Influence of Occupant Behaviour Regarding Use of Area on Indoor Air Quality in Residential Building

Virkningen av Beboers Atferd Vedrørende Bruk av Areal på Inneklima I Bolighus

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***Abstract*—** Energy consumption in households stand for approximately 30% [1] of the total energy consumption in Norway, this is related to a number of factors, implying that energy use in buildings can also be optimized in various fields. Occupants behavior is considered to be one of the factors influencing the energy consumption as well as the indoor environment. However, the influence of occupants' behavior is complex and hard to predict, thus under-recognized or over simplified in most cases. This thesis focus on the interaction between occupants and their surroundings in residential buildings, mainly on the issue of furniture settings. Increasing our knowledge about how the space and the equipment will be used by occupants, what their preferred device and furniture setting will influence the room condition in relation to temperature and air velocity.

The study takes place in an apartment located in Trondheim, Norway, more specifically the living room. Using a ventilation meter and thermal camera to perform a series of tests and measurements to gain information about the indoor environment, size of furniture and the rooms dimensions. Thereby adopting software such as Solidworks and ANSYS to recreate a geometrical representation of that selected room and preform a series of numerical CFD simulation based on these measurements. Various setting of the furniture is simulated (four to be exact), each one is different from the other but has the same boundary conditions.

Introducing Microsoft Kinect for occupant migration monitoring in the selected living room, conduct investigation regarding the thermal comfort sensation. This device was placed in the living rooms corner for almost a week, recording occupants' movement throughout all four different room scenarios. Recorded data is obtained in form of clock data (Y/M/D/h/min/s) and point location (25 points in 3D [X, Y, Z]) distance from device [m]. [2]
Processed data from the Microsoft Kinect device demonstrated how the furniture setting had a noticeable influenced the occupant behavior (pattern). As it successful managed to detect occupant preferred furniture, and place accordingly.

ANSYS numerical CFD simulation achieved 88-98% result accuracy, according to the set boundary conditions and method used. Several figures, charts, and tables are introduced in chapter 6, describing temperature, air velocity and air volume across all four selected room scenarios. Most of the results gathered from the CFD simulations support the idea that furniture settings could impact conviction flows in living room, even if its marginal. The person living in that apartment also mentioned that some room scenarios where more convenient than others, in terms of his mobility, access to other room furniture and air quality. His idea of a better room scenario also matched the one predicted by the CFD study.

Keywordst; Occupant behavior in buildings; Furniture settings; Indoor enviroment quality; Indoor air quality; Numerical CFD Simulation; ANSYS; SOLIDWORKS

I. INTRODUCTION

Throughout history, humans have adjusted to protect themselves against extreme climatic conditions or other being. At first, we resorted to caves which is relatively safe compared to open environment. From then managed to establish dwellings to provide a comfortable internal atmosphere. Building all types of designs and structures to improve on what can be considered a "home" today. As many have tried do define the meaning of "home" away from the physical structure, it is clear for us that safety and comfort plays a huge role. [3] [4]
In modern society people spend majority of their time indoors, either home or at work, which increased the interest in building design optimization, building performance, and indoor environment quality studies [5]. Making sure that consumers

live in a good healthy environment, as well as keeping employees in optimal condition.

Energy related occupant behavior in buildings is a key issue for building design optimization, energy diagnosis, performance evaluation, and building energy simulation due to its significant impact on real energy use and indoor environmental quality in buildings. However, the influence of occupant behavior is under-recognized or over-simplified in the design, construction, operation, and retrofit of buildings. Having deep understanding of occupant behavior and being able to model and quantify its impact on use of building technologies and energy performance of buildings is crucial to design and operation of low energy buildings.

The aim of this project is to study the interaction between occupants and their surroundings in residential buildings, particularly in terms of furniture settings/placement. In the concept of the building and equipment design, it is always difficult to establish exact knowledge about how the space and the equipment will be used by occupants. An essential element to know is how users preferred device and furniture setting will influence the room environment in terms of surface temperatures and air flow patterns. The thesis is following the work done in the project assignment where the main purpose was to analyses and visualize such effects and achieve awareness how it can be compensated by design measures. The main objective of the master thesis is to perform a series of measurements and numerical CFD simulations, analyze simulation errors and check if simulations are converged.

II. Tools

The two main computer programs used in this project, ANSYS and Solidworks. Equipment used to measure and describe the conditions of the room are; TSI velocicalc multi-function ventilation meter 9565-p [6] and FLIR E60 thermal camera [7]. While Microsoft Kinect is adopted for occupant migration monitoring in selected living room with the use of a depth registration camera. [8]

III. Method

A. Implementation of measurements

Any solid geometrical recreation or numerical CFD simulation is dependent on strong foundation of data and measurements, minimizing errors/miscalculations/losses in the results. Divided into three sections:

1. Room and furniture size

The apartment selected for this study is located in Stavset, Trondheim, which happens to be a 3rd floor "loft apartment". This apartment was easily accessible by the student, having a variety of furniture to adjust, makes it a suitable candidate to work with.

To construct a high-quality mesh, and less time consuming calculations, furniture and room dimensions are simplified. For example; most object curves are compensated with few additional millimeters and a 90º angel.

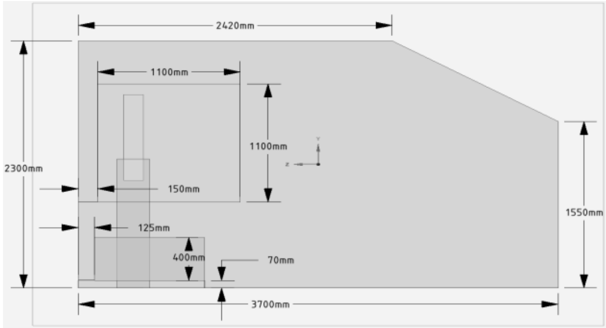


Figure 1: Side- view of the living room, showing the roof decline

There are technically six movable furniture found in this living room; TV, TV-stand, Sofa, Table, Shelf and Chair.

2. Ventilation meter

The ventilation meter is used to measure four different locations in the living room; The window (inlet), Door (outlet), Mid. point (center of the living room, 1,15m from floor and 1,85m from door) and Point X (1,15m from floor, located 3,7m from the door). Displayed in the figure below:

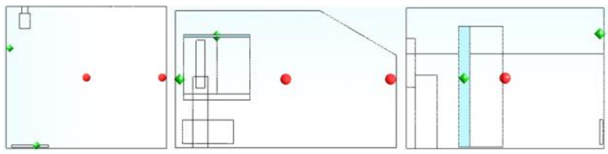


Figure 2: Four measuring points inside the selected room

The average value of the measured data of each location happen to be as follow:

Table 1: Average values of the measured data at all four locations

The average of the measured data			
Location	**Velocity [m/s]**	**Temp. [K]**	**Temp. [°C]**
Window	0,700	290,90	16,75
Door	0,092	294,46	20,31
Mid. Point	0,028	294,12	19,97
Point X	0,021	294,96	20,81

Total average value of inlet velocity is calculated to be 0,7 m/s, average inlet temperature is 290,9 K, as presented above in Table 1.

3. Thermal camera

Pictures of the living room where taken and then processed in MATLAB in order to identify heat maps colors and transfer it into Celsius [C°] data.

Table 2: TV screen door and walls recorded temperature

Surface	Temp. [K]	Temp. [°C]
Walls/furniture	295,06	29,91
Door (outlet)	294,46	20,31
TV-Screen	295,38	26,03

The temperature around the window area was unstable, had to be divided into four pieces:

Table 3: Average value of all four window zones

Window	**Temp. [K]**	**Temp [K]**
Top (inlet)	18,9	293,05

Right	23,64	297,79
Left	21,79	295,94
Bottom	24,04	298,19

These preformed measurements (of velocity, temperature, room and furniture size), set the bases for the boundary conditions.

B. Stratigy/furniture setting

In order to study the interaction between occupants and their surroundings in residential buildings, specifically on the issue of furniture settings (as well as heater locations). It is necessary to discuss a method (a strategy) for such issue. Building the fundamentals of this project on a case-based analyses, where different living room scenarios are simulated.

Designing a living room with the inlet, outlet and heater location fixed in all scenario as well as their attributes, with the help of SolidWerks and ANSYS. Furniture settings should be the main difference between each case. Subsequently, helps on analyzing and finding the influence furniture placement has on the indoor environment in terms of surface temperatures and air flow patterns. Microsoft Kinect is thereby used to gather and recreate body movement inside the selected living room. Such data can further be used to find potential discomfort zones inside the selected living room.

Four different room scenarios were selected to for this study. Each scenario is possible to be recreate in real life, realistic furniture placement, allowing the occupant to interact with each object. First scenario is described as "empty room scenario", were every removable furniture is taken out of the geometry. The other three scenarios consist of small adjustment in furniture placement, without removing any of them.

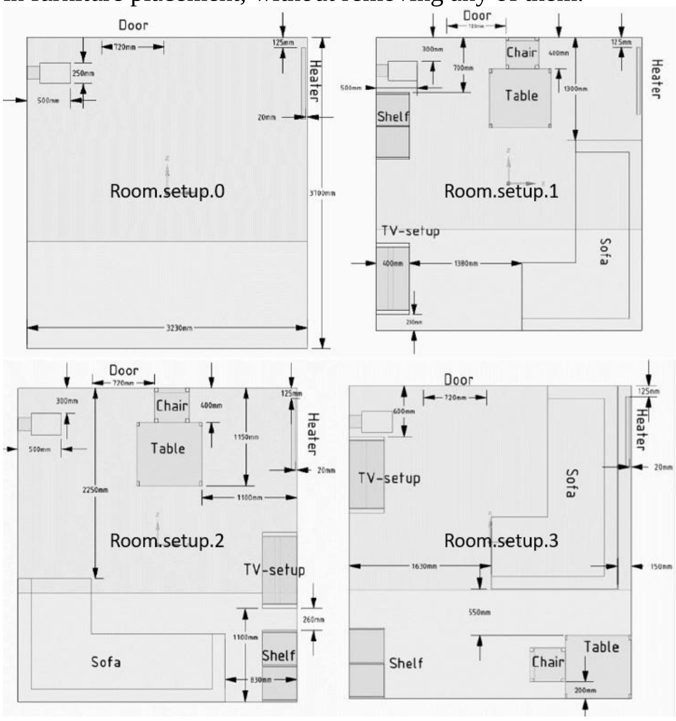


Figure 3: two-dimensional top view of each room setup (0-3)

Figure 3: two-dimensional top view of each room setup (0-3) (above) shows a two-dimensional top view of all four room scenarios, displaying the exact furniture location (scaled in mm).

C. ANSYS Workbench

Every process starts with a body model (geometry), that model is then meshed into small cells, resulting in a grid with a large number of nodes.

ANSYS Workbench project schematic display each sell in its right order: Geometry → Mesh → Fluent → Results. [9]

- Mesh:

High mesh quality is very crucial to any accurate level of predictions (results). By trying out different meshing methods, techniques and sizing values, it is possible to arrive to a high-quality grid. Judged by Aspect ratio, element quality and skewness. Assembly meshing using ANSYS Fluent, allows/provides for two algorithms: CutCell and Tetrahedrons. As for this project, Assembly meshing method "CutCell" is very useful to provide hexahedral dominant representation of the grid in hand. To achieve that, some of the default settings needs to be changed as follow: [9]

Table 4: Assembly meshing CutCell

Defaults	
Physics preference	*CFD*
Solver Preference	*Fluent*
Relevance	*0*
Export format	*Standard*
Sizing	
Size Function	*Curvature*
Relevance Venter	*Medium*
Curvature Normal Angel	*Default (18,0 º)*
Min Size	*0,01 m*
Max Face Size	*0,04 m*
Growth rate	*Default (1,2)*

Face Sizing is selected to increase the cell number at areas (faces) considered to be interesting, such as; walls, window, heater and door.

Table 5: Mesh Face Sizing

Definition	
Suppressed	*No*
Type	*Element Size*
Element Size	*0,01 m*
Advanced	
Defeature Size	*0,005*
Size Function	*Uniform*
Behavior	*Soft*
Growth Rate	*Default (1,2)*

- Fluent: set-up boundary conditions

Permit the pressure-based Navier-Stokes solution algorithm, enable absolute velocity formulation, steady flow solver and include gravity at a value of -9,81 m/s. (the right axis, might differ from geometry to another) [9] [10]

The "models" task page Contains a listing of the various models available in ANSYS Fluent, such as multiphase, energy, viscous, radiation, heat exchanger, species, discrete phase, solidification & melting, acoustics, eulerian wall film and electric potential.

[9]. Two main "Models" activated for this project, are "Energy" and "Viscous" (at k-epsilon (2eqn)). Activating the ENERGY gives access to determine criterion linked to energy or heat transfer in a model. while the VISCOUS MODEL dialog box is used to enable turbulent flow calculations, along with inviscid and laminar flow. Turbulent flow can be calculated using one of three - k-ε models: [9] [10]

1. Standard 2. RNG 3. Realizable

The Standard k-ε turbulence model is arguably the most applied model in CDF calculations as well as being the default model for ANSYS Workbench Fluent 18.1. Launder and Spalding are the founders of this model in 1974, introducing a collection of equations used for a variety of turbulent calculations. [11] [12]

Transport equations for standard k-epsilon model are as follow:

- For turbulent kinetic energy "k" [9] [11] [10]:

$$\frac{\partial}{\partial t}(\rho k)+\frac{\partial}{\partial x_i}(\rho k u_i)=\frac{\partial}{\partial x_j}\left[(\mu+\frac{\mu_t}{\sigma_k})\frac{\partial k}{\partial x_j}\right]+G_k+G_b-\rho\varepsilon-Y_M+S_k$$

- For the rate of dissipation "ε" [9] [10] [11]:

$$\frac{\partial}{\partial t}(\rho\varepsilon)+\frac{\partial}{\partial x_i}(\rho\varepsilon u_i)=\frac{\partial}{\partial x_j}\left[(\mu+\frac{\mu_t}{\sigma_\varepsilon})\frac{\partial\varepsilon}{\partial x_j}\right]+C_{1\varepsilon}\frac{\varepsilon}{k}(G_k+C_{3\varepsilon}G_b)-C_{2\varepsilon}\rho\frac{\varepsilon^2}{k}+S_\varepsilon$$

G_k: Generation of turbulence kinetic energy due to mean velocity gradients
G_b: Effects of Buoyancy on Turbulence in the k-ε Models
Y_M: The contribution of the fluctuating dilatation in compressible turbulence to the overall dissipation rate

While $C_{1\varepsilon}$, $C_{2\varepsilon}$ and $C_{3\varepsilon}$ are all consider to be constant. Turbulent Prandtl numbers (Pr_t) are represented in σ_k and σ_ε. μ_t describes the eddy viscosity, also calculated as follow [3]:

$$\mu_t = \rho C_\mu \frac{k^2}{\varepsilon}$$

In the table below each changeable constant is mentioned with its default value:

Table 6: Model Constants (by default) [9] [10]

C_μ	$C_{1\varepsilon}$	$C_{2\varepsilon}$	σ_k	σ_ε	Pr_{Energy}	Pr_{Wall}
0,09	1,44	1,92	1,0	1,3	0,85	0,85

Three types of BC where selected (Wall, Velocity-inlet, Pressure-outlet), for separate set of zones: [9]

Table 7: Boundary Conditions

Zone	Type	Velocity/ Pressure	Temp. [K]
Walls/furniture	Wall	-	295,15
Heater	Wall	-	304,15
Door	Wall	-	294,46
Door opening	Pressure-outlet	0 Pascal	294,46
Window opening	Velocity-inlet	0,7 m/s	290,90
Window right	Wall	-	297,79
Window left	Wall	-	295,94
Window bottom	Wall	-	298,19
Geom-solid	Wall	-	295,15
TV-screen	Wall	-	300,18

Reference values is the last task page on the setup of ANSYS Fluent 18.1, before running calculations. There aren't many significant changes done in this task page.
Starting with task page "Solution Methods":

Table 8: Solution Methods

SIMPLE	
Gradient	*Least Squares Cell Based*
Pressure	*Second Order*
Momentum	*Second Order Upwind*
Turbulent Kinetic Energy	*First Order Upwind*
Turbulent Dissipation Rate	*First Order Upwind*
Energy	*Second Order Upwind*
Wrapped-Face Gradient Correction	*On*

Next step is to decide initialization method, given two options: Hybrid or Standard. Hybrid Initialization is implemented, to solve the Laplace equations and produce a velocity and pressure fields. Other variables such as temperature, turbulence, species fractions, volume fractions, and so on, will be automatically fix/corrected/patched by this method. [9] [10]
Lastly "Run Calculation" (to start the solver iterations at Steady-State Calculations): number of Iterations can vary from file to file, for accurate results, it's advised to run calculations until the solution has converged. [10] [9] [13]

D. *Occupant migration monitoring*

Thermal measurements of the selected room should be completed at this stage, along with the furniture design, ANSYS geometrical model, mesh and CFD solution. The next step of this process would require data (information) of temperature and air velocity positioning in of the geometry (living room).
To conduct investigation regarding the thermal comfort sensation with a use of newly developed occupant behavior bot, Microsoft Kinect had to be placed in the top corner of the selected living room. The devices stayed there for one week, to capture occupant behavior in that period of time. Furniture setting is changed /switched as described in chapter X, starting with room setup1 24-25/04/2018, then room setup.2 29-30/04/2018 and finally room setup.3 27-28/04/2018. The skeleton (limbs) works as colleting points moving across the living room collecting data in all directions. [2]

Number	Joint name	Number	Joint name
1	Spine Base	14	Knee Left
2	Spine Mid	15	Ankle Left
3	Neck	16	Foot Left
4	Head	17	Hip Right
5	Shoulder Left	18	Knee Right
6	Elbow Left	19	Ankle Right
7	Wrist Left	20	Foot Right
8	Hand Left	21	Spine Shoulder
9	Shoulder Right	22	Hand Tip Left
10	Elbow Right	23	Thumb Left
11	Wrist Right	24	Hand Tip Right
12	Hand Right	25	Thumb Right
13	Hip Left		

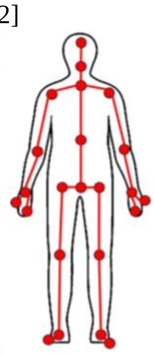


Figure 4: Skeleton model hitch points [2]

List of all 25-skeleton model (SM) joints, with a figure to the right illustrating how the limbs of the skeleton model is divided.

By the help of Microsoft Kinect devise built-in software, it is possible to derive the positioning of the body in 3D (X, Y, Z). The positioning data is given from the distance between each joint and the reference point (0,0,0). Which is the measurement device (the Microsoft Kinect decide, located in a mass center of the device). Evidently the placement of the Microsoft Kinect device could affect the accuracy of recording movement within the living room. Jacub W. is credited for helping on collecting data information from the SM joints. [2] [14]
The movement where processed via Matlab, transferred as polyline into CFD-post, and then exported the value of velocity and temperature for suck points/lines! Once the data is exported from CFD-post, it can be processed once again using Matlab code.

IV. PESULTS

This chapter hold several results collected from ANSYS and SolidWorks files. Starting with the furniture model, mesh and convergence accuracy. Followed by data gathered from comparing room setup by their temperature change, air velocity, air volume and occupant pattern. All geometries are based on the recreated furniture models found inside of the selected living room, also the four different furniture settings (placements) scenarios. To describe mesh quality figures and tables of Aspect ratio, Element quality and Skewness are included, as it plays a huge role in deciding results accuracy (reliability).
CFD calculation are compared to the measured points to establish accuracy, as described in previews chapters. Room scenarios are then studied through point probing, plane average, air quality volume as well as occupant patterns. To be able to identify discomfort zones inside selected living room. Obtained results aim to show identification of the existence of potential discomfort zones inside the selected room.

1. *Furniture:*

Figure 5 shows a three-dimensional representation of each furniture model (movable objects) found inside the living room.

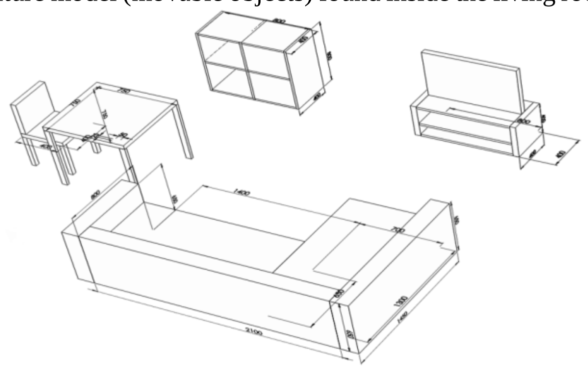


Figure 5: Three-dimensional sketch of all furniture (scaled in millimeter)

2. *Mesh:*

Figure 6 show a cross-section of a random wall in the geometry, showing the different layers in the grid.

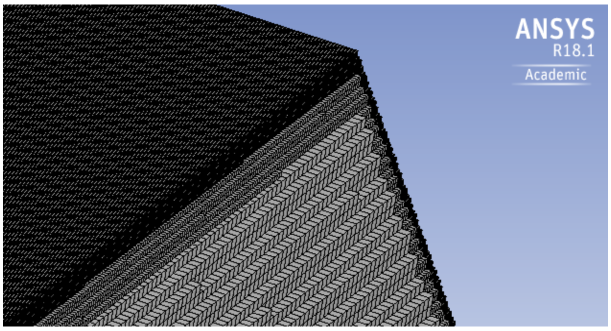


Figure 6: Cross section of geometry mesh

Testing grids; Aspect ratio, element quality and skewness, for all four meshes (room scenarios)

Table 9: Mesh metrics

Room setup.0 (empty room)			
Mesh Metric	Aspect Ratio	Element Quality	Skewness
Min	1,0052	0,28914	$1{,}3057e^{-10}$
Max	12,324	0,99999	0,8995
Average	1,0259	0,99804	$4{,}3797e^{-3}$
Room setup.1			
Mesh Metric	Aspect Ratio	Element Quality	Skewness
Min	1,0022	0,45936	$1{,}3057e^{-10}$
Max	4,5086	1,00000	0,79601
Average	1,0243	0,99713	$4{,}4963e^{-3}$
Room setup.2			
Mesh Metric	Aspect Ratio	Element Quality	Skewness
Min	1,0052	0,19268	$1{,}3057e^{-10}$
Max	12,324	0,99999	0,89591
Average	1,0243	0,9958	$4{,}4963e^{-3}$
Room setup.3			
Mesh Metric	Aspect Ratio	Element Quality	Skewness
Min	1,0052	0,28914	$1{,}3057e^{-10}$
Max	7,1511	0,99999	0,8995
Average	1,0358	0,99589	$3{,}8336e^{-3}$

Mesh metric test: [9] [10]

- Aspect ratio is recomended to be close to 1 (as ideal) cant be below the value of 1.
- Skewsness value can varey between 0-1 (0 concidered to be excellent, 1 degenerate)
- Element quality value of 1 is considerd to be "ideal", 0 "unacceptable".

3. *Convergence*

The figures below contain the residual scale (Continuity, X-velocity, Y-velocity, Z-velocity, Energy, K and epsilon) of each study (room scenario) on their own, as well as the number of iterations required to complete convergence.

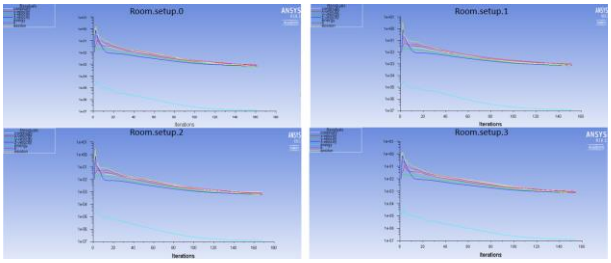


Figure 7: Residuals chart

The residuals are clearly decreasing with number iterations, a healthy look for the results. The convergence happens to be completed between 150-200 iterations.

4. *CFD-post results*

Table X contain data from all four probing points according to the locations measured earlier.

Table 10: Measured Data for four different locations

Location	Velocity [m/s]	Kelvin [K]	Celisus [°C]
Window	0,700	290,90	16,75
Door	0,086	294,04	19,89
Mid. Point	0,026	293,44	19,29
Point. X	0,024	293,85	19,70

Describing the indoor averment using air volume. The figure below contains a three-dimensional view of the room temperature change; scaled from 290K to 295K.

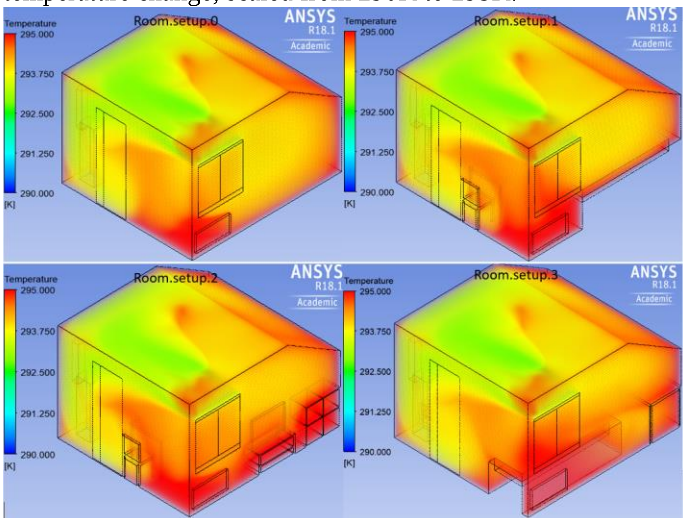


Figure 8: Three-dimensional view of the temperature change (for all four room scenarios)

Table 11: Percentage of the temperature falling between 20-22℃ describe total air volume and of zones of air volume between 20-22 [℃] (293,15-295,15 [K]) and the prostate. (of each scenario)

Table 11: Percentage of the temperature falling between 20-22℃

Room setup	Volume $[m^3]$	Zone 20-22 ℃	In [%]
0	25,797	23,362	90,56
1	24,494	21,980	89,74
2	24,494	22,153	90,44
3	24,494	22,139	90,39

Percentage of areas with low velocity are presented in Table 12

Selected two zones close to stationary air movement;

Zone 1: velocity below 0,01 m/s

Zone 2: velocity below 0,02 m/s

Table 12:Percentage of the velocity found below 0,01m/s and 0,02m/s

Room setup	Volume [m^3]	Zone 1	[%]	Zone 2	[%]
0	25,797	1,729	6,7	4,228	16,39
1	24,494	2,315	9,4	4,765	19,45
2	24,494	1,884	7,7	4,035	16,48
3	24,494	2,351	9,6	5,218	21,31

5. *Occupant activity*

Occupant activity captured by the Kinect device.

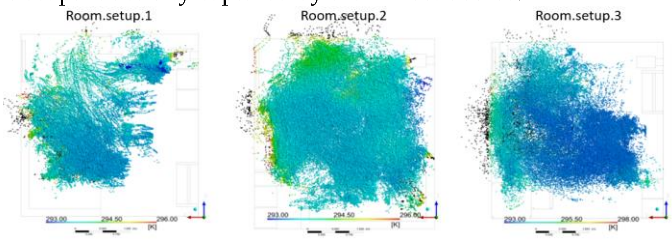


Figure 9: Activity captured by the Kinect device

V. Analysis

This chapter will analyze simulation errors and assess the impact furniture setting has on the occupant and their surroundings.

1. *Mesh quality:*

The mesh quality is hard to judge at first glance. Figure 6 demonstrate this by showing a random cross-section of the mesh without any noticeable/unwanted change in cell sizes or other deficiencies. Hence, it's necessary to go through the mesh metric data provided in Table 9. Judging of the average value of the Aspect ratio, Element Quality and Skewness, this is considered to be an acceptable mesh, even though there still is place for improvement, as the Aspect ratio hit 12 at some cells, and the skewness as high as 0,8.

2. *Convergence*:

CFD convergence should be tested by examining the residual values, as it has a massive influence on the outcome (results). The point of convergence expresses the level of accuracy the problem been solved at. A healthy setup would lead to a continuous decline in residual value, depending on the number of iteration, and is considered completed (acceptable) once all residuals hit a value of at least three order of magnitude (10^{-3}), while the scaled energy residual hits about $x * 10^{-3}$. Table 13 contains the residual data taken from Figure 7, found in the previews chapter.

Table 13: Collected residual data

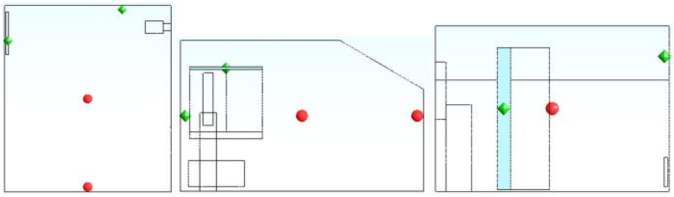
Setup	0	1	2	3
Iterations	161	152	168	153
Continuity	$7{,}69 * 10^{-4}$	$8{,}96 * 10^{-4}$	$9{,}63 * 10^{-4}$	$9{,}99 * 10^{-4}$
X-velocity	$8{,}49 * 10^{-4}$	$9{,}70 * 10^{-4}$	$8{,}17 * 10^{-4}$	$9{,}52 * 10^{-4}$

Y-velocity	*6,34** 10^{-4}	*6,64** 10^{-4}	*6,09** 10^{-4}	*7,03** 10^{-4}
Z-velocity	*6,82** 10^{-4}	*7,12** 10^{-4}	*6,28** 10^{-4}	*7,50** 10^{-4}
Energy	*1,22** 10^{-7}	*1,25** 10^{-7}	*1,26** 10^{-7}	*1,27** 10^{-7}
K	*7,45** 10^{-4}	*8,33** 10^{-4}	*6,7**10^{-4}	*8,22** 10^{-4}
epsilon	*6,37** 10^{-4}	*6,74** 10^{-4}	*5,96** 10^{-4}	*6,99** 10^{-4}
Time	*7:47*	*7:13*	*7:55*	*7:20*

CFD convergence happens to be completed after a total of 150-200 iterations, all residuals reach a value of $x * 10^{-4}$, while the energy residual reaches $x * 10^{-7}$, which is considered acceptable for steady state calculations.

3. *Measured Data compared to the CFD simulations*

The four tested locations in the room are as displayed in Figure 2. Green marker; Inlet and outlet, Red marker; Mid. point and Point. X.



CFD Post results accomplish a quite accurate results judging from the four measured points, compared with the CFD results.

Table 14:Temperature and velocity accuracy

Room.Setup.0	**Velocity Accuracy**	**Temperature Accuracy**
Window	100,00 %	100,00 %
Door	93,34 %	97,93 %
Mid. Point	92,02 %	96,57 %
Point. X	88,57 %	94,67 %

Potentially 88-98 % accuracy in across the locations/points tested, the window accuracy would always be 100% (as it reflects on the inlet BC). This is only compared to the measured data on that day and ANSYS CFD simulation, it's not put in stone (could be questionable). The indoor air quality changes throughout the day, month and year as well.

4. *Furniture setup*

Referring to Table 11and Table 12:

Room.setup.2 stands out as favorite/healthier alterative, with only 7,69 % of the total volume below 0,01 m/s and 16,48% below 0,02 m/. Compared to Room.setup.3 with a total volume of 2 351 $[m^3]$ (9,6 % of the total volume) below 0,01 m/s and 21,31 % below 0,02 this is not an ideal percentage, only compared to the other two furniture settings. This could of lead to more dust/ bad air quality and unhealthy environment in general.

There are some differences between the room scenarios according to the CFD simulations, but nothing drastic. Here are some points that could explained why:

- The living room selected for this project was relatively small, which makes it difficult to drastically change the furniture setup.
- low air velocity: Especially on the day of measuring it the in the living room, reducing the effect a window opening has on such apartment.

5. *Occupant activity*

In context of the building and equipment design, it is always difficult to establish exact knowledge about how and the equipment will be used by the occupants. An important element to know is how users preferred devices and furniture setting will influence the room environment in terms of surface temperatures and air flow patterns. Microsoft Kinect managed to track occupants' activity successfully (with high accuracy), achieving a better understanding of the users' lifestyle. Tracing all 25 nodes simultaneously, with information about node location and time.

The obtained results show that most of the occupants' movement was influenced by the sofa and TV placement, all three different furniture settings have that in common. This observation is interesting and can prove that furniture placement influence occupants' activity, naturally influence the environment surrounding them.

The person living in the apartment also got asked about his assessment on the different furniture setup that he experienced. His answer seems to agree with the prediction accomplished using this method, as he stated that room setup nr.2 was continent in terms of extra room space, air quality and his mobility.

VI. CONCLUSION

Occupant behaviour impacts building structure by movement or actions, witch by default determines the buildings indoor environment quality (IEQ) and energy consumption. Due to the inconsistency of the occupant movement and actions in most cases makes it hard point out one particular factor, making the prediction very complex. On the other hand, buildings energy use and indoor environment can affect the occupant both physical and mental health.

In this thesis, emphasis is placed on how furniture location would have an effect on the occupant and their environment, in residential buildings. Preforming a number of measurements and numerical CFD simulations using ANSYS, it's been possible to reach an accuracy of 88-100%. According to the set boundary conditions and the solution method, described in chapter 6.

ANSYS and Microsoft Kinect are capable of providing helpful data regarding the room environment, occupant behavior and potential discomfort zones. Processed data show that the furniture setting didn't affect the indoor environment drastically, but had a noticeable impact on the occupant pattern. Some room scenarios where more convenient than others; namely Room.setup.2 covering 83,52% of its total air volume velocities above 0,02 m/s, which is 4-5% higher than other room scenarios with furniture.

The user of the selected apartment seems to agree with the prediction accomplished via ANSYS, as he ended up leaving the furniture placed as described in Room.scenario.2. According to him this furniture setup gave a feeling of more mobility, better access to the rooms furniture, air quality and extra space for activity in comparison with other setup.

VII. References

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