each building function: the aggregated energy demand is calculated based on such database in real time. The Energy Module is currently in its beta version and entirely developed in Java Script.

SITE-SCAN MODULE

Developed in PowerBI and MapBox and currently in its beta version, the Site-Scan Module visualizes and processes a series of geolocalized data (currently only in the Netherlands). The tool makes quick scans of the existing situation of project sites and provides necessary inputs to the user. An overview of the data stored in the Site-Scan module can be found in Figure 2.

In the future, the tool will be used to directly provide data to all the other modules. At the moment, the module can collect information about the year of construction, building height and ground-floor area, energy labels and function of all buildings in a selected area. By elaborating this data and using the same algorithm of the Energy Module, the Site-Scan Module estimates the aggregated energy demand profile of the selected buildings. The module will be expanded for working with more geolocalized datasets, for instance local mobility, recorded urban heat island effect, noise levels, etc. The tool is already being used in commercial projects, specifically in collaboration with Gemeente Zwolle for the development of a large district heating grid.

URBAN COMFORT MODULE

The objective is to create a tool that is able to calculate in real time the distribution of wind speed, heat stress risk, solar access and noise levels in the public spaces. In order to achieve real-time speed, any form of simulation is avoided. For this reason the tool uses machine learning. A first experiment has been successfully completed, in which a Machine Learning algorithm has been trained with the results of Computational Fluid Dynamics (CFD) simulations: the algorithm calculates in a fraction of a second the wind speed at pedestrian level around a simple group of buildings. The plan is to run a much larger number of CFD, noise and sun simulations on a larger number of urban geometries and train the algorithm with the results. A tool able to generate infinite variations of urban geometry has already been developed and it works.

Figure 2: Site-Scan module: collection of information from the existing building.

MOBILITY MODULE

The prototype is developed in Grasshopper. A 3D map of an area can be directly downloaded from the open data platform, which includes layers of both buildings and infrastructure together with their functional data. By simulating the 10min walking range from essential amenities (shops, restaurants, schools, post offices, pharmacies, parks, etc.) the tool calculates the "walkability" score of a particular neighborhood, as visualized in Figure 3. Similarly, the Mobility Module can also calculate the risk of car traffic congestions in specific locations. In this way, the tool can be used to anticipate the consequences of adding a new amenity or a new pathway in a neighborhood or to give suggestions to improve the distribution of certain amenities.

Figure 3: Mobility module: calculation of the street network within 15 min walk from a specific amenity.

WATER MANAGEMENT MODULE

It calculates the water run-off from a groups of buildings and the adjacent surfaces. It analyses differences between the current and planned situation in the development area. The increase of hard surface of the built area increases the water runoff in case of rain event, leading to higher load on the sewage infrastructure. A local water management strategy is needed. The tool calculates the required local water storage capacity according to LEED, BREEAM and local Planuitwerkingskader (PUK). It evaluates different low-impact measures such as gutters, infiltrations strips, bioswales as strategies for reducing the required local water storage capacity. It evaluates the impact of design choices such as surface cover, roof-types on water run off capacity.

The final goal remains to create a platform that would allow not only Oosterhoff Group, but also third parties to easily connect, collaborate and share knowledge and data. With Urban Layers we plan to smoothen the communication between different stakeholders and the decision making process, offering an integrated, evidence-based view on several aspects of urban projects. By avoiding extensive and costly engineering studies, Urban Layers will allow science-based decisions already in the very early stage of the urban design. Municipalities and designers will be able to elaborate urban visions based on data which normally are too complex to elaborate in early design. In turn, this will allow a more effective urban design and more certainty in meeting sustainable development goals. Urban Layers is still under development: therefore Oosterhoff Group and ABT are actively looking for bright minds willing to contribute to the project and, of course, concrete urban case studies to show its potential. ■


Photo Fernando Guerra FG+SG

Building ambitions

Do you want to work on leading projects in an organization where development and innovation are of paramount importance? Together with our clients and partners we develop the buildings of the future!

We work on projects that matter. Think of the largest courthouse in the Netherlands: Amsterdam Courthouse. The integral project was realized for Rijksvastgoedbedrijf by consortium NACH (consisting of Macquarie Capital, DVP, KAAN Architecten, Heijmans, Facilicom and ABT). The new sustainable, future-proof and safe Amsterdam Courthouse exudes approachable authority as a stately yet inviting institution for public discourse.

Knowledge development
What characterizes us is our curiosity, our eagerness to learn and our passion for technology. ABT invests in knowledge development and innovation. Building envelope engineering, BIM, concept development, computational design, refurbishment, parametric design and AR: we apply it all in our projects.

Building zero impact
With all the engineering disciplines under one roof, ABT can offer - through our integrated design approach - an optimal mix of sustainability measures in the field of energy, water and materials. The result is a healthy building for the user.

Working at ABT?
Looking for a challenging internship or graduation assignment? Or ready for your first step after your graduation? We are happy to get to know you and curious to see if you are the perfect fit for our team in Delft, Enschede or Velp (Gld.).

Find our current internships, graduation topics and vacancies at werkenbijabt.eu. We look forward to your application.

Lustrum Symposium

Authors
ing. N.H. (Nora) Kuiper
ing. J.J.C. (Jesper) Priester
ing. M.M. (Maud) Staassen
ing. B. (Brent) Wiebes

INTRODUCTION

This year Mollier celebrates its 25th birthday and with that comes the 5th Lustrum. The opening activity was the Lustrum Symposium, that took place in the afteroon on the 16th of March. The whole event was streamed live from Blauwe Zaal in TU/e's own Audtitorium. To make the event as interactive as possible, the audience from home was treated with a goodie bag. This custom linnen bag, of course purple, was filled with drinks, snacks, specialist literature and merchandise, offered by our lustrum partners. To make it even more interactive, the audience had the opportunity to ask questions to the speakers. In this article, you can find a recap of all speakers of the Lustrum Symposium.

WELL BEING, PERFORMANCE AND HEALTH

The first speaker of the symposium was dr. ir. Marije te Kulve, lighting and indoor climate specialist at bba binnenmilieu. bba binnenmilieu is a part of the company DGMR and focuses on the indoor environment; indoor air quality, thermal comfort and light. At this moment, they are conducting research about the COVID-19 virus where the large majority of infections takes place indoors (96,1%) (Figure 1). bba cooperated with Fieldlab to test how to organise a safe event with so many people. They did an experiment at the Ziggo Dome, where they monitored the CO2 concentration in the room to see if it is generally safe in terms of arousal transmission. They also did an experiment at rehearsals of singing because during singing people producing a lot of small particles, so the chances of infection are much higher when singing compared to talking slowly. They are currently working on a research in sports environments because of the production of particles during high intensity training and heavy breathing. Other than these events, long exposure is also a topic that needs investigation, so they also do research within a shipping company and long term care facilities.

Marije also spoke about their expertise in healthy buildings, which includes the influence of a building on productivity, comfort and health. Not only is it important to have healthy buildings in the sense of the wellbeing of people, but it also has a big influence on the revenues of companies. Less sickness absence and more productivity are factors that for certain need to be taken into consideration when (re-)designing a building.

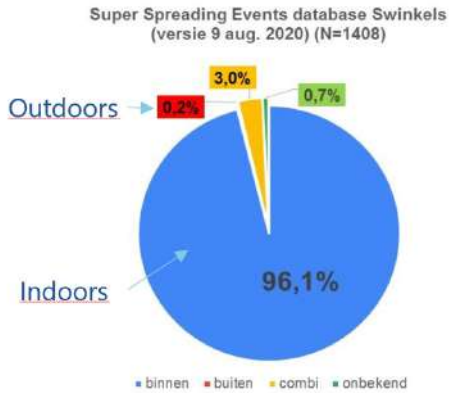


Figure 1. Super Spreading Events database Swinkels, version of August 9th with N=1408

THE RISE OF INTERNET OF THINGS IN THE BUILDING ENVIRONMENT

The second speaker of the day was Joshua van den Heuvel for Johnson Controls. His presentation is on the role of Internet of Things (IoT) in the Built Environment, especially within the optimization of building performance. IoT describes the network of physical objects "things" that are embedded with sensors, software and other technologies for the purpose of connecting and exchanging data with other devices and systems via the Internet. IoT has been developed since 1982, starting with the connection between a coke vending machine and a toaster. The term "Internet of Things" was first introduced in 1999. Today, over 30.3 billion devices are connected with IoT.

We live in a country where most (office) buildings already have a Building Management System (BMS). The systems in these buildings are considered 'operational' (Figure 2). The sensors in the building and schedules of the BMS are often not well connected, so not used to their full efficiency. By improving the connection, the efficiency of the BMS can be improved. The ultimate goal is a "self-thinking" building that is predictive, insightful and can adapt itself to the user of the building. This can be achieved with machine learning, based on model-based mathematical optimization. Johnson Controls uses four steps in performance optimization, starting with proper equipment models. A system of equation will then be used to formulate predictions and finally to optimize the performance. The different steps are assessed based on their effect, whether one approach deserves a reward or a penalty. This assessment will lead to a better performance.

Figure 2. The evolution of buildings

In the future, it is expected that IoT becomes more and more prominent in the Built Environment, especially for office buildings. The capabilities of the technologies are expected to double, while the costs halve. This will lead to an overall better performing Built Environment.

LCA, CIRCULARITY & ENVIRONMENTAL PERFORMANCE

LBP|SIGHT is an independent consulting and engineering firm. René Kraaijenbrink graduated in mechanical engineering and industrial ecology and focusses on life cycle assessment (LCA) in the built environment (Figure 3). LCA becomes more important in the building industry because of the fast, global depletion of raw materials and environmental impact on nature. In the Netherlands shadow cost is a principle that is used in LCA to prevent the environmental effects. The question arises, what would it cost to prevent the environmental impact of a product, or what does it cost to reduce this impact as much as possible.

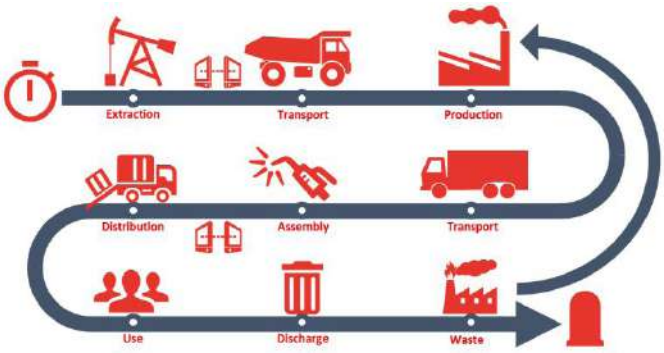


Figure 3. Schematic on the life cycle of a material

For new, non-private building permit applications, an MPG calculation in Dutch (milieu prestatie gebouw) is required. Data used for this calculation can be found in the National environment database. LBP|SIGHT uses the LCA as a method next to other strategies like eco design strategies R-model of circularity to advise there clients as good as possible. René is sceptic about some approached that are taken in the re-use and recycle phase at the end of a life cycle of products and improvements can still be made at this stage. A second eco-design strategy is the value hill of a product. Increase the value of a product or prevent the value loss of a product. Comparison these methods to LCA have led to different ways of thinking, is our product the best? Do we need the product, or can we use something with a lower environmental impact? Quoted by Buckminster Fuller "Do more with less".

THE ADDED VALUE OF BIOBASED MATERIALS

From the Centre of Expertise Biobased Economy (CoE BBE), Willem Böttger enriched us with a presentation on bio-based building. Bio-based engineering goes way back in history: before the industrial revolution, mainly organic materials were used as building materials. These buildings had a much lower CO2 and energy footprint than the buildings of today. Besides the footprint of today's buildings, the building industry has also been thoroughly using up raw materials, resulting that as of today, the list of critical raw materials (CRMs) is now consisting of 31 CRMs. A third problem with the building technology of today, is the mixing of raw materials, making it difficult and very energy intensive to reuse or recycle the different elements. It is therefore interesting to take a step back and seek the potential in bio-based building.

The focus of the research group Biobased Building is on research into the properties of bio-based materials, both technical and aesthetical. Technical aspects include their strength and stiffness, acoustical properties, thermal insulation properties and whether they are anti-bacterial (Figure 4). CoE BBE also researches the market for bio-based buildings, trying to obtain a lower cost price and giving the properties of bio-based materials and buildings an economic value. Some examples were given, with a focus on fiber reinforced composite materials. Fibers (e.g. flax or hemp) give a material its strength, a binder (e.g. bio-polymer, $CaCO_3$ and mycelium) keeps the fibers together. Bio-based additives give extra value to the material. Despite the mixing of materials, circularity of the ensured by only using bio-based raw materials.

Figure 4. Strength testing of the bio composite bridge, a project that was done together with the TU/e

According to CoE BBE, bio-based building has the future. It is not only about (re-) designing products and buildings, but also about redesigning materials, law's, taxes and economy. They will continue developing new bio-based materials, that will contribute to a sustainable future.

CREATING HEALTHY LIGHTING CONDITIONS

For the field of Lighting Mariëlle Aarts of the building lighting group was next to take on the stage. Her talk was on Creating Healthy Lighting conditions in two different application areas namely offices and hospitals.

Light is perceived via the visual pathway via rods and cones but there is a second non-image forming pathway. Via the iPRGC's, the so called intrinsic photosensitive ganglion cells, light follows the path via the suprachiasmatic nucleus and the pineal gland. This is a process regulator like the biological clock via via endocrine processes (hormones). Since all light quantities are related to the spectral sensitivity of the cones, new ways to describe and to measure light are needed to communicate and study these non-image forming effects.

Within companies staff costs are typically a dominant factor and it therefore beneficial to look at the workers. This way they are healthy, satisfied and productive which is all beneficial for the company itself. Alertness is a factor that is mostly linked to tiredness and productiveness. Differences in surroundings, type of work and personal make large differences in subjective alertness of office workers. Via a field study it was found that personal lighting conditions were influenced by: fixed and flexible personal characteristics, time management and office characteristics. The last two are changeable by the office worker him/herself by going for a walk or opening the curtains. Even though all was not in line with the hypotheses (Figure 5), results show that there are lot of different individual differences. Moreover there is an importance of light exposure and its duration.

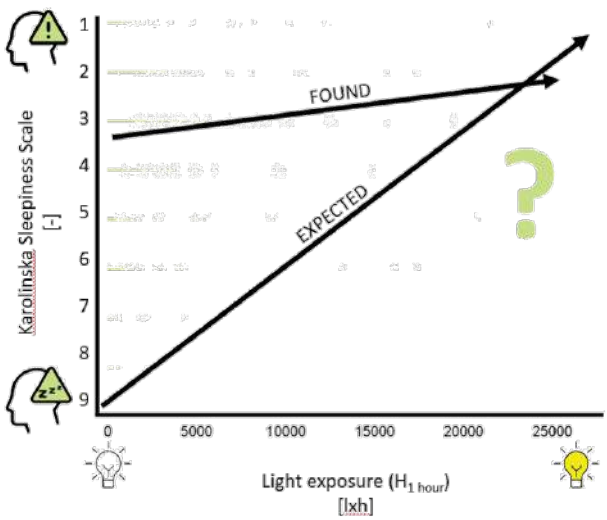


Figure 5. The effect of light exposure on the Karolinska Sleepiness Scale

IMPORTANCE OF ROOM ACOUSTICS & ACOUSTIC MATERIALS IN THE BUILT ENVIRONMENT

Bram Botterman, alumnus of Mollier and founder of Matude started his company one year after graduating in BPS at the TU/e. Matude, Part of the Legit Forum Group focuses on parametric design in predicting sound absorbing properties, consultancy in room acoustics and creating acoustic materials. The sound absorbing properties of a material can measured in a reverberation room what gives a standard result, but what happens when the parameters of the material chance? In his graduation project he conducted research into the most used material about characterizing, modelling, and optimizing the sound absorption of the wood wool cement boards (see INSide Information, December 2015).

After his graduation he also worked with Anne Struiksma (TU Delft) on a project where they experimented with perforated, sound absorbing glass as a transparent acoustic solution for monumental buildings. The common sound absorbing materials block the view where in for example a church, this not desired because of the visual experiences in the building. The panel consists of one micro perforated panel and a solid panel with an air cavity between the two panels. This product could actually be a new solution for the market. However, due to the high production cost of the glass panels, production has not started yet.

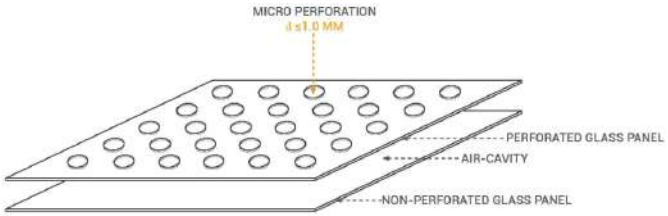


Figure 6. Buildup of the sound absorbing glass panel

For the future of room acoustics, the focuses on the sustainable and circular acoustics materials increases. The use of natural materials and the use of waste products like plastic bottles increase in popularity to minimize the ecological footprint. Innovation in this department is increasing at a rapid rate. It was therefore that the presentation was concluded with three important messages: pay attention to the room acoustics while designing a project; pay attention to the different parameters; and make the right environmental choices.

With the presentation by Bram Botterman as the closing presentation, the first official Lustrum event came to an end. With this article, the Lustrum Committee hopes to have triggered your interest in the presentations. It is possible to view back the Lustrum Symposium via the YouTube stream. If you did not purchase a ticket yet, you can still buy the link to the stream via our webshop.

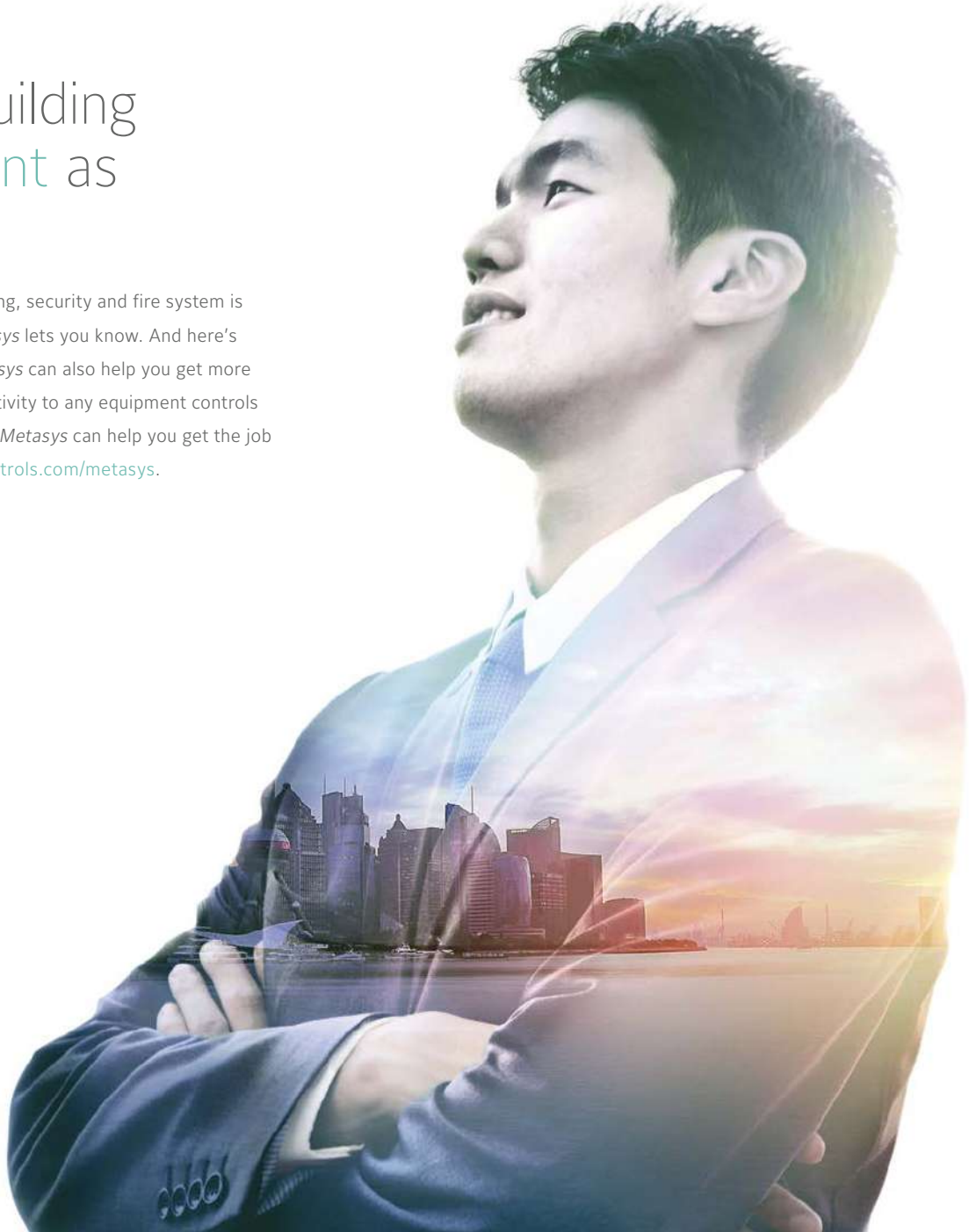
We would like to thank all our speakers once more, and also in particular our lustrum partners bba binnenmilieu, Johnson Controls, LBP|Sight and NVBV for making the event possible.

We hope to see you all soon at our future events: the Lustrum Party on the 9th of September and the Lustrum Gala on the 19th of November! ■

Why can't a building be as intelligent as its occupants?

Metasys® checks that every HVAC, lighting, security and fire system is functioning as it should. If it's not, *Metasys* lets you know. And here's something else that's really smart. *Metasys* can also help you get more from your investment with open connectivity to any equipment controls system. Just one of the innovative ways *Metasys* can help you get the job done. To find out more, visit johnsoncontrols.com/metasys.

METASYS®
MASTER YOUR ENVIRONMENT.



Johnson Controls

Comparison of Two Room Acoustic Parameter Measurement Methods

ir. C. (Constant) C.J.M. Hak
M. (Michail) E. Terzakis, MSc

Author
X. (Xueying) Guan, BSc

INTRODUCTION

In this study, the ISO 3382-1 acoustic parameters measured with two measurement methods are compared and discussed. The conventional measurement method of room acoustic parameters according to ISO 3382-1 is to measure room impulse responses using omnidirectional microphones and figure-of-8 microphones. Alternatively, the ISO 3382-1 room acoustic parameters can be obtained from tetrahedral microphone array measurements: The four channel raw signals captured by the tetrahedral array, after a proper processing provides an omni-directional and three figure-of-eight signals oriented along the Cartesian axes[1], which can be used to calculate the ISO 3382-1 parameters.

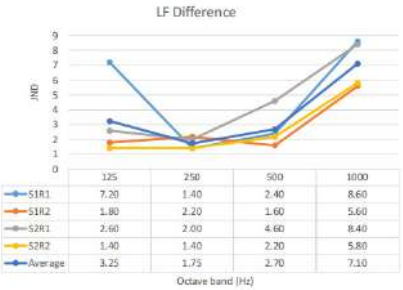
METHODS

Measurements were obtained at four source-receiver positions in the 1300-seat Muziekgebouw Eindhoven, using a RØDE NT-SF1 microphone (Figure 1) and an omnidirectional and figure-of-8 microphone pair (Schoeps MK2 and MK8). The room acoustic parameters involved in the study are two omnidirectional measures EDT (Early decay time) and C80 (Clarity), as well as two spatial measures J_{LF} and J_{LFC} (Early lateral energy fractions).

Various studies [2]-[4] showed that despite following the prerequisites in ISO 3382-1, parameters measured with different microphone types can still have significant deviations that are above the just noticeable difference (JND), and there is typically more uncertainty associated with spatial measures using a figure-8 microphone than with omnidirectional measures. For this reason, it is difficult to compare the results using different types of microphones.

In order to make the results measured with a tetrahedral microphone array and conventional measurement microphones comparable, it is necessary to identify and evaluate the measurement uncertainty. Witew and Dietrich [5] presented a practical uncertainty assessment method for the measurement of room acoustic parameters based on the ISO/IEC Guide 98-3 Guide to the Expression of Uncertainty in Measurement (GUM), which is to evaluate the contribution of each source of uncertainty by analyzing the variations of the output quantity when varying the source of uncertainty. In this study, the measurement uncertainty contributed by the source orientation was investigated by rotating the dodecahedron sound source five times for each source-receiver position and calculating the standard deviations of the measurements. The units of the results are all converted to Just Noticeable Difference (JND) for inter-parameter comparison.

Figure 1. A commercial tetrahedral microphone array, RØDE NT-SF1.



	125	250	500	1000
S1R1	7.20	1.40	2.40	8.60
S1R2	1.80	2.20	1.60	5.60
S2R1	2.60	2.00	4.60	8.40
S2R2	1.40	1.40	2.20	5.80
Average	3.25	1.75	2.70	7.10

Figure 2. The difference of J_{LF} with two methods at four S-R positions, expressed in JND.

RESULTS

Overall, it is found that the differences in the measured parameters with the two methods are perceptually noticeable, as shown in Figure 2. Much larger differences can be observed for the spatial measures J_{LF} and J_{LFC} than for EDT and C80. The hypothesized reasons are the rotational misalignment of the RODE microphone and the non-flat frequency response of the Schoeps MK8 figure-of-8 microphone. It is also found that the difference in J_{LFC} is slightly smaller than J_{LF}, which may be due to the cosine dependence of J_{LFC} and the square of cosine dependence of J_{LF}. The average standard deviation results, which lie below 1 JND for all examined parameters, indicate that the source orientation does not have a large contribution on the measurement uncertainty in general. However, an increase in measurement uncertainty can be well recognized above 1000Hz for all measurements, which is expected, as the dodecahedral source used in the measurements has non-ideal omnidirectionality above 1000Hz, and the measurement uncertainty due to the source orientation is higher for the tetrahedral microphone array.

LIMITATIONS

To further explore the reasons behind the significant differences between results obtained with two microphone configurations, it is necessary to correct the rotational misalignment of the RODE microphone and the frequency response of the Schoeps MK8 figure-of-8 microphone, as well as other systematic errors, which may be left for further work. Due to limited time, The study only investigated four parameters and one source of uncertainty. Therefore, more measurements are required to include other parameters and to evaluate more sources of uncertainty, such as the uncertainties introduced by the microphone placement and orientation. When all sources of uncertainty are quantified, it is possible to calculate the overall uncertainty budget in the measurements with a tetrahedral microphone array. ■

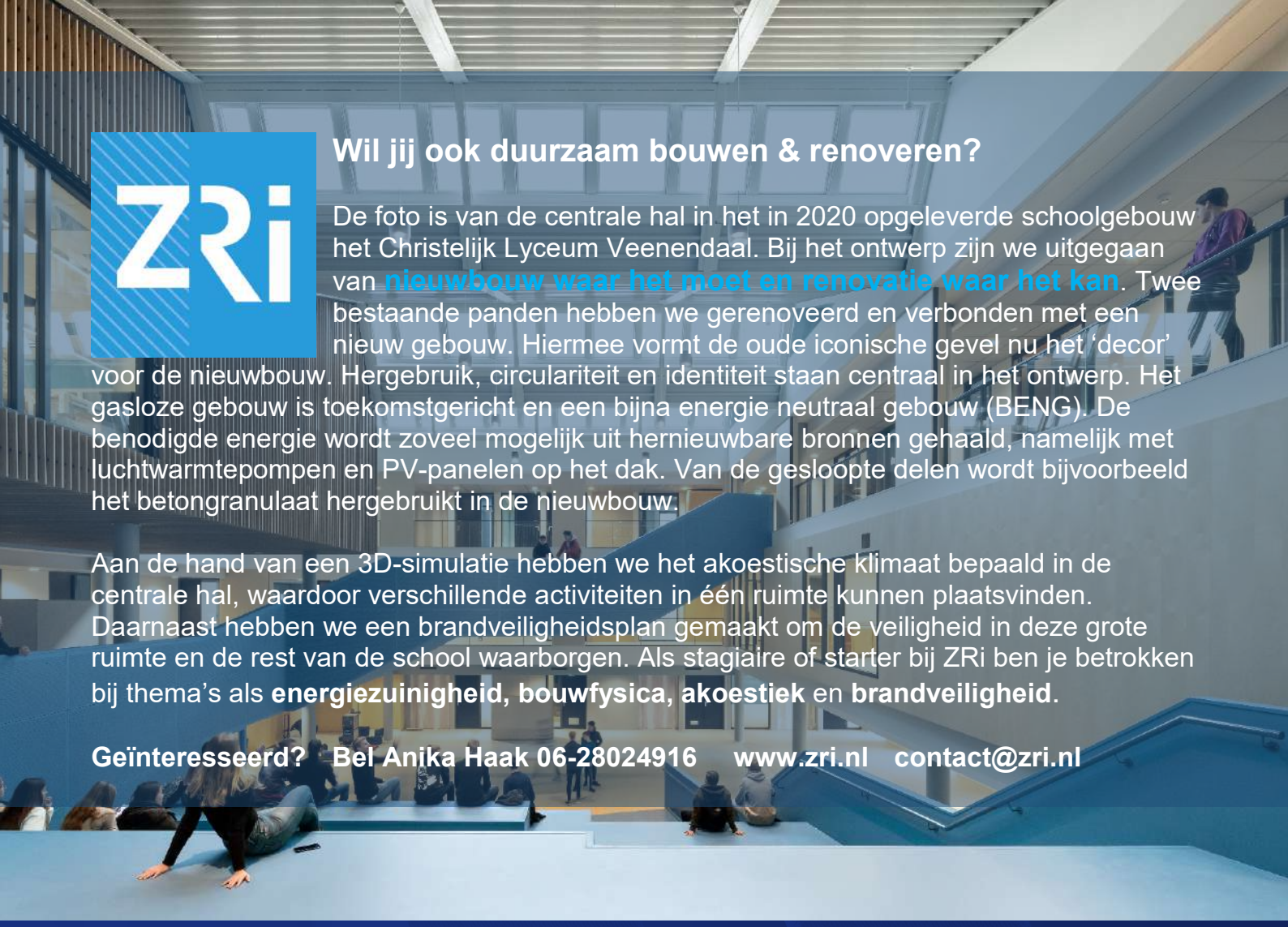
[1] F. Martellotta, "On the use of microphone arrays to visualize spatial sound field information," Applied Acoustics, vol.74, no.8, pp.987–1000, 2013.

[2] A.Lundeby, T.E. Vigran, H.Bietz, and M. Vorländer, "Uncertainties of Measurements in Room Acoustics," ACUSTICA, vol.81, 1995.

[3] M.C. Vigeant, C.B.Giacomoni, and A.C. Scherma, "Repeatability of spatial measures using figure-of-eight microphones," Applied Acoustics, vol.74, no.9, pp.1076–1084, 2013.

[4] I. Witew, G.K. Behler, and M. Vorländer, "Spatial Variation of Lateral Measures in Different Concert Halls," in International Congress on Acoustics, Kyoto, 2004.

[5] I. Witew, and P. Dietrich, "Assessment of the Uncertainty in Room Acoustical Measurements," in 19th International Congress on Acoustics, Madrid, 2007, pp.2–7.



Wil jij ook duurzaam bouwen & renoveren?

De foto is van de centrale hal in het in 2020 opgeleverde schoolgebouw het Christelijk Lyceum Veenendaal. Bij het ontwerp zijn we uitgegaan van **nieuwbouw waar het moet en renovatie waar het kan**. Twee bestaande panden hebben we gerenoveerd en verbonden met een nieuw gebouw. Hiermee vormt de oude iconische gevel nu het 'decor' voor de nieuwbouw. Hergebruik, circulariteit en identiteit staan centraal in het ontwerp. Het gasloze gebouw is toekomstgericht en een bijna energie neutraal gebouw (BENG). De benodigde energie wordt zoveel mogelijk uit hernieuwbare bronnen gehaald, namelijk met luchtwarmtepompen en PV-panelen op het dak. Van de gesloopte delen wordt bijvoorbeeld het betongranulaat hergebruikt in de nieuwbouw.

Aan de hand van een 3D-simulatie hebben we het akoestische klimaat bepaald in de centrale hal, waardoor verschillende activiteiten in één ruimte kunnen plaatsvinden. Daarnaast hebben we een brandveiligheidsplan gemaakt om de veiligheid in deze grote ruimte en de rest van de school waarborgen. Als stagiaire of starter bij ZRi ben je betrokken bij thema's als **energiezuinigheid, bouwfysica, akoestiek** en **brandveiligheid**.

Geïnteresseerd? Bel Anika Haak 06-28024916 www.zri.nl contact@zri.nl

Werken bij Klictet

De volgende stap in jouw loopbaan.

Klictet is hét innovatieve installatie adviesbureau dat altijd een stap verder gaat. Daarom zijn wij continu op zoek naar talent om ons ambitieuze team te versterken. In ons gloednieuwe kantoor in de Schoenfabriek in Oisterwijk hangt een informele en inspirerende sfeer en werken we samen hard om onze dromen en ideeën waar te maken. Doorgroeimogelijkheden vind je hier dan ook volop! Groei jij met ons mee?

Breng samen met ons techniek tot leven. Mail je CV en motivatie naar info@klictet.nl of kijk op klictet.nl/werken-bij-klictet

KLICTET

The Expert in Anything Was Once a Beginner

An interview with Kim Bodde about her transition from a student to a young professional

What is it like to start working at a building physics consultancy firm and what kind of issues will you be dealing with? We discuss this in an interview with Kim Bodde. Kim started working at ZRi last year, after achieving her bachelor's degree in Architecture at Saxion University of Applied Sciences and her master's degree in Building Physics and Services at the Technical University of Eindhoven.

What is your role at ZRi?

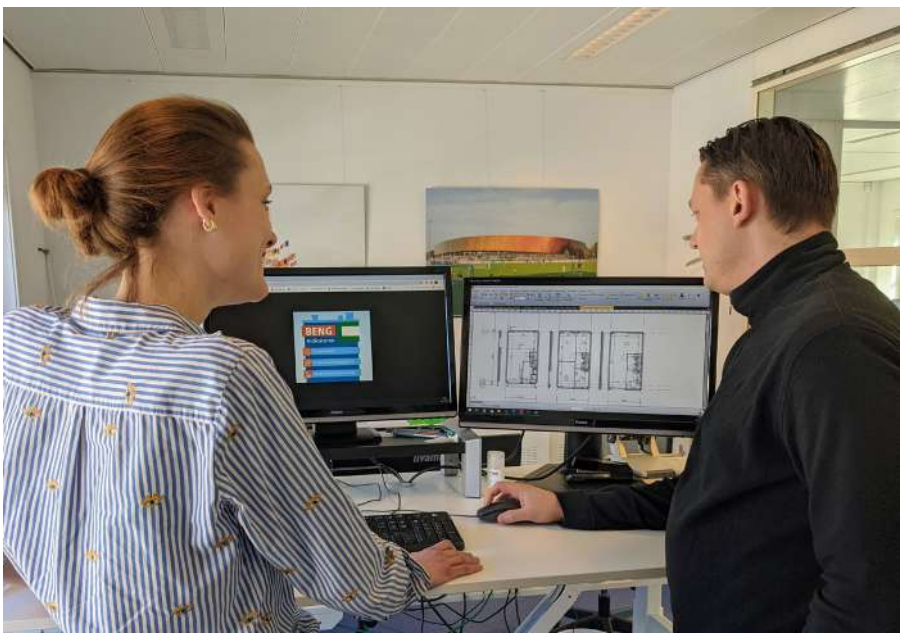
I work as a project employee. My day to day role involves giving advice on the multiple aspects of building physics: sustainability, energy rating, acoustics, fire safety, daylight, ventilation, thermal insulation, etc. I perform calculations and check if a design complies with the requirements in accordance with the Dutch Building Decree and any additional requirements set in the Technical Program of Requirements of the project. Some days I go out in the field and perform measurements to investigate if existing buildings need improvements or to check if new buildings meet the design requirements.

Is this in line with your expectations when you started working at ZRi?

I did not expect that the projects were that diverse and I would work on so many projects simultaneously. The projects I work on vary from newly developed projects to renovation projects and from residential buildings (image 1 and 2) to schools (image 3) or healthcare buildings. In addition, I work on different building physic aspects within each project. This makes an integrated approach possible and therefor optimization of a project, which is challenging. To give an example: If you increase the window size to improve daylight entry, the thermal comfort could change and also the energy use for heating, cooling and lighting.

Wow, that sounds overwhelming! How do you manage to keep up with that workflow?

It helps me that ZRi has such an open culture where you can ask anyone anything. I always work with at least one colleague on a project, which offers the possibility to learn a lot from each other. Everyone is willing to share their knowledge and experiences with me, therefore I learn new things every day and experience a steep learning curve. Even though I have not been working at ZRi for a long time and started working during the COVID period, I feel part of the team already. I am given enough freedom to forward my ideas, make mistakes and contribute, which really encourages me to develop my technical and personal skills.



Can you give an example of something you learned during the first months?

During my studies the legislation related to designing buildings was underexposed. My first day of work consisted of reading and understanding the Dutch Building Decree. I still look into the Dutch Building Decree every day and find myself understanding it more and more. It is interesting to see that not only I, but also the legislation is evolving. For example, since this year a new requirement is set for designing nearly zero-energy buildings (nZEB or BENG in Dutch). Previously the Energy Performance Coefficient (EPC) was used to measure how energy efficient buildings are. The EPC combined all energy measures into one dimensionless number. This calculation method offers little insight into how the energy performance is achieved. BENG uses three separate indicators: energy demand (BENG 1), primary energy usage (BENG 2) and share of renewable energy (BENG 3).

What effects will this have on the built environment?

I am currently working on my first BENG-project, a large residential complex of 153 dwellings. For this project the new BENG indicators mean that the building must be well designed with a highly insulated and airtight building envelope, in order to limit the energy demand. It is no longer possible to compensate for a buildings high energy demand by adding extra PV panels. This means that we have to work closely with the architect and building services consultant to achieve a BENG project. For example, we optimize the architectural details to

limit the thermal bridges. Together with the building services consultant we are able find the most optimal installations for the building, but sustainability is not only about energy efficiency.

What other aspects of sustainability do you work with?

Besides reducing the energy demand, using circular materials is very up and coming. A recent project, Mooijburg Amsterdam (image 1 & 2), which was technically very challenging and enjoyable, was a new apartment building consisting of a wooden structure from Cross-Laminated Timber (CLT). CLT elements consist of multiple layers of wooden beams that are laid-out cross-wise and laminated together to form solid wood panels for floors and walls. CLT as a wood construction technology is very sustainably and interesting, due to the large storage capacity of CO2. I am more familiar with the characterizations of concrete as a material (thermal, hydric, acoustical, mechanical, etc.). The growing use of CLT as building material has been accompanied by extensive research on the characteristics of this construction material, but some aspects have not been researched yet. This makes it challenging as a consultant to make decisions about the best way to reach acoustic requirements, thermo-hygrometric well-being, fire safety, etc.

What are your future aspirations?

I am looking forward to enhance my technical and personal skills. To begin with, I would really like to continue growing as a professional at ZRi and improve my skills as a consultant. In the future, I hope to deliver added value in projects based on designing buildings that are comfortable to occupy, easy to use and light in their environmental impact. When I compare myself with the Kim of nine months ago, I see professional and personal progress. That makes me feel very proud and satisfied.

Thank you very much for giving us a glimpse into the working life. What would you advise students who are looking for a job?

While some people are lucky enough to just know what they want to do and end up in satisfying careers without giving it much thought, I was not. When you do not have a career plan, thinking about the future in combination with all the choices you have can make you feel totally overwhelmed.

My first advice for you is to give yourself the time and thought to find out your interests, preferences, values, and make the work options clear for yourself. Actively seek out the information you need. A simple tip is to ask yourself some questions which can help you to point in the right direction. For example: "What are my passions and drives? What gives me energy and motivates me? Which course did I or did I not like during the master and why?". Other questions are: "How important is working life for me? Do I prefer a relaxed relationship between work and private life? To what extent am I willing to give up some time in the area of leisure and family?"

1. CLT project Mooijburg (outside) | Image: Natrufied Architecture

2. CLT project Mooijburg (inside) | Image: Natrufied Architecture

3. Christelijk Lyseum Veenendaal | Image: Katja Effting

I would advise you to gather information by talking to people in the work field to get their advice and talk about it. This can also be other students or the student advisor at your university. You can also discuss your job search with your friends and family. Theycan be supportive and useful.

My third advice is to obtain a good view and experience of the work life during your student days by following an internship, a project at a company or maybe a side job. It allows you to set realistic expectations and my experience is that is makes the job search often easier. During my search, I felt the pressure to look for the "best" job. I weighed all the factors over and over again and so got stuck in my head. At the end, I made the decision with my heart. I hope you can see your job search as an exciting new chapter in your life. Enjoy the ride and good luck! ■

Ice Breaker
Menno Peijnenborgh

Hey, I am Menno, a hardworking student who is eager to learn and likes problem solving.

I am currently doing the bachelor Built Environment at TU/e and hope to move on to a master in building physics next year. During high school I did not have a clear idea on what study I wanted to continue with, but I did dream of building and designing my own farm someday, so I figured this study was the right place. At the start of the study I thought of being an architect, though this shifted to the calculation side at the end of the first year. It actually took a while before I decided whether to pursue structural design or building physics. I chose building physics as it seems to have more (career) options and different aspects to learn and alternate between, which suits me well because I like learning. Besides, it also has a bigger influence on the occupants on daily basis.

If I could choose a job after my masters it would be designing the acoustics of concert halls as the details that go with it interest me, also the result would be satisfying. Though I am still figuring out what I want as right now my interests are very broad. I am thinking to take a half year after my bachelor and try to get an internship or job, with different aspects of building physics and services, which I would try to combine with my

master after I get the hang of it. Hopefully this will give me more direction and will help me make a decision with which aspects I would like to continue. Right now I would choose to work at a small company as you would know everybody better and in my experience the atmosphere is also very nice, not to say this is not true for larger companies. From the meet and greet ZRI and Klictix seemed great for example.

In my free time I like to game a lot, mostly with friends. We often play League of Legends or TFT with some occasional chess or other games. My other main activity is watching series and puzzling, I am one of those guys that rewatches a lot of series. Most of the time I put on sitcoms on the background as they are comforting and easy to watch. I do like to switch this up with new 'more serious' 40 minutes series every now and then. I also really like dogs and used to train often with my parents dog before I moved out.

When I was younger I played judo quite competitively with which I have earned a black belt. I stopped during my final year in high school. I have really enjoyed sports and went on quite some bicycle trips and mountain vacations with my family. During my studies I took a break from all sports to focus more on study and work. Half a year ago I started up again with swimming with friends, but this is also on a break now due to the lockdown.

Besides my study I also like to learn different things, last year I completed an NLP practitioner program for example where you learn about the human behavior and how to trick yourself, or someone else, to overcome a trauma or get rid of unwanted habits. ■

Kuijpers

Resultaat door betrokkenheid

Kuijpers & Mollier

Robert Snoeren, trainee Kuijpers
Wouter Flach, recruiter Kuijpers

Kuijpers is een technisch dienstverlener, actief sinds 1921. We zijn altijd op zoek naar jong talent. Daarom bouwen we heel bewust aan contacten met studieverenigingen, scholen en technische opleidingen van alle niveaus. Robert Snoeren (voormalig lid van Mollier) studeerde building physics and services aan de TU Eindhoven. Stage lopen hoort er daar helaas niet bij. Om toch ervaring op te doen, deed hij mee aan de meet & greets met bedrijven, georganiseerd door Mollier. Zo kwam hij bij Kuijpers terecht, één dag in de week. Die ene dag per week werd na Roberts afstuderen (in 2016) een tweejarig traineeship bij Kuijpers. En dat door de meet & greet met Wouter!

Echte mensen.
Echte oplossingen.

www.kuijpers.nl

Fire-safe Use of Traffic Areas in Residential Buildings

Ir. Ruud van Herpen FIFireE
Fellow Fire Safety Engineering TU/e

INTRODUCTION

According to the Dutch Building Code, a building of any size must contain at least two escape routes, which give access from any fire compartment in the building to the public road. In order to keep the escape routes usable in the event of a fire, they are located outside the fire compartments, they are 'extra protected escape routes' in terms of the Building Code. A fire compartment is a part of the building designated as a maximum extension area of fire. There are no restrictions to the fire load in a compartment.

Logically, the idea is that fire is not taken into account in an extra protected escape route, and that therefore the escape route must be kept free from fire loads. A fire load is a combustible object or a collection of combustible objects, such as a chair, couch, standing lamp, bicycle, wheelchair, mobility scooter, etc. Are they really prohibited in an escape route? That is not realistic in practice. But if we do allow them in the escape route, what is the risk for fire safety?

The restrictions on fire loads in escape routes have been determined by a simulation study. The reason for this was the fire in the entrance of an apartment building on the Gelderseplein in Arnhem on New Year's Eve 2019 (Figure 1). In the entrance, part of the extra protected escape route, two benches were lit by fireworks. The escape route and the elevator shaft quickly became covered in smoke. This has cost the lives of two people in the elevator. The conditions in the apartments in the building remained safe.

WHETHER OR NOT TO EVACUATE IN CASE OF FIRE?

The Building Code is based on an evacuation concept in case of a fire emergency. This means that in case of fire the building will be evacuated. It is assumed that the majority of building users are self-reliant. They can therefore independently use the escape routes and staircases in a building. Objects in that escape route must not impede escape. So there must be enough free space left.

However, evacuation is not an option in case of fire in the escape route. In case of a fire in the escape route, the risk of casualties is considerably greater if the building users try to evacuate from the relatively safe fire compartment that they were previously in. The fire compartment must of course remain sufficiently safe during the fire in the escape route. At all costs, fire spread in the escape route needs to be prevented: the object on fire should not lead to combustion of any other objects by flashover. In addition, the conditions in the escape route must not become a threat to the adjacent fire compartments.

In short, fire load in the escape route can be allowed but with restrictions to ensure that the load does not impose a threat to the fire compartments designated on that escape route.

ASSUMPTIONS AND BOUNDARY CONDITIONS FOR SIMULATION

The fire load that can be permitted in the escape route depends not only on the object, but also on the traffic zone through which the escape route leads. In large traffic zones, the conditions become less threatening to the adjacent compartments than in small traffic zones. The following classification of traffic zones was used in the simulation study:

- Small traffic zone (volume < 150 m³)
- Large traffic zone (volume between 150 and 500 m³)
- Atrium (traffic zone with void over two or more floors with a volume > 500 m³)

In addition, the source of ignition is of importance. The probability of ignition increases with an ignition source. Taking this into account, the fire load is divided into the following categories:

- Category A. Fire load without ignition source
- Category A1. Small fire load (< 500 MJ)
- Category A2. Large fire load (< 1000 MJ)
- Category B. Fire load with ignition source
- Category B1. Small fire load (< 500 MJ)
- Category B2. Large fire load, including charging option (< 1000 MJ)

Figure 1: Entrance residential building Gelderseplein in Arnhem after the fire

- Category C. Very large fire load with ignition source, including charging option (< 3000 MJ)

A fire load of 500 MJ contains circa 25 kg combustible material, 1000 MJ contains 50 kg and 3000 MJ contains 150 kg combustible material.

Below are some examples of objects that can be classified in the aforementioned fire load categories:

- Category A1: table, chair, seat, closet, bicycle
- Category A2: couch, sofa, mattress, or various objects from A1 together (Figure 2)
- Category B1: lamp, monitor, TV, electric clock, printer
- Category B2: electric wheelchair, electric bicycle or scooter, electric tools with charging option (Figure 3)
- Category C: mobility scooter with charging option

Whether fire load can be permitted in the escape route depends on the quality of the separation construction between fire compartments and the escape route. The floor area and height of the escape route also play a role. After all, no flashover or fire spread to other objects may occur in the escape route. In addition, in a compartment adjacent to that escape route, the conditions for a safe stay must be guaranteed throughout the entire fire scenario.

The following assessment criteria were used:
In the escape route:
- Gas temperature < 300 °C

Table 1. Combinations of traffic zones and fire load categories, with minimum distance between separate local fire loads in the traffic zone

Traffic zone (escape route)	Fire load Category	Acceptable Y/N (min. distance)
Small (< 150 m³)	A1	Y (> 3 m)
	A2	N
	B1	Y (> 3 m)
	B2	N
	C	N
Large (150 - 500 m³)	A1	Y (> 3 m)
	A2	Y (> 4 m)
	B1	Y (> 3 m)
	B2	Y (> 4 m)
	C	N
Atrium (> 500 m³)	A1	Y (> 3 m)
	A2	Y (> 4 m)
	B1	Y (> 3 m)
	B2	Y (> 4 m)
	C	Y (> 5 m)

In an adjacent fire compartment:
- Gas temperature < 45 °C
- Radiation flux < 1 kW/m²
- Visibility > 30 m

ACCEPTABLE FIRE LOAD IN THE ESCAPE ROUTE

When the internal separation constructions between the fire compartments and the escape route are airtight and fire-resistant for at least 20 minutes (from the escape route to the fire compartments), combinations of traffic zone and fire load categories according to Table 1 are possible. This table also indicates the needed mutual distance between several separate local fire loads in the escape route, in order to prevent fire spread.

Under certain conditions, fire load in the traffic zone of a residential building is acceptable. The clear passage width in the traffic zone needs to be 0.50 m (minimum) to 0.85 m (when using aids such as a walking frame or a walker), in order to keep the escape route available in case of fire in a compartment.

When a fire load category is used in a traffic zone that is not suitable for this according to Table 1, measures must be taken. Measures can vary from removing the fire load, reducing the ignition probability, to reducing the fire scenario.

The fire load can be removed by moving it to a fire compartment. A specific separate compartment can be created for mobility scooters.

It is possible to reduce the ignition probability by isolating the ignition source. Especially during charging of batteries there is a high ignition probability. It is best to only allow charging of batteries in charging facilities designed for this purpose, located outside the traffic zone. This considerably reduces the fire risk in the escape route.

Reducing the fire scenario is possible by a fire-resistant hood or screen over the fire load. However, actively controlling the fire scenario by a built-in extinguishing system is also an option. In a sprinklered building, where the escape routes are also sprinklered, a fire load with an electrical source and charging option is possible without additional measures. ■

Figure 2: Examples of Category A2

Figure 3: Electric wheelchair (left, category B2) and Mobility scooter (right, category C)

A Multi-Domain Approach to Thermal Comfort in Office Buildings

prof. dr. H. (Helianthe) S.M. Kort
dr.ir. R. (Roel) Loonen
dr.ir. M.(Marcel) G.L.C. Loomans
dr. ir. Y. (Yasin) Toparlar
ir. C. (Cristina) J. Lopez

Author
Ir. E. (Eugene) Mamulova

INTRODUCTION

Adults working in the tertiary sector tend to spend one third of their day at the office, where they are continuously exposed to external stimuli, generated by the environment and its users. Thermal comfort in offices is studied due to its relation to energy consumption, energy consuming user behaviour, user satisfaction and user productivity. Current engineering standards aim to prescribe a comfortable baseline for office environments. However, they do not account for non-thermal stimuli and do not always yield accurate predictions. The issues are addressed in current literature via the multi-domain approach, which models thermal comfort as a combination of environmental and personal stimuli. Figure 1 presents four primary domains that influence thermal comfort.

This research adopts the multi-domain approach to thermal comfort and consists of two primary parts. The first part aims to assess the scalability of existing thermal comfort models via a literature review. The literature review defines the concept of scalability which is subsequently echoed throughout the article. The literature review covers 62 studies. It is hosted on Kaggle and is open to the public: https://www.kaggle.com/eugenemamulova/literature-review-on-thermal-comfort-in-offices. The second part of this article is focused on thermal comfort modelling in response to the findings of the literature review.

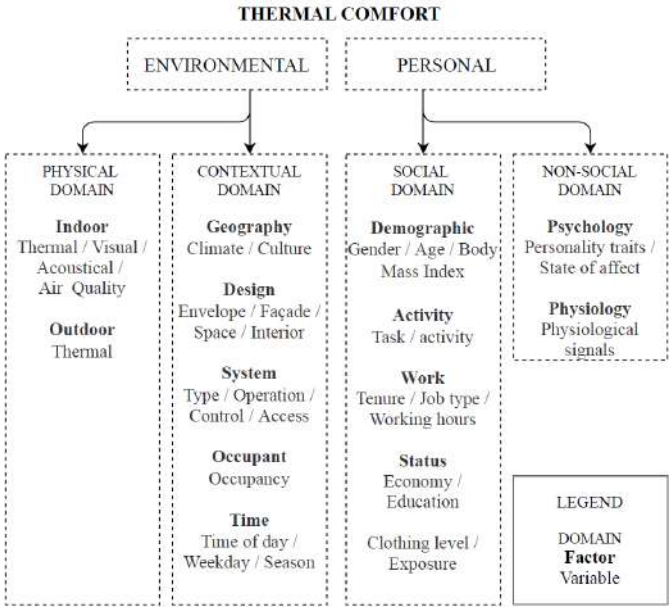


Figure 1. Physical, social, contextual and non-social domains.

PART A: LITERATURE REVIEW

SCALABILITY

Despite the consistent influx of multi-domain studies on thermal comfort, the outcomes thereof tend to remain unemployed. Discontinuity in the field is largely attributable to a lack of usable outcomes. Existing reviews cover existing approaches, results and limitations to a great extent. On the other hand, no review article with a focus on usability is identified throughout the course of this study. Usability of the outcomes constitutes the main focus of this review and is henceforth referred to as scalability. In this research, scalability is defined using four indicators, namely; scope; resolution; portability; and performance.

Scope is a term that alludes to matters of sight or aim. It represents the fraction of the world that is captured. The concept lends itself nicely to thermal comfort research, where the real world can be said to have infinite scope, while the scope of thermal comfort studies is finite and largely reliant on the objective of the individual study.

Following the optical narrative, where scope delimits the field of vision, resolution is defined via the zoom function. Resolution concerns precision and granularity. In the context of thermal comfort research, resolution refers to the precision of the experiment setup and the granularity of the respective outcome.

Portability implies mobility or the ability to move. In the context of thermal comfort research, portability is defined as the ease of implementation of a specific outcome in a different setting. For example, Fanger's PMV/PPD model is developed in a laboratory and it is currently used in mechanically ventilated buildings.

Performance is a measure of how useful an outcome is. For example, if the outcome is a predictive model, its predictive capabilities indicate its usefulness. Common expressions of performance are accuracy, effectiveness, goodness-of-fit and goodness-of-prediction. Depending on the research outcome, quantifying its performance may prove challenging. For the sake of comparability, the performance of existing research outcomes is not examined in this literature review.

The main research questions follow the proposed definition of scalability and are as follows:

1. What are trends and limitations concerning the scope of existing research outcomes?
2. What experiment resolution and outcome resolution is observed in multi-domain research?
3. What trends and limitations arise regarding the portability of existing research outcomes?

The most common research outcomes are explanatory thermal comfort models and predictive thermal comfort models. The former aim to understand and explain thermal comfort for a given data set, while the latter aim to train a model and subsequently test its capacity to predict thermal comfort.

METHODOLOGY

This research constitutes a scoping review, as it builds upon the works of Torresin et al., 2018 [1], Wu et al., 2020 [2] and Schweiker et al., 2020 [3] and is accompanied by a systematic search. The search is conducted on May 30, 2020, using the Scopus platform. The final literature selection comprises 62 multi-domain thermal comfort studies.

RESULTS

Each of the four scalability indicators is subject to research trends. Certain trends contribute to the advancement of the research field, while others are destructive. The latter formulate a literature gap that can be addressed via more scalable research practices. The trends identified in this scoping review reveal that the average thermal comfort experiment is not designed with scalability in mind. Key trends and limitations in multi-domain thermal comfort modelling are discussed below.

DISCUSSION

Scope:
The scope of existing thermal comfort studies is largely limited to physical variables that describe the indoor climate. Social characteristics and psychological parameters are rarely studied, despite their apparent relevance to the topic. The combined inclusion of physical, contextual, social and non-social variables is almost non-existent in multi-domain literature.

Experiment Resolution:
Thermal comfort studies involving more than 500 participants are scarce.

Outcome Resolution:
Less than 50% of existing literature includes interactions between different thermal comfort variables. Interaction effects are mostly limited to laboratory studies.

Portability:
Explanatory thermal comfort models may generate interesting results but they are rarely tested for their predictive potential.

Predictive models are only included in approximately 15% of studies. Thermal comfort survey design practices are not transparent and may contribute to the lack of follow-up research. Survey quality is questionable and the validity of existing questionnaires is uncertain. In conclusion, existing studies on thermal comfort in offices do not display any propensity towards scalable research practices. This review identifies several directions that have the potential to transform the landscape of the research field into one that is more oriented towards practicable research, some of which are addressed in the second part of this article.

PART B: THERMAL COMFORT MODELLING

METHODOLOGY

In response to the findings of the literature review, two thermal comfort models are constructed. Firstly, Structural Equation Modelling (SEM) is used as a means to explain and understand thermal comfort for a given set of data. The outcome is referred to as an explanatory model. Secondly, machine learning classification is used as a way to predict thermal comfort. The predictive potential of the explanatory thermal comfort model is tested via its transformation into a parsimonious predictive model and testing on an independent data split. Both models are constructed using an existing dataset which includes physical, contextual, social and non-social variables collected during the summer in two Dutch office buildings. The measurement protocol is outlined in the conference proceedings [4]. 623 office employees participated in the study. Table 1 provides a summary of the occupant demographics.

Table 1. Summary of social characteristics for buildings B1 and B2.

Gender		B1 ($N = 324$)		B2 ($N = 200$)	
		$\mu \pm \sigma$	N	$\mu \pm \sigma$	N
Male			154		88
	Age	43±10		47±8	
	I_{clo}	0.5±0.1		0.4±0.1	
Female			170		112
	Age	43±10		45±8	
	I_{clo}	0.5±0.1		0.5±0.2	

Table 2. Overview of variables included in the model.

Effect	Domain	Symbol	SEM Notation	Variable [unit]
Main	Physical	$e^{T_{in}}$	x_8	Indoor temperature [^{o}C]
		SPL	x_9	Sound pressure level [$dB(A)$]
	Non-social	g_1	x_1	Gregariousness [−]
		g_2	x_2	Gregariousness [−]
		g_3	x_3	Gregariousness [−]
		h_1	y_1	General discomfort [−]
		h_2	y_2	Lower body discomfort [−]
		h_3	y_3	Upper body discomfort [−]
Interaction	Physical	$SPL \cdot E \cdot T$	x_{10}	Sound pressure level, illuminance and temperature [$db(A)lx^oC$]
	Physical and non-social	$T_{in} \cdot a_1$	x_4	Indoor temperature and assertiveness [^{o}C]
		$T_{in} \cdot a_2$	x_5	Indoor temperature and assertiveness [$^o C$]
	Contextual and non-social	$N_{occ} \cdot g_1$	x_6	Occupancy count and gregariousness [−]
		$N_{occ} \cdot g_4$	x_7	Occupancy count and gregariousness [−]

EXPLANATORY MODEL

The structural equation model is based on a series of hypotheses regarding direct effects, M_i, and indirect effects, I_i on summer thermal discomfort:

M_1: Indoor temperature exerts a positive effect on thermal discomfort.

M_2: Sound pressure exerts a positive effect on thermal discomfort.

M_3: Occupant gregariousness exerts a negative effect on thermal discomfort.

I_1: Occupant assertiveness exerts a positive effect on the effect of indoor temperature on thermal discomfort.

I_2: Indoor temperature exerts negative effect on the interaction effect between sound pressure level and illuminance on thermal discomfort.

I_3: Occupancy count exerts a positive effect on the effect of occupant gregariousness on thermal discomfort.

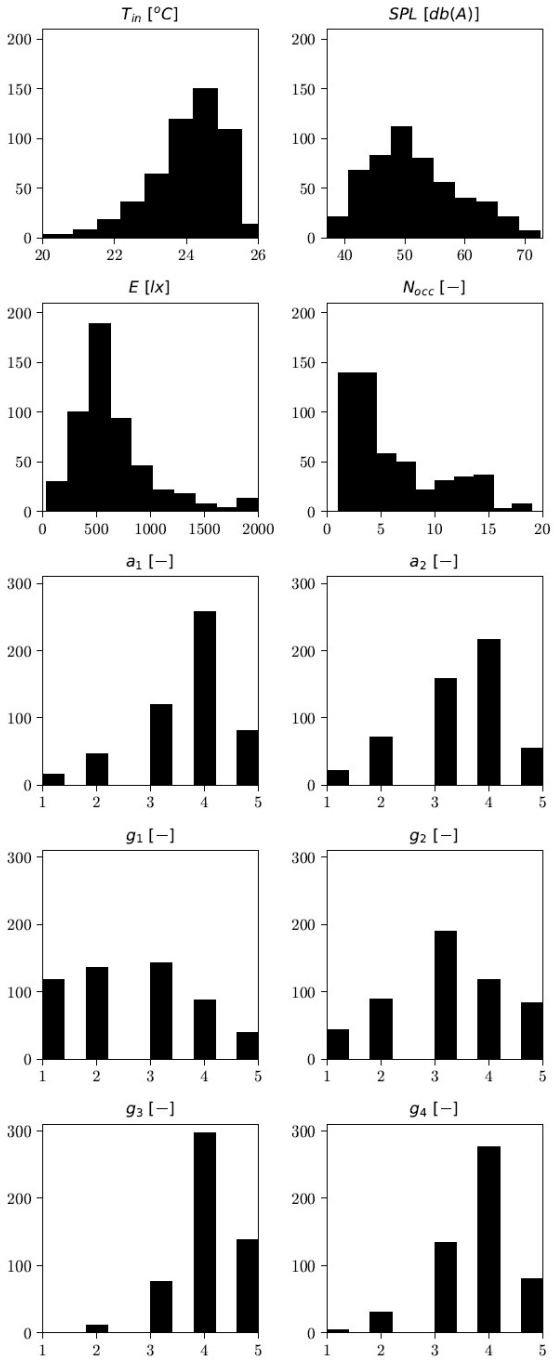


Figure 2. Visual summary of continious and ordinal variables.

The hypotheses are formulated on the basis of the 62 studies. In short, an increase in either indoor temperature or sound pressure level is expected to increase thermal discomfort. An uncomfortable indoor temperature is expected to decrease the effect that sound pressure level and illuminance would have in a comfortable thermal environment. Assertive individuals are expected to be more thermally uncomfortable at higher temperatures than unassertive individuals, who are expected to be more lenient. Gregarious individuals are expected to be more thermally comfortable than non-gregarious individuals and the effect is expected to become more apparent as the number of occupants in the room increases. Table 2 lists all variables that are included in the final data set. Figure 2 provides a visual summary of the underlying distributions. The final data set comprises 13 variables and 524 observations.

RESULTS

Figure 3 shows the parameter estimates, variance/covariance estimates and factor loadings for the explanatory model. Table 3 provides a summary of the parameter estimates, according to which M_3 and I_1 are rejected. Meanwhile, the model estimates do not reject M_1, M_2, I_2 and I_3.

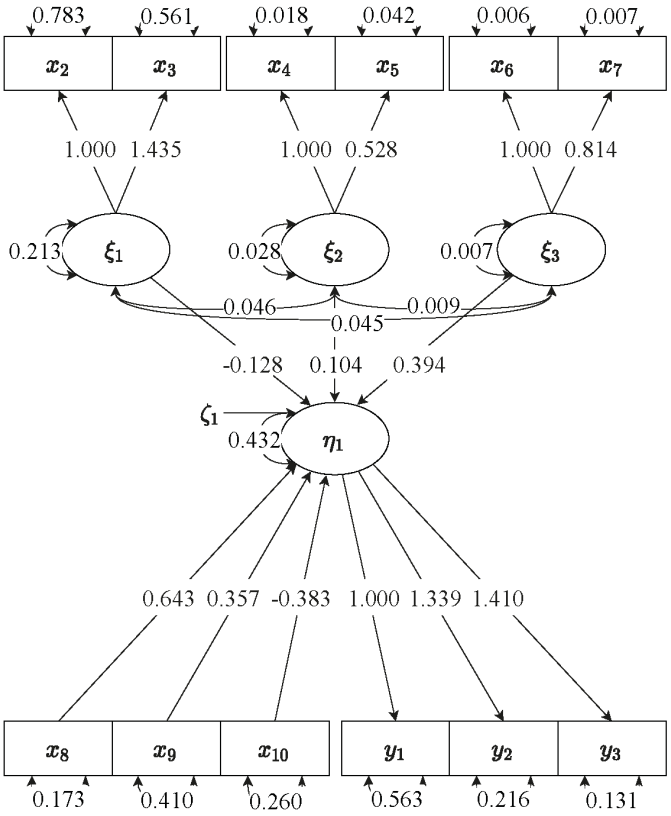


Figure 3. Graphical representation of model estimation – A1

Table 3. Parameter estimations for model – A1

Parameter	γij	SE	Z	$P(>\|z\|)$
x_8	0.643	0.203	3.177	0.001***
x_9	0.357	0.151	2.368	0.018**
x_{10}	-0.383	0.196	-1.951	0.051*
ξ_1	-0.128	0.174	-0.736	0.462
ξ_2	0.104	0.382	0.272	0.785
ξ_3	0.394	0.198	1.988	0.047*

*** CI = 99.9%, ** CI = 98%, * CI = 95%.

DISCUSSION

Firstly, M_1 and M_2 indicate that indoor temperature and sound pressure level exert a positive effect on thermal discomfort. M_1 and M_2 are in good agreement with existing literature. On the basis of the results, the authors encourage the inclusion of both stimuli in future models. I_2 suggests that audiovisual stimuli are heavily mediated by indoor temperature conditions. The inclusion of the three-way interaction provides considerable insight into the physical domain. The findings encourage future studies to consider multi-dimensional interactions in the interest of better predictions. I_3 indicates that occupant gregariousness mediates the influence of occupancy count on thermal discomfort due to heat. The outcome supports the notion that the effect sizes of various external stimuli are not constant across an office population, and that additional research concerning inter-occupant differences in the form of personality traits could yield better predictions. Furthermore, the findings constitute a premise for the exclusion of the gregariousness facet, as a direct influence, from future models. Similarly, the findings do not support the inclusion of the assertiveness facet as a mediator for indoor temperature. Nevertheless, the individual hypotheses are unprecedented and may be explored further via follow-up research.

PREDICTIVE MODEL

The predictive model is based on the results of the explanatory model and includes four variables, namely; indoor temperature; sound pressure level; the three-way interaction between sound, illuminance and temperature; and gender. Four classification algorithms are tested. Table 4 provides an overview of the predictive models. During the testing phase, models B_1-B_4 are trained on 308 observations and are then tested on the remaining 77 observations.

Table 4. Summary of model characteristics.

Model	Classification Algorithm
B1	Logistic regression
B2	Random forest ensemble
B3	Linear support-vector machine
B4	Non-linear support-vector machine

RESULTS

Figure 4 shows the confusion matrix for the test run. The number of true predictions for the four models ranges between 42 and 46. No major classification imbalance is observed save for a marginally higher number of positive predictions for model B_2. All four models show difficulty classifying thermal discomfort, as indicated by the large number of false negative predictions.

DISCUSSION

Looking at all four outcomes, it is possible that the quality of the survey data introduces noise and masks the patterns necessary for making reliable predictions. However, real world data is noisy and constitutes a pitfall for even the most prevalent models. Therefore, a predictive model can be expected to perform even worse in practice than it does on the mother data set. With that in mind, the predictive potential of models B_1-B_4 is found to be insufficient. This does not imply that the model features are not significant but it can be taken as an indication that additional features are necessary to account for the noise present in the data.

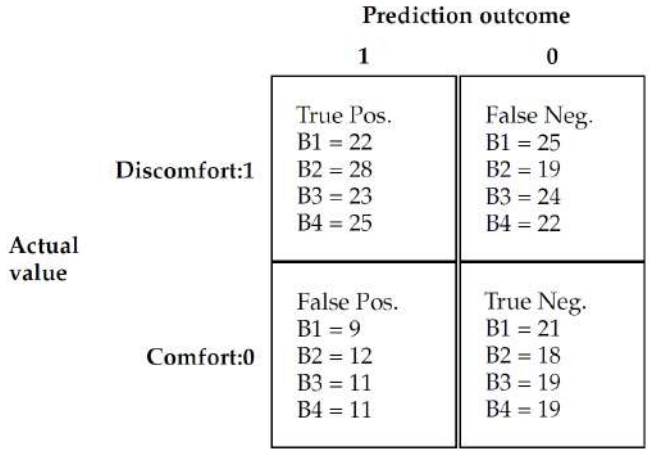


Figure 4. Confusion matrix for test set for Models B1 – B4.

The results show that significant influencers are not always adequate predictors. Likewise, adequate predictors are not necessarily relevant to the domain in question. Both aspects can be controlled by treating explanatory and predictive models as two essential steps of a thermal comfort study.

CONCLUSION

This research aims to address scalability in multi-domain thermal comfort modelling. Broadening the research scope is expected to yield a better understanding of the contribution of the different domains on thermal comfort. The expectation is fulfilled, as the explanatory model suggests that indoor temperature, sound pressure level, occupant gregariousness and occupancy count exert a significant influence on occupant thermal comfort in offices during summer. It is also expected that a wider scope results in better predictive performance. However, machine learning models B_1-B_4 are not able to adequately distinguish between thermal comfort and discomfort during summer. The conclusion that is drawn from the poor model performance is that significant variables are not always adequate predictors.

The inclusion of interaction effects shows that physical, contextual and psychological factors do not always influence thermal comfort directly and they do, in fact, moderate one another. The identified interaction effects are limited to the variables included in the study. A significant limitation of the study is the exclusion of social variables, such as work hours and job type, due to their absence from the explanatory model. Similarly, variables such as age, air velocity, relative humidity, clothing insulation and metabolic rate are excluded. Future research involving a larger number of variables is likely to uncover a larger number of interactions that improve our understanding of thermal comfort and, possibly, our predictive capabilities. The results also show that the academics in the field of thermal comfort should combine exploratory modelling and predictive modelling in a single framework, in order to test whether variables that are relevant to the domain are useful for prediction and vice versa. ■

[1] S. Torresin, G. Pernigotto, F. Cappelletti, and A. Gasparella, "Combined effects of environmental factors on human perception and objective performance: A review of experimental laboratory works," Indoor Air 28, 525–538 (2018).

[2] H. Wu, Y. Wu, X. Sun, and J. Liu, "Combined effects of acoustic, thermal, and illumination on human perception and performance : A review," Build. Environ. 169, 106593 (2020).

[3] M. Schweiker, E. Ampatzi, M. S. Andargie, R. K. Andersen, E. Azar, V. M. Barthelmes, C. Berger, L. Bourikas, S. Carlucci, G. Chinazzo, L. P. Edappilly, M. Favero, S. Gauthier, A. Jamrozik, M. Kane, A. Mahdavi, C. Piselli, A. L. Pisello, A. Roetzel, A. Rysanek, K. Sharma, and S. Zhang, "Review of multi-domain approaches to indoor environmental perception and behaviour," Build. Environ. (2020).

[4] H. W. H. Brink, "Quality and satisfaction of thermal comfort in Dutch offices," in 15th EuroFM Research Symposium, (2016), pp. 1–11.

INSide Information Committee Vacancy

Are you interested in sharing knowledge and bringing the latest news of our field by creating an attractive magazine, filled with articles by our students, our alumni, the unit BPS and our partners? And at the same time developing your editorial and Adobe InDesign skills?

We are looking for someone with some fresh perspectives on the design of INSide Information to strengthen our committee. Becoming an INSide Information committee member gives you the freedom to design the magazine however you like, everything lay-out-related is possible in that department.

Would you like to have a say in what the next edition will look like? Let us know!

The Parametric Approach of Building Physics

ir. B. (Bart) van Nimwegen
ir. Y.J.C. (Youri) van de Ven

As a building physics consultant at Cauberg Huygen, you are closely involved during the entire design process, from the first draft, until the commissioning of the projects. With our expertise, we actively contribute to sustainable (area) development and provide insight into the choices to make ambitions into reality. Throughout the design process, the consultant advises the design and construction team on all building physics related topics. This can be on an urban scale, with for example insolation or wind hindrance analyses. However, most of the advice is given on building related aspects, like daylight and acoustic quality, energy performance and fire safety. These separate pieces of advice are not independent, rather, most of them are interrelated. This integrality offers great opportunities for implementing a more parametric way of consulting.

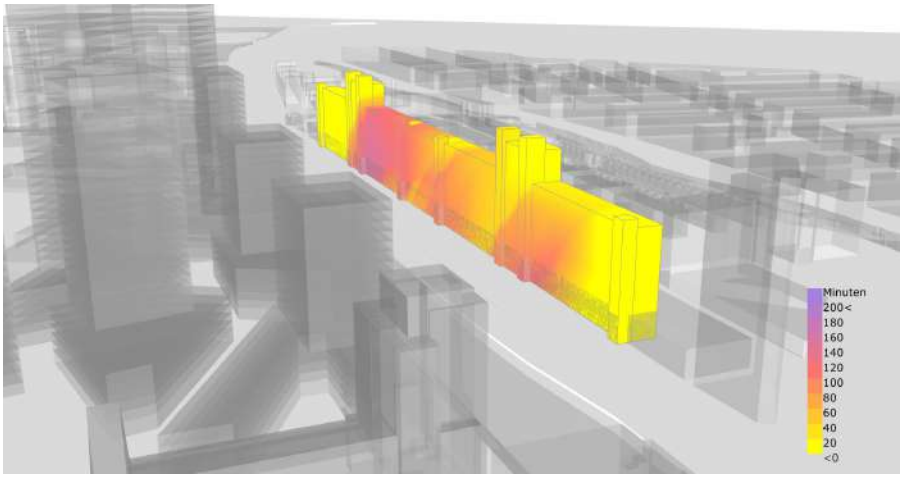


Figure 1: The effects of a new high rise project on the insolation conditions in the nearby residential areas can be clearly visualized, using the Rhinoceros software. This image shows on which part of the neighbouring buildings experiences the highest decrease in insolation hours.

By using this parametric approach, Cauberg Huygen has started to adopt a new method of computer based consultancy. With this new working strategy, it will become attainable to give our clients better and more integral advice since design alternatives can be assessed and evaluated more quickly by using optimization strategies. Using this, the most suitable solutions can be advised, based on the wishes of the client. This article will give an insight into the contemporary implementation of parametric design at Cauberg Huygen, along with our ambitions for the near future. Presented calculations and visualizations are made with Rhinoceros, a 3D software package that is already frequently being used for architectural design. However, with the Grasshopper plug-in, which is a visual scripting environment, the software is very suitable for running and visualizing physical calculations as well. In this article, two examples are presented in which the benefits of using Rhinoceros software in consultancy work by Cauberg Huygen are highlighted.

PARAMETRIC DESIGN IN URBAN PHYSICS

The first case concerns a project on an urban scale in which the effects of seven new high rise residential towers on the daylight access of the houses in the nearby residential areas is investigated. The Dutch Building Code does not impose any regulations concerning the degree of sunlight entering our dwellings. However, because receiving some degree of sunlight into our living rooms is desired, guidelines have been drawn up to assess the amount of sunlight entering a residential building.

The case includes an area where largely retail functions are built with a height of up to 30 meters, which will be replaced by a new planning area in which a commercial plinth will be established with seven residential towers up to a height of over 120 meters. In situations like these, municipalities can claim an

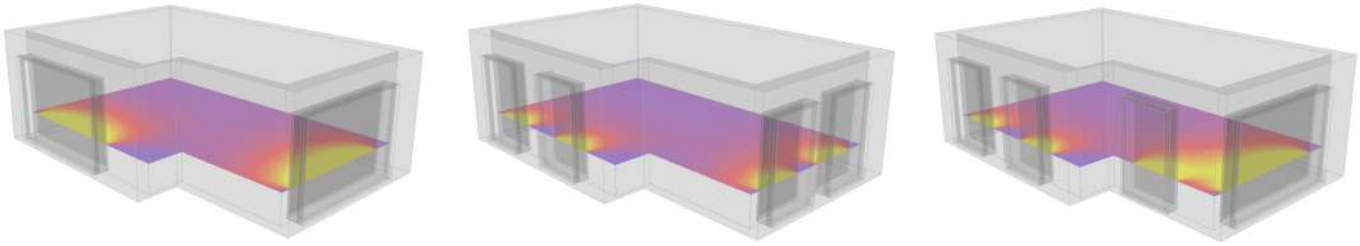


Figure 2: Daylight simulations can be quickly calculated and visualized in Rhinoceros. This allows for a quick daylight assessment of various design alternatives. The position and size of the windows can be easily altered to improve the daylight conditions in a room.

insolation study in which the effect of the new buildings on the amount of sunlight entering the surrounding, existing residential buildings is assessed.

Using Rhinoceros, the reduction in daylight hours in homes in the nearby residential area is assessed. With the help of this software package, we have been able to visually indicate the reduction in the number of hours that the building recieves sunlight. Figure 1, as an example, displays which houses will encounter the largest hindrance from the new plan area to be built on an assessed day, indicated by the darker colors. By visually representing the loss in the numbers of hours receiving sunlight, it becomes noticeable which houses are experiencing the greatest hindrance. Additionally, it can be traced back to which components of the plan area this hindrance is caused.

Contemporary architecture regularly includes unique building contours that can change during the design process. Due to these design changes it is an asset to make use of parametric design in this situation. Using this tool, we can advise the architect early in the design phase, keep the results in sync with the design changes, but perhaps more importantly, supporting these pieces of advice visually.

DAYLIGHT AND ENERGY PERFORMANCE

Having a sufficient amount of daylight is a vital part of the overall comfort of living areas in residential buildings. Several studies have shown that a good daylight quality improves the health, wellbeing and productivity of people drastically [1]. This has resulted in a design trend in which the daylight quality in indoor spaces is continuously being improved. However, the wish to make windows larger is beginning to contradict the ever growing demand for a sustainable built environment. These windows improve the daylight conditions in a room but simultaneously result in a larger heat loss from the building. With the advent of the NZEB regulations and three building energy factors instead of the previously used single factor, limiting heat losses has become even more important. This energy-daylight contradiction has resulted in a new challenge for designers: How can daylight entering the living areas of homes be optimized, but at the same time heat losses be limited?

With the use of parametric design, it becomes possible to get a better insight into the daylight quality of a room and how to improve it, while simultaneously monitoring the energy balance of a building. Using the Honeybee plug-in, the daylight conditions of a room can be made visible and be updated in real time, adapting to the changes made in the building design. An example of these calculations are shown in Figure 2. The same can be done for the energy performance of a building. With the energy factors adapting in real time, the consequences of design choices on the energy performance of the building can immediately be seen. With these live updates, the impact of increasing the width of a window on the daylight quality in a room can be visualized, while simultaneously monitoring whether the building still meets the required energy performance.

This energy performance does not only take the transmission loss into account, but also the energy demand and supply are integrated into this calculation. With Grasshopper the energy balance of a building can be calculated, based on the building services and the energy generated via solar panels. The amount of generated energy depends enormously on the shape of the building and similar to the insolation study, this building shape can be optimized to maximize the amount of energy generated with solar panels.

With these real-time calculations and visualizations, immediate feedback can be given about certain design choices. This is very useful for us as consultants, but it can also give the client the opportunity to control this optimization process. The client can have certain priorities for his design, like having an excellent daylight quality, or an outstanding energy performance. With the Grasshopper software it is possible to optimize the design to the preferences of the clients and let them decide to which extent these preferences have to be realized. This gives clients more control in the process which eventually will lead to a better design.

CONCLUSION

With a parametric approach, new opportunities arise in building physics consultancy. It offers possibilities that can be valuable in the consultancy process. By using the Rhinoceros and Grasshopper software, design adjustments can be calculated immediately and presented visually. This method provides a better optimization process, which can be adjusted based on the clients' ambitions.

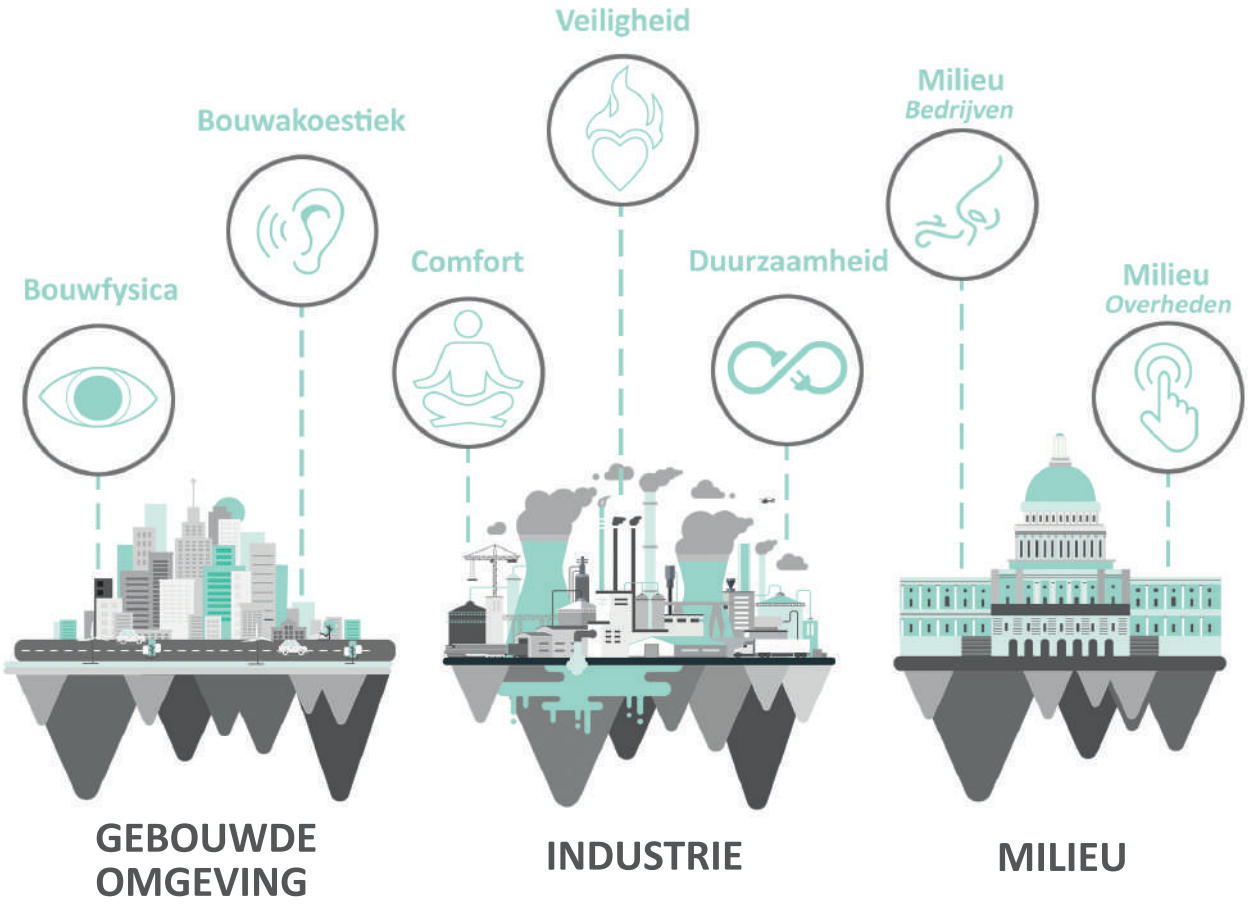
This approach can be implemented on both urban and building scales and can eventually be stretched towards all fields of urban and building physics. The cases given in this article are only examples of pieces of advice that can be achieved with the use of parametric design. For instance, the described urban insolation analysis can be combined with a wind and sound hindrance analysis to determine the overall comfort in the urban environment. For instance, on a building scale the daylight and energy calculations can be extended with overheating and fire flash-over calculations. Eventually, an integral model can be made that covers all fields of building physics and visualizes the relationship between those different topics.

The implementation of parametric design in building physics has only just taken off and the development of the software will eventually determine to which extent it can be used in the world of building physics consultancy. Cauberg Huygen has already started to adapt its workflow, thereby preparing for these future possibilities that can and eventually will change the contemporary way of consulting in urban and building physics. ■

[1] "Groot deel Nederlanders krijgt te weinig licht: enorm effect op onze gezondheid," RTL Nieuws, 24-Oct-2019. [Online]. Available: https://www.rtlnieuws.nl/nieuws/artikel/4889306/licht-daglicht-winterdepressie-kantoor-slaap-stemming-concentratie. [Accessed: 14-Apr-2021].

CAUBERG HUYGEN

CAUBERGHUYGEN.NL
HR@CAUBERGHUYGEN.NL
088-5152505



COME JOIN US!

Als adviseur bij Cauberg Huygen werk je in opdracht van een klant in een hecht team aan de realisatie van duurzame, comfortabele en veilige gebouwen.
>> What's not to like? <<

WIE BEN JIJ?

- Gezellig
- Ambitieuze student/starter Bouwkunde of Civiele Techniek
- Enthousiast over bouwfysica, akoestiek en brandveiligheid
- Loopt over van ideeën
- Proactief en gedreven

WAT BIEDEN WIJ?

- Gezelligheid
- Onmisbare kennis
- Doorgroeimogelijkheden
- Vakinhoudelijke uitdagingen
- Marktconform salaris

- En natuurlijk de leukste collega's!

Our main sponsors

CAUBERG HUYGEN

ENGINEERING THE EXPIERIENCE

EEN WERELD CREËREN DIE COMFORTABELER, VEILIGER EN DUURZAMER IS

Johnson Controls

Kuijpers

ECHTE MENSEN.
ECHTE OPLOSSINGEN.

samen maken we de toekomst

unica

Our sponsors

SEE YOU AT OUR LUSTRUM ACTIVITIES

s.v.b.p.s. Mollier
Eindhoven University of Technology
PO Box 513
5600 MB Eindhoven
Secretariaat, BPS, Vertigo, Floor 6
T +31 (0)40 247 4406
E: inside@mollier.nl
www.mollier.nl