Academic year 2019 - 2020 #2 | June

Study Association
Building Physics and Services

MOLLIER inside information

MOLLIER | UNIT BPS | STUDENTS | ACTIVITIES | MEMBERS

Personal lighting conditions of office workers
dr. ir. J. (Juliëtte) van Duijnhoven

Assessing Energy Flexibility Using Thermal Mass
ir. M.Z. (Mohamed) Tantawi

Study of mycelium-based composite as foam like insulation material
V. (Vesta) Tsao


LOWERED THERMOSTAT SETPOINTS TO REDUCE ENERGY CONSUMPTION AND COSTS...
HOW MANY CUPS OF COFFEE DO I NEED TO FEEL WARMER AGAIN?
YOU JUST NEED A LITTLE BOOST, RICHARD!
Pleur.
KRT 2020
RICHARD
BY KOERT STAVENUITER

Foreword

Laurens Castenmiller

Dear INSide reader,

In front of you is laying the second edition of the INSide magazine of the year 2019/2020, which does represent the closure of the academic year 2019-2020. A year where many BPS students did, happily, graduate, and did, sadly, left the Vertigo building. Also, the COVID-19 pandemic was significantly present at the last semester. This did not stop us from producing this second INSide Information of 2019-2020. We have provided you with some interesting reading material to keep you occupied during these long, boring days at home.

Some BPS students did run into delays, and many BPS-related activities, as well as the fun activities, were canceled because of the pandemic. In the last quarter of this academic year, we should have visited Taiwan on our annual study trip. Sadly, due to national regulations, this was not allowed. The relocation of the date of this study trip was too early before the relaxation of the regulations. Fortunately, the creativity of Mollier is high, and now most physical activities have been replaced by online activities (like an online cocktail party and a first ever online pizza lecture).

This edition of the INSide features some master- and graduation projects of our students, in which various BPS subjects are highlighted. These include a graduation project about lighting by Jantje Edelbroek ("Optimal Lighting Conditions for a Post Anaesthesia Care Unit") and a graduation project about performance by Mohamed Tantawi ("Assessing Energy Flexibility Using Thermal Mass"). Thesse master projects presented will give you some inside in the findings regarding performance, fire safety and services. This has led to a wide variety of topics represented in this magazine. Besides these student projects, there is the IceBreaker where Judith de Wilde i introduces herself.

ABT, TVVL and ZRi have provided us with company articles on VR acoustics, an introduction to YOUNG TVVL and a look into the life of a ZRi'er. Joshua van den Heuvel gives an inside in his life as alumni of Mollier, and has been working at Johnson Controls since 2017.

As always, the INSide committee has worked hard to maintain the quality of the magazine. If you are enthusiastic about being an editor within the INSide committee, and want to help to design the next INSide you are more than welcome to contact us. We hope you enjoy reading the INSide!

Yours Sincerely

Laurens
Editor In-Chief

INSide Committee
Laurens Castenmiller, Meghana Kulhalli, Nora Kuiper

COLOPHON

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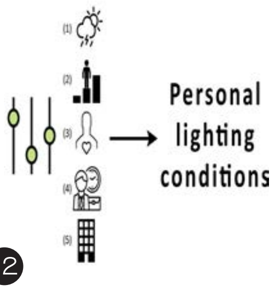
This INSide



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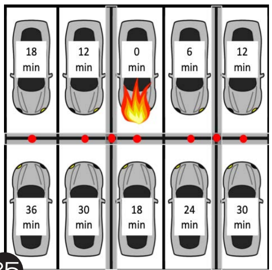

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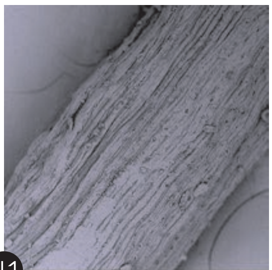

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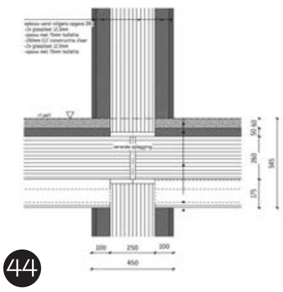

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Mollier Activity Calendar

MULTIDRINK
On the 29th of November, we were present at the Multidrink. During this day, the third year bachelor students set up their projects at Microlab on Strijp-S. We rewarded their efforts with some free beers, together with the other built environment study associations.

RICHARD'S BIRTHDAY TEA TABLE
On the 30th of November, Richard turned 156 years old! And how else to celebrate a birthday than with cake? We celebrated the birthday of our father in style by organizing a special Birthday Tea Table on the 2nd of December, with home-made cheesecake and brownies provided by the board. It was a birthday to never forget!

SET YOUR SHOE
Also this year, Sinterklaas did not skip the Mollier members, so we all set our shoe on the 5th of December to hopefully receive some treats. Apparently, everyone has been good in 2019, because no one got the roe. Because Mollier has a lot of international members, Sinterklaas himself tried to get some delicious international-oriented treats.

ATLAS EXCURSION BY VALSTAR SIMONIS
On the 18th of December, we had an excursion to our very own Atlas building on Campus, organized by Valstar Simonis. The excursion started of with a really nice presentation by old board member of Mollier, Peter van Mierlo, who explained all the technical details implemented by Valstar Simonis. After this presentation, it was time to have a tour through the building, that took us all the way from being actually on the roof to the basement and the archive located there. The morning ended with a luxurious lunch provided by Valstar Simonis and the caterer of the TU/e.

We would like to thank Valstar Simonis, and especially Peter van Mierlo, again for organizing such an interesting tour in one of our own campus' buildings!

NOVEMBER AND DECEMBER

STUDY TRIP REVEAL

On the 12th of December, we could finally reveal where we are going for our Studytrip in 2020. In 2020, we will travel to Taiwan! Originally, we were set to take off in May, but due to the pandemic COVID-19, the study trip had to be moved. We managed to postpone it to the last two weeks of August, but unfortunately, this moment is still too early for a trip this big.

LUNCH LECTURES ORGANIZED WITH OUR PARTNERS

This academic year, we moved into Trappenzaal for the lunch lectures. By choosing a more public location, we got some unexpected new visitors. The companies presented some very diverse topics. In November, ABT and Cauberg Huygen kicked off with technical presentations, on which you can read a short recap in the previous edition of INSide Information. For the second lecture in December, Nelissen and Voort gave presentations which were focused more on soft skills and also showed the design process of an engineer. Next up, in January, TNO gave a lecture about specialized applications of building physics in healthcare and greenhouse horticulture. In February, Royal HaskoningDHV gave the last lunch lecture of this academic year. They gave a really interesting presentation about parametric calculation models. We hope to be able to host more intriguing lectures on campus again in the near future!

COMFORT KITCHEN

The 24th board of Mollier wanted to provide some stress relief during the second exam period, so they prepared a proper 5-course Italian dinner, with the help of Daria and Meghana. It was a lovely evening, and definitely worth repeating. Maybe, a new tradition is born?

MOLLIER PUBQUIZ

We organized our first very own Mollier Pub-quiz in a typical Dutch "bruine kroeg". Strapped with a pen in one hand and a beer in the other, the Mollier members were put to the mind-bobbling and brain jurgling-test. Ranging from topics regarding from General Knowledge to Movies, but also the ever-important question of: The Pub-quiz committee also slipped in some rather personal questions (we all know what happened with the mayo). No braincell was left unturned, no beer was left orphaned. The winners of the night were Sietse, Meghana and Kay. Congratulations, we hope you have put the €20,- giftcard to good use among the three of you!

BPS EXHIBITION 2020

Last year, the 23rd board hosted the first ever BPS exhibition, inspiring a very motivated committee to follow in their footsteps. This year, we chose a common theme. Health and Comfort; two distinct notions that unite the underlying disciplines in one common goal. The exhibition featured research by the materials, lighting, acoustics, computational fluid dynamics, performance and services research groups. It may not have been open for long before the university closed, but it certainly did not go by unnoticed; the photos should tell you why that is.

PREMIERE ONLINE LECTURES

Besides having to cancel the study trip to Taiwan this year, and having to postpone the Meet & Greet to December, the 24th board was challenged to think of a solution to be able to organize lunch lectures with our partners. If you can't lure in students with a free lunch, what about a free dinner? After getting a pizza delivered by the board or a local Dominos, our members enjoyed an intriguing online lecture by Strukton and Kuijpers on intelligent buildings. We would like to thank Strukton and Kuijpers for their contribution to the first Mollier online dinner lecture and are looking forward to the upcoming online lectures!

ONLINE COCKTAILPARTY

On the 17th of April, the first-ever Mollier online cocktail party was organized. All the participants were delivered a box of ingredients ranging from shots of Jägermeister to a variety of fruits, to make four extraordinary cocktails. Despite the recipes and video call quality being challenging for some people, the party was a great way to enjoy the company of a lot of Mollier members while being at home.

Mining the Influence of Occupancy on Heating System Performance

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In a world where the building sector is responsible for 36% of the global energy consumption [1], a climate-induced paradigm shift demands the design of energy efficient buildings, as well as the optimization of those that already exist. Building occupants and their behaviour are among the key factors which influence building energy consumption [2]. Existing literature sets a premise for exploring the relationship between occupancy and building services [3], as well as a need for insight into how partial occupancy affects HVAC system performance [4]. The objective of this research lies in the investigation of heating sub-system performance in response to large occupancy variations.

METHODOLOGY

The research methodology is divided into the knowledge domain and the data domain. The knowledge domain examines the case study building and its building service sub-systems. The data domain adopts the well-known Knowledge Discovery in Databases methodology [5]. The case study concerns an office building in Utrecht, the Netherlands, where the occupancy count drops from 130 in 2018 to 55 in 2019. The performance of the building is monitored and controlled via a Building Management System. The building is heated primarily through the vents, ducts and floor. The data extracted from the BMS concerns the climate, the occupancy, the heat-pump sub-system and the air handling sub-system. Figure 1 shows a summary of the variables pertaining to the analysis of the air handling sub-system.

Data Set B: Exploratory Data Analysis
Data Set C: Model Selection

Data	Unit	Sensing strategy	Temporal	Spatial granularity
Outdoor Temperature	C	On-site weather station	8 minutes	-
Indoor Temperature	C	Temperature sensors	8 minutes	Room
Indoor Setpoint Temperature	C	-	8 mintues	Room
Indoor Temperature - Outdoor Temperature	C	-	8 minutes	Room
Indoor Temperature - Indoor Setpoint Temperature	C	-	8 minutes	Room
Occupancy count	-	-	Year	Building
Air Supply Temperature	C	Temperature sensor	8 minutes	Room
Preheating Valve Position	%	Position sensor	8 minutes	Room

Data Set D: Model Testing

Data	Unit	Sensing strategy	Temporal	Spatial granularity
Indoor Temperature - Outdoor Temperature	C	-	8 minutes	Room
Indoor Temperature - Indoor Setpoint Temperature	C	-	8 minutes	Room
Occupancy count	-	-	Year	Building
Air Supply Temperature	C	Temperature sensor	8 minutes	Room

Figure 1. Air handling and distribution data set summary

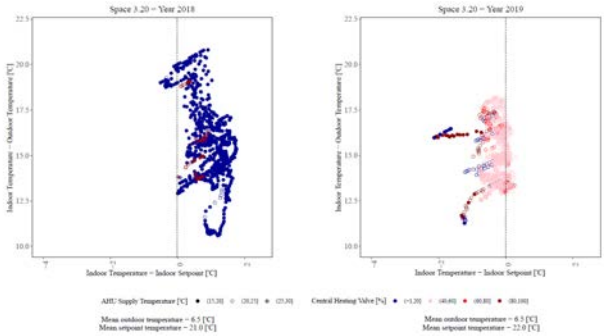

Figure 2. Data Set B: Floor 3

RESULTS AND DISCUSSION

The analysis of the heat pump sub-system is not conclusive but suggests that the heat pump performance may have been influenced by the occupancy count. The analysis of the air handling sub-system is in line with the observation. In 2018, the air handling sub-system displays a propensity towards matching or exceeding the indoor setpoint temperature, despite a lower average air supply temperature. The findings shown in Figure 2 support the possibility that partial occupancy contributes to an increase in heating demand and a decrease in air handling effectiveness. In support of the exploratory analysis, a logistic regression model is trained to classify occupancy count. The final model is of the form:

Logit(OCCUPANCY) =81.11+(- 3.84)(SUPPLY TEMPERATURE)+ (- 0.16)(INDOOR - OUTDOOR)+(+ 5.07)(INDOOR - SETPOINT)

The logistic regression model is tested against two out-of-the-box classifiers; support-vector machine; k-nearest neighbours, all of which are found capable of distinguishing between a building level occupancy count of 130 and 55. The logistic regression model is evaluated at an accuracy of 0.82 and an area under curve of 0.93.

CONCLUSION

Results affirm the importance of investigating the influence of partial occupancy. Occupants contribute to heating system performance in direct and indirect ways and their behaviour can be beneficial or detrimental to indoor conditions. Additional studies involving occupancy movement, tracking or identity at high spatiotemporal resolutions are needed. ■

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Personal lighting conditions of office workers

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My name is Juliëtte van Duijnhoven and I'm currently working as a postdoc researcher at the unit BPS within the faculty of the Built Environment. 29 November 2019, I defended my PhD dissertation and this article will be about the topic of my PhD research [1]. Currently, I'm involved in both lighting research and education and I would like to invite all students who are interested in light to do a master/graduation project with us.

INTRODUCTION

Lighting controls in offices are still mainly focused on energy savings. However, the numbers from CBS (Central Bureau for Statistics, the Netherlands) showed that the costs for employees are much higher compared to the energy costs and that the employees are the real value of the company [2]. It would be highly efficient to look at possibilities to lower the peak of employee costs. Focusing on a potential productivity increase of office workers would lead to much higher savings in company costs. A less alert office worker performs a task worse compared to a more alert office worker. My PhD project aimed at investigating possibilities to increase the alertness of an office worker when needed and certainly only when desired.

Alertness is a term that overlaps with the meanings of arousal and attention. It includes the wakefulness of arousal and the ability to cognitively function of attention. In this project, we measured alertness only subjectively, always using the Karolinska Sleepiness Scale (KSS). This validated scale only includes one question and was therefore the least obtrusive method for participants. There are many aspects influencing alertness (e.g., nutrition, caffeine, sleep hygiene, time of the day, colleagues, noise, air temperature). One of these many aspects is light. The relationship between light and alertness has often been investigated. In this project, we tried to identify the relationship between light and alertness in field studies.

When light enters the eye of an individual, it falls on the retina located in the back of the eye. The retina contains three types of photoreceptors. The rods and cones initiate image-forming processes and therefore enable vision. In addition, the ipRGCs (intrinsically photosensitive retinal ganglion cells) can initiate non-image-forming effects such as the regulation of the core body temperature, mood, the hormone production, and alertness. The amount and type of light exposure differs per individual. Therefore, we recommended everyone to look at individual's light exposure, so called personal lighting conditions. The term personal lighting conditions is defined as the lighting conditions falling on the eye of the individual, continuously gathered for the entire day [3]. Since this term is new, an approach was proposed to systematically consider these personal lighting conditions (Figure 1). The approach consists of four parts:

1. Gathering personal lighting conditions
2. Interpreting personal lighting conditions
3. Identifying predictors of personal lighting conditions
4. Relating personal lighting conditions to subjective alertness.

1. GATHERING PERSONAL LIGHTING CONDITIONS

The findings of our literature review regarding light and health in offices demonstrate that different light quantities have been included in light effect studies [4]. Illuminances and correlated colour temperatures were the most commonly used light quantities to map a lighting condition. Furthermore, there were many light quantities or factors (e.g., light directionality or timing of light exposure) not even included once in the included papers of the review. It is recommended to identify the lit environment as comprehensively and precisely as possible assuring, valid outcomes [5]. Therefore, it may be essential to include continuously measured personal lighting conditions consisting of multiple light quantities and factors simultaneously. It is expected that these personal lighting conditions cause a more accurate and reliable measurement of the lit environment around the individual. This may be

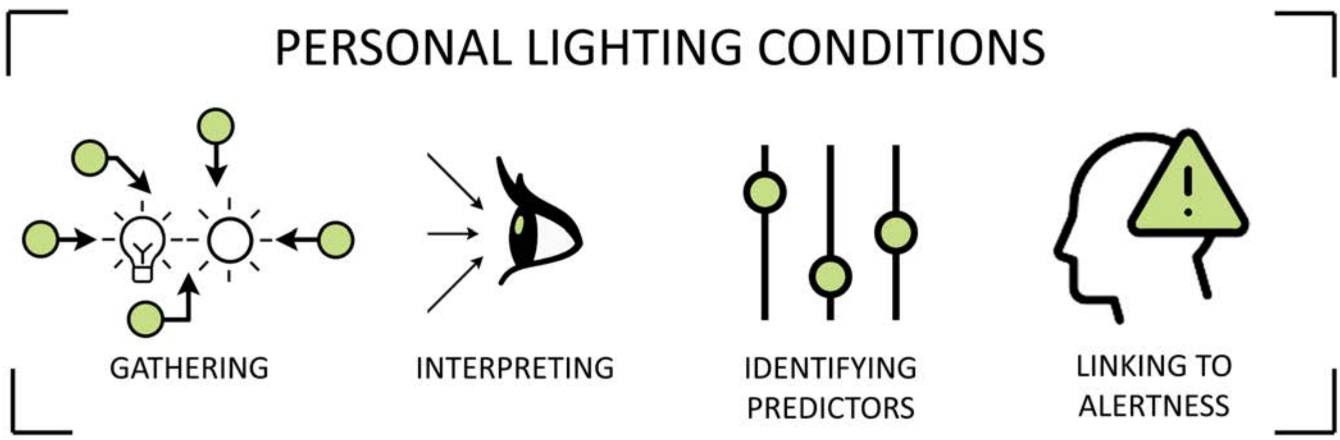

Figure 1. The developed systematic approach to consider personal lighting conditions

essential when performing a light effect study. In order to gather continuous personal lighting conditions, one can perform Person-Bound Measurements (PBM), Location-Bound Measurements (LBM), or estimate them via a newly developed Location-Bound Estimations (LBE) method [3]. This method estimates continuous lighting conditions based on a predictive model and a reference measurement instrument which continuously measures the lighting conditions at a certain reference location. Although this method complies with the continuous measurements, it only estimates the lighting conditions at locations which are specified with a predictive model. The location of the office workers needs to be tracked and inserted in this method to obtain personal lighting conditions [6]. Although the LBE method was less obtrusive for office workers, the method was not fully developed yet. Therefore, we decided to use person-bound measurements (PBM) in the majority of the project (Figure 2). The performance and wearing comfort of seven different wearable light measurement devices were investigated and these findings definitely need to be taken into account when applying PBM to gather personal lighting conditions in field studies [7,8].

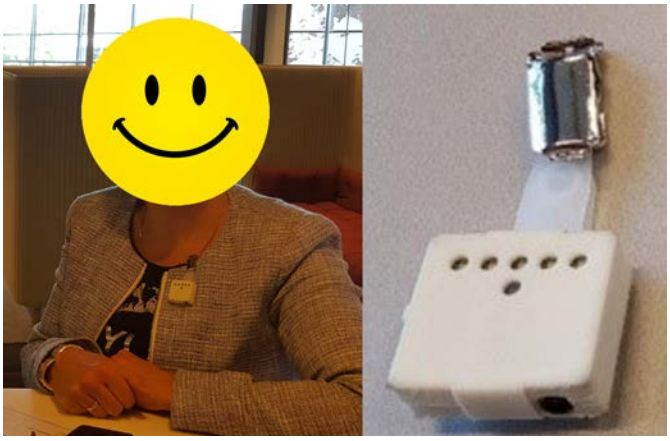

Figure 2. A participant during one of our field studies wearing a PBM device to gather personal lighting conditions.

2. INTERPRETING PERSONAL LIGHTING CONDITIONS

Although there is no consistency yet about a threshold or recommendation for lighting conditions to cause an effect on subjective alertness, the light factors quantity, spectrum, directionality, timing, duration, and history were identified to initiate non-image forming effects [9]. In order to explore these light factors, light measurements at the individual level need to be performed. Since the relationship between light and subjective alertness, besides light quantity and spectrum, may depend on the timing, duration, and history of light exposure, it is recommended to include continuous measurements of light exposure throughout a light effect study. Most of the previous light effect studies were performed in controlled environments whereas the lighting conditions before and after a certain experiment may be equally relevant [10]. Normal patterns of light exposure people receive are usually dissimilar to the lighting conditions participants receive in a controlled laboratory study [11]. Applying continuous light measurements ensures the option to investigate for what timing and for which duration the light exposure is essential to initiate effects on subjective alertness.

Personal lighting conditions of 62 Dutch office workers gathered during a two-week field study in spring 2017 were interpreted according to five light factors identified to initiate non-image-forming effects (i.e., light quantity, light spectrum, timing, duration, and history of light exposure). Despite the large individual differences, some general trends were visible (Figure 3 and 4). The light quantity (averaged over all participants) peaked three times during the day (one in the early morning, one during lunchtime, and one in the late afternoon). In addition, the light quantity "elsewhere" (i.e., all locations except "at work" and "at home") was significantly higher than "at home" or "at work". And last, the average light spectrum (represented as correlated colour temperature in the field study) did not vary much throughout the day (Figure 4).

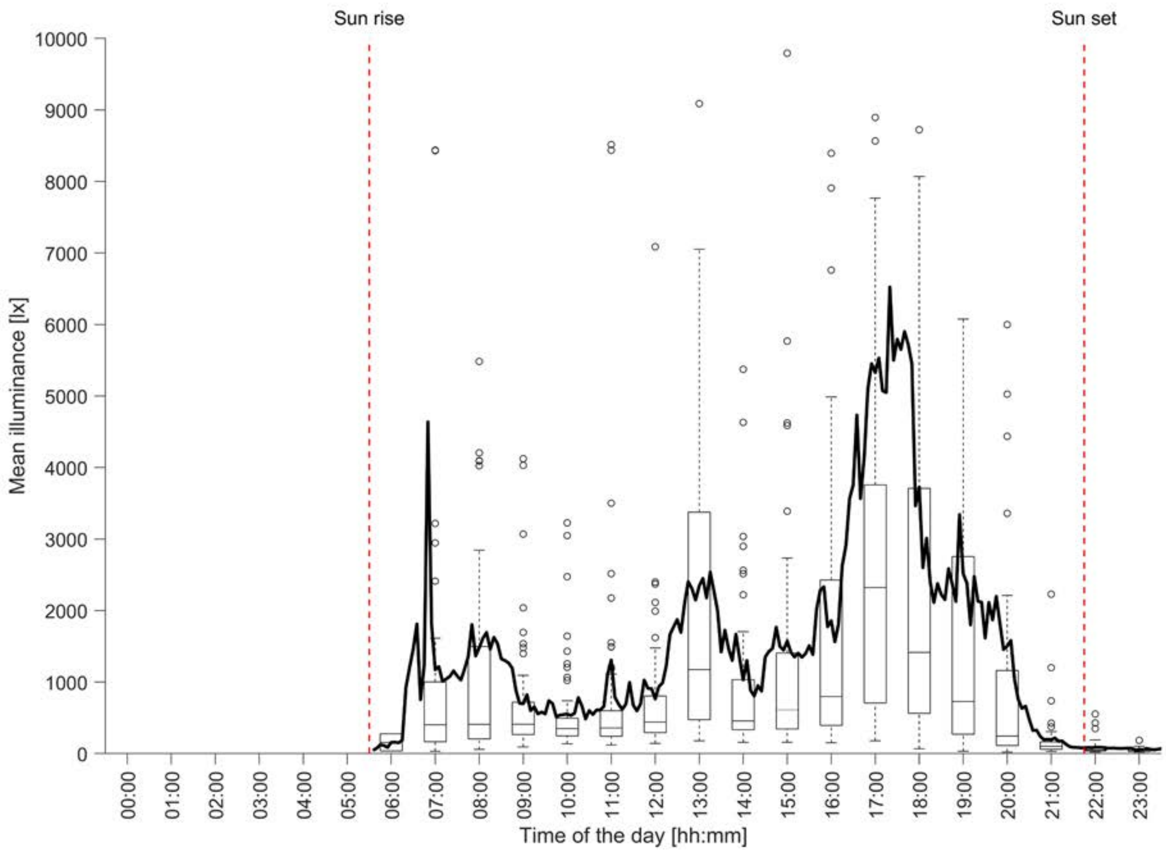

Figure 3. Boxplots demonstrating the variation in mean illuminance between participants. The bold black curve represents the average mean over all participants..

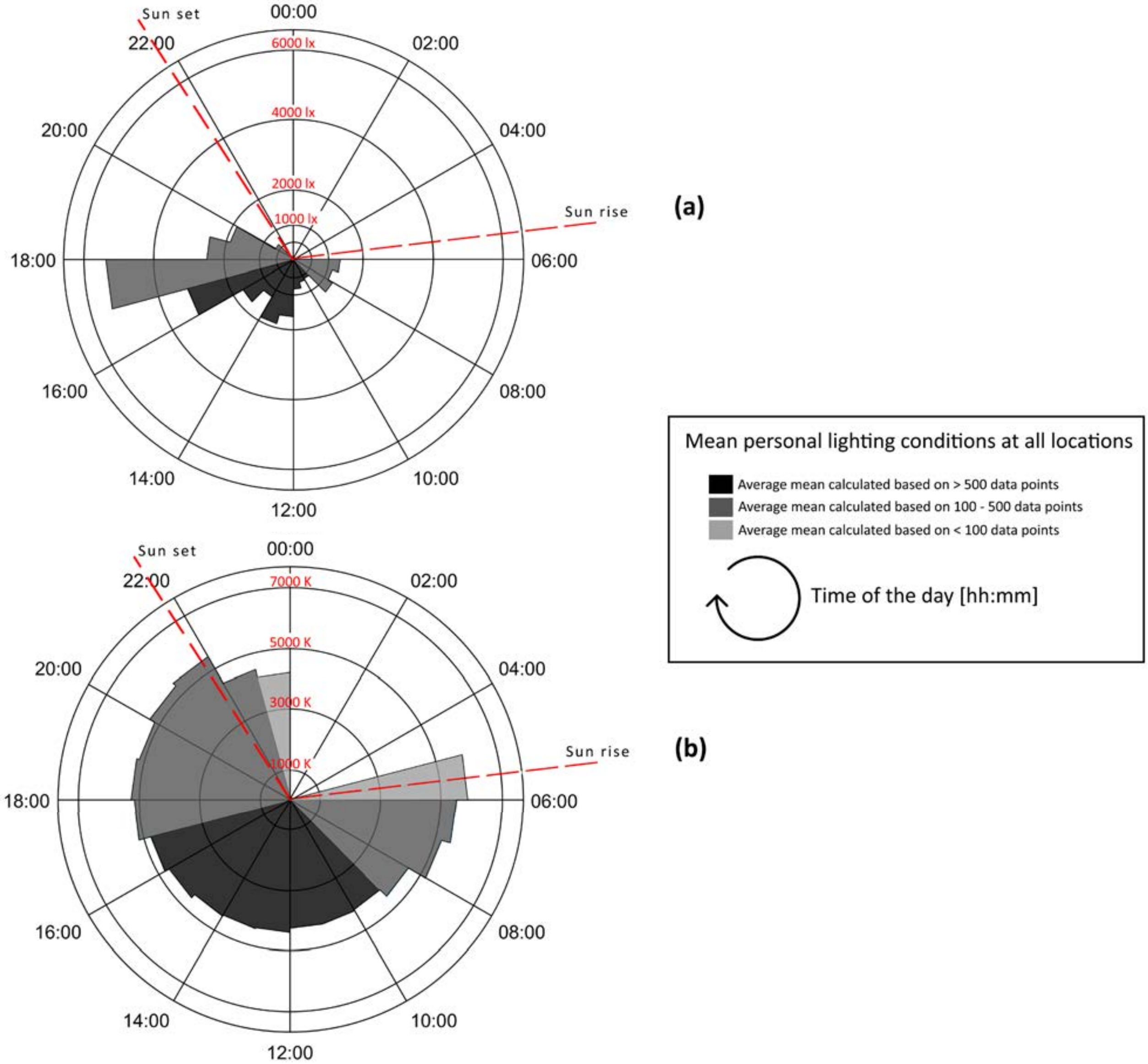

Figure 4. Average mean illuminances (a) and correlated colour temperatures (b) over the day. The average means are calculated by calculating the mean within participants and afterwards by taking the mean over all 62 participants.

3. IDENTIFYING PREDICTORS OF PERSONAL LIGHTING CONDITIONS

The same field study was used to identify predictors of personal lighting conditions. Weather conditions, fixed and flexible personal conditions, the daily schedule of the office worker (i.e., time spent "at work", "at home", or "elsewhere"), and office characteristics were found to associate with personal lighting conditions. Although, not all categories of predictors are controllable by the office worker him/herself, it is of high importance to raise awareness that office workers can adjust their personal lighting conditions themselves. Since not all office lighting systems can be controlled per luminaire to change personal lighting conditions at work, these categories of predictors act as alternatives. It may be possible to direct the office workers to their best personal lighting conditions at work by recommending a desk which fits the lighting conditions best for them. Selecting a workplace is often based on many aspects; however, we strived to raise awareness for office workers that personal lighting conditions should be considered.

4. RELATING PERSONAL LIGHTING CONDITIONS TO SUBJECTIVE ALERTNESS.

The influence of lighting conditions on subjective alertness was often demonstrated by comparing two or more different light scenarios. In the field studies performed in this project, the lighting conditions were uncontrolled and varied per individual and throughout the entire day. This discrepancy in lighting conditions may explain the lower number of significant correlations found between light and subjective alertness in our field studies. In an exploratory field study in the Netherlands, the data from only 6 out of 46 participants showed a significant correlation between light and subjective alertness [12]. This low number of correlations may also be explained by the type of office workers participating in the field study. The relationship between light and subjective alertness was tested in a second field study as well (N=62). Besides light quantity, light spectrum and duration of light exposure were included in the investigation of the relationship between personal lighting conditions and subjective alertness as well. This field study demonstrated that the duration of light exposure may be relevant in this relationship. Nearly all dose-response curves between personal lighting conditions and subjective alertness determined in this study turned out to be not significant ($p<.05$). However, the results may be of high importance in the exploration of the exact relationship between personal lighting conditions and subjective alertness.

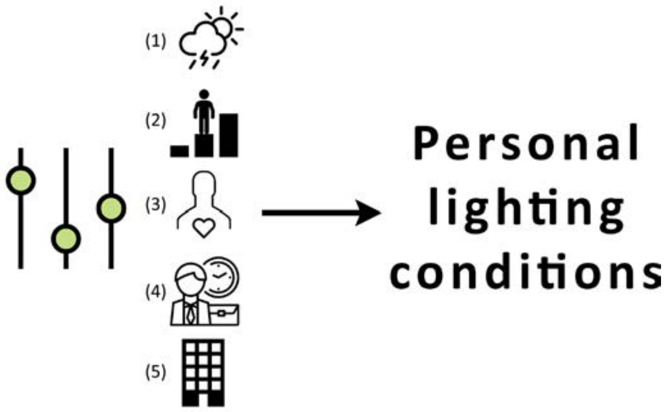

Figure 5. Framework to demonstrate the relationships between (1) weather conditions, (2) fixed personal conditions, (3) flexible personal conditions, (4) the daily schedule of the office worker, (5) office characteristics and personal lighting conditions.

CONCLUSION

The above-mentioned systematic approach conveys personal lighting conditions, predictors of personal lighting conditions, and its relationship with subjective alertness. These aspects can be inserted in intelligent systems to optimize alertness of office workers (Figure 6). Such systems would provide recommendations for office workers to adjust their own personal lighting conditions as an alternative rather than adjusting the electric lighting at the location of the office worker. This type of system may not only be energy efficient (since it uses the availability of daylight to its optimum) but also practical because it can be applied everywhere as long as it concerns the (indoor or outdoor) environment of an individual. The system can be used by companies to support their office workers to experience their optimal subjective alertness during the entire day. The office workers would feel more alert whereas the employers would see productivity gains to help them reducing their company costs. ■

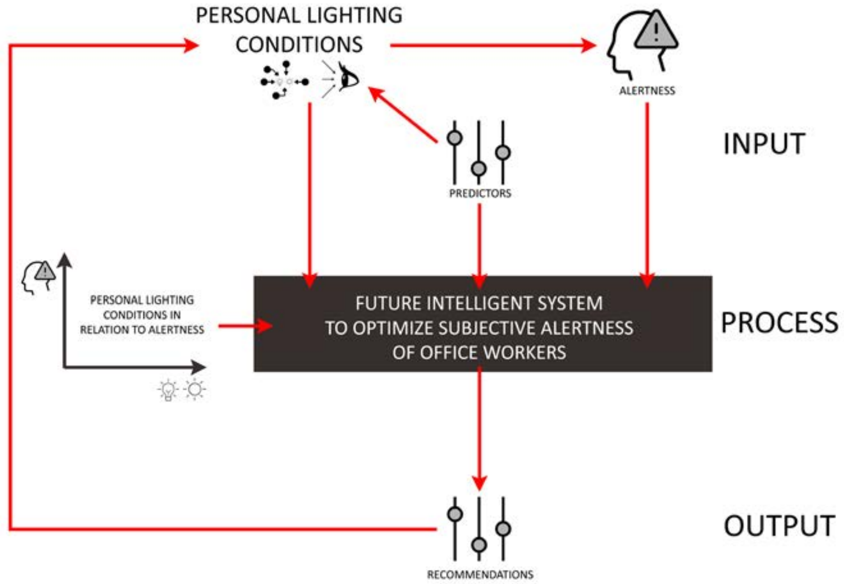

Figure 6. An example of an intelligent system using personal lighting conditions, predictors of personal lighting conditions, alertness levels, and the relation between personal lighting conditions and alertness as input to provide recommendations to optimize the alertness of an office worker.

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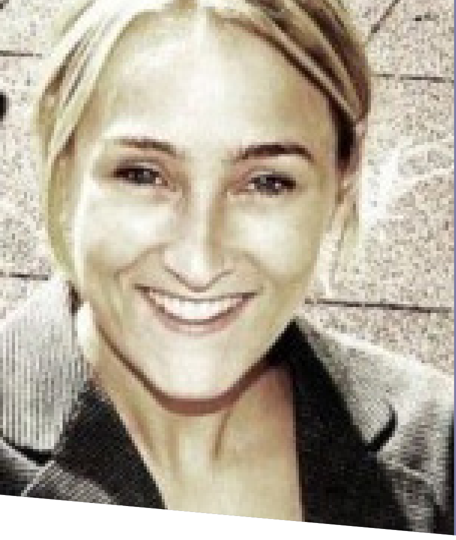

TVVL is Dedicated to Bring Energy for the Future!

TVVL is a knowledge platform and community in the installation technology sector. At different levels and with different disciplines. Technology does not only mean a technical story, more interesting are the people behind the technology and the effect of technology on people and society.

With the long lasting theme 'Beyond smart cities' TVVL has set its strategic focus on the challenges our industry is facing. In order to make its contribution to these challenges and opportunities, TVVL does not only focus on technical services in buildings, but considers the developments in a broader perspective. TVVL has committed itself to Connect2025, a vision on the most important developments for the Netherlands and the installation sector.

The world is changing fast. To keep pace with developments that will change the way we live today, we all have to make our contribution. We focus on all professionals in our sector, from scientists to HVAC system designers, manufacturers, building system consultants and students. By motivating and inspiring the entire sector we truly believe we can make a difference. Especially for students at the start of their career it is essential to be part of this energy and connect with like-minded people.

DEVELOPMENT OF KNOWLEDGE

TVVL explores trends and developments at an early stage. We look at the challenges and problems and bring the right people together to tackle these issues. What knowledge is needed and what role can TVVL play in this? At TVVL we make the connection between knowledge and people. With input from everyone's expertise, we look for new, smarter solutions. We work together towards a better future and a sustainable living environment.

SHARING

TVVL is completely dedicated to sharing knowledge, inspiration and motivation. Sharing knowledge to face the challenges ahead, inspiration to think outside the box and come up with innovative solutions and motivation to step up and work together to make a difference. More experienced members are willing to help you at the start of your career and TVVL wants to grow with you.

In addition to our knowledge, we also share our network. We do this through courses, events, TVVL Magazine and TVVL Connect. TVVL Connect is an interactive online platform on which our members can share their thought on current topics and events. On this platform you can introduce yourself and connect with other engineers. You can also drop a question or dilemma and find assays or internships. Take a look at www.tvvlconnect.nl and explore.

EXPERT GROUPS, COMMUNITIES AND REGIONS

Knowledge about projects and studies is also shared in many groups and regional communities. From practical studies to visionary insights about (new) techniques, applications and innovations. All these developments arise within our expert groups and communities. Together we create an environment in which you as a professional get the chance to excel. We are always open to hearing young talented people's vision and ideas.

COURSES AND SPECIALIZING AFTER YOUR STUDY

Besides that, TVVL offers an extensive range of professional courses for employees in the installation sector. Knowledge is accessible to everyone, but knowledge is not always correct or directly applicable. In addition to theoretical knowledge, applicable knowledge also requires experience in the field. The content of the courses TVVL offers are based on the practice from our experts. TVVL will continue to align its courses to current times with current laws and regulations in order to maintain a valuable, timely and practical offering of education. So after their study young professionals can absolutely benefit

from these practical lessons. The courses focus on technical design skills, integrated collaboration, project management, BIM, energy and personal growth.

YOUNG AND WELCOME

Building a business network can take years and you can never start early enough. YOUNG TVVL helps young professionals with work, career and networking. YOUNG TVVL brings new insights and new contacts and makes young professionals:

- feel at home within TVVL
- starting and expanding your network and speeding up your career
- connect with colleagues and the sector

YOUNG TVVL is committed to achieve these goals by bringing young professionals together in a relaxed and supportive environment. We do this through the organization of various fun events and activities focusing on personal development and technical innovation. Together with like-minded people, who are young at heart, we build a strong community and increase cooperation. Because you can only progress when you are willing to share. Ideas and initiatives are always welcome! YOUNG TVVL likes to hear what you need. For example, you can start a discussion on TVVL Connect, ask questions or share experiences.

BOOST YOUR UPCOMING CAREER AND JOIN OUR COMMUNITY FOR FREE!

TVVL is aware of the value of young professionals. New energy is more than welcome. Therefore we have a free membership for professionals under the age of 26.

All member benefits:

- Admission to all knowledge of TVVL
- Free entrance or discount on seminars, events, excursions or conferences
- 15% discount on our Post HBO courses
- TVVL Magazine 6 times a year (containing a wide range of technical scientific articles)
- Access to a large network of professionals

If you want to discover TVVL visit www.tvvl.nl or visit our LinkedIn page. We look forward to meeting you! ■

Because of COVID-19 YOUNG TVVL had to adjust the year program for 2020:

JUNE: YOUNG TVVL WEBINAR FIRST DATES

The theme of the webinar in June is First Dates. During the webinar the host and participants will go on a virtual date with their choosen subject. Subscribe for the webinar on our website.

OCTOBER: YOUNG TVVL WATERSTOFREIS (HYDROGEN JOURNEY)

Later this year we go on an exclusive 2-days journey, traveling through the Netherlands. We will travel by hydrogen bus and we are visiting various hydrogen companies to learn about sustainable energy storage and possibilities for the future. Are you interested in joining this exclusive journey? Win one of the 9 wildcards by sending your motivation to join this journey to m.hamaker@tvvl.nl. Creativity is appreciated!

NOVEMBER: YOUNG TVVL LEDENLUNCH (COMMUNITY LUNCH)

Every year members of YOUNG TVVL meet during a nice three course lunch to meet and get to know each other with some extra entertainment. After the lunch the TVVL Techniekdag (Technique day) starts. This is a complete day with multiple lectures about subjects ranging from climate, electrical and sanitary technology to hydrogen and building management automation.

DECEMBER: YOUNG TVVL EINDEJAARSFEEST (END OF YEAR PARTY)

Because of COVID-19 we could not organize a lot of big events and we had to reschedule some events in our year program. We decided to throw an end of year party. We will start with some lectures about current themes and innovative technological developments and we end with an nice networking party.

A taste of YOUNG TVVL 2021

MARCH: YOUNG TVVL TOEKOMSTVISIE TVVL KENNISPARTNERS BIJ VAN NELLE

We will discuss the future of building services engineering.

JULY: YOUNG TVVL ZOMERFESTIVAL 'FUTUREPROOF IN HET BOS!'

In the summer of 2021 we will organise the first YOUNG TVVL Zomerfestival. You certainly don't want to miss this! Themes: hydrogen, proptech, circularity en artificial intelligence.

Visit tvvl.nl/ytvvlagenda for our most up-to-date program (in Dutch).

What did we do in 2019?

YOUNG TVVL BEYOND THE FRAME: SUSTAINABLE, AUGMENTED REALITY (AR) AND BUILDING SERVICES

We visited NEP the Netherlands, the broadcasting service. We've seen the green rooms used for augmented reality (AR) and they told us about the usage possibilities of AR.

YOUNG TVVL ZOMERFEEST 'WIND & ENERGIE': GET READY TO BE BLOWN AWAY!

On a boot we sailed along the biggest wind farm in the Netherlands (Windpark Noordoostpolder). A guide learned us everything about wind energy whilst enjoying a cold beer and the summer tunes of a live DJ.

YOUNG TVVL ENERGIE VOOR DE TOEKOMST (ENERGY FOR THE FUTURE)

Together with over 100 young professionals we discovered the secret places of Johan Cruijff ArenA.

This football stadium has the mission to become the most sustainable stadium in the world. We had a tour into the wonderful world of smart technologies & cool innovations in the ArenA.

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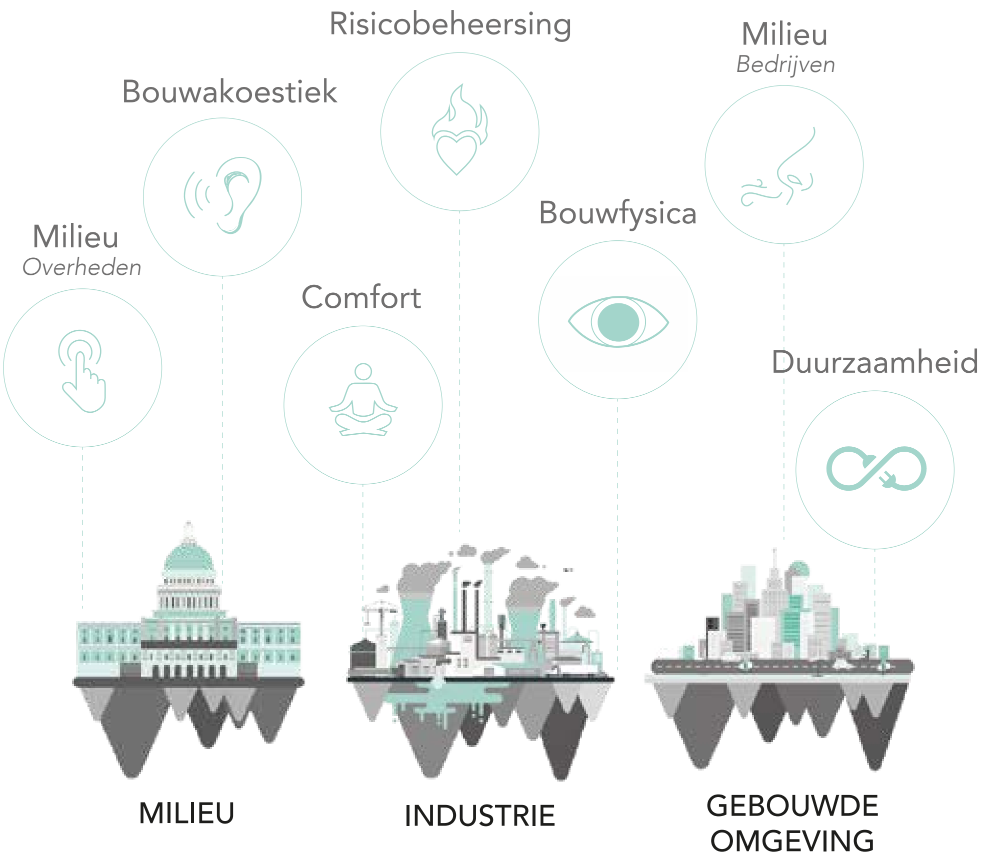

JOIN US NOW!

Wij zijn Cauberg Huygen. Onze Ingenieurs bundelen dagelijks hun krachten en werken samen met onze klanten aan de uitdagingen van morgen. Als adviseur zorg je samen met je team voor veilige, comfortabele en toekomstbestendige gebouwen.

WIE BEN JIJ?

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

WAT KRIJG JE VAN ONS?

- Gezelligheid
- Onmisbare kennis
- Doorgroei mogelijkheden
- Vakinhoudelijke en persoonlijke ontwikkeling
- Marktconform salaris
- Leuke collega's!

Sub-hourly Simulations for Advanced Solar Shading Strategies

Author
ing. W. (Wesley) van der Sommen

Supervisors
dr. ir. R.C.G.M. (Roel) Loonen
ir. S.B.D. (Samuel) de Vries

INTRODUCTION

For achieving a good balance between daylight admission, views to outside and solar gains, it is often necessary to install solar shading systems in high-performance buildings. Simulation studies are often used to assist in finding a balanced trade-off among these competing performance aspects. Information about local weather conditions is considered as one of the important boundary conditions in building performance simulations. Especially for climate based (daylight) modeling, it was found that the simulation outcomes are heavily dependent on the characteristics of available weather data [1].

In this study, the aim was to quantify the difference of daylight quality using different weather data timesteps. Specifically, 1-minute weather data modeled from hourly data using the Skartveit Olseth method in comparison with actual 1-minute weather data. The investigations were performed on a reference office equipped with different fenestration systems (i.e., clear glazing, roller blinds and suntracking vertical blinds) using weather data from Eindhoven using the three-phase simulation method.

METHODOLOGY

Dynamic daylight simulations are performed using the RADIANCE-based simulation environment DAYSIM. Weather data is available that is used to make simulations with a resolution of 1-minute. Furthermore, a modified version of the Skartveit Olseth model is used to model weather data with a timestep smaller than 60-minutes. These simulations can be compared with simulations using hourly weather data to investigate the added value of sub-hourly irradiance data.

As for the performance indicators, spatial daylight autonomy 300lux 50% (sDA300,50%) is used to allow the characterization of daylight quantity using a single value. Secondly, in order to assess the glare, simplified Daylight Glare Probability (DGPs) is used [2]. The DGPs formula can be used to assess glare, using vertical eye illuminance, without the need of simulating pictures. The DGPs could be derived with eq. 1:

$$DGPs = 6.22 \cdot 10^{-5} \cdot E_v + 0.184 \qquad (1)$$

The last performance indicator used in this study is the annual artificial lighting demand for electric lighting. This is calculated using a closed loop strategy using two ceiling-mounted lamps with integrated illuminance sensors facing towards the floor.

RESULTS

The results of the modified Skartveit Olseth model for a single day (figure 1) show that it is possible to model 1-minute irradiance data for Eindhoven that contains short-term dynamics of daylight using 60-minute data as input. However, the stochastic behavior of the model causes inaccurate results. Due to the stochastic behavior of the Skartveit Olseth model, high peaks occur which are compensated with low valleys. The high peaks affect the performance of the shading systems since they exceed the threshold, while the valleys barely affect the performance. The simulation of spatial daylight autonomy shows a slight overestimation compared with measured 1-minute irradiance data. Due to the high peaks from the stochastic behavior, the 300lux threshold is exceeded more often, which is beneficial for the spatial daylight autonomy of the room. The (simplified) glare probability cannot be accurately simulated using the modified Skartveit Olseth model. Where the suntracking solar shading system follows the sun and allows daylight to enter the room, the roller blinds system closes completely and is not affected by the high peaks. This confirms the tendency towards increased simulation errors with increasing brightness of the office. For calculating the annual artificial lighting demand, the model can accurately be used. The small difference between 60-minute data and 1-minute data shows that hourly data suffices for practical purposes of the lighting demand. Timesteps of 15 and 30 minutes can be used to reduce simulation and post processing time, but result in a reduced accuracy compared to 1-minute data. ■

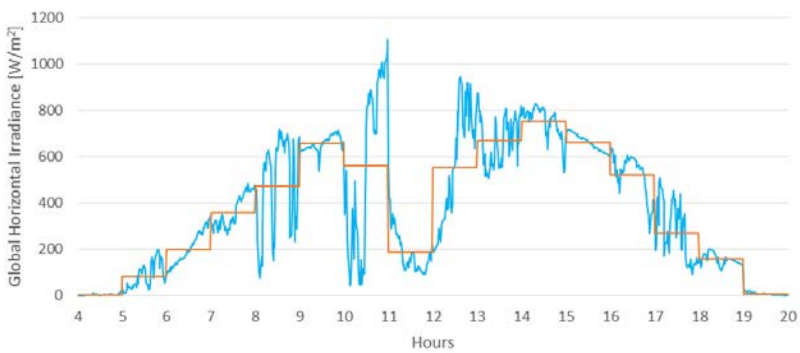

Figure 1. Modelled 1-minute (blue) and measured 60-minute (orange) Global Horizontal Irradiance values on June 23rd 2016

[1] Iversen, A., Svendsen, S., & Nielsen, T. (2012). The effect of different weather data sets and their resolution on climate-based daylight modelling. Lighting Research & Technology,45(3), 305-316. doi:10.1177/1477153512440545

[2] Wienold, J. and Christoffersen J, 2006. "Evaluation methods and development of a new glare prediction model for daylight environments with the use of CCD cameras," Energy & Buildings 38[7], 743-757

Alumni at Work

Author
J.T. (Joshua) van den Heuvel, MSc.

Hi! My name is Joshua van den Heuvel and I was raised in Deurne (NL). During the period of my (pre-) master I lived in Eindhoven and we recently bought an apartment in Utrecht and moved there a couple of weeks ago.

What did I do before joining s.v.b.p.s. Mollier? In 2009, I started a Bachelor of Applied Science in Building Engineering at the Avans University of 's Hertogenbosch. During my graduation project, I started to understand for myself that the options in the field after graduation were not the right ones for me, so I decided to start the pre-master of BPS directly after graduating. I also didn't mind an extension of my student life!

Eventually, I started the master in February. I wanted to broaden my circle within the BPS master, and so I joined the 20th board of s.v.b.p.s. Mollier. Three months into our board year, we noticed I had never signed up yet as a member. Oops! I became the 'Commissioner of Activities', together with the great commissions and fellow board members responsible for organizing the study trip, lunch lectures, meet & greet and last but not least all the fun activities. It truly was a BLAST!

Back to the master and some more work related matters. The department which triggered me the most during the master was building services and especially how to improve the building performances using a data driven approach. This interest resulted in my graduation project where I analyzed the performance gaps of a Dutch hospital building and discussed the role of continuous commissioning in solving these gaps. I have seen the building environment and data science growing towards each other, I also fulfilled one of my free electives in data science where I learned the fundamentals of machine learning. Where, in my daily work, I still reap the benefits of the latter.

After graduation, I took the opportunity to start working at Johnson Controls, the company I also worked at for my graduation, and I have been working here just over a year now. From the beginning, I was an odd man out since most of my colleagues have a mechatronics background. However, I think otherwise, since having an understanding of building services is key for an optimal control. The role I fulfill at Johnson Controls is Solution Development Engineer which is part of a relatively new branch of our organization, Digital Solutions. My tasks consist of fitting solutions designed by our R&D departments in Ireland and the US to the Dutch market, designing and engineering custom solutions to meet a costumer's ambition for improving their building performances and together with our service department I provide consultancy in the field of durability and sustainability to our service costumers.

The solutions I am talking about are, what can be considered, "Smart Building" solutions. When asking people about the meaning, one would get a lot of different reactions. One of my tasks is to help customers, when asking for a smart building, to track down their meaning of a smart building and the reasoning behind it to design a plan to reach their goals. A great development I've seen is a shift from business cases being built around an ROI solely based on energy consumption towards ones where indoor climate is part of the equation. Keeping in mind that the productivity of a company's personnel is cost-wise, in many cases, much more important than the energy consumption. Nonetheless, being in the COVID-19 crisis at the moment will possibly shine a new light on the perception of indoor air quality within buildings.

How do I see the overlap between study and work? I am doing mainly work with a 1-on-1 overlap with my graduation project and have learned a lot over the year about building management systems and their infrastructures. But there is still a lot to learn in the field of building automation and I will be doing so in the future.

I hope you have enjoyed reading my experience of the master and my career for so far. Please let me know if you are interested to know more about what I do and we can have a coffee or a beer (preferred). ■

Group picture of the study trip of 2016

Group picture of "Bierfysica", a group of friends existing of only BPS students

ARCADIS Design & Consultancy for natural and built assets

CREATING A SUSTAINABLE FUTURE TOGETHER!

Wie zijn we?

Van klimaatverandering tot razendsnelle verstedelijking. Onze wereld wordt steeds complexer. De ruimte in steden moet optimaal worden benut en onontgonnen land moet bewoonbaar worden gemaakt. Juist op deze terreinen creëren wij buitengewone en duurzame oplossingen. Onze mensen werken gezamenlijk aan het creëren van meerwaarde door gebouwde en natuurlijke elementen naadloos in te passen in hun omgeving. Van winkelcentra in Shanghai tot een nieuwe metro in Doha en het terugdringen van luchtvervuiling in Los Angeles. Arcadis. Improving quality of life.

Duurzaamheid

Of het nu gaat om het duurzaam optimaliseren van de ruimte in de stad of het beschikbaar houden van (natuurlijke) grondstoffen in het productieproces, Arcadis behaalt uitzonderlijke en duurzame resultaten voor haar klanten. Het is onze passie om de kwaliteit van de leefomgeving duurzaam te verbeteren door waarde toe te voegen op sociaal, economisch en ecologisch vlak.

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Consequences of a Travelling Car Fire on Load Bearing Elements

Author
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Supervisors
ir. R.A.P. (Ruud) van Herpen
prof.ir. W. (Wim) Zeiler

INTRODUCTION

In an open carpark a localized fire cannot develop to a compartment fire. The hot layer, from a car fire, will not reach flashover conditions, due to the open façades of an open carpark. A pre-flashover fire (localized fire) is hardly hazardous for load bearing building structure. However, when it is not possible to put out the localized fire, this fire becomes a travelling localized fire with many cars involved. This travelling car fire results in a more severe thermal load than a localized fire, with more load bearing elements exposed.

BOUNDARY CONDITIONS

The parking garage, 70% open façade, consists of a steel construction with lightweight concrete floor slabs. In the longitudinal direction HEA-140 beams are used (secondary beams) and IPE-600 in the transverse direction (main beams). A fire starting in the middle of the row can be seen as the worst case, with the fastest fire propagation. Because of the open façades of the carpark, the fire remains fuel controlled during the whole fire scenario.

METHODOLOGY

The localized thermal load on the construction is determined by CaPaFi, a result of the European DiFiSek program: Dissemination of fire engineering knowledge [1]. With CaPaFi the heat release rate of the cars and the burn-out pattern is used to determine the temperature in the steel construction close to the car fire. This localized thermal load is depending on the distance to load bearing elements. The global thermal load is determined by the multi zone simulation program CFast, calculating the evolving distribution of smoke, fire gases and temperature throughout zones and compartments of a building during fire [2].

RESULTS

The multizone model CFast confirms that the global thermal load is not higher than or equal to 300°C in each zone, meaning that flashover to a compartment fire will not occur. The global thermal load has no consequences for the load bearing function of the steel structure. However, the local thermal load, simulated with CaPaFi, results in a maximum steel temperature of 557°C for the HEA-beams in the longitudinal direction and a maximum steel temperature of 631°C for the IPE-beams in the transverse direction.

To determine the consequences, the calculated temperatures were compared to the critical steel temperatures of load

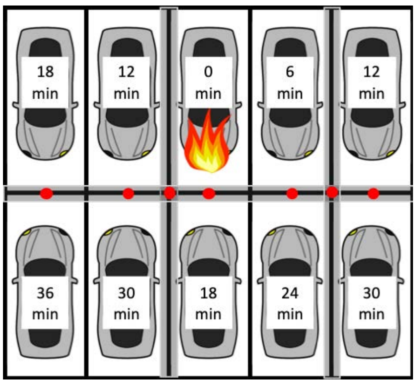


Figure 1. Propagation fire parked cars and measurement points in CaPaFi

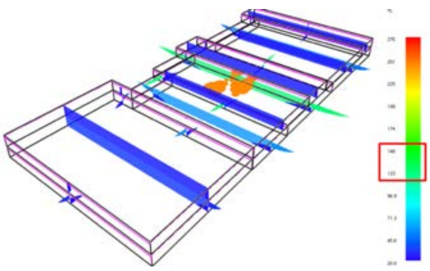


Figure 2. Model of CFast with modeled vehicle fire

bearing beams in parking garages. The safe value is set at 554°C [3]. In this safe value the load bearing structure is assumed to be optimized for the mechanical load. In many cases the load bearing structure is not really optimized, resulting in a higher critical steel temperature. It can be seen that both values are above the safe value of the critical steel temperature. By oversizing and introducing other profiles, the steel temperature can be lowered below the safe value.

CONCLUSION AND LIMITATIONS

It can be concluded that with the experimentally determined fire propagation from car to car, the temperatures in the load bearing beams, close to the car fire, are higher than the safe value of the critical steel temperature. The local thermal load is heavier than the global thermal load. Flashover to a compartment fire does not occur.

A remark to this conclusion is that the experimentally determined fire propagation from car to car is an extremely important parameter for the localized thermal load. This parameter contains a large uncertainty and can be seen as a significant stochastic boundary condition [4].

By oversizing the beam profiles, the steel temperature can be lowered below the safety value. However, the parking garage cannot be considered as a lightweight structure anymore, although that is needed for demountable parking. Protection of steel beams by intumescent paint or fire-resistant boards is not desirable. Perhaps a solution in which the primary heavy IPE beams are fire protected and the lighter secondary HEA beams are oversized is the best solution. ■

[1] CaPaFi. (2002). European DiFiSek program
[2] NIST. (2019, October 16). CFAST. Retrieved from https://www.nist.gov/services- resources/software/cfast
[3] Hamerlinck, A.F. (2015). Veilige waarden voor de kritieke staaltemperatuur bij ontwerp en aanbesteding. Bouwen met Staal.
[4] Mattheus, C.E.L. – Fire propagation in an open car park – Eindhoven University of Technology, February 2017 (master thesis)

Silver Lining

5th Lustrum

1996 - 2021

SVBPS

MOLLIER

"To look for the silver lining" is a suggestion that has been said so often it may appear trite to some. But it actually contains a very deep wisdom, that can help us all to get through difficulties.
- Urban Dictionary

SAVE THE DATE!

Opening Lustrum year
1st of October 2020
Café Thomas, Eindhoven

Symposium
10th of March 2021
Location t.b.a.

Lustrum Gala
5th of June 2021
Location t.b.a.

OUR HISTORY

S.v.b.p.s. Mollier was originally established in 1996 as the Installatietechnische Studie Vereniging (I.S.V.) Mollier, named after the physician Richard Mollier. This study association was founded to improve the exchange of knowledge and experience amongst students. In the 90s, the professional field panted for students who studied building services. Therefore, the desire of the founders of I.S.V. Mollier was to become an independent study association, and thus not part of CHEOPS, the study association for the Built Environment. After winning the debate with FSE, the Federation of Study Associations Eindhoven, there was the establishment of I.S.V. Mollier.

In 2011, I.S.V. Mollier merged with Studieveringing Bouwfysica Flux. Flux was originally established in 1980 under the name Fysische Aspecten van de Gebouwde Omgeving, FAGO, and later renamed Flux. The decision of the TU/e to merge the faculties of Building Physics and Building Services, lead to two associations within one faculty with the same interests, and this was of course undesirable. Therefore, the decision was made by Flux and I.S.V. Mollier to continue together as one sub association of CHEOPS under the name of Studievereniging Building Physics and Services Mollier. This is how we know the association nowadays.

A lot has happened with s.v.b.p.s. Mollier in the past 25 years, and we are honoured that we can celebrate the 25th birthday of the association in the upcoming year! Hereby, the lustrum committee would like to proudly present to you, the theme of the 5th Lustrum, that will be “Silver Lining”, and the main activities that will happen next academic year!

Study of Mycelium-Based Composite as Foam like Insulation Material

Author
V. (Vesta) Tsao, BSc

Supervisor
dr. F. (Florent) Gauvin

Nowadays, circular economy and sustainability aspects of materials are taking a huge role in consumer decisions. Wall insulation materials are usually synthetic or petroleum derived materials, which are less environmentally friendly. Mycelium based composites, on the other hand, utilized fungal mycelium, an interwoven network of hypha to bind with substrates and produce composites with high porosity. The main composition of mycelium are natural polymers, such as cellulose, proteins, chitin, chitosan, etc. It is a biocomposite and completely biodegradable. Review papers summarized commercial products made by mycelium based composites across from building material such as insulation material, acoustic absorption panels, structural material to packaging foam material, furniture, particleboards, etc [1]–[3]. Studies have shown mycelium composite can be an alternative sustainable material to replace petroleum derived foam as current conventional insulation materials, such as XPS and EPS I[1], [4], [5]. "The Growing Pavilion" exhibited in annual Dutch Design Week in 2019 was a showcase building of timber structure combined with panels made from mycelium based composites.

The process of producing mycelium based composites are very similar to other edible fungal growing industry. Three major components of the material are including substrates (the medium which provides nutrients for fungal growth), fungal strains (the growing process of hypha creates a 3D interwoven network), and water, as Figure 1 shows. The composition is rather simple and trivial, however, the growing conditions and processes are the important factors to determine the quality and quantity of end products. From a material science point of view, substrate composition has tremendous impact on material mechanical and physical characteristics such as densities, porosity, and strength, as Table 1 shows.

Mycelium based composites received attention in recent scientific research field, however, literature is still scarce. In

Table 1. Parameters affect material characterizations

Fungal Strains	Saprophytic fungi convert waste into mycelial mass
Substrate Types	Composite density, porosity, strength...
Substrate proportions	Optimal growth condition of mycelium
Growing conditions	Temperature, RH level, CO_2 level, light
Shaping	Non press/cold/heat press, depends on molds

total 40 scientific papers were found, 43% of them focused on material characterizations, which has indicated that this material is still on early development, as Figure 2 shown. Moreover, it is hard to compare results between different studies due to a large range of parameters can be altered. In other words, a systemic way of studying mycelium based composites is still lacking in the research field. Like other natural biocomposites materials, there is some weakness of this material to be used as building materials, especially one considers durability as an important factor. Due to a large portion of the material is consisted of agricultural residuals, the hydrophilicity is the main concern. High water intake and absorption have been shown in various mycelium based composites studies (from 200% to 300%), which will increase thermal conductivity and reduce material performance as insulation. Durability can be addressed by studying its morphology, water absorptive, and other physical properties. There are many ways of improving the durability of a material. Question is to find a method that has the least cost, easier to upscale (in the production process), and apply the material according to its natural characteristics. ■

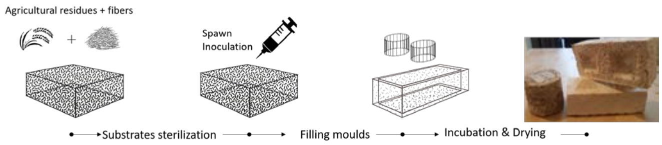


Figure 1. Production process of mycelium based composites

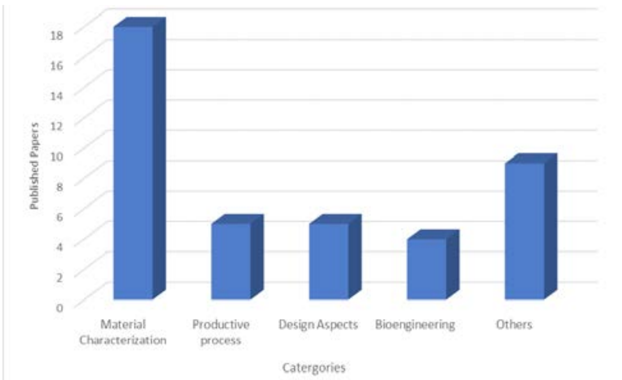


Figure 2. Scientific research paper about mycelium by categories

[1] M. Jones, A. Mautner, S. Luenco, A. Bismarck, and S. John, "Engineered mycelium composite construction materials from fungal biorefineries : A critical review," Mater. Des., vol. 187, p. 108397, 2020.

[2] F. Heisel and D. E. Hebel, "Pioneering Construction Materials through Prototypological Research," Biomimetics, vol. 4, 2019.

[3] R. Abhijith, A. Ashok, and C. R. Rejeesh, "Sustainable packaging applications from mycelium to substitute polystyrene : a review," Mater. Today Proc., vol. 5, no. 1, pp. 2139–2145, 2018.

[4] M. Jones, H. Chun, R. Yuen, and S. John, "Waste - derived low - cost mycelium composite construction materials with improved fire safety," Wiley, no. April, pp. 816–825, 2018.

[5] C. Girometta et al., "Physico-Mechanical and Thermodynamic Properties of Mycelium-Based Biocomposites : A Review," sustainability, vol. 11, 2019.

Ice Breaker
Judith de Wilde

Hi there! My name is Judith de Wilde and I'm 23 years old. I grew up in a village called De Meern, near the city of Utrecht. I have been living in Eindhoven for a couple of years, where I am finishing my bachelor's degree in Architecture, Urbanism and Building Sciences. I'm really looking forward to starting the Building Physics and Services master track.

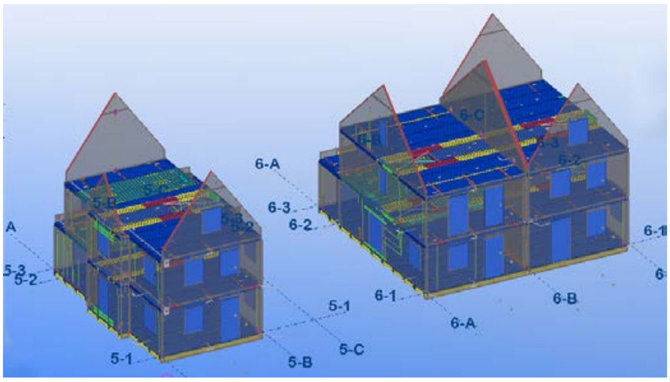
As a child I was really creative. I loved colouring, painting and all other types of crafting, I also was rather curious. I still have the tendency to investigate or look up information if I don't know or understand something. Due to this constant search for knowledge from a young age, I developed practical and technological insights. For an art project in high school I designed a small light installation. Although I don't have two left hands like some of my family members, I still can be quite clumsy. Knocking over a water bottle during a presentation has happened more than once.

The Architecture bachelor here in Eindhoven was a great outlet for my technologically orientated creativity and I made the choice to study here when I was sixteen, at the beginning of the carrier orientation period in high school. At the age of 14, it had already become my goal to study Architecture. I have even found a comment in a friends booklet of six-year-old me, 'vriendenboekje' for the Dutch readers, where I had written that I either wanted to be a pilot or an architect. My dream to become an architect has been long gone, because I found out, while searching for a subject for my profile project, that studying building physics and services was far more enjoyable. Finding the statistic that 90 percent of the population spend their time indoors certainly influenced this decision. I am particularly interested in the effect of the building environment and the indoor air quality on the health of people.

High school art project.

Since September I have combined my study with working part-time at the engineering company Vericon in Veldhoven as a 3D modeler. Three days a week, I am working on different projects where I get to design the concrete casco elements, like walls and floor, based on an architectural IFC model for prefabrication. I also have to discuss possible issues with the in-house constructor, contractors and sub-contractors. It's great that I have this opportunity to already gain work experience, although at times it's a juggle to manage my time.

Some days after working or studying, I can be found at activities of the student association SSRE or at my mixed fraternity. In my free time, I also like to read stories with a lot of intrigue, cooking and meeting up with friends. I try to go swimming at least once a week at the SSC and like all other students I cycle a lot. In the summers, I love to go sailing. I have been doing that since I was twelve. Of all the sports I have tried of the years, sailing makes me feel the most alive, healthy and free I have ever felt. I want to realise atmospheres in buildings that replicate this feeling, that are open, healthy, and serene. ■



Example of a Vericon project.

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Towards Acoustic Virtual Reality for the Architectural Design

Dr. ir. Giacomo Vairetti
Acoustic specialist at ABT

The acoustic comfort is one of the most complex, yet often underestimated, aspects in building engineering. The architectural design of a space that 'sounds' good and pleasant results from the ability to define the right geometries and select appropriate surface materials and building elements. It is the job of the acoustic consultant to advise architects in the early stages, before the room is built, so that acoustic measures can be implemented and seamlessly integrated in the design. If the process goes well, the final result is a visually beautiful and acoustically comfortable space. This article shows how the modern acoustician can assist the architect not only by estimating room acoustic parameters through computational modeling and advanced simulations, but also by making the room acoustics hearable through the process of auralization and the concept of acoustic virtual reality.

MODELING AND SIMULATING ROOM ACOUSTICS

The well-known formulas by Sabine and Eyring for estimating reverberation time are very useful in case of simple rectangular rooms, but less so for spaces with complex geometries and large dimensions. Luckily, recent years have seen a rapid development of methods for estimating room acoustic parameters in any type of space by means of computational modeling [1]. These aim at reproducing the room impulse response (RIR), i.e., how sound travels from a source to the listener, both directly along the line of sight and indirectly after being reflected multiple times off the room surfaces. This is done by simulating how sound physically propagates in the room (wave-based methods) or by approximating it as a multitude of travelling sound rays or particles (geometrical methods). Wave-based methods are computationally demanding and are normally confined to simulations of low-frequency sound. Thus, methods used in room acoustic simulation software, e.g. ODEON, EASE, CATT-Acoustic, I-Simpa, and RAVEN, are mostly ray-based. Early reflections, i.e., sound reflected off the walls a small number of times before reaching the receiver, are normally modelled as a ray coming from an image source specularly placed on the other side of the reflecting surface. Late reverberation, which has a more random nature, is instead modelled as sound rays or particles whose energy is partially absorbed each time a surface is hit (see Figure 1).

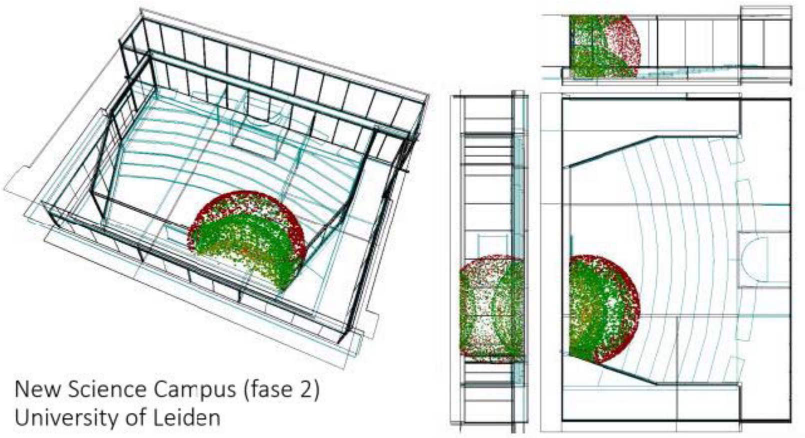

Figure 1. Sound particles propagating from a source in a lecture hall (software: ODEON)

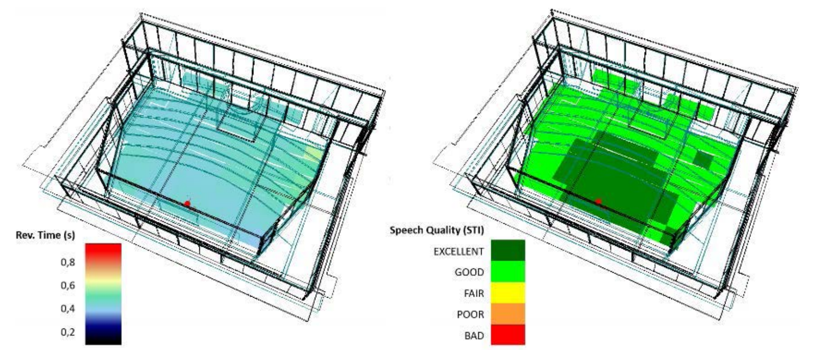

Figure 2. Simulation results for reverberation time and speech quality for the room in Figure 1

At ABT, we perform room acoustic simulations in our daily work within both the knowledge group (KG) Building Physics, Installations and Fire Safety and the KG Advanced Simulations. The starting point for a room acoustic simulation is the creation of a room model, which can be a somewhat simplified version of the architectural model obtained using a 3D modeling software, such as Sketch-up, Revit, Rhino or Blender. Each visible surface in the model is then assigned a specific material. From an acoustical point of view, this means giving to each surface the right absorption, scattering, and transmission coefficients at different frequencies. These determine how much sound energy of the incident sound particle is dissipated, scattered in directions different than the specular one, and transmitted through the surface, respectively.

Once a room model is created, a source and a receiver can be placed at the desired positions, and the RIR can be simulated. This we had done for a large number of sources and even more receivers in order to predict the reverberation time for the large public areas of the new Terminal Schiphol, so as to achieve an

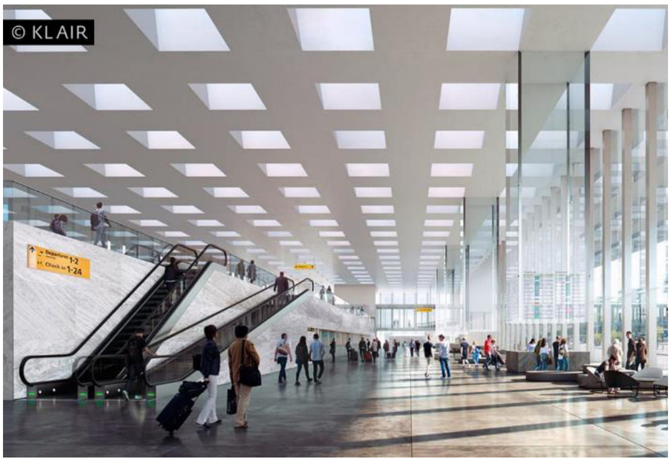

Figure 3. The departure hall of the New Terminal Schiphol (by KL AIR)

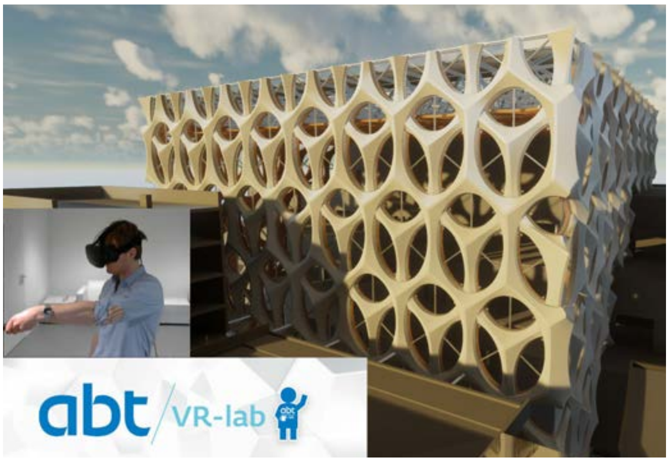

Figure 4. The façade of the Museum Naturalis as seen through the headset of the ABT VR lab

optimal integrated architectural and acoustical design (see Figure 3). Apart from the reverberation time, a number of room acoustic parameters can be calculated from the simulated RIR. These parameters, defined in the ISO 3382-1 [2], are very important to assess the acoustics of performance spaces, such as concert halls and auditoria. In addition, by simulating the RIR at multiple source-receiver positions, it is possible to visualize the parameter values in space in the form of color maps, very useful to communicate the results of our study with architects and our clients (see Figure 2).

Another important aspect in acoustic simulations is the possibility of defining the source characteristics. By adjusting the sound energy and the directivity of the source, we can simulate a speaking person inside the modeled room. This allowed, among others, to assess the noise levels in the atrium during busy lunch time of the new C23 Shell building in Den Haag, to estimate the acoustic comfort in the open-plan offices (according to ISO 3382-3 [2]) of the New Amsterdam Court House, or to predict speech quality in the auditorium of the new Science Campus of the University of Leiden (see Figure 2). It is also possible to define the source characteristics as those of loudspeakers. In this way, we can simulate a public address system and find out which specific type of loudspeaker provides the highest intelligibility of speech in a public space such as a train station. The source can also be modelled as a surface or as a line in order to assess the noise generated, for instance, by industrial machines or by HVAC ducts.

AURALIZATION – LISTEN TO THE ROOM

So far we discussed about simulating how sound propagates in spaces in order to estimate acoustic parameters. But sound matters only in relation to how we perceive it. So the picture is not complete until we include our ears. In order to do so, we need to model how sound is reflected off our shoulders and torso, attenuated by our head and modified by our pinnae. All this information is contained in the so-called head-related impulse responses (HRIR). Auralization is the process of making the result of these acoustic simulations audible, so that it can be listened to (normally through headphones) and analyzed [1]. As an analogy, auralization is for the acoustic engineer what visual rendering is for the architect. The process in a nutshell consists of taking a dry sound signal, such as that of a person speaking or playing an instrument recorded in an anechoic chamber, and mix it with the simulated RIR using an operation called convolution. The result is further convolved with the left and right HRIRs for a given angle of sound incidence. The intended effect is to be able to hear the sound signal as if it was played at a certain position inside the simulated space.

The potential of auralization in the work of the acoustician is manifold. As a tool, it helps in evaluating different design choices from an acoustic point of view and to communicate results and advices more effectively to architects, team members and clients. Of particular interest is the possibility of rendering activity sounds in large public spaces such as atria, auditoria and transport hubs, so as to assess the perceived noise and the ease of conversation. Or to be able to evaluate the intelligibility of speech of a public address system. Or to hear the quality of the acoustic design of a concert hall, where each musical instrument is modelled as an individual sound source on the stage and the receiver is sitting in the audience. Other possibilities include the auralization of sound transmission of building elements, such as a wall or a façade, and of urban scenarios, such as that of a car pass-by.

TOWARDS ACOUSTIC VIRTUAL REALITY

The next step becomes almost obvious. What if we incorporate auralization into the virtual reality (VR) environment? VR is already part of our integral advisory work thanks to the work of the KG Architecture and the KG Computational Solution. In ABT's VR labs in Velp and Delft, every 3D model can quickly be converted to a virtual environment, where adjustment and variants can be made in real-time with the help of parametric design (see Figure 4). Incorporating sound and acoustics into the VR sphere adds another dimension to the experience. Acoustic VR makes the immersion more believable, and in the context of building design, easier and more intuitive to explore different acoustic designs and soundscapes. We only need to make the auralization to operate in real-time. Every time the listener rotates the head, we update the HRIR, and every time it changes position (or the source moves) we update the RIR.

In reality (the real one), even though it is possible to perform real-time convolution with precomputed RIRs and HRIRs, it is not yet feasible to simulate a full new RIR every time something in the scene changes [3]. Future developments and technological advances will likely bring us even more powerful tools and more accurate acoustic simulations in real-time. Another interesting future application will be the combination of acoustic VR with parametric design tools, which will allow us to directly link the architectural design to its perceived acoustic comfort and to investigate solutions in early stages. One day, we will just wear our VR headset, change some model parameters to modify the geometry of the room or the shape and material properties of a surface, and hear how the acoustics has changed while we "walk" around the room. ■

[1] Vorländer, M. Auralization—Fundamentals of Acoustics, Modelling, Simulation, Algorithms and Acoustic Virtual Reality; Springer: Berlin/Heidelberg, Germany, 2010.

[2] ISO 3382—Acoustics—Measurement of room acoustic parameters . International Standards Organisation, 2008–2012

[3] Vorländer, Michael, et al. "Virtual reality for architectural acoustics." Journal of Building Performance Simulation 8.1 (2015): 15-2

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Optimal Lighting Conditions for a Post Anaesthesia Care Unit

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INTRODUCTION

Employees of a Dutch university medical center experience the lighting conditions in the post anesthesia care unit (PACU) as unpleasant, especially during night shifts. A PACU is a space in a hospital where patients recover from anesthesia usually after surgery. During night shifts the PACU is relatively dark to allow patients to rest, sleep and recover. The dark environment makes it difficult for employees to stay alert, it also reduces visual performance and visual comfort. When checking up on patients, employees can either switch on the bright overhead light or use a flashlight which results in poor uniformity. The general lighting conditions are also unpleasant for patients since the bright overhead light affects the resting (neighboring) patients.

In this study, an in-depth examination is executed of the PACU to develop recommendations for implementation of the night-time lighting conditions. The lighting needs for personal and patients residing at the PACU are considered.

In Figure 1 the floor plan of the current layout of the PACU can be seen. Plans for changes are being made in which this project aims to present recommendations.

To identify the cause of the problem, the current lighting conditions in the PACU were assessed.

The current lighting conditions of the case study PACU during the night show conflicting interests: on the one hand, employees experience the PACU as too dark. Consequently, employees encounter trouble in staying alert, and it also reduces visual performance and visual comfort. On the other hand, patients need a dark environment for good sleep.

The case study PACU needs to provide care 24 hours a day for 5 days a week, this makes shift work necessary to cover all these hours. PACU employees work an irregular 3-shift system, meaning they work alternating day- evening- and night shifts. Especially in hospitals where shift work is common, creating a work environment that induces alertness and reduces sleepiness during night work is important.

LIGHT DURING THE NIGHT

Reduced job performance is apparent with almost all night shift workers [1]. The displacement of work to the circadian phase (circadian misalignment), a long period of wakefulness prior to the work shift, in combination with a poor (daytime) sleep prior to the work shift results in reduced sleep quality and quantity [1], [2]. As a consequence of this short and low-quality sleep, the employee alertness also reduces [2], [3].

Besides the negative influence on job performance, shift work also affects the health of the employees in the short- and long term. The health risks of working night shifts are partially caused by the non-image forming effects of light [4]. One non-image forming effects of light is the regulation of the internal clock (circadian rhythm). A 24-hour light-dark cycle resets the circadian rhythm every day [4].

Shifting the circadian rhythm can help with increasing job performance and with improving health during and directly after night shifts [5]. Shifting the circadian rhythm can be done with the non-image forming effects of light [4]. These are related to the luminous factors; spectrum, quantity and directionality and the temporal factors; timing, duration, and history of light exposure [6]. For the circadian rhythm to shift with light exposure, periodic light exposure is needed [7].

The higher the corneal illuminance, the larger the influence on the circadian rhythm. A corneal illuminance as low as 100 lux can already influence the circadian rhythm, a corneal illuminance of 200 lux can yield a melatonin reduction of 25%. Exposure, before the minimum body temperature is reached, will delay the circadian rhythm [7].

Short bright light pulses of around 15 minutes periodically throughout the shift are most efficient for shifting the circadian rhythm. For patient sleep lighting on the patient beds, should be kept at a minimum.

The optimal night-time lighting conditions considering visual performance during a night shift are defined by literature. Worldwide there are many different recommendations regarding the illumination of the workspace and

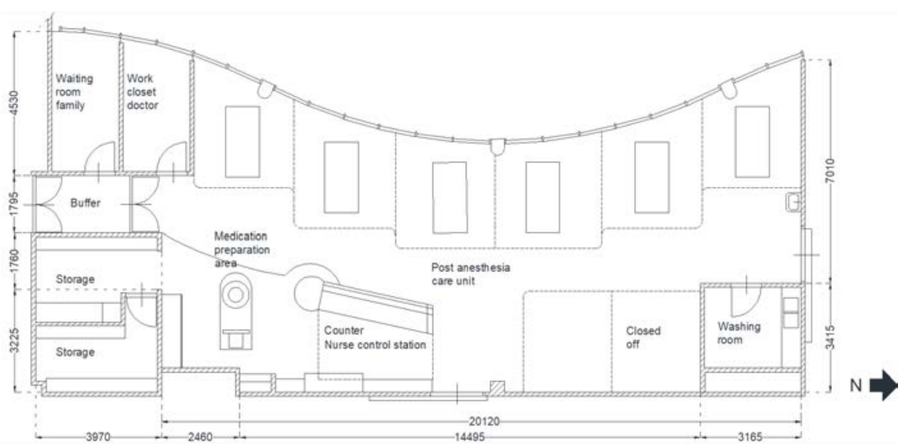

Figure 1. Floor plan of the case study PACU (dimensions in mm)

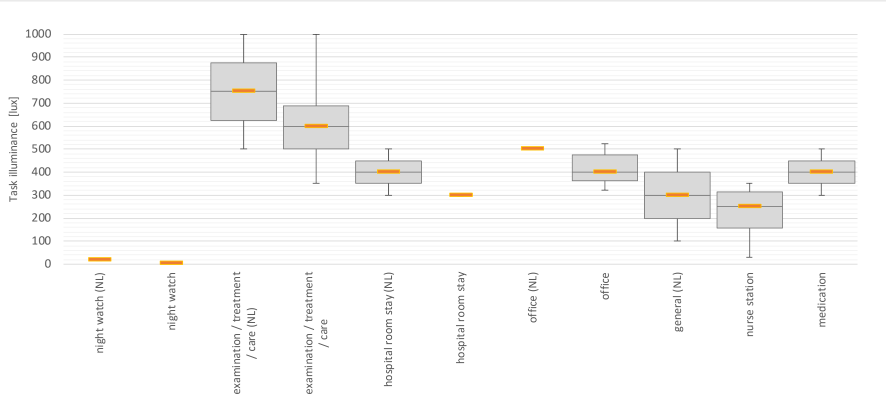

Figure 2. Minimum range of recommended task illuminance per area

hospital environments. Current lighting standards for office- and hospital environments (not regarding daylight) are assessed in Figure 2. Standards from different countries are considered in this assessment.

It should be noted that these standards give minimum recommended or required illuminance levels.

These recommended values are based on visual performance. Even though exposure to dim light might already suppress melatonin production, long exposure to dim light does not stimulate the circadian rhythm to shift [8]. In conclusion, periodic bright light, in combination with normal work light exposure will have the biggest impact on the circadian rhythm [9].

METHOD

To get a better idea of the current conditions, the illuminance throughout the space is measured on a set grid and on task areas. The illuminance is measured under the following conditions: night-time with lighting off; night-time with lighting as during night shifts; night-time with lighting set to its maximum. The measurements of night-time with lighting as during night shifts contains useful information on the current situation. The other measurements are used to validate the simulation model.

An observation study is conducted to examine the occupation of the PACU throughout the different shifts. With this information, it can be determined where an intervention could be most useful. Observations are conducted during a day-, evening- and nightshift.

During the observational study, the locations of the working employees are kept track of defining their location and activity. During the observed night shift, three nurses were working. The observation took around 120 minutes.

A survey is held amongst the PACU employees (N=23). The survey assessed general information, fatigue during the last hours of the night shift, what measures night shift workers take before-, during- and after their night shift, what potential measures to combat tiredness night shift workers already know of and which measures they are willing to take.

Lighting simulations are performed to analyze potential changes in the PACU. The lighting simulations are performed with Radiance. Radiance is a validated, physically-based backward ray-tracer that can simulate indoor illuminance and luminance distributions for complex building geometries [10].

RESULTS

Measurements

The horizontal illuminance with lighting during night shifts is ndicated in Figure 3.

During the night shifts, the illuminance of the task area (the desk) is around 2 to 5 lux. Comparing these measured values to the recommended/required minimum values of Figure 2, it can be concluded that the current illuminance values are insufficient according to the considered standards.

Luminaires are also installed directly above the desk. However, these lights are not turned on at night in order to not disturb the patients.

Observation study

The data of the observations are processed in heatmaps, showing the most occupied space in red and the least occupied space in green. In Figure 4, the heatmap of the occupation distribution during the night shift is shown.

From these observations, it can be concluded that during a night shift, nurses spend most of their time at the nurse control station. The occupation differs each night shift. However, when unexpected complications occur with a patient, the bright overhead lights will be turned on. From the surveys it was found that fatigue is more prevalent when there is little work to be done.

The proposed improvement plans are based on the conclusion from this observation study that during the night shifts most time will be spent at the desk at the nurse control station. Thus, improvements will be applied to this area.

The mean of all the recommended values from different guidelines as shown in Figure 2 for "nurse station" is 250 lux.

Survey

Participants indicated that they are more tired during a night shift compared to a

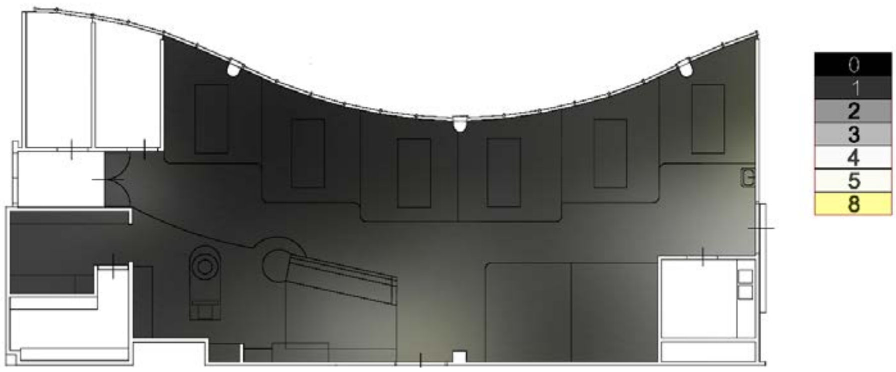

Figure 3. Horizontal illuminance heatmap with lighting set to night-shift conditions (dimmed)

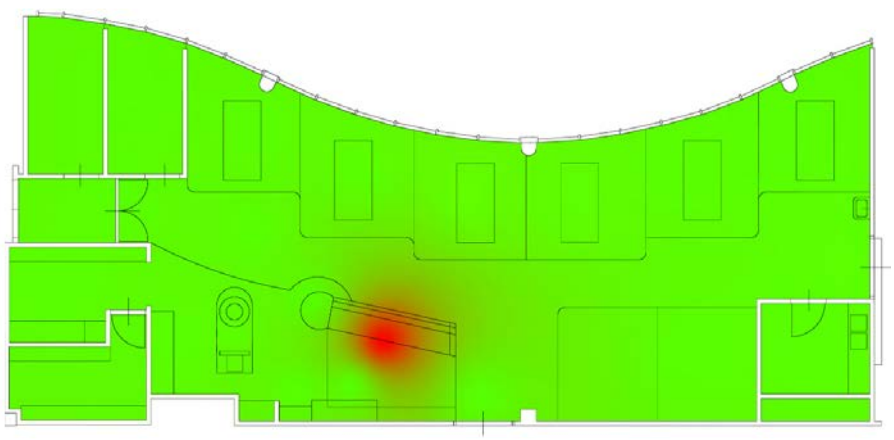

Figure 4. Heatmap occupation distribution night shift

day shift. They claimed to not make more mistakes, but some literature suggests that tiredness is linked to a higher error rate. Furthermore, sleep after night shifts, is often quantitively and qualitatively insufficient.

In the survey, questions were included regarding the use of light therapy. Light therapy could be a potential measure if employees are willing to participate. A lightbox would be considered if requirements are met that are currently not met, like designated time slots and a space for it. Most employees are not willing/able to take a power nap or wear light glasses. Therefore, it can be concluded that these measures will not be useful in the PACU, considering only a small percentage of the employees would apply the therapy.

Because employees are affected by working night shifts, an intervention is needed. In the following paragraph, improvement plans are pitched and simulated in order to map the effects.

Simulations

The aim of these lighting simulations is to assess the requirements in order to suggest a new lighting design.

A validated model is used to create improvement plans. Different improvement plans will be proposed in this paragraph, they will be elaborated upon with simulation results, mapping the effects of the improvements.

Because this research stemmed from a practical question, practical solutions were considered. Requirements from the PACU (employees) are considered here. During a meeting with PACU employees the following additional requirements were given to potential renovation plans:

1. Employees must be able to directly look at the patient beds from the nurse control station
2. Light at patient beds should be kept at a minimum

Changes in the PACU will need a permit. Plans on installing a wall between the nurse control station and the patient beds have already been proposed and declined. However, there was no research backing up these plans. Therefore, in this research, adding a wall between the nurse control station and the patient beds is considered as a potential improvement plan.

A minimal improvement that is easy to install (adding spots at the desk) is considered, because it was mentioned by PACU employees that the cheaper and easier the improvement is to install, the bigger the chances of it being applied.

The last improvement suggestion is a built-in light therapy device. This would be a solution because in the survey employees indicated that they are willing to participate in light therapy, but there is currently no time or space to do so.

For all the improvement plans only small additions were made to the current interior design next to the lighting.

This results in the following improvement plans that are simulated to map the effects:

1. Wall: add a wall between employee-area and patient beds (see Figure 5).
2. Local improvement: add dimmable spots at the desk (see Figure 6), do not change the layout of the space.
3. Combination: add a wall between employee-area and add dimmable spots at the desk.
4. Built-in light therapy: add dimmable diffuse bright light above the existing desk (see Figure 6).
5. Combination 2: add dimmable diffuse bright light above the existing desk and add wall between employee-area and patient beds.

In improvement plans where a wall is added, the layout will be as shown in Figure 5. The alterations are shown in red.

The view from the workplace at the nurse control station is simulated for the five improvement plans. Figure 7 until Figure 11 shows the view in the improved situations.

Figure 7. Fisheye from the workplace with improvement plan 1

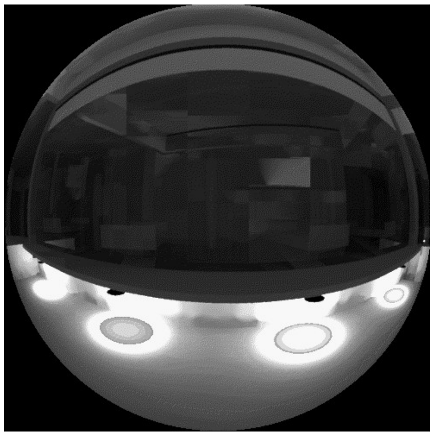

Figure 8. Fisheye from workplace with improvement plan 2

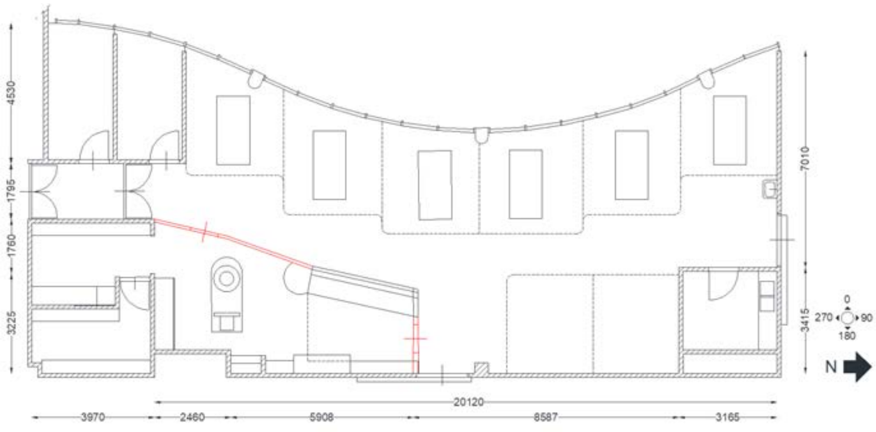

Figure 5. Renovation plan: added walls

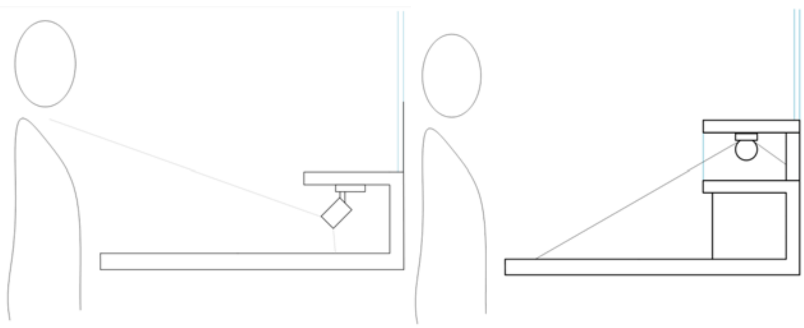

Figure 6. Renovation plan: add spots (left), Renovation plan: add diffuse bright light (right)

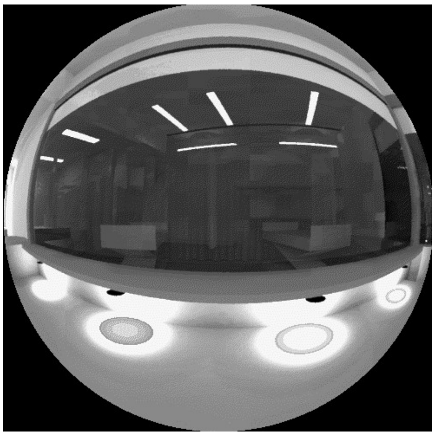

Figure 9. Fisheye from workplace with improvement plan 3

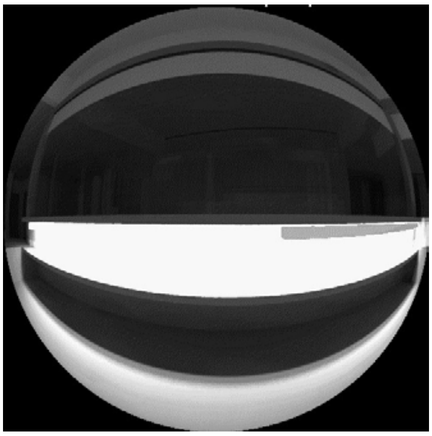

Figure 10. Fisheye from workplace with improvement plan 4

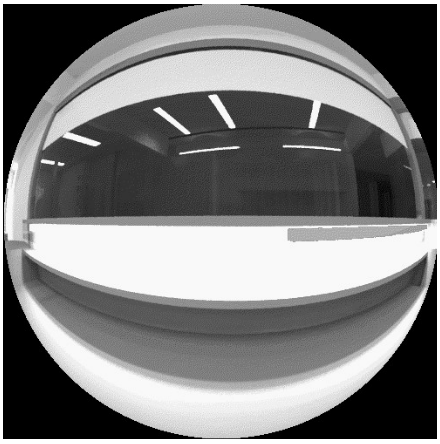

Figure 11. Fisheye from workplace with improvement plan 5

In table 1 the effects of these improvement plans can be seen.

Improvement plan 2 will take the least amount of work to create, but the glare ratings are intolerable for improvement plans 2 and 3. Improvement plan 5 increases the illuminance of the patient beds the most, which should be kept as low as possible. The highest corneal illuminance was reached in improvement plan 5.

CONCLUSION

There is aimed for periodic bright light of at least 200 lux (melatonin reduction of 25%), in combination with normal work task illuminance of at least 250 lux for nurse stations (Figure 2). Furthermore, employee- and patient glare and the illuminance of the patient beds should be kept at a minimum. Also, closing off the employee area from the patient beds and illuminating the employee area will yield the best uniformity in the space.

Which intervention will be applied will depend on the currently unknown criteria such as budget and time restrictions. Based on the efficiency of the improvement plans, improvement plan 5 would be recommended. The bright diffuse light is dimmable so that different conditions can be created. The exact usage of the diffuse bright light should be researched further, finding a good schedule for shifting the circadian rhythm, whilst not lowering sleep quality and quantity after the work shift. ■

Table 1. Overview impact of improvement plans

	Average corneal illuminanc form desk [lux]	Average horizontal illuminance form desk [lux]	Employee glare	Horizontal illumination patient beds	Patient glare	Alterations
Improvement plan 1	49	402	Imperceptible	Increased max 2-3 lux	Perceptible	Add wall
Improvement plan 2	130	526	Intolerable	Increased max 1-2 lux	Imperceptible	Add spots
Improvement plan 3	184	887	Intolerable	Increased max 2-3 lux	Perceptible	Add wall & spots
Improvement plan 4	709	989	Disturbing	Increased max 1-2 lux	Imperceptible	Add lights
Improvement plan 5	803	1321	Perceptible	Increased max 3-4 lux	Perceptible	Add wall & lights

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Bouwkunde Bedrijvendagen 2021

Understanding the mechanical properties of coir fibers

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Supervisor
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INTRODUCTION

The building industry is the second largest consumer of raw materials after the food industry [1]. The currently used materials, such as concrete, steel, glass, and plastic require a lot of energy and water throughout the production process. Moreover, not all of them are reusable or recyclable. Waste fibers and processed natural fibers could be a good replacement of synthetic fibers.

Natural fibers (NF) are ecologically friendly, widely available at low cost, and collected from fast-growing plants. They consist of five main constituents. Wax and pectin are protecting the fiber as they reduce the absorption capacity, while cellulose acts as a reinforcement. The microfibers of cellulose are bonded together by hemicellulose and lignin [2]. NF has good mechanical properties and moreover, due to their low density, products from NF are very lightweight. However, they also have several drawbacks which need to be solved before introducing them to the building industry as a construction material. Their high water-uptake, risk of swelling, and leaching can cause durability issues in composites. The mechanical properties of composites are affected by the fiber-matrix adhesion, as it guarantees a good stress transfer from the matrix to the fiber.

As opposed to other plants which were cultivated purely for their fibers, coconut palms are unique. The fruit of the tree is used by the food industry, while the husks are abandoned in the nature which is a waste of natural resources and it causes environmental pollution. About 55 billion coconuts are harvested annually, but only 15% of the husk fibers are re-used. Coconut coir has a porous structure and a close chemical composition to wood, so it can be assumed that similar treatment could significantly increase the strength of coir, paving the way to new applications in the composite field using waste materials.

METHODOLOGY

This study focuses on the mechanical properties of coconut fibers and is based on research by Song et al. [3], in which alkaline solutions and thermomechanical treatments were applied to woodblocks. Alkaline solutions improve the interface between the fiber and matrix by removing unwanted constituents from the surface of the fiber. In the recent experiment the fibers were immersed in two alkaline solutions for various durations; an aqueous solution of $NaOH + Na_2SO_3$ and a 1% NaOH treatment. After the chemical treatments, several trial and error samples were produced in the hot-press. The temperature and pressure used by Song et al. could not be applied due to the structural differences between a woodblock and coir fiber.

RESULTS

Figure 1 visualizes the changes on the surface of NaOH and Na_2SO_3 treated fiber with the increasing temperature. The loss of protecting constituents, such as wax and lignin, and opened pores are visible on the fiber heated to 90°C.

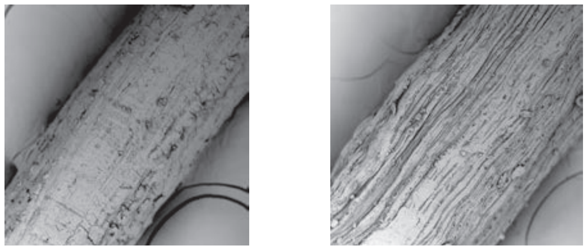

Figure 1. Surface of $NaOH + Na_2SO_3$ treated fibers, heated on 40°C (left) and 90°C (right).

Song et al. [3] observed in their study that the densification of wood is not effective without applying chemical treatment first. To test this concerning natural fibers, raw coir fibers were hot-pressed. The thermomechanical treatment caused a significant drop in tensile strength. The effect of various treatments can be seen in Figure 2.

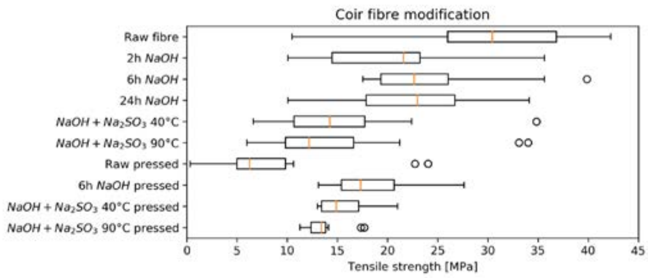

Figure 2. The effect of various treatments on the tensile strength of coir fibers.

CONCLUSION

After the evaluation of results, it can be concluded that the observation of the changes of coir helped in the understanding of the reaction of fibers to various treatments. Even though the tensile strength decreased, the adhesion between fiber and matrix might have been improved. Further research is needed for the development of a methodology to improve the properties of natural fibers for use in biocomposites. This research can be considered as a first step towards the wider application of coir in the building industry. ■

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A Day in the Life of a ZRi'er

Ir. J.E. (Jorinde) Bijpost

Hello, my name is Jorinde Bijpost and I work at ZRi. I started working here right after my graduation, almost 4 years ago. I studied at the Technical University of Eindhoven and graduated in two disciplines; Architecture and Building Physics & Services. When I graduated I wasn't sure whether I wanted to start working as an architect or as a building physicist. In the end I chose to work in building physics because of the variety of activities and projects. I would like to give you an impression of how I spend my days in a building physics consultancy practice and show you how divers my day actually is!

In my current job I am a project leader. At ZRi we have three job types; project employee, technical specialist and project leader. Most people who join ZRi start as a project employee. In this role you will be making calculations and investigate different technical issues for a variety of projects. In this way you will learn something new every day and have a steep learning curve. I really liked this way of learning on the job and getting insights in so many different projects. We work on the designs of schools, residential buildings, offices, hotels, nursing homes, etc. This can be new buildings or renovation projects.

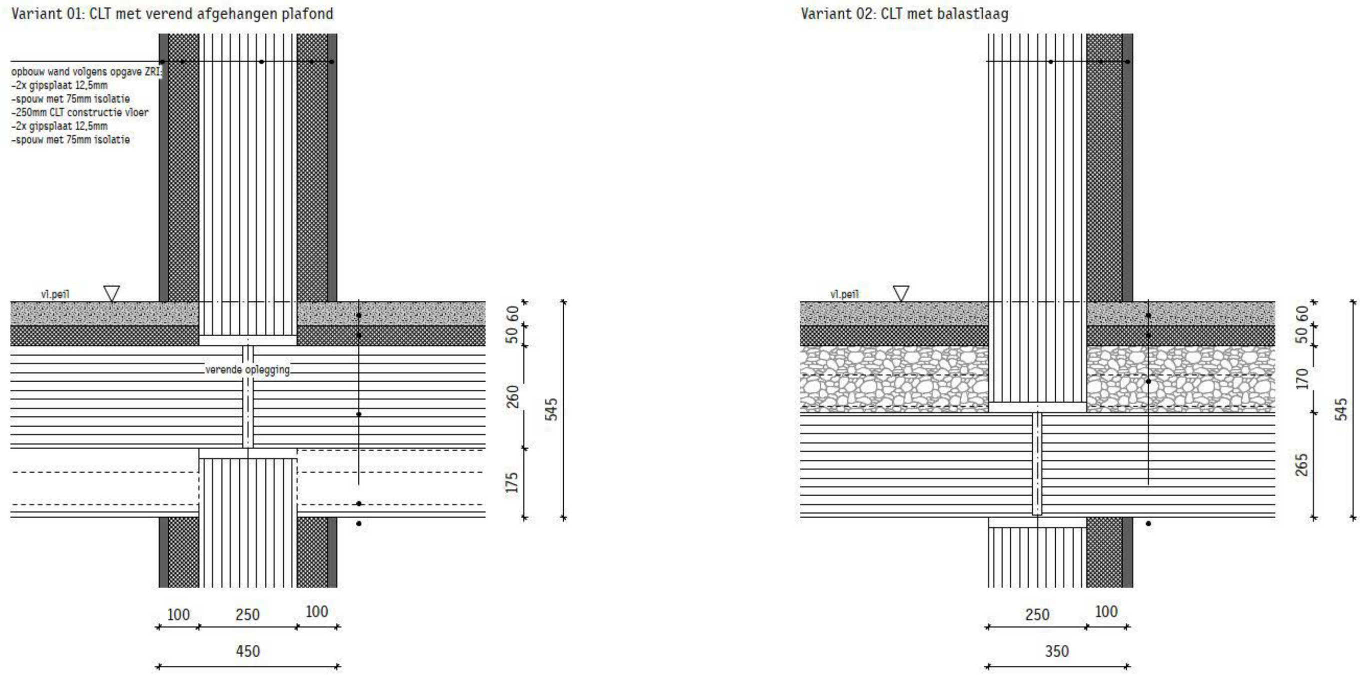
Once you develop yourself, you get more and more responsibility. As a project employee you can develop yourself as a technical specialist or as a project leader. To become a technical specialist you will grow in a specific field; acoustics, sustainability, building physics or fire safety. You will mostly be learning from your colleagues on the job, but there is also a possibility to follow courses in a specific subject. I, for example, followed a course in environmental noise. As a project leader you will bring in your own projects and manage them both internally and externally. You manage the quality of the project and make sure everything is delivered in time and on budget. Personally, I prefer this role above working as a technical specialist, because as a project leader you are more on the road, get to know a lot of new people with different insights and see a lot of different places and projects.

A DAY IN MY LIFE

When I arrive at the office (after a train ride from Utrecht to The Hague), I'll get a fresh cup of tea and speak to a couple of colleagues about their weekends. We start the week with a meeting with all the project leaders. In this meeting we divide the activities which have to be done this week amongst the project employees and technical specialists. In most projects we work in a team of two or more persons; a project leader and a project employee or technical specialist. We work in a dedicated team for each project, but the composition of team members varies for every project. Therefore, I work with almost all my colleagues all the time and learn something from everyone. We divide the activities in new projects based on experience, personal development goals, capacity in the planning and subject.

After planning I start my computer and open my mailbox. I see that a lot of new e-mails have entered my mailbox and answer some of them myself. I forward the e-mails, that need more research or for example adjustments in a calculation, to the project employees who are working on the specific projects. There is also an e-mail about an interesting project of mine. In this project we are researching the differences between developing a building in wood or in concrete. Because of the circular properties of wood, the developer, a social housing corporation, has an ambition to construct the residential building in wood. Because it is a relatively new and unknown building method for the client we will design the building both in wood and concrete. In this way we can show the differences in building time, risks, circularity and costs. I really enjoy this type of projects, because the way of building is not standard and thus is a nice technical challenge for me and the team. When we build in concrete we know what the thickness of walls and floors needs to be to make sure it is safe and there will be no complaints about the acoustics. With wood, this is a whole other story. Wood has a smaller density than concrete, which results in poor sound insulation. Therefore, extra retention walls, drop ceilings and floors with a resilient layer are necessary to make sure the sound insulation meets the requirements. Of course, that is

A project meeting at our office



Two solutions we are researching to meet the acoustic requirements in the residential building with a wooden structure

not what the architect wants, because the beautiful wooden walls, floors and ceilings will then be hidden behind other materials. So we need to find a creative way to solve this! Besides the acoustics, fire safety is an important issue, wood behaves differently in a fire… it burns.

After discussing these subjects with the architect and the structural engineer, it's time for lunch. At ZRi, we lunch with the whole company (20 persons) at one big table. The lunch is delivered, so no need to make your own sandwiches at home. After lunch, we take a walk in the neighbourhood, which is the beautiful and lively Archipelbuurt in the city centre of The Hague, to get some fresh air and to refresh our brains.

The afternoon starts with a project meeting with a colleague. He has made some calculations for a new school. These are daylight, ventilation and acoustics calculations. He also made a fire safety concept to make sure that a potential fire can be contained (fire comparting) and to make sure that all the people can escape the building in time. We look at the calculations and check if all his assumptions are correct. We double-check to make sure that no mistakes were made and share our conclusions with the design team (architect, structural engineer, building installation advisor and project manager).

Then I realise that I am almost late for my next meeting. Luckily I can borrow a bike from a colleague and ride to my appointment. It is a meeting about the renovation of a nursing home. Together with the design team we talk about the possibilities of adding thermal insulation to the outside of the existing façade. This is preferred from a building physics point of view, because the existing façade will be at the warm side of the facade and moisture in the façade will never become a problem. However, from an architectural point of view this is "not done", because the beautiful existing façade will not be visible anymore. Luckily, we found an alternative solution that we can present to the design team. One of our technical specialists made some calculations to show in what way insulating the façade at the inside will also be effective and will not cause moisture problems in the future. I discuss these conditions with the design team and we choose to follow that path.

I am back in time for the most important time of the week; the Friday afternoon drinks. We like to close the week with a group of colleagues and have a couple of drinks in a bar around the corner of the office. After the drinks I go to the train. Tired and satisfied to start the weekend and recharge for next week!

Do you like to work in a fun and social team with young colleagues? And do you also like to be challenged and work on a variety of different project and specialities? We have a couple of vacancies, so go to our website, www.zri.nl, and sent us your CV!

We also offer a possibility to do an internship for one day at our firm, where you can experience a day at the office of ZRi yourself! ■

Assessing Energy Flexibility Using Thermal Mass

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INTRODUCTION

The 'klimaatakkoord' (Climate Agreement) of the Netherlands is an agreement that aims, by 2030, to have 70% of all electricity supplied by renewable energy sources (RES), with the primary alternatives being solar PV and on/offshore wind power [1].

Wind and solar energy have an intermittent and stochastic power output due to their dependence on weather conditions. The result is a large variability and peaks in the residual power load in the low and medium voltage level. Furthermore, there is an uncertainty factor due to 'forecasting errors', which becomes significant with the expected increase in wind power capacity until 2050 [1]. These characteristics, require the Dutch power system to have power reserves and sources of flexibility [1], [2].

Balancing electricity supply and demand is necessary to maintain grid stability. There exist many alternatives to tackle flexibility and power reserves including grid reinforcement, distributed or large-scale energy storage and fast-response generating units. However, it has been shown that demand response (DR) is a cost-effective measure to accommodate for variable RES integration. Benefits include lower system operation costs and reduced grid-reinforcement and generation capacity requirements [3], [4].

Currently, natural gas plants provide flexibility to continuously meet the demand and maintain the balance of the system; where the levelised cost of energy (LCOE) is around €100/MWh [5]. The cost of other storage technologies such as NiCd batteries, which can have a mean LCOE €337/MWh [6], show that electrochemical batteries are yet to constitute a competitive alternative as a source of flexibility. On the other hand, a building's existing structural mass as a 'heat battery', requires a negligible amount of investment and, in aggregation, may provide the energy flexibility necessary through demand response events (DREs), where heating, ventilation, and air-conditioning (HVAC) systems or other end-uses are controlled [3], [7].

Two types of markets generally exist for solving system imbalances: (1) balancing markets and (2) ancillary service market. In the Netherlands, zonal pricing is used in the electricity market and is based on full-hour contracts. This becomes problematic in an energy transition to RES when in comparison to natural gas plants, energy storage needed for RES such as electrochemical storage, hydrogen storage or hydro-storage have very high investment costs [6], [8]. In the US, DR (Figure 1) through aggregations and atypical pricing schemes have been widely applied such as in the PJM electricity market. DR support schemes in the PJM are set up such that end-users can participate through "Curtailment Service Providers", which serve as intermediary agents or in more recent terms, through "aggregators" [9].

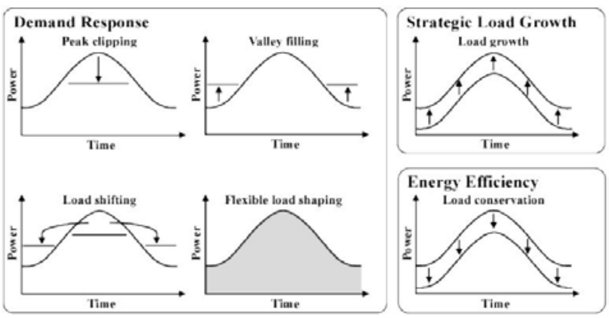

Figure 1. Demand Response Programs

The main research objective is to *assess the energy flexibility provided by a heat pump system when utilizing the thermal mass as the heat storage medium.* Indicators are chosen so as grid operators or aggregators can obtain knowledge on the building's heating system capabilities in a future scenario, where buildings will provide services in stabilizing the surrounding energy network.

The research question can be specified as follows including sub-questions that will aid in the main answer:
How much energy flexibility can the case study office building offer with a heat pump system through its thermal mass?

1. How much energy flexibility do climate control schemes provide during heating season?
2. Is it currently feasible for the building owner to use its building compound to solely participate in the electricity market?
3. How does thermal mass perform with historical demand (DREs) effects?

METHODOLOGY

The approach taken in this study is utilizing a computational building performance simulation (BPS) model to simulate DR programs. The energy and comfort performance, due to changes in indoor air temperature set-points, are investigated. As a result, a theoretical upper limit of the energy flexibility potential is determined. The most important factors in the model are therefore the building and the heating and ventilation system.

Future outcomes are uncertain for electricity market prices, therefore current real-time pricing (RTP) of ancillary and balancing markets are used. The markets have a 24-hour cycle with a 15-minute time step.

To address the *first and second part of the research question* in quantifying the energy flexibility, DREs are simulated using the BPS model. DREs were limited to downward regulations, i.e. reducing the set-points. Findings from the previous study of the same case study building [10] showed that upward regulation of the set-point increased overall energy consumption in relation to the total energy shifted, leading to a loss for the building owner or aggregator. A parametric analysis was used to obtain the load shifting and peak clipping potential, which

Table 1. Control strategies as input parameters used in the parametric analysis

Parameters	Possible values
Set-point changes [°C]	-1 ... -4
DRE starting hour [24-Hours]	06:00 ... 17:00
DRE duration [Hours]	2, 4, 6

results in a spectrum depending on different control strategies (input parameters) specified in Table 1.

Previous research has already shown that the frequency of charging and discharging thermal mass with heat may conflict in more than 24-hour periods. Therefore, this impacts the participation in demand response (DR) due to thermal comfort constraints and as a result, an understanding of the historical effects of demand response events (DREs) is needed. This aids the electricity market actor responsible for bids to predict the extent of flexibility the building is able to provide. To understand such dynamics and address the *third part of the research question*, the difference in behavior between two cases, one including- and the other excluding historical DRE effects, indicates the degree of impact and dependency between two or more DREs.

CASE STUDY

The case study, building "D", is an office building located in the Netherlands. Currently, the building is heated using gas-fired boilers. In response to a need for an alternative heating source, a heat pump is added as a retrofit to the building in place of the current gas-fired boilers. The choice of a heat pump is due to its capabilities of responding promptly to control signals (≈ 15 min) and higher energy efficiency compared to gas boilers.

The building characteristics are summarised in Table 2.

The building is part of a larger compound consisting of eight office buildings. The total floor area of the compound is

Table 2. Case study Building D characteristics

Elements	Amount	Unit	Remarks
Area	3	Floors	1284 m²
Age	2002	Year	-
Occupancy	74	Persons	-
Ventilation	4	ACH	Balanced
Heating	3x65	kW	Gas boilers

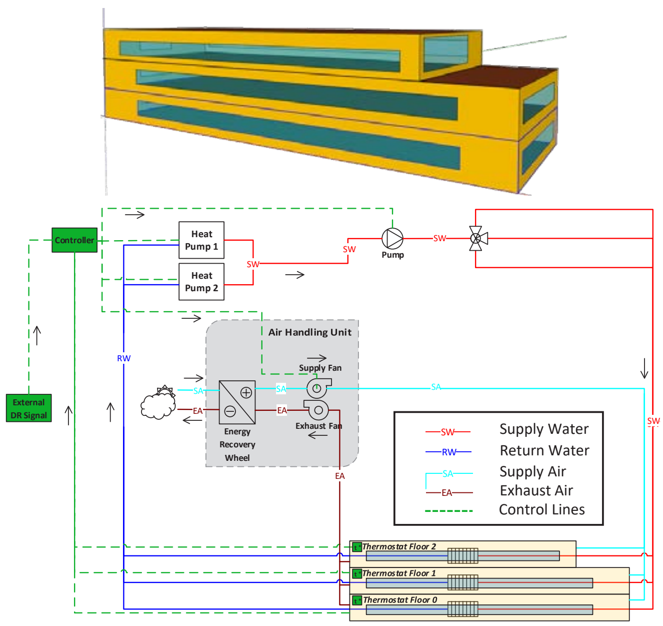

Figure 2: Geometric model in TRNSYS of building D (top) and schematic of heating and ventilation system model in TRNSYS (bottom)

approximately 17000 m² . Each building in the compound is nearly identical to one another from a typological, structural and architectural perspective. Therefore, it was assumed the case study building may be a representative building of the compound. It should be noted however, building orientations vary therefore heating demand profiles may vary between each building due to different solar gain profiles.

Building D was modelled in TRNSYS and validated in a previous study [10] as shown in Figure 2. In this study, a detailed heating and ventilation system was modelled and added as shown in Figure 2 below. An air-source heat pump was chosen as the heat source based on the discounted payback period method. Furthermore, the model was validated according to manufacturer specifications at design conditions.

KEY PERFORMANCE INDICATORS

Grid operators pay attention to the energy side such as peak clipping (π^-), load shifting or conservation (ε^-) and duration of time of each (t). Whereas, building owners and ESCOs focus on costs incurred on the building including energy costs and thermal comfort. Equation 1 and 2 show how these indicators are calculated.

$$\pi^- = P_{flexible}(t) - P_{reference}(t) \qquad (1)$$

$$\epsilon^- = \int_{t_{DRE\,Start}}^{t_{DRE\,End}} [\pi^-_{flexible}(t) - \pi^-_{reference}(t)]\,dt \qquad (2)$$

where $P_{flexible}$ (t) is the total energy consumed by the HVAC system including the heat pumps, circulation pumps, and air handling unit fans when a DRE is performed in kW, $P_{reference}$ (t) is the same as $P_{flexible}$ (t) but without any DRE performed, $t_{DRE\ Start}$ and $t_{DRE\ End}$ are the starting and ending times of the DRE event.

Addressing the second part of the research question, i.e. on an aggregated level of BAM's building compound the 'energy flexibility intensity', formulated in Equation 3 is used to calculate the energy flexibility provided by the compound.

$$E^- \; or \; \Pi^- = \frac{\epsilon^- or \; \pi^-}{A_{case\ study}} \times A_{compound} \qquad (3)$$

where, E^- is the load shifted or partially conserved of the whole compound in kWh, Π^- is the peak clipping potential in kW, $A_{case\ study}$ and $A_{compound}$ are the floor areas of the case study building and all buildings in the compound respectively in m².

As for thermal comfort , Linden et al. [11] investigated the adoption of adaptive comfort limits in the Netherlands. It was stated that during heating season, where mean outdoor temperatures are below 11-12°C, type 'Beta' operative indoor temperature limits apply. To take the best-case scenario in providing flexibility to the grid, the 65% acceptability limits were taken into account that ranges between 18 and 19°C for lower limits, depending on outdoor temperatures.

The service of providing flexibility is assumed to be financially incentivized in the electricity market context, in line with the ambitions of the EU [12]. Ensuring a current best-case scenario, the maximum imbalance market price, excluding outliers, is taken into account as shown in Table 3. The market data set also includes ancillary services. Depending on the capacity of the energy flexibility, buildings may take part in scheduled-activated frequency restoration reserve (mFRRsa). The minimum allowable capacity assumed is 1 MW (as per market regulations) [13].

Equations 4, 5 and 6 formulate the net earnings calculated, where the flexibility service is considered a revenue due to the building owner perspective and the energy imported from the grid as a cost.

$$R = \epsilon^- \times C_{max}(t_0) \qquad (4)$$

$$\Delta C_{imports} = \sum_{t_0}^{t_7} C_{flexible}(t) - \sum_{t_0}^{t_7} C_{reference}(t) \qquad (5)$$

$$P = R - \Delta C_{imports} \qquad (6)$$

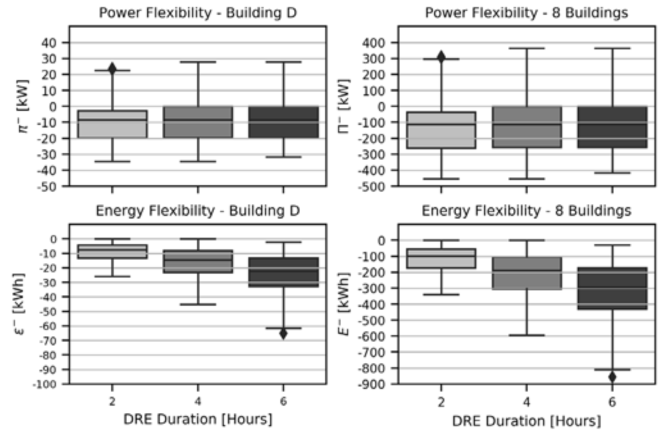

Figure 3. Load shifting (bottom) and peak clipping (top) capacity for case study (left) and whole compound (right)

where, P is the net earnings in €, R is the revenue generated from performing a DRE in €, $\Delta C_{imports}$ is the difference in total electricity importing costs between the reference case ($C_{reference}$ (t)) with no DRE and the flexible case ($C_{flexible}$ (t)) with DRE in €, t_0 and t_7 are the representative day and the day in the subsequent week. By taking into account the energy consumption of the following week, the "rebound effect" is included, in case the overall energy consumption varies.

RESULTS

Figure 3 provides four distributions of the energy (ε^- and E^-) and power (π^- and Π^-) capacity categorized by the duration of the DRE for both building D and the whole building compound, i.e. all 8 buildings. The distributions are a result of the parametric analysis including all representative days and set-point change magnitudes, which amount to a total of 360 simulations. Based on these results, it can be deduced that heat pumps solely are insufficient to participate in electricity markets due to the minimum 1 MW requirement previously mentioned. Furthermore, the down regulation does not continuously keep the heat pump off, due to the thermostat maintaining the minimum indoor air temperature. This may be improved by implementing pre-heating strategies with a predictive controller as opposed to the real-time, rule-based control (RBC) controller used in this case.

The power capacity is mostly negative due to the downward set-point regulations during the DREs, while the positive top 25th percentile, represents the heat pumps maintaining the minimum indoor air set-points. Both indicators are normally distributed for 4- and 6-hour DREs, while the 2-hour DRE is skewed more to the lower power, i.e. higher flexibility. Such behavior is due to the lower impact 2-hours DREs have on thermal comfort compared to DREs with longer duration. The same behavior is observed for energy capacity (ε^-). However, the power capacity (π^- and Π^-) have approximately the same median, regardless of duration.

Figure 4 shows the load shifting capacity (E^-) categorized by DRE duration for the whole building compound. It must be noted that each bar is the maximum energy flexibility for each representative day (T_{out}) and associated set-point change magnitude ($\Delta T_{set\text{-}point}$). Moreover, each bar represents one parametric run, meaning no previous or subsequent DRE were performed. Based on a simple visual inspection, it can be deduced that the load shifting capacity is proportional to duration (time) and set-point change magnitude, however, the trend is not the same for net earnings. The reason for this is, net earnings include not only the revenue due to the provided flexibility, but also the increased or decreased energy import costs ($\Delta C_{imports}$) which is a consequence of the downward set-point regulations. Furthermore, the dynamic pricing of the electricity market varies between the different representative days (Table 2).

Table 2. Days chosen in the representative month of February

Description	Statestic	Day	$T_{ambient\text{-}average}$ [°C]	Electricity Price [€/MWh]
$T_{out\text{-}min}$	Minimum	Feb 14	2.3	57.2
$T_{out\text{-}mean}$	Mean	Feb 07	7.6	46.9-
$T_{out\text{-}max}$	Maximum	Feb 22	10.9	60.5-

Based on the parametric analysis, Figure 4 shows that one DRE per day will potentially result in positive net earnings to the building owner, considering only energy costs. Results may differ depending on other operational costs including labor, maintenance and other administrative costs.

Figure 5 show the difference in load shifting capacity and net earnings between cases of including- and excluding historical DREs. In this case, only one DRE per day is simulated, where a drop of up to 37% in load shifting capacity may occur. This may increase if more than one DRE is conducted per day. As an indicator of the thermal mass's state, surface temperatures are presented, where it can be seen that there is a steady drop in the case when historical effects are included. Such results show the limitations of rule-based control (RBC) if the objective is to determine a seasonal or annual potential of energy flexibility. Despite the flexibility is reduced, the earnings are still positive meaning a profit for the owner.

DISCUSSION

Longer duration DREs may have higher load shifting or load conservation potential, however, this may have a 'discharging' effect similar to what is seen in batteries, where the effect is evident in the trend of surface temperatures as shown in Figure 5. This further strengthens the need for a model-based predictive controller, which translates the state of a building to the controller before implementing any control strategy.

It is important to note the variance in the COP between the

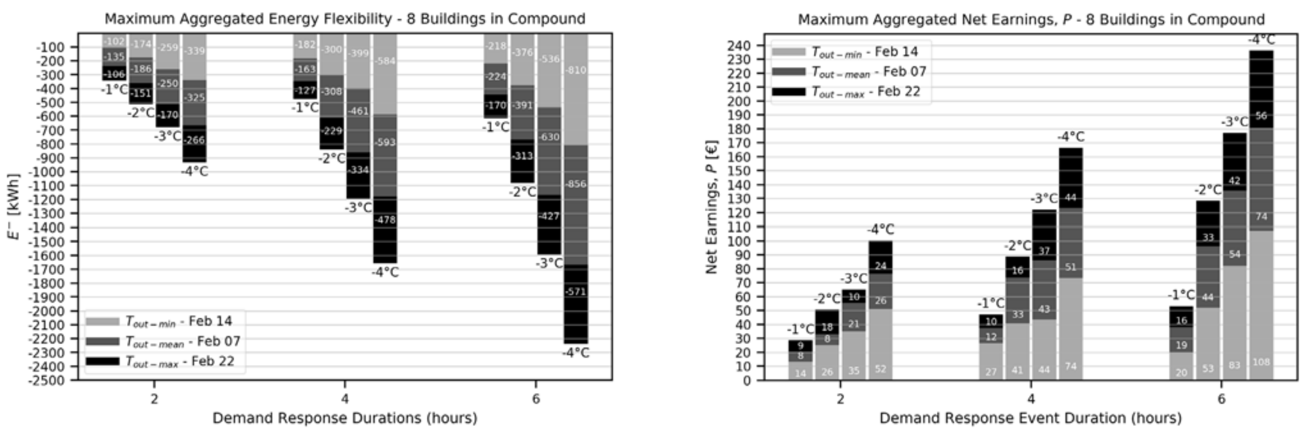

Figure 4. Maximum load shifting capacity (left) and associated net earnings per control strategy and representative day (right)

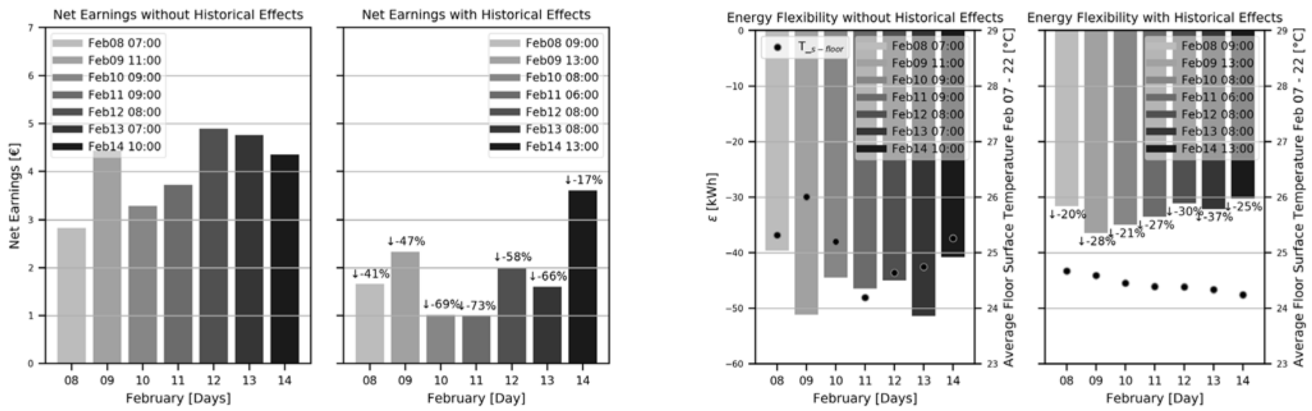

Figure 5. Comparison between excluding- and including historical DRE effects for net earnings (left) and load shifting capacity and surface temperature (right)

representative days, where the median COP for $T_{out\text{-}min}$, $T_{out\text{-}mean}$, $T_{out\text{-}max}$ are approximately 1.6, 2.3 and 3.1 respectively. Therefore, the power capacity clipped and energy capacity shifted/conserved are impacted due to the increased energy consumption. Albeit the total load during colder days being higher, the available flexibility is theoretically lower due to the higher conductive and convective losses to the outside. As may be seen in Figure 3, the amount of flexibility provided in the days of $T_{out\text{-}min}$ and $T_{out\text{-}mean}$ have similar values despite a difference in 0.7 in the median of COP. Such behavior may be explained due to this difference in COP, where the magnitude of power is higher over a shorter period of time.

The reduced energy flexibility due to historical effects adds a degree of complexity for electricity market actors including system operators (SOs) and aggregators to forecast and therefore bid on behalf of the building. The risk is also higher due to the rules of the electricity market, where if a specific amount is promised, the market will penalize a seller's lack of commitment. Currently, quantification methods of energy flexibility using thermal mass is limited to control strategies that provide higher flexibility, where apart from model-based methods and as to the authors' knowledge, no holistic control strategy takes into account a thermal mass' state of charge in addition to other factors such as electricity prices, comfort constraints, weather and system efficiency. Further research is required in order to establish the possibility of an approach in quantifying energy flexibility given the state of the building when no model-based control system exists.

CONCLUSION

In this paper, a theoretical upper limit of energy flexibility provided by an air-source heat pump through a case study's thermal mass was calculated. Furthermore, a preliminary analysis on the behavior of thermal mass' charging and discharging characteristics was performed by comparing two cases, one including and one excluding historical DRE effects. The latter provides an important aspect, which needs to be considered before extrapolating the quantification to multi-day or annual scale. The quantification aside from the temporal aspect also is far from simple in the climatic aspect as not only is the building heating demand varies, the COP of the heat pump also varies.

However, based on the results, it can be concluded that exploiting thermal mass may be rewarding both for the owner and system operators. Questions still remain as to who will manage the HVAC system operations and monitor the availability of flexibility. This may be an added cost if buildings are to participate in electricity markets. Regardless of whomever takes such responsibility, quantification methods should begin with the current state of a building for each time step in order to adequately obtain the possible load shifting/conservation or peak clipping potential when bidding to the electricity market ■

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