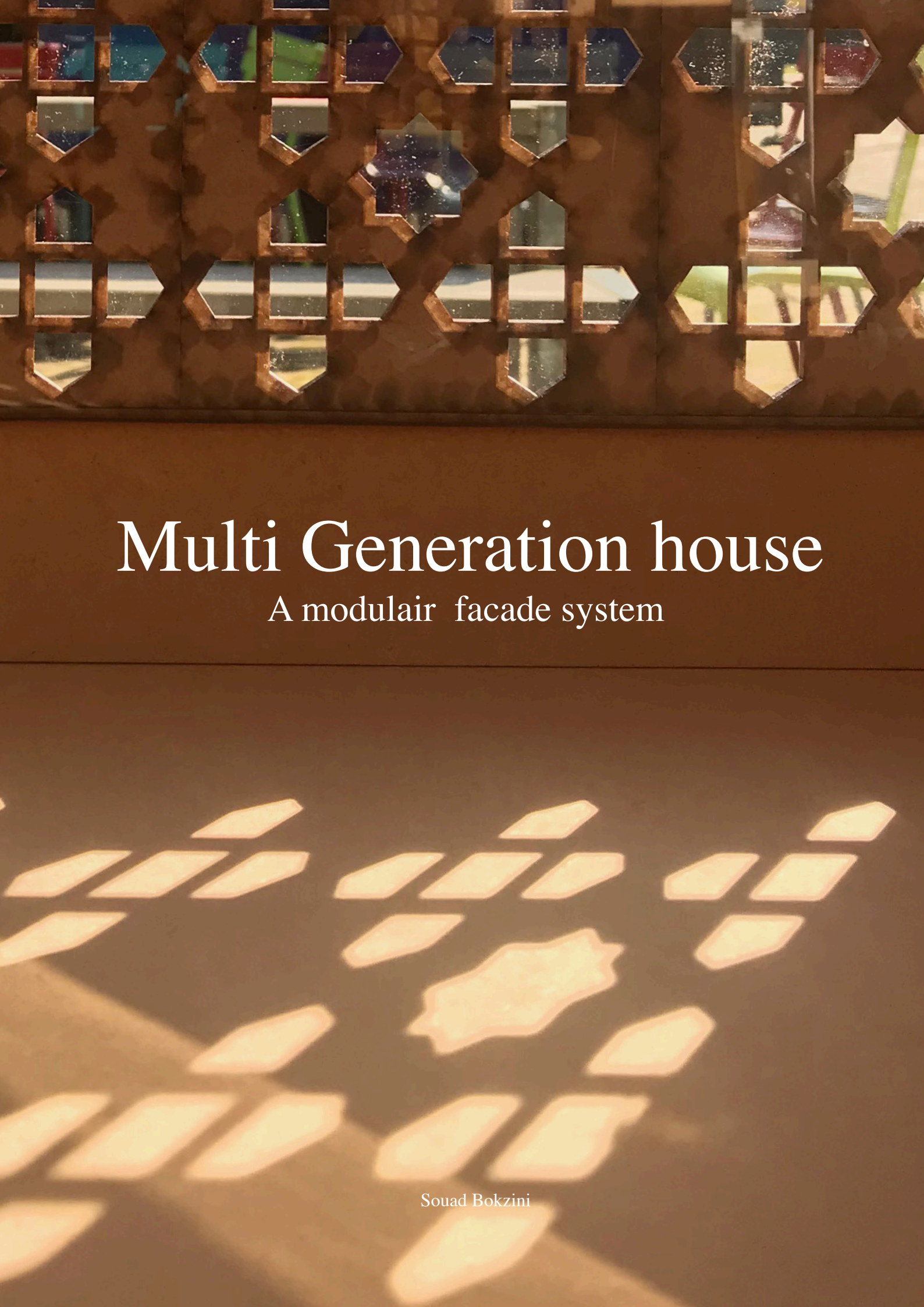


Master Building Technology

Thesis

N^o 1





Multi Generation house

A modulair facade system

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Preface

This report contains the thesis titled “Multi generation house”. The thesis was written in the context of my graduation project for the Msc in Building Technology from TU Delft.

Throughout my research, my supervisors Dr Truus Hordijk and Ir. Koen Mulder were constantly supportive. They always answered my numerous questions patiently and encouraged me in the continuation and completion of my research.

I would like to thank my supervisors, my colleagues and my friends for their guidance and support during this process. I would also like to thank all the participants who took part in and invaluable contributed to this research. I would not have been able to complete this thesis without their voluntary cooperation.

Additionally, I would like to thank my friend Tasmana Khorshed Alam for allowing me to discuss my research freely with her. I have also received much advice from my family and they supported me mentally during this process. In particular, my parents, with their wisdom and motivational words, helped me finish this thesis.

I wish you much reading pleasure.

Souad Bokzini

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Chapter 1 Research methodology

This chapter is an introduction to the report. It will contain the problem statement, aim, objectives, research questions, research design and methodology. This will be clearly explained in sub-chapters. This chapter will end with a graphic description of how the research will be conducted.

1.1 Problem statement

The sharp rise of the ageing population will become a problem in the near future. In the last few decades, the population of elderly over 65+ has increased in the Netherlands. In 2040, they expect approximately 26% of the total population to be 65+ (Aarts & Westerlaken, 2005). More senior dwellings are needed. The statistics are shown in figures 1, 2 and 3.

Some elderly move to nursing homes because they felt lonely or need care. This happens mostly when one partner has died, or they no longer have social contacts other than their busy children. Nowadays, a lot of people have a lot of excuses for not having the time to visit their parents. A solution to

this problem would be to find a way for children to live with their aged parents separately, but together in a smart way.

In nonwestern countries, it is already common to live together with multiple generations. The Netherlands counts 200 different nationalities, measured by the CBS in 2005. Some of those people live with their families in one house because they care, or they have strong family bonds. While the Netherlands already has multi generation houses like the Kangeroe woning, these have their disadvantages, such as the lack of privacy and an empty place after the parent has passed away.

Throughout the years, there has been a lot of changes in the behavior and physiology of the

human body. As a result, there are new requirements needed for thermal and visual comfort. Thermal comfort consists of parameters that influence the heat balance of an individual. It has an important role in the performance of the building, because approximately one-third of the primary energy that is used in the country is consumed by heating, ventilation and air conditioning.

As the visual comfort changes with ageing, it is necessary to look at the specific requirements of the elderly. Preventing the decline of eyesight that occurs with ageing can contribute to preserving the independency of the elder for as long as possible.

Figure 1. 65 years old born in 1934, year 2000 (CBS).

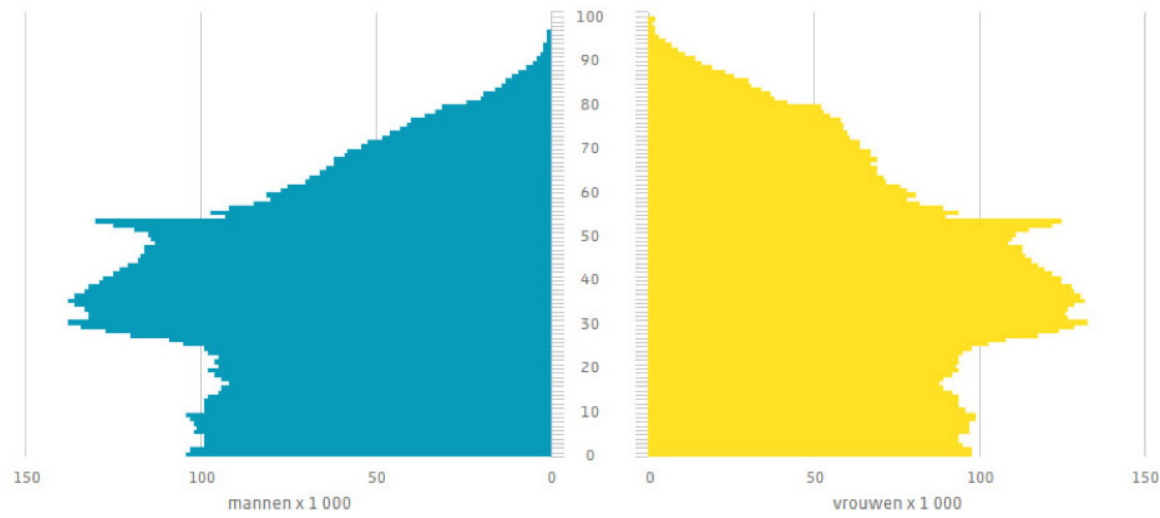


Figure 2. 65 years old born in 1951, year 2017 (CBS).

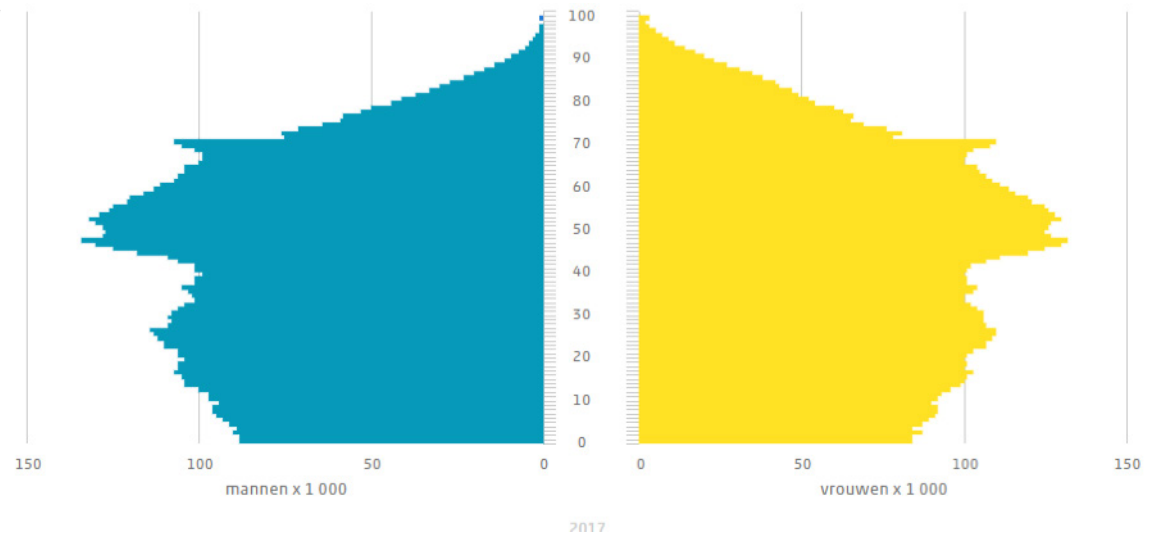
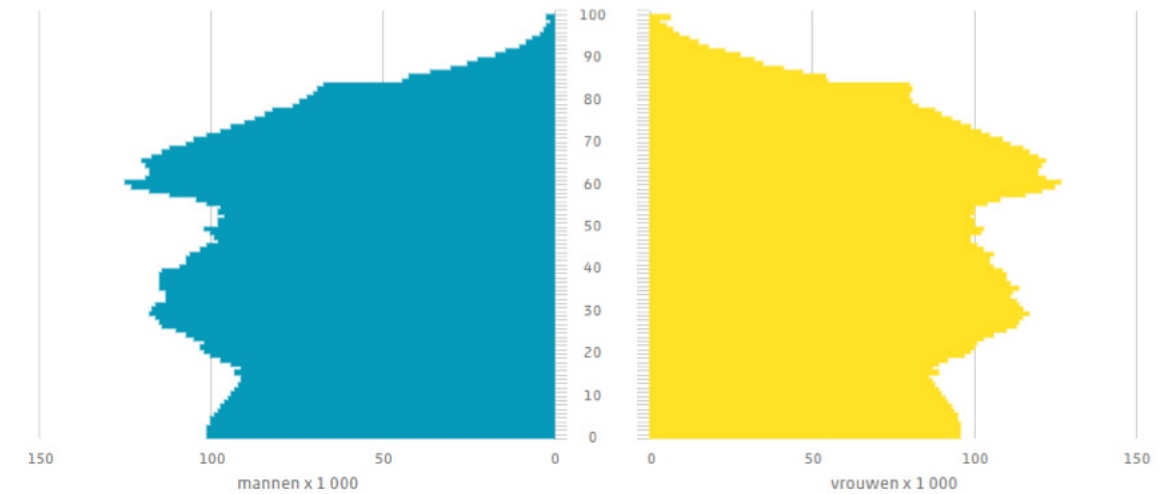


Figure 3. 65 years old born in 1964, year 2030 (CBS).



1.2 Research aim

The aim of this research is to design the façade of an independent house for the elderly in the Netherlands. This house should be able to stand in the garden of, or being an extension of their children's homes. The house has to be flexible in such a way that it is possible to make it bigger and smaller when it is no longer required "ikea concept". It should be possible to customize the house for each consumer. This can be done through a customizable facade that can help to distinguish one house from another.

The house needs to accommodate the thermal and visual requirements of the elderly of different ethnic groups who live in the Netherlands. Hence, the house should be able to accommodate different levels of visual and thermal comfort. This can be done by customizing the design and composition of the façade for each client. This customized facade can be chosen when the house is leased from the company providing them. Hence, this house should be customizable not only in size and function, but also in levels of thermal and visual comfort.

1.3 Research objective

While there are other design proposals for elderly housing that is flexible and low cost, they do not address the differences in thermal and visual comfort within the elderly population itself. In a multi-cultural society like the Netherlands, many nuanced different standards of thermal and visual comfort will coexist side by side. For example, immigrants from warmer countries will have a higher tolerance for heat and glare, and a lower tolerance for cold. They will also require higher levels of sunlight to maintain sufficient levels of vitamin D. The aim is to propose a design which does not stop at the generic requirements of the elderly. The design should be customizable so as to accommodate differences in standards of thermal and visual comfort that exist within the elderly population of the Netherlands.

1.4 Research questions

The main research question is: *"How can a façade be designed for a house for elderly people, where their children can take care for them in close proximity, while being flexible enough to customize for the thermal and visual comfort of a multicultural population?"*

Sub-questions:

- *What types of houses already exist for multi-generational families that want to livetogether?*
- *Which ethnic groups live in the Netherlands?*
- *What is thermal comfort?*
- *To what extent can thermal comfort be regulated for the elderly?*
- *What is visual comfort?*
- *To what extent can visual comfort be regulated for the elderly?*
- *What are the different standards of thermal and visual comfort within the different ethnic groups in the Netherlands?*
- *To what extent do the elderly feel visually comfortable in their existing homes?*
- *To what extent do the elderly feel thermally comfortable in their existing homes?*
- *What are the possibilities for designing a façade?*

1.5 Constraints

Who: *Elderly people from different cultural backgrounds.*

Research is conducted to understand the different standards of thermal and visual comfort in elderly from different cultural backgrounds. Results will be integrated into the flexibility of the façade and how it contributes to the design of the house.

Where: *The Netherlands*

The façade of the house will be designed for the thermal and visual comfort of the different groups of elderly residing in the Netherlands. It should be able to stand in the garden of an existing house.

What: *A visually and thermally comfortable house for the elderly where the flexibility of the facade is an important component of the design.*

The house should be flexible and customizable in a such way that it can be placed in different gardens and with the opportunity to increase or decrease its size in order to accommodate different functions. The design of the facade should facilitate the requirements of visual and thermal comfort as researched in this report.

1.6 Research design

Research into the visual and thermal comfort of the elderly population in the Netherlands will be conducted alongside the design of the facade. Findings from the research will be funneled into the design and new questions that arise from the design process will be addressed through the research. In this way, both processes are tightly connected. The research findings on visual and thermal comfort will be analyzed and create new requirements for the design of the facade. This facade design will then be analyzed and evaluated in order to inform the second phase of facade design. Furthermore, the results of this report will facilitate the continued design of this elderly house typology in the ‘Architectural Engineering’ track.

1.6.1 Defining the reference building

An existing house, the “Kangeroewoning” will be analyzed. Together with the most common characteristics of the house, the advantages and disadvantages of the design will be identified. The facade of the building will also be studied to understand how it was used to address thermal and visual comfort requirements.

1.6.2 Literature review

The literature review will firstly highlight the different requirements for thermal and visual comfort of the elderly, as compared to the younger generation. This will lead to a search for definitions of thermal and visual comfort of the elderly. Additionally, the report will look at the different ethnic groups of elderly people who live in the

Netherlands. The result will be the design of a brief, upon which the design of the house can be based on, and where the focus will be on the design requirements of the façade.

1.6.3 Design process

There will be a design phase for the façade. The facade should help to fulfil two requirements of the overall design of the house. Firstly, the house should be flexible enough to customize in scale and function. Secondly, the visual and thermal comfort of the design should also be easily adjustable in order to meet different standards of comfort. This design phase will be analyzed and reflected upon in relation to the comforts of the elderly.

1.6.4 Data analysis

In order to understand the requirements of this proposed house for elderly people of different ethnic backgrounds, research will be conducted through the use of questionnaires. These questionnaires will be completed by elderly participants from different ethnic groups. Additionally, the existing homes of these elderly participants will be measured for thermal and visual comfort levels in order to better understand their needs.

1.6.5 Design test

From the final design, a physical model will be made to test the visual comfort. This will be done by measuring the light which enters the room in the model.

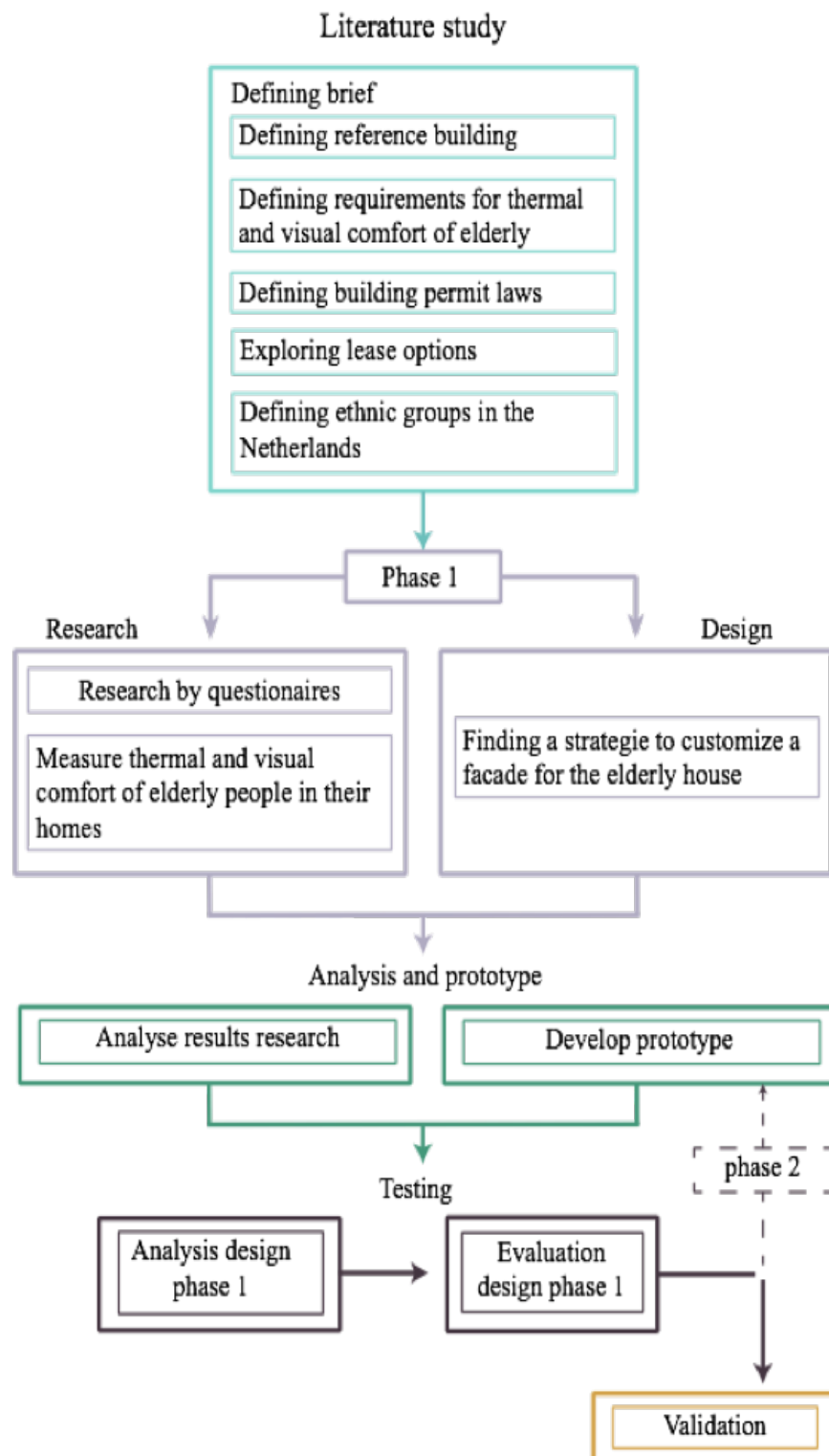
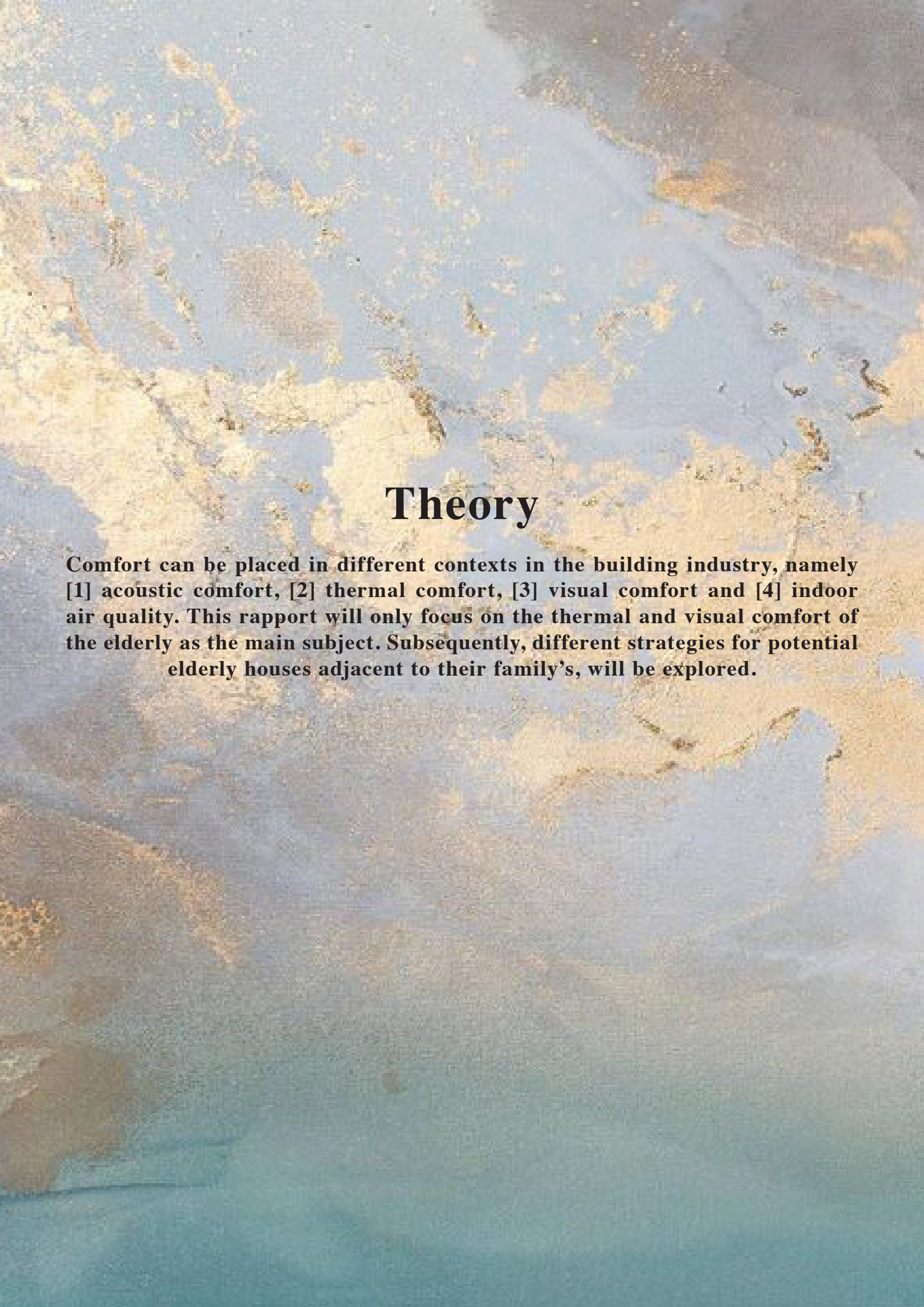


Figure 4. Research methodology..



Theory

Comfort can be placed in different contexts in the building industry, namely [1] acoustic comfort, [2] thermal comfort, [3] visual comfort and [4] indoor air quality. This rapport will only focus on the thermal and visual comfort of the elderly as the main subject. Subsequently, different strategies for potential elderly houses adjacent to their family's, will be explored.

Chapter 2

Generation houses

Chapter two will firstly explain what multi generation houses are and what options already exist within the Netherlands, for those wanting to live with their parents. The second part will explain which of the ethnic groups in the Netherlands this report will focus on. To understand better the different ethnic groups that live here, data from the Centraal Bureau of Statistiek (CBS) will be looked at. The third part of the chapter will explore options for a new design for a house for the elderly. Finally, there will be a conclusion that will answer the following questions: “What types of houses already exist for multi-generational families that want to live together?” and “Which ethnic groups live in the Netherlands?”

2.1 Multi Generation houses

Multi generation houses have existed for a long time. They were especially popular in the past, when newly married couples would reside with their parents until they could afford accommodation of their own, a process that often took a long time. This practice is still common in other cultures and countries. Living together has its benefits but it also has many disadvantages. Hence, elderly homes exist for children who do not have the time or ability to take care of their elderly parents. However, there are still people who want to take care of their elderly parents, especially people from foreign cultures, where this is expected or customary.

As of 1990, The Netherlands counted 1350 care homes in total. The government has decided that the elderly need to live at home longer, in order to reduce this number of care houses. One solution to this that already exists are the Kangaroo houses, which will be explained in two case studies in this chapter.

2.2 private and common room

Most of the problems in multi generation houses arise from the different privacy requirements of the groups of people that are living together. Gerards, Nuyts and Vandrie report, “Drie generaties onder één dak”, researched these requirements using questionnaires. The aim was to understand which spaces of a house the elderly consider to be private and which spaces the younger generation consider private.

Most of the problem in the generation houses is the privacy of the people that live together. The report of Gerards, Nuyts and Vandrie searched what are the most private spaces for elderly and younger people, with questionnaires. The results will be specified by the function of the room.

- Private bathroom: A private bathroom is not an essential requirement for both the younger generation and the elderly. The fact that a bathroom can be locked when in use was enough for all parties.

- Private living room: Younger people with partners have more need for a private living room, especially when they live in a multi generation house. However, when trying to save on cost, they are able to compromise and share a living room. In comparison, the elderly do not want to share their living spaces at all

- Private desk: Younger men have more need for a private desk compared to women and the elderly.

- Private kitchen: Younger men have less need for a private kitchen. Older one want more a private kitchen, especially people with a partner. However, when the elderly can live together with them, the need of a private kitchen is less. Young single men have little need for a private kitchen. Younger couples prefer a private kitchen but are able to compromise and share a kitchen when saving on costs.

- Private dining room: The Elderly prefer a private dining room, especially those between the ages of 54 and 77. The more importance attached to lower living costs, the easier it is to share a dining room. Conversely, the more importance attached to the disadvantages of forced contacts, the less willing to share the dining room.

- Private storage: Ages between 66 and 77 have more need for private storage. Non-university graduates and singles are more willing to share storage space.

- Private garden: A private garden is not essential to any generation. However, if there is a possibility to have one, younger people would prefer to. The more satisfaction with living conditions, the less need for a private garden (Gerards et al., 2015).

2.3 CASE STUDY: KANGEROEWONING

The Kangeroe woning is located in Rotterdam. This building consists of different generations living separately but within a single building envelope. ‘Kangeroe’ is the Dutch word for kangaroo, the animal that is recognized by the pouch in which it carries

its child. In the context of this building, it refers to a family taking care of their own when the first generation gets older. A clear advantage of this concept is that the elderly can live long together with their family. Each house has two separate households with its own front door, kitchen, sanitary facilities and living rooms. To reduce costs, there are also shared spaces, such as a common storage, laundry and drying facilities.

The home is available in various sizes, with a flexible interior which results from a lack of bearing walls. The house has a steel skeleton construction, with innovative materials such as high-end sandwich panels, triple glazing and robust aluminum frames and doors. For the façade, there is the opportunity to choose from different materials such as wood, slate or cortex steel. The building can be constructed in a month and the costs are between €300.000,- and €500.000,-.

- Flexibility: The interior of the house is flexible, which is useful when welcoming in a new generation. However, if the children no longer want to live with their parents, or the elderly generation passes away, there is no opportunity to do something with the leftover space. The interior partitions which are no longer needed cannot be demounted and sold back to the company to recover some of the initial investment.

- Mobility: The house is not mobile and built up in an open area, allowing it to be as large and flexible as needed. The size of this kind of house does not allow for it to be built in common gardens of homes.

- Lifespan: The house has a long lifespan and the materials used are innovative and sustainable.

- Custom made: These buildings are exclusive as the architect designs it to the specific needs and wishes of the client.

- Costs: It is very expensive, even for people that can afford to buy a house. However, the cost can be split between the generations. The cost can be reduced if the

houses are not unique from each other and people can set it up by themselves. This could be done through a website where they can choose the components they want.

- Comfort of the elderly: Visual and thermal comfort levels can be most accurately checked through taking measurements in the physical house. However, the visual comfort looks to be good because of the open spaces of the loft.



Figure 5. Kangeroe woning in Rotterdam retrieved from: <https://lofthome.nl/lofthome/modellen/>



Figure 6a. Kangeroe woning in Rotterdam interior retrieved from: <https://lofthome.nl/voorbeelden/referenties/>



Figure 6b. Kangeroe woning in Rotterdam interior retrieved from: <https://lofthome.nl/voorbeelden/referenties/>



Figure 6c. Kangeroe woning in Rotterdam interior retrieved from: <https://lofthome.nl/voorbeelden/referenties/>

2.4 SKILPOD SMALL ENERGY HOUSE MODULE: Home for the elderly in the garden

The Limburgs company Skilpod developed the Small Energy House Module which provide a solution of taking care for the elderly adjacent to your own home. They have created modular 3D prefabricated mini homes which can work as an extension to an existing home. These homes are 48 square meters each, and constructed from cross laminated timber. The houses have their own climate systems that make it zero energy. these include solar panels, heat pumps, ventilation systems with heat recovery and automatic sun protection. The cost of those houses start at €59.900,-.

- Flexibility: The interior of the house is flexible and easy to customize. Different groups of people can also live in it. Apart from the elderly, younger people who want to live with their parents but in their own space can also inhabit these homes. However, if the space becomes empty, there is no opportunity to sell parts of the house to make it smaller and transform its function into something different, like storage or a sauna. The house can only be sold back in its entirety. This

could be solved if the house was made out of components which can be sold back independently.

- Mobile: The house can be placed in almost any area and is transportable with a truck.

- Lifespan: This house has a long lifespan, as it is moveable and can be resold to other people who need to take care of their elderly. However new customers will not have the possibility to change it to their own style.

- Custom made: The houses are not exclusive and made out of 3D prefab elements in a company in Belgium.

- Costs: The costs of this house is not very high. However there is no possibility to rent or lease the house for people that cannot afford to buy it.

- Comfort of elderly: The comfort of the elderly is not looked at in detail in the design of these houses. However, the pictures show that the house has a lot of glazed openings, which are good for visual comfort, but not ideal for thermal comfort.



Figure 7. Energy house module retrieved from: <http://www.architectura.be/nl/dossiers/inspirerende-tuinhuizen-en-poolhouses/12570/skilpod-small-energy-house-module-sociale-woning-of-grootouders-in-de-achtertuin>

2.5 Ethnic groups in the Netherlands

The Centraal Bureau voor de Statistiek (CBS), is an agency which in 2005, measured approximately more than 200 different nationalities in the Netherlands. It would not be feasible to search for the thermal and visual comfort of all the different groups. Therefore, we look at following graph produced by the CBS, showing the most common nationalities that live in the Netherlands.

Figure 8 shows three different groups of nationalities in the Netherlands. The first group on the left shows the nationalities that have increased the most in numbers. This group comprises of Turkish, Moroccans, Surinamese, Antillian en Aruban nationalities. The second group shows nationalities who are from war torn areas: Afghans, Iraqis, Iranians and Somalis. The third group are immigrants from Eastern Europe: The Polish, Romanian and Bulgarian. It is clear from the graphs that most foreigners in the Netherlands are from the first group.

2.6 Lease

Many companies outside of the building industry offer the opportunity to lease items like a car or a phone. Lease subscriptions give customers the possibilities to pay the costs of the item monthly or in terms, when they cannot pay it at once. In this system, the item always belongs to the company while monthly or term payments are being paid. However, upon negotiation with the company, there is the opportunity to purchase the item with a top up payment of its remaining value. In renting, however, there is no opportunity for transfer of ownership and this is strictly regulated by law, in section 7a of the Burgerlijke Handboek.

2.6.1 Leasing in the car industry

The car industry has used the concept of leasing for years, with different options such as [1] financial leasing, [2] operational leasing and [3] full operational leasing.

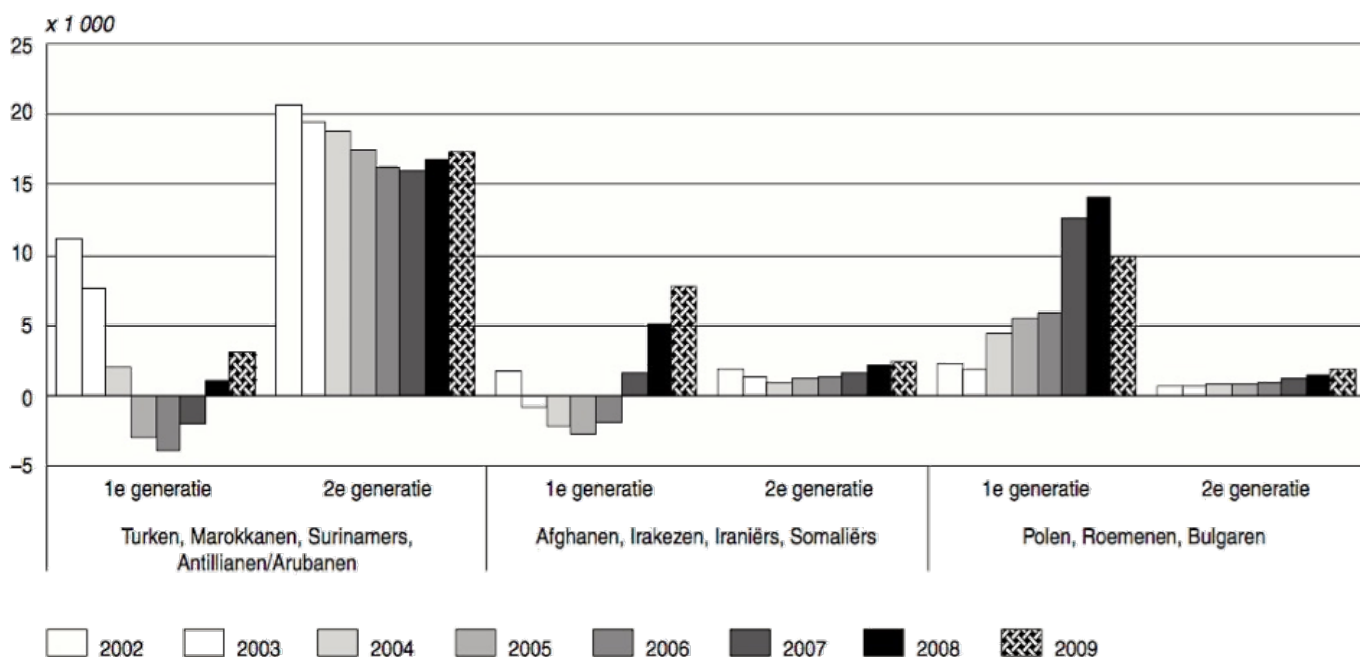


Figure 8. The most common Nationalisten in the Netherlands measured in 2010 (Nicolaas et al., 2010)

Financial leasing:

The car is in the name of the lease who is paying monthly. The lease company charges the cost of the car and receives monthly payment with interest. Risks of this kind of lease is that the lease is responsible for maintenance, insurance and taxation. The leases also bears economic risk in the event that the car is rendered useless.

Operational leasing:

In this type of lease, the car is in the name of the leasing company. Costs are charged to the profit and loss account on a monthly basis. This form of leasing can be differentiated by closed and open calculation. For closed calculation, a monthly amount of costs is set up. There are no risks included. However, the kilometers travelled in the car will be compared to what is stipulated in the lease contract and recalculations will be made. In the open operational lease contract, the lease has the opportunity to look into the calculations made by the company and as a result, shares in the risk with the company.

Full operational leasing:

The company bears all the costs for the car, with the exception of fuel, insurance premium and car taxes.

2.6.2 Leasing in the façade industry

Learning from other industries, the building industry is looking to give home owners the opportunity to lease building components, such as the facade. This is a strategy that can be used to implement innovative forms of multifunctional facades that have the potential to provide higher levels of indoor comfort. These new facades can also help to generate the energy required to control and monitor the indoor comfort conditions (Azcarateaguerre and Tillman, 2017).

2.7 Permittance to add object in the garden

The Netherlands has a lot of rules and this has to be clear for people who want to live with their parents. Possibilities should be explored in advance, so that the family is not surprised

too late along the process. To realize an object in the garden there are three possibilities that need to be accounted for:

[1] buildings which are built within 2,5m of the main building.

[2] buildings that are located out of the 2,5m zone.

[3] small buildings in the front garden that are not more than 2m² and not more than 1m.

For the multi generation house, we do not need to consider option 3 as front gardens are not typically large enough in the Netherlands to accommodate a house. The other two options are described in scenarios where no permission is required:

1.Option 1: buildings that are built within 2,5m of the main building:

Maximum height of 4 meters,

No more than 0.3 meters higher than the first floor of the main house.

Not higher than the main house.

2.Option 2: buildings that are located out of the 2,5m zone:

Maximum height of 3 meters (measured from the lawn or pavement).

Total area may not exceed 30m² (This includes the storage outhouse).

The strip within 1 meter of a neighbor's courtyard can have a maximum area of 10m².

The object built cannot be used as a bedroom or kitchen. However it can be used as a garage, storage room, utility room, studio or hobby room.

Furthermore, there are other points to consider: [1] the distance between the building and public area is at least 1m [2] the properties of the project may not be provided with a roof terrace, balcony or other type of outdoor space, [3] the area of the object cannot be more than the half of the total area available, and [4] the object may not be built as an extension to a caravan. If one of these requirements is overwritten, a premittance must be requested from the Ministeriele regeling omgevingsrecht (Mor).

2.8 Conclusion general houses

In the conclusion, the sub-questions that were introduced in the beginning of the chapter will be answered:

“What types of houses already exist for multi-generational families in the Netherlands that want to live together?”

In the Netherlands, living together as a multi general family was common in the past. However, this has changed throughout the years and is no longer the case. An example of a house in the Netherlands that is designed for multi generational use, is the Kangaroo house. The house is designed such that two families can live together without compromising on their privacy, the main drawback of multi generational homes. However, the high cost of these houses makes them inaccessible to many. A way to make such houses accessible could be to introduce the option of leasing the house.

Leasing is common in the car industry. It gives customers the option to pay the cost monthly or in terms. For the design of the house, it means that the designer has to look for solutions that will allow the house to be leased easily. An example could be that the façade will be made of components that can be leased separately. Hence, the customer can decide on a composition or design where the price is optimal for him.

Another benefit of leasing is that components always belongs to the the company. Hence, the company can lease the products again when they have ben returned. This is also a sustainable way of building a house, as the individual components can be reused multiple times.

“Which ethnic groups live in the Netherlands?”

The Netherlands counts more then 200 ethnic groups. Each group can have its own opinion about thermal and visual comfort. Hence, it would not feasible to design a house that can fulfil the thermal and visual comfort requirements of every group.

The largest number of immigrants in the Netherlands consist of the following ethnic groups: Turkish, Moroccan, Surinamese, Antillean and Aruban. The second group consists of immigrants from war torn areas: Afghan, Iraqis, Iranians and Somalis. The third group consists of immigrants from Eastern Europe: Polish, Romanian, Bulgarian. For this report, the first group of immigrants will be focused on, as it is the largest group.

Chapter 3

Thermal comfort

This chapter will explain what “thermal comfort” is and which models have been used in earlier research to test the comfort of people, such as the Fanger and De Dear and Bager model. The main focus of this chapter will be on the elderly. To understand their levels of thermal comfort, it is necessary to know how the body works, and this will be explained in the sub-topic of the thermal regulation of the human body. Subsequently, the adaptive behaviors of the elderly will be looked at and the requirements for the thermal comfort for the elderly will be set up. At the end of the chapter, there will be a conclusion that will answer the following questions: “What is thermal comfort?”, “To what extent can thermal comfort be regulated for the elderly?” and “What are the preferred requirements for the thermal comfort of the elderly?”

3.1 Thermal comfort

Thermal comfort is “that condition of mind which express[es] satisfaction with the thermal environment” (Frontczak & Wargocki, 2011). In a thermally comfortable building, the occupants wishes to feel neither warmer nor cooler. Thermal comfort consists of

- [1] mean radiant temperature
- [2] relative air velocity
- [3] humidity
- [4] activity level and
- [5] clothing thermal resistance.

The exact definition of thermal comfort is different for each person. Hence, in practice, it is

not always feasible to provide an optimal thermal comfort for occupants (Olesen, 1982).

However, psychological comfort is also important for humans. Individuals refer to their own different, specific frames of reference in order to evaluate their level of psychological comfort.

There are four components that correspond to deep psychological needs of comfort, namely,

- [1] personalization, where the inhabitants recognize themselves in their own space by the choice of decor and furniture
- [2] freedom of choice and the

possibility to have your own quite place

- [3] space, having the necessary space related to the function of the room and

- [4] warmth, well- being and the pleasure of light (Pineau, 1982).

Looking at the context of the Netherlands, there are people of various cultures, making it even more challenging to achieve suitable levels of comfort for all. The Netherlands count 200 different nationalities, measured the CBS in 2005, giving building engineers an important challenge in designing buildings that are comfortable for different types of

occupants.

3.2 The Fanger and Adaptive model from De Dear and Bager.

3.2.1 The Fanger model

Thermal comfort indicates to what extent men is cold or hot in a certain space (Diehl and Koenders, 2009). To determine the best temperature in a space, there are several models that have been set up. One of these models is the model of Fanger (1970). It is based on an energy balance of the human body in stationary situation. Fanger was one of the most referenced researcher in the field of comfort (Schellen, 2014). He developed Predicted Mean Vote (PMV) (Chalres, 2003) and the Predicted Percentage Dissatisfied index (PPD-index). “The PMV model is based on thermoregulation and heat balance theories” (Chalres, 2003) that are capable of predicting thermal sensations for a large group of occupants (Kolokotsa et al., 2001). It consist of four physical and two personal variables. The physical variables are:

- [1] air temperature
- [2] air velocity
- [3] mean radiant temperature and [4] relative humidity.

The two personal variables are:

- [1] clothing insulation
- [2] activity level.

Figure 9 shows the scale of values rating the indoor climate.

According to Fanger, variables such as age, difference in sex or country of origin and race have no measurable influence. Differences may be due to the fact that different people, for example, under the same conditions have different metabolism, which will be explained in the chapter on the thermo-regulate system of the human body. Fanger worked with fixed groups of mostly male students between the ages of 20 and 30. These students were also, to a certain extent, physical trained. However, the Fanger model has limitations as that it only applies within the comfort range, and assumes a stationary situation. Hence, you cannot appreciate the climate for short-term activities (30 minutes) in an area. Differences between occupants concerning

the thermal comfort will be reflected in the PPD-index (Kuijpers-van Gaalen et al., 2006) .Figure 10 shows the link between PPD and PMV. Assume that the neutral temperature is defined in a PMV index, the PPD model will indicate that 5% of the occupants are dissatisfied with the thermal comfort of the given area (Chalres, 2003).

3.2.2 De Dear and Brager model



Figure 9. Measurement scale of the PMV model (Kuijpers-van Gaalen et al., 2006)

The adaptive model from De Dear and Brager provide new insight into the building user appreciation for the indoor climate. In 1998, they analyzed 99 buildings and found out that there are large differences between PMV and actual thermal sensation in naturally ventilated buildings (Chalres, 2003). In reality, there is a psychological impact if a person is able to manually control windows and this is accounted for in this model. The person is mostly able to has control of the window by himself, which has to do with the psychology, the model of De Dear and Brager include this aspect.

The Dear and Brager model makes a distinction between two types of buildings: alpha and bèta buildings. Alpha buildings have open able windows that allow the users to influence the indoor thermal climate by them self. On the other hand, bèta buildings have closed facades and centrally

controlled treatment. The results in the stationary situation of the Fanger model is equal to the β buildings of De Dear and Brager. However, the thermally neutral situation of Alfa buildings differ from the Fanger model, as is shown in figure 4 (Kuijpers-van Gaalen et al., 2006).

3.3 Thermo-regulate system

3.3.1 Thermo- regulate system of the human body

It is necessary to know how the body regulates the thermo-system of the human being. The internal heat must be equal to the external heat loss (Nicol

et al., 2012). This can be done by a body that is influenced by the physical and personal variables with a nearly constant temperature of 37°C. However, there will be individual differences in temperatures of approximately 1 °C higher or lower Physical variables are:

- [1] air temperature
- [2] air velocity
- [3] mean radiant temperature
- [4] relative humidity.

The personal variables are:

- [1] clothing insulation and
- [2] activity level

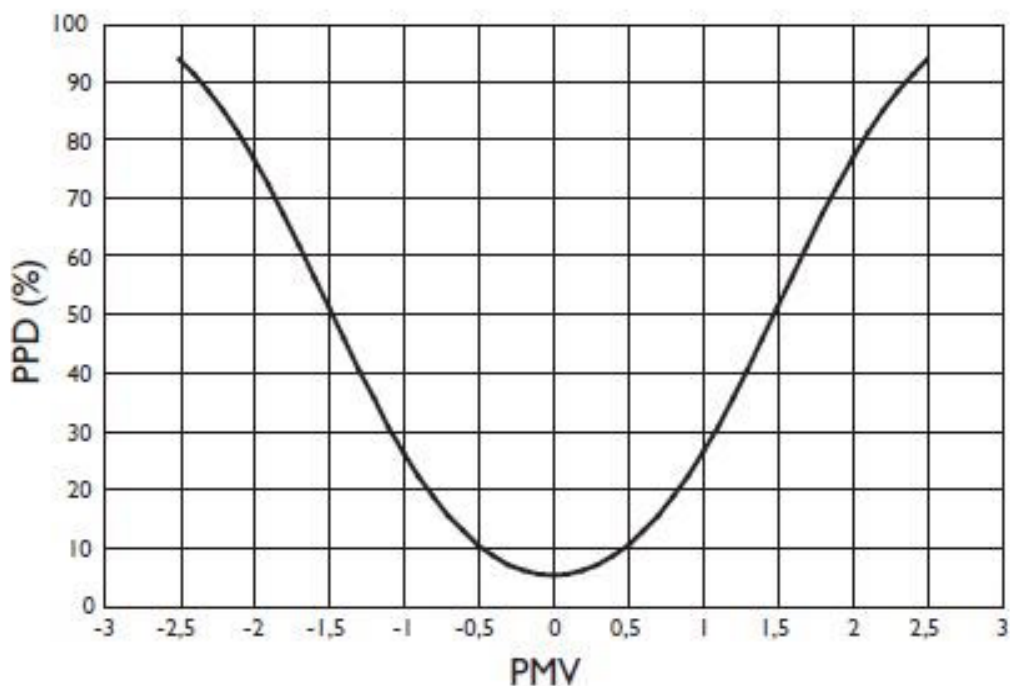


Figure 10. PPD/PMV model retrieved from <https://www.beswic.be/nl/themas/fysische-agentia/thermische-omgeving/indexen-van-thermisch-comfort-en-belasting/pmv-en-ppd-indexen-van-thermisch-comfort>

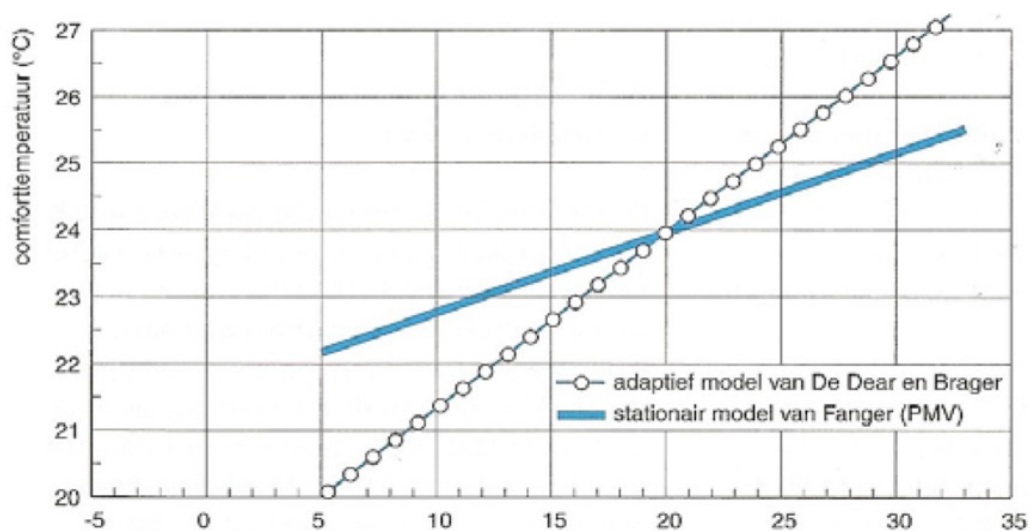


Figure 11. The Fanger model compared with the De Dear en Brager model (Kuijpers-van Gaalen et al., 2006)

The brain consists of many parts, and one of these parts is the hypothalamus, which controls the heat balance. It receives information from cold-warm receptors that are influenced by temperature changes (Olesen, 2012). With this information, the hypothalamus sends signals. A heat reaction causes sweating or a cold reaction to shivering (Nicol et al., 2012). The heat loss depends on the thermal insulation of the skin (fat layer) with a range between 0.1 – 1.0 clo, which stands for the heat insulation of clothing. People with higher fat content are more resistant to cooler environments, in comparison to those with lower fat content (Karyono, 1998).

3.3.2 Metabolism

The balance between the heat loss and heat production is noted as, $S = M \pm W \pm R \pm K - E - RES$ with [S] heat storage, [M] metabolism, [W] external work, [R] heat exchange by radiation, [C] heat exchange by convection, [K] heat exchange by conduction, [E] heat loss by evaporation and [RES] heat exchange by respiration. However, we are active daily and change clothes, so the heat balance changes as well and will be $M \pm W - E - RES = \pm Kcl = \pm R \pm C$ where [Kcl] = the heat conduction through clothing. The unit that mostly is used for metabolism is “met” where 1 met = 58,

15 W/m² with a surface area for a normal person of approximately 1,8 m². The table below shows a list with activities and the amount of energy as they consume in the average person (Olesen, 2012). It is clear to see that the metabolism increases with the amount of activity.

3.3.3 Metabolic rate of the elderly

Looking at the elderly, many studies show that the metabolic rate at complete rest decreases with ageing. Phoelman et al (1996) revealed that the metabolic rate of the elderly is lower compared to the metabolic rate of younger adults because of the decrease in muscle mass (Schellen et al., 2010) and increase in the fat mass to become approximately 45% of the body weight (Jansen et al., 2007). Reduction in muscle mass reduces the resting- and basal- metabolic rate (Schellen et al., 2010). The basal metabolic rate is, on average, 4.7 W/m² lower than that for someone in their early twenties (Hwang & Chen, 2010).

3.3.4 Clothing level

The clothing resistance in the elderly also differs in comparison to that of younger people. This is because the elderly are less active and spend more time sitting or lying down. The thermal resistance of a seat is between 0.1-0.4clo and for a bed, 3.0clo (Descamps and Verheyen, 2007). Table 2 shows different clothing combinations and their resulting resistance. The evaporation from the skin is transported through the clothing.

3.3.5 Thermal adaptive behaviors of elderly

Hwang and Chen (2010) researched the adaptive comfort of the elderly through surveying and observation. Their research focused on Taiwanese elderly above the age of 60 years old and they investigated the thermal sensations these elderly people felt in their own homes. The results shows that during the summer, 8% used an adaptive strategy, such as mechanical cooling. 34% used an electric fan and 90% used the opening of windows. In the winter, they observed 30% using window closing and mechanical heating was not used at all. The results have to do with the time of observation and this is influenced by the outdoor climate which is not stable (Hwang & Chen, 2010). Figure 13a and figure 13b shows the types of the thermal

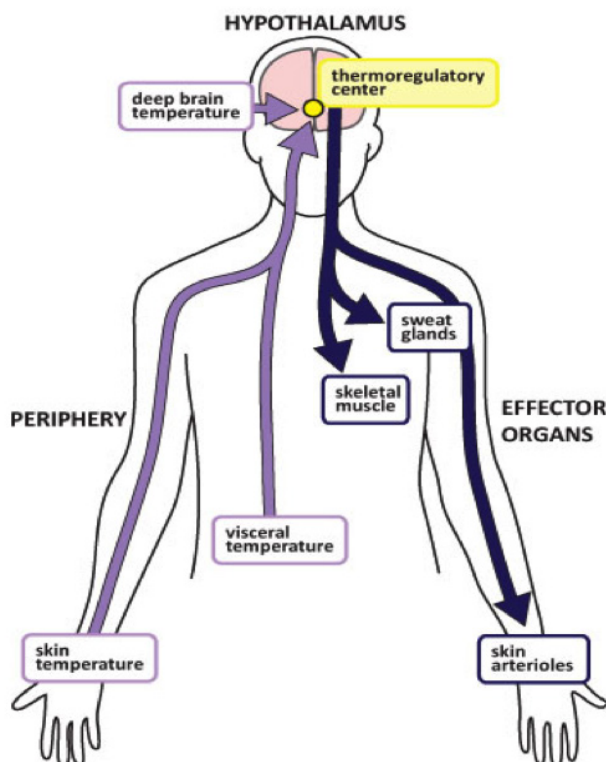


Figure 12. Working of the Hypothalamus. Retrieved from: <http://www.delbelloosteopathie.ca/en/thermoregulation-and-exercise-a-review/>

ACTIVITY	met	W/m ²
Lying down	0.8	47
Seated, quietly	1.0	58
Sedentary activity (office, home, laboratory, school)	1.2	70
Standing, relaxed	1.2	70
Light activity, standing (shopping, laboratory, light industry)	1.6	93
Medium activity, standing (shop assistant, domestic work, machine work)	2.0	117
High activity (heavy machine work, garage work)	3.0	175

Table 1. Activity rate (Olesen, 2012)

CLOTHING COMBINATION	clo	m ² K/W
Naked	0	0
Shorts	0.1	0.016
Typical tropical clothing outfit (briefs (underpants), shorts, open-neck shirt with short sleeves, light socks, and sandals)	0.3	0.047
Light summer clothing (Underwear, cotton working shirt with long sleeves, working trousers, woolen socks, and shoes)	0.5	0.078
Typical indoor winter clothing combination (Underwear, shirt with long sleeves, trousers, sweater with long sleeves, heavy socks and shoes)	1.0	0.155

Table 2. Different clothing combinations and their resulting resistance (Olesen, 2012)

adaptation adopted by the elderly during summer and winter.

When compared to the actions of young adults, both groups show that window-opening is the most popular strategy.

3.4 Requirements of the thermal comfort for elderly

The requirements for comfort of the elderly are different compared to those of other age groups (Pannemans & Westerterp, 1995). This is because the elderly are physiologically and psychologically unique and spend more time in the indoor environment. However, the elderly have a lower capacity to adapt a change in temperature in the

room (Hwang & Chen, 2010). Schellen's paper (Schellen et al., 2012) confirmed this by referring to several studies where the thermal neutral

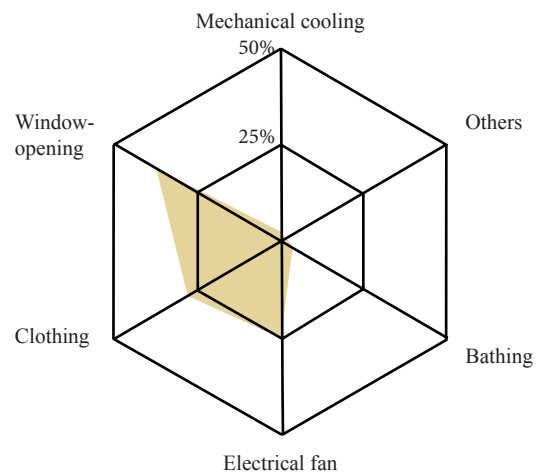


Figure 13a. Thermal adaptation adopted by the elderly during summer (Hwang & Chen, 2010).

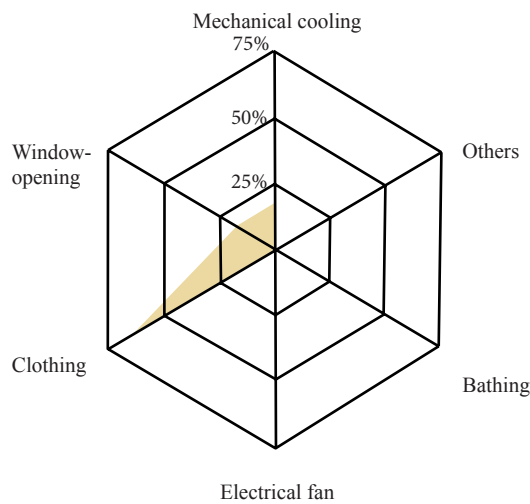


Figure 13b. Thermal adaptation adopted by the elderly during winter (Hwang & Chen, 2010).

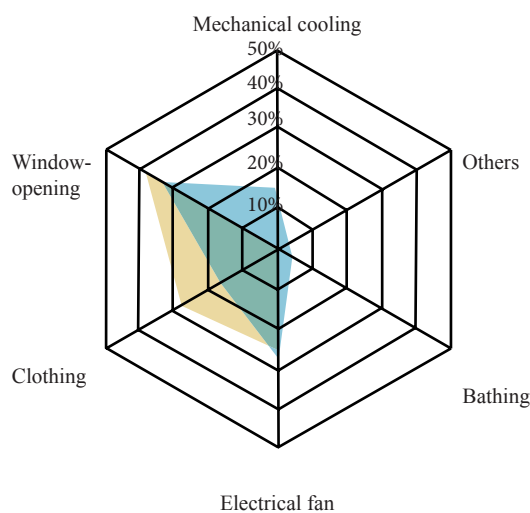


Figure 13c. Thermal adaptation adopted by the elderly compared with non-elders (Hwang & Chen, 2010).

temperature and optimum thermal condition of the elderly differs from that of young adults. Olesen's paper also (2005) summarized results of comfort studies on different age groups in Denmark and in the United States of America. The results of the different studies from Olesen's paper are combined in table 3 below. The mean age for those studies was 21 to 84 years and the results were identical to each other. The results of the studies are noticed in table 3.

According to the table, the elderly prefer the same thermal environment as younger adults. However, the elderly, in practice, mostly have a higher ambient temperature level at home. As mentioned earlier, this has to do with the lower activity level of the elderly (Olesen, 2010). The elderly experience a thermal sensation that is 0.5 lower on the 7points

scale than younger people (Schellen et al., 2012).

3.5 Conclusion thermal comfort

In the conclusion, the sub-questions that were introduced in the beginning of the chapter will be answered:

"What is thermal comfort?"

Thermal comfort consists of five categories:

- [1] mean radiation temperature
- [2] relative air velocity
- [3] humidity
- [4] activity level
- [5] clothing thermal resistance.

In addition to these five categories, psychology is another factor that can influence the thermal comfort of a person. To determine the best temperature in a space, the Fanger model and the Dear and Bager model can be used. To know the body reacts to thermal comfort, it is necessary to know how the body regulates the thermo-system. The body has a constant temperature of 37 °C, with some individuals having a difference of approximately 1 °C. In the brain, the hypothalamus receives information from cold- and warm receptors that are influenced by temperature changes. To be thermally comfortable, the internal heat gain must be equal to the external heat loss. The heat loss depends on the thermal insulation of the skin (fat layer) and the metabolism. For each activity, there is a metabolism value. The metabolism increases with the amount of activity. For the elderly which are more inactive with less muscle mass, the metabolism is lower when compared with the metabolic rate of younger adults.

"To what extent can thermal comfort be regulated for the elderly?"

Hwang and Chen's research showed that most of the elderly prefer to open the window instead of using mechanical cooling. In winter, they wear more layers of clothing. Hence, the elderly prefer to regulate their thermal comfort manually, instead of by complex mechanical systems. This is a point that should be taken into consideration when designing.

Another option for increasing the thermal comfort of the elderly, is to encourage them to go outside

more and to engage in higher levels of physical movement.

“What are the preferred requirements for the thermal comfort of the elderly?”

Olesen’s paper summarized the results of several comfort studies and according to these studies, the ideal temperature for the elderly is between 25,4 and 25,7 degrees. In comparison, the ideal temperature of a younger person is 25,6. However, the elderly have a higher ambient temperature and this might have to do with rates, muscle mass and activity level.

Study	Mean age (yr)	Preferred ambient temp. (°C)	Mean skin temp. at comfort (°C)	Evaporative weight loss during comfort (g/m²/hr)	Number of subjects
Nevins et al. [23]	21	25.6			720
Fanger [2]	23	25.6		19.2	128
Fanger [2]	68	25.7		15.3	128
Rohles and Johson [30]	74	24.5			228
Fanger & Langkilde [5]	23	25.0	33.5	18.0	64
Langkilde [15]	84	25.4	33.2	12.4	16
Comfort equation, Fanger [2]		25.6			

**subjects were tested under the following standardized conditions: sedentary activity, light standard clothing 0-6 clo, rel. velocity < 0.1 m/s, rel. humidity 50%, mean radiant temperature = air temperature. (Olsen, 2005)*

Table 3. Results of comfort studie on different age groups in Denemark and United States.

Chapter 4

Visual comfort

This chapter will explain what “visual comfort” is. To explain this, the workings of the eye will be looked at and how it works in a younger person, as compared to an elderly person. Common diseases of the eye will also be looked at. The aim is to understand how the building designer can make it easier for the elderly in an early stage of design. At the end of the chapter, there will be a conclusion that will answer the following questions: “What is visual comfort?”, “To what extent can visual comfort be regulated for the elderly?” and “What are the preferred requirements for the visual comfort of the elderly?”



4.1 Visual Comfort

Visual comfort is a term that is related to lighting performance and human psychology. The term is not specific defined. “Some researches qualified visual comfort as illumination level; some treat it as luminance balance; and some name it as the satisfaction with visual environment” (Xue et al., 2016).

4.1.1 Light

Light is an important basic requirement for the human body and it has an effect on physical, physiological and psychological behaviors (Bellia, 2011). It is defined as “radiation that is visible for the human eye”, with a wavelength between 380 and 780 nanometer. The light moves in a rectilinear manner in an area until it touches a material. It can be moved in three different ways, like:

- [1] reflection
- [2] absorption and
- [3] transmission.

Mostly light moves in a combination of these possibilities. (Beek et al., 2006)

4.1.2 Daylight

Daylight is the natural source of light that comes from the sun. The strength of light changes during the day. Factors that influence the construction of the light on its way to the earth's surface are as follows:

- [1] the length
- [2] population density
- [3] pollution of the atmosphere.

The daylight has a wide flat spectrum, which is seen as the best light for health (Beek et al., 2006). Aarts and Westerlaken conducted research on daylight in the interior of buildings in the Netherlands and found that on a clear day, there is a maximal horizontal illuminance of 800 lux next to the window (Aarts et al., 2005). However, light also has radiation that causes problems for the thermal comfort of the indoor environment. The solar radiation provides heat which will be removed by air-

conditioning, which is bad for sustainability (Xue et al., 2016).

4.1.3 Artificial light

Thomas Edison invented the light bulb in 1879. The artificial light sources are electrically powered lamps that work either on the phenomena of incandescence or luminescence. It allows us to work after sunset. A lot of research is undertaken to improve lighting in all aspects of life. Nowadays, technology has revolutionized artificial lighting sources, some have the ability to emit quality white light and save energy. Artificial light that mimics the spectrum is better compared to light that is made up of bad single wavelengths. However, material research is necessary to develop new light resources that have sustainable properties, for the future.

Artificial light can be classified in three categories, namely, [1] filament heating (incandescent and halogen lamps), [2] gas discharge lamps (high-intensity discharge (HID) lamps, and fluorescent lamps) and [3] recombination of electrons and holes (LEDs and OLEDs).

However, the type of light has to do with the circumstances of the area and depends on several factors. Those factors are:

- [1] Efficiency, this is the amount of light expressed in lumen with the supplied electrical energy in Watt. Small light bulbs have an efficiency of 10lm/W, while the fluorescent lamp has a maximum efficiency of 100lm/W and the low pressure sodium lamp has a maximum efficiency of 200lm/W.
- [2] Color properties, where the color can be used.
- [3] Lifespan, this can vary between 1000h (small light bulb) and 50.000h (LED).
- [4] ballast, the gas discharge lamps and LED cannot directly be connected to the power grid.
- [5] Switching behavior, artificial light with a high pressure needs more time to shine the maximum light they can.
- [6] Dimension, how much area gain light from

the source.

[7] Dimming, which has a disadvantage for the efficiency, color properties and lifespan of the artificial light. (Beek et al., 2006)

4.2 Biological clock

The amount of light that comes in to the eye is important for the biological clock (Beek, 2006). Short wavelength radiations stimulate a wide range of physiological systems such as the resetting of the time of the circadian pacemaker, suppressing nocturnal melatonin production and improve alertness (Sinoo et al., 2011). Study from 1958 by J. Woodland Hasting and B. M. Sweeney looked at the effects of different wavelengths. They concluded that blue light has a big effect on resetting the daily rhythm. Green light has less impact, while red shows relative small peaks in the wavelength. This study corresponded with the research of G. Brainard. Rods react extremely to wavelengths of 507nm, and the cones react to the green light with a wavelength of 555nm. According to this research, the peak is most sensitive for the production of melatonin between 459 nm and 485 nm (Brainard et al., 1997).

Melatonin is a hormone that influences the sleep- wake rhythm (Brainard et al., 1997) discovered in 1958 by A.B. Lerner when he was researching epiphysis. The production of this hormone is during the night, and has the function of the time clock for sleep. Administered melatonin causes induced light sleep and there is a decrease in the body temperature and alertness (Beek, 2006). However, it is also been noted that the hormones shut the metabolic activities down in some cells, which causes forms of cancer, such as breast cancer (Bellia et al., 2011). The elderly are indoors more often, giving the melatonin a negative effect compared to younger people (Aarts & Westerlaken, 2005). The biological rhythm will be weakened, causing that elderly tend to stay awake, and this in turn can lead to reduced alertness and mood deterioration (Beek, 2006).

Cortisol is also an important hormone for the human being to be active at day time.

The production of this hormone is between 6:00h and 7:00 AM. It regulates the digestive processes and the blood sugar content of the body. (Beek, 2006)

4.3 The eye

4.3.1 Working of the eye

The working of the eye needs light to send images to the brain. Figure 15 shows the section of the eye. Light falls onto the retina which consist of cones, rods and the retinal ganglion cell (RCG) The cones are used to see during daylight hours, and are located in and around the fovea (TNO rapport). The fovea covers the central part of the eye that is able to see. Rods are used to see in night hours and they are located in the periphery and in the band of the retina. Furthermore, the retinal ganglion cell provide various non-visual areas in the brain of light information to the biological clock that drives the body processes. Subsequently, the nerve impulse leave the eye from the optic nerve to the brain through different stages to the brain (Aries et al., 2010).

Before the light reaches the retina it shines through different components of the eye namely [1] corneal cornea, [2] eye chamber, [3] lens and [4] the vitreous body. The first two components break the light and are controlled by the circular muscle. In the middle of the circular muscle is the iris, which increase or reduces the pupil that regulates the light amount taken in (Aries et al., 2010). Thereby the image will be displayed well. Figure 9 showed the luminance differences our eye can perceive. When the luminance difference exceed the limits there will be glare or there will be black shadows visible.

4.3.2 Visual field

The visual field is divided in the ergorama and the panorama, as shown in figure 17. The ergorama is a cone with a top angle of 30°, centered about the main line of sight, and the panorama is a cone with a top angle of 60°.

To feel visually comfortable for a task, the

direct background needs a lower luminance than the subject where you will focus on. According to Meyer, Francioli, & Kerhoven (1996), maximum luminance ratios of 1:10 in the ergorama and 1:30 in the panorama should be respected. The real panorama is not perfectly circular, due to the presence of our nose. It cuts the lower part of our visual field. Furthermore, our visual field is not a perfect circle, because it is normally larger. This has to do with the fact that we have two eyes.

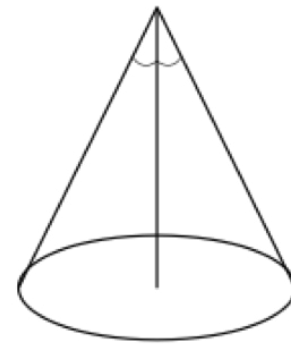


Figure 16. Panorama cone

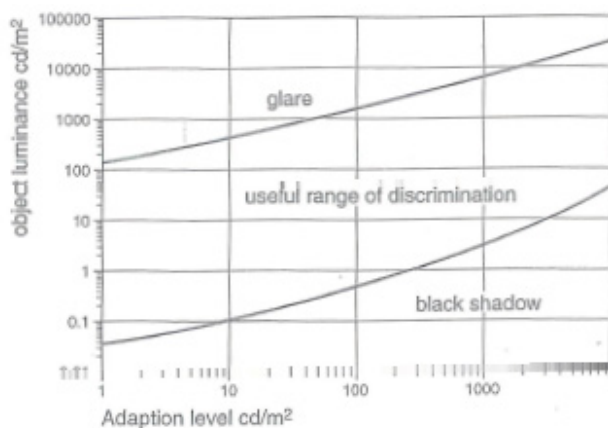


Figure 14. Luminance differences our eye can perceive

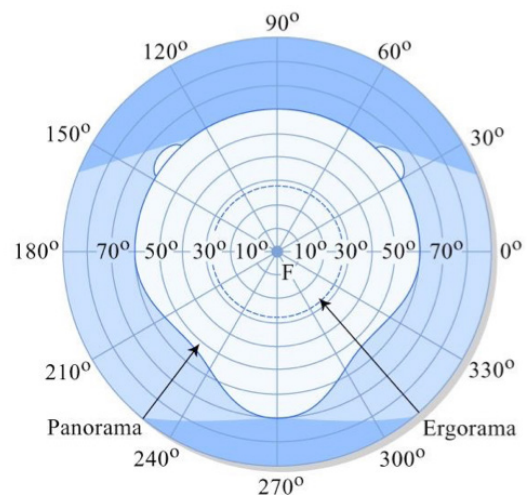


Figure 17 The ergorama and panorama

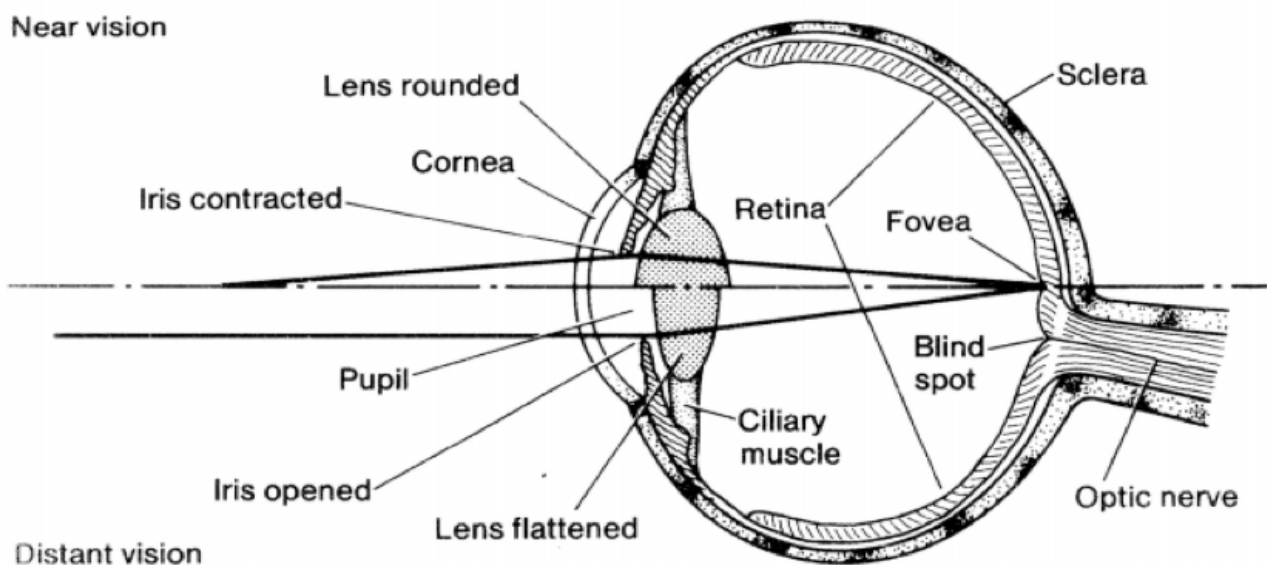


Figure 15. The eye .

4.4 The ageing eye

The quality of the eye decrease with ageing. The amount of light on the retina decreases compared to that of younger people, due to the changes in the lens, fovea and the pupil (Werner et al., 1990). In optical terms, the range of the object distance that can be brought to the retina decreases, as well the size of visual field, as shown in figure 18 (Boyce, 2003).

According to the Nederlandse Stichting voor Verlichtingskunde (NSVV), the quality of the eye decreases through factors such as;

[1] eye moisture, the regulation aggravate which reduces visual perception.

[2] Blurring, which means that the contrast sensitivity is reduced (Beek et al., 2006). Figure 19 shows the contrast sensitivity of four observers of different ages, where the open circles stands for near view distance and the filled circles represent far view distances (Boyce, 2003). The figures show that contrast sensitivity decreases as people age. For near view distances, the contrast sensitivity of a 33 year old is 100 times higher than that of a 94 year old. For far view distances, the contrast sensitivity of a 33 year old is 20 times higher than that of a 94 year old.

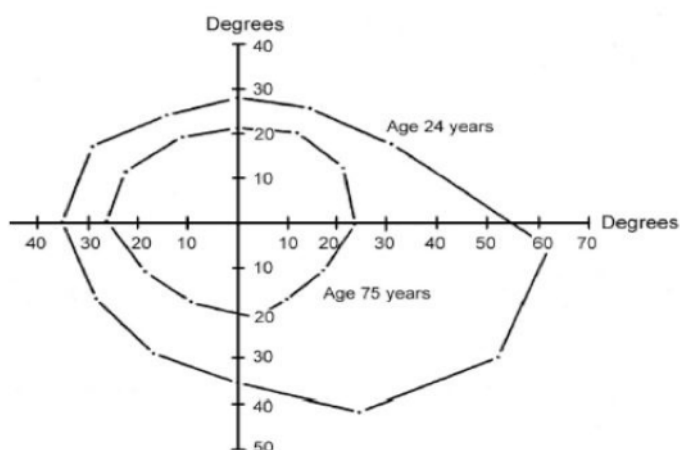


Figure 18 Visual field of elderly (75 years) compared with a younger people (24 years) (Boyce, 2003).

[3] Illuminance, elderly gain less light on the retina compared with younger people, because the maximal of the pupil diameter decrease with approximately 40%. (Werner et al., 1990)

[4] less blue light on the retina, objects tend to be observed darker than they actually are (B.12, which means that the elderly have poor color discrimination. (Boyce,2003) [5] reduced visual acuity, the elderly need much more effort to see objects sharply when the light situation changes (Beek et al., 2006). Figure 21 shows the change in visual acuity plotted against the age. (Boyce,2003)

4.4.1 Ageing eye diseases

According to figure 21 the eye changes the most after 75 year. An increase in age leads to a reduction in visual acuity. Many seniors have one or more of the following common eye diseases: cataract, macular degeneration, diabetic retinopathy and glaucoma (Boyce, 2003).

Cataract can recognized when the visual acuity and contrast sensitivity is reduced in the visual field. The distinction of color is difficult and there is a high sensitivity to glare. More light can help the person to overcome the increased absorption. However this is not the best solution and cataract can be solved by surgery that remove the eye lens and place there a fixed focus plastic lens (Boyce, 2003).

The macular is a circular yellow-pigmented area of the retina with a diameter between 2-3mm which is centered on the fovea. The presence of the macular damages the fovea, and daily activities which focus on details, such as reading or distinguishing faces, will become impossible. People can be helped in the early stages by providing more light when conducting their tasks. It also helps to increase the retinal image or to move closer to the object (Boyce, 2003).

Diabetic retinopathy, has to do with the chronic diabetes mellitus. The diabetes destroys part of the retina, as changes in the blood vessel (VUMc). The effects of these changes depend on where in the retina the changes occur. Blindness occurs approximately twenty-five percent more in the diabetic population, compared to the non-diabetic

population (Boyce, 2003).

Glaucoma reduces the outflow from the aqueous humour. The outflow keeps the eye bulb in the eye position. After a while glaucoma reduces contrast sensitivity, creates poor night vision and a slowed transient adaptation. However, the resolution of the detail can be seen till the last stage, which is blindness (Boyce, 2003).

Figure 22 illustrates how people see with one of those common eye diseases that are common to the developed world. However, cataract differs in the third world countries, because approximately between 30 to 60% of the blind population can develop trachoma and onchocerciasis. Looking at the Netherlands, ophthalmologist Ten Doesschate exposed in 1982 the results of one hospital and a foundation for blind care in the period between 1990 and 1993. The researched was performed in

Rotterdam in the village “Ommoord” by Erasmus Rotterdam Gezondheid en Ouderen (ERGO). The results of the study shows that a lot of native people are blind or have a bad field of vision compared to the foreigners who are have 3-6 times more likely to be diabetic (people from Turkish, Moroccan and Surinamese origin) and 2-4 times more likely to have glaucoma (people from African and Asian origin) (Limburg, 2005).

ERGO, de gepoolde data and WHO analysed the most common causes of eye diseases in the Netherlands. In addition to the four common eye diseases (figure 22) discussed above, the elderly in the Netherlands also have refraction abnormalities (refractieafwijkingen). The results of this research are shown in table 4. The consequences of uncorrected refraction abnormalities are not mentioned in these studies.

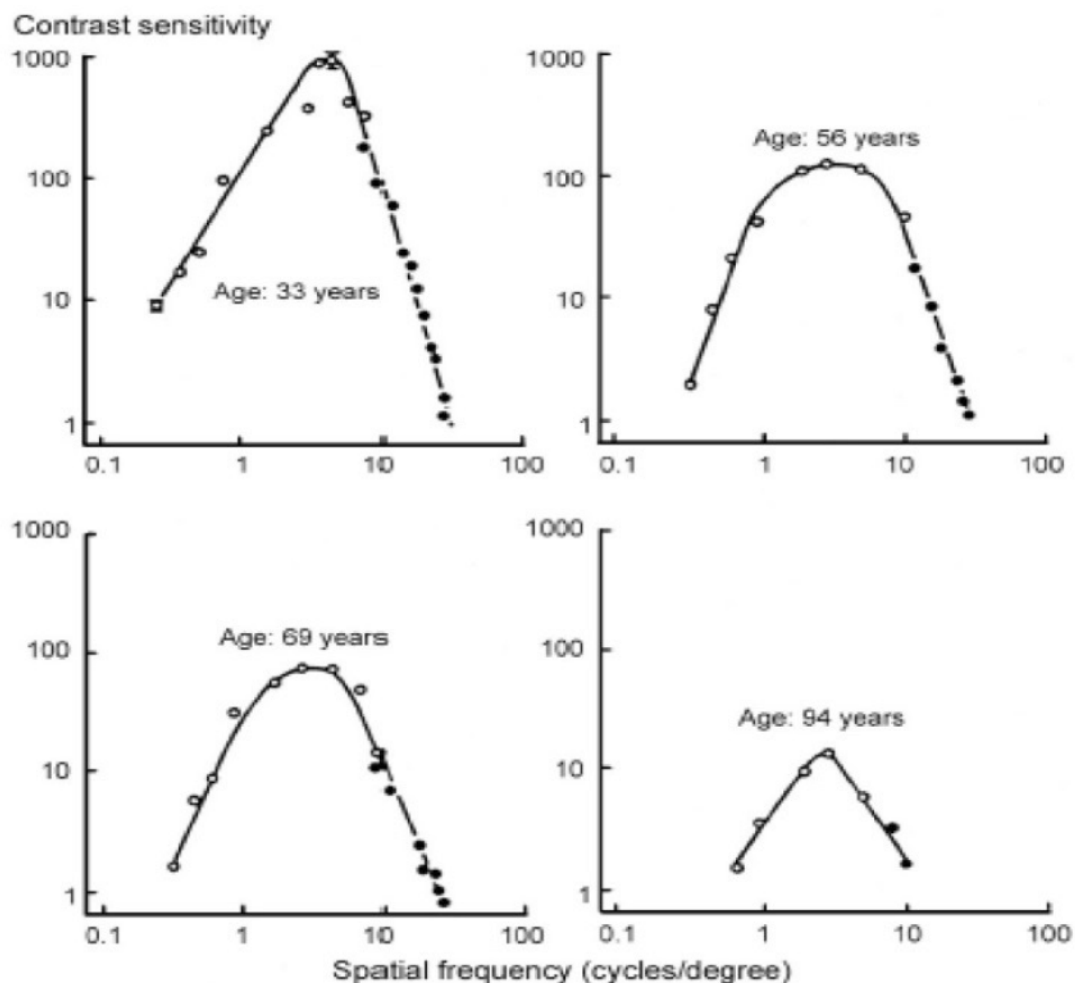


Figure 19. Contrast sensitivity of four observers of different ages (Boyce, 2003).

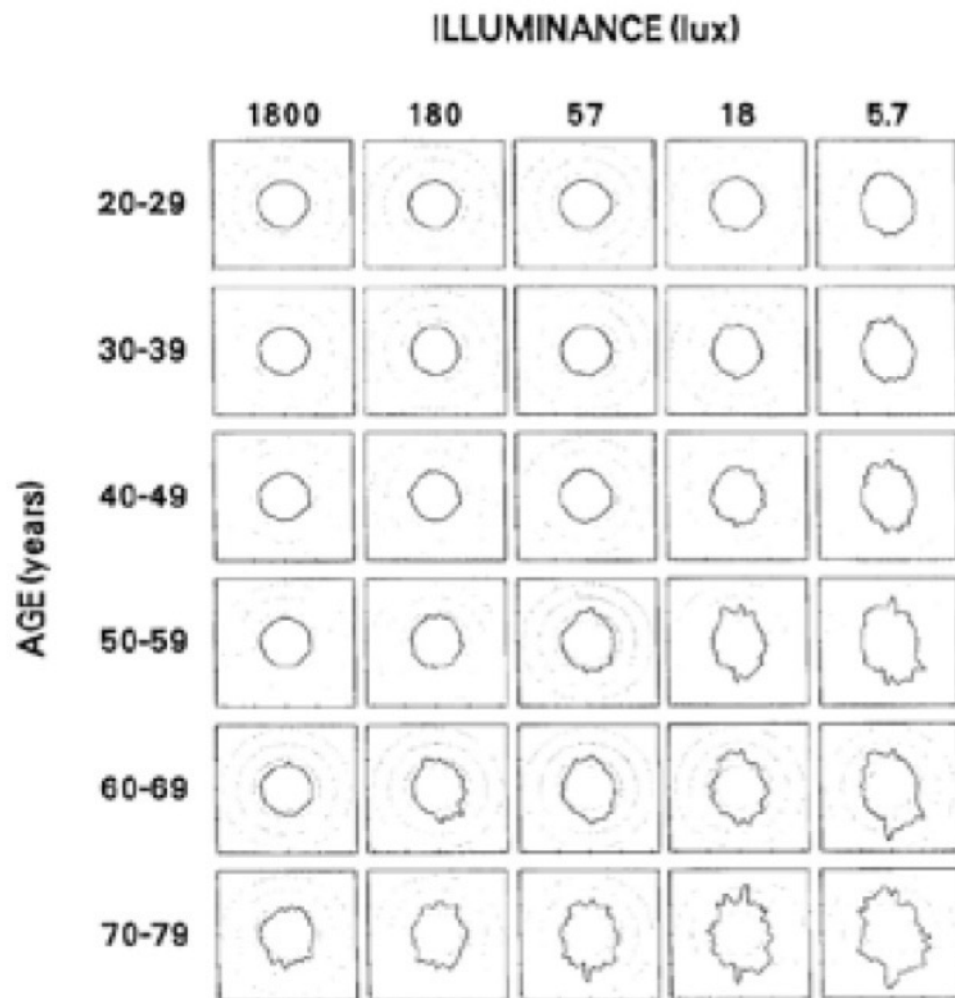


Figure 20. Illuminance of elderly compared with younger people .(Werner et al., 1990)

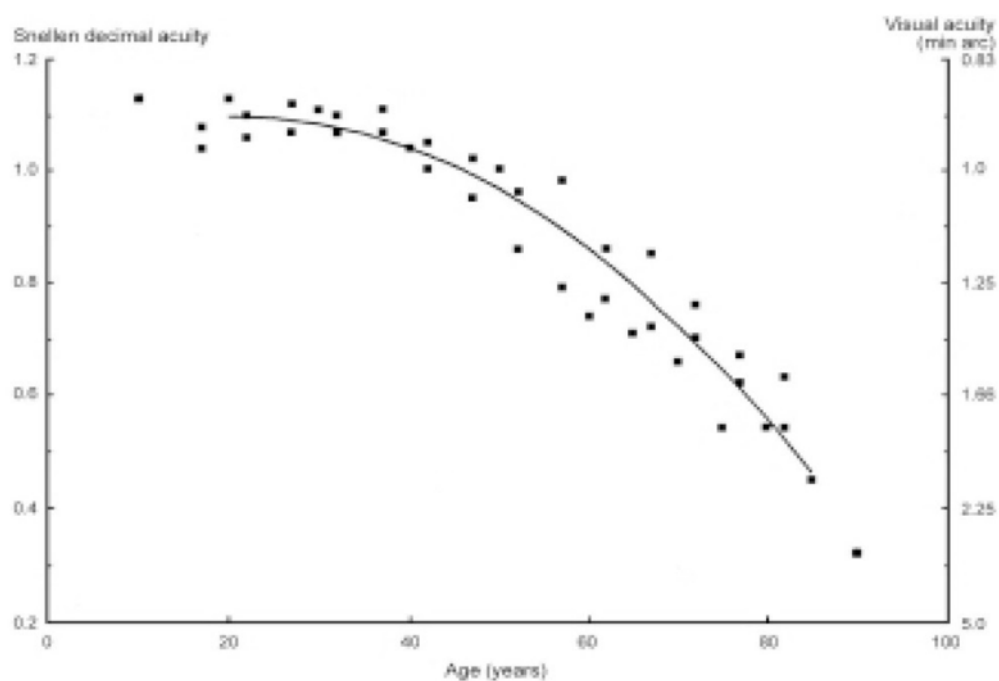


Figure 21. The change in visual acuity plotted against the age (Boyce, 2003).



Figure 22. Visualization of the Ageing eye diseases.

Oorzaak	ERGO		gepoolde data		WHO	
LMD	58%	11.020	54,4%	24.480	50%	16.650
Cataract	6%	1.140	8,7%	3.915	5%	1.665
Glaucoom	8%	1.520	6,4%	2.880	18%	5.995
Diabetische retinopathie	0%	0	5,4%	2.430	17%	5.660
Overige oorzaken	28%	5.320	25,1%	11.295	10%	3.330
Totaal	0,12%	19.000	0,28%	45.000	0,21%	33.300
Refractie afwijkingen (schatting)	27%	5.130	27%	12.150	27%	8.990
Prevalentie en totaal blind	0,15%	24.130	0,36%	57.150	0.27%	42.290

LMD = Leeftijdsgebonden Macula Degeneratie

Table 4. The most common causes of eye diseases

4.4.2 Statistics of the eye diseases

The age of a person has a significant influence on the visual quality of the eyes. Table 5 shows the international definitions of partial sight and blindness that are based on a classification of the vision developed by the World Health Organisation.

According to this system, the visual acuity are noted as number1/number2. The first number which is always 20 refer to the distance that a person needs to recognize a detail compared to the second number. This mean that a person with 20/20 has the best vision (Bron boyce,2003).

Furthermore, there are many studies that searched for partial sight and blindness in different populations. One of those study was made in an urban area in the United States with 5308 residents aged 40 years or older. The results are shown in table 6, which shows the blindness and partial sight of caucasians compared to african americans.

According to the, it shows that the African American people, on average, in all different age ranges, seem to be at higher risk for blindness and partial sight.

The Netherlands counts 200 different nationalities, as measured in 2005 (CBS). Table 7 shows the

percentage of people will a minimum of one limitation and the percentage of people who have limitations in view, within the different populations groups, namely:

- [1] the native
- [2] western-foreign 1e generation, which includes people from all European countries, except Turkey,
- [2] western-foreign 2e generation
- [3] nonwestern-foreign 1e generation, which includes people from Africa, Asian, Turkey and Latin-America
- [4] nonwestern-foreign 2e generation (CBS, 2015).

Furthermore, the table shows that in 2013, 18.4 % of the people between the ages of 65-75 had at least one limitation, as compared to 3.4% in 2016. However, in the category of those 75 years old and above, the percentage of people with at least one limitation did not decrease in the period between 2013 and 2016 (CBS, 2017).

4.5 Requirements

The lighting level for the elderly has to be three times higher than that for a younger person with healthy eyes (Aarts & Westerlaken, 2005). According to the NEN-EN 12641, which specifies the lightning requirements for people with normal vision in interior space, 500 lux is needed to perform normal visual tasks such as reading or writing. In table 8 are different activities showed with the lux value that is required for each task.

The European norm NEN-EN 12464 Licht en verlichting is a standard sheet that was introduced in 2003. It describes the conditions that the lighting systems for workplaces must meet in order to ensure that visual tasks can be carried out in comfort and safety. This standard sheet is concerned not with the general lighting of the room, but the lighting levels required for specific visual tasks. While 100 lux was previously deemed to be sufficient for a

Category	Grade	Criteria
Normal vision	0	20/25 or better
Near normal vision	0	20/30 to 20/60
Partial sight		
Moderate visual impairment	1	20/70 to 20/160
Severe visual impairment	2	20/200 to 20/400
Blindness		
Profound visual impairment	3	20/500 to 20/1000 or a visual field less than 10°
Near-total visual impairment	4	Worse than 20/1000 or a visual field less than 5°
Total visual impairment	5	No light perception

Table 5. The international definitions of partial sight and blindness (Boyce, 2003)

Age range (years)	Blindness (Whites)	Blindness (Blacks)	Partial Sight (Whites)	Partial Sight (Blacks)
40-49	0.6	0.6	0.2	0.6
50-59	0.5	0.7	0.7	1.3
60-69	0.2	1.6	1.1	3.4
70-79	0.6	2.9	5.2	8.1
80+	7.3	8.0	14.6	18.0

Table 6 the blindness and partial sight of Caucasians compared to African Americans (Boyce, 2003)

living room, these norms changed over time to become more concerned with the specific tasks being conducted, instead of the type of room the tasks are executed in.

4.6 Conclusions for visual comfort

In the conclusion, the sub-question that was introduced in the beginning of the chapter will be answered:

“What is visual comfort?”

Visual comfort is a term that is related to lighting performance and human psychology. Light, in general, is an important basic requirement for the human body. It has an effect on physical and physiological behaviors. Because of its wide spectrum, daylight is considered to be the best type of light for health. Daylight is the natural light that comes from the sun and its strength changes during the day. One of the hormone for which

	% persons with min. 1 limitation (period 2013)	% limitation in view (period 2013)	% limitation in view (period 2016)
65 – 75 years	18.4	8.4	3.4
75 years +	38.3	11.4	11.4
Native	12.3	5.6	-
Western- foreign 1e generation	17.7	8.4	-
Western- foreign 2e generation	13.4	6.6	-
Nonwestern- foreign 1e generation	18.9	9.9	-
Nonwestern- foreign 2e generation	7.0	3.8	-

Table 7. Limitation in view of people from different countries (CBS, 2015) (CBS, 2017).

Activities	Lux value
Writing, typing, reading	500
Meeting rooms	500
Storage	100
Halls	100
Stairs	150
Waiting rooms	200

Table 8. Requirements for Light according to NEN-EN 12641.

daylight is important, is the hormone melatonin. This hormone influences the sleep-wake rhythm. To have a positive effect on this hormone, people should spend more time outside, in daylight.

Furthermore, light is important for daily activities as the eye needs light to send images to the brain. The eye can perceive different levels of luminance. When the luminance difference exceeds the limits, there will be glare or black shadows will be visible. As for the elderly, they receive less light in the retina than younger people, because the maximal of their pupil diameter decreases by approximately 40%. Hence, to feel visually comfortable when carrying out a task, the direct background needs a lower luminance than the subject being focused on.

“To what extent can visual comfort be regulated for the elderly?”

Since the quality of the eye decreases with age, the visual comfort requirements of the elderly are different from those of younger people. As people age, the visual field decreases and the amount of light received by the retina decreases. Additionally, the contrast sensitivity for both near and far view distances decreases with age. The elderly also have poor color discrimination and they need more effort to see objects sharply when the light changes.

Furthermore, many elderly people suffer from common eye diseases. Various studies have looked at partial sight and blindness amongst the elderly. Some of these studies researched the differences between ethnic groups and one such study was conducted in an urban area in the United States. The study concluded that African Americans are at a much higher risk for blindness. Similarly, there might be differences like this within the various ethnic groups in the Netherlands.

Every year, the Central Bureau Statistiek looks at people from different populations, who have limitations. They concluded that the elderly ages 75 and above, have higher visual limitations in comparison with those who are younger. Differences were also found within the different ethnic groups. In 2013, they found that 2e generation nonwestern foreigners had the least visual limitations. On the other hand, 1e generation nonwestern foreigners had the highest visual limitations

Hence, the visual comfort for the elderly can be regulated by adding more artificial light inside the house, for daily activities. However, this artificial light will not have the wide spectrum that daylight has and will hence, not be as beneficial for the health of the human body.

“What are the preferred requirements for the visual comfort of the elderly?”

According to NEN-EN 12641, a person will need normal vision requires 500 lux to complete visual tasks such as writing or reading. This lighting level has to be three times higher for the elderly, as compared to younger people. For example, an elderly requires 150 lux to safely climb a flight of stairs. Unfortunately, not all buildings are designed to fulfil such requirements and there is a present need for buildings and their facades to enable these requirements of visual comfort to be fulfilled.



Practice

Chapter 5

Questionnaire and the results

This chapter will discuss how the questionnaire is set up, and which of the ethnic groups in the Netherlands it will target. From this, a questionnaire will be produced in Dutch and the results obtained will be discussed. The results are in two parts. The first part is about the thermal comfort where they will be looked to each group separately. The second part is about the visual comfort which also includes the different result of each group. At the end of the chapter, there will be a conclusion that will aim to answer the following question: “What are the different standards of the thermal and visual comfort in different societies?”

5.1 Number of deaths

In chapter 2.5, figure 8 showed which nationalities had increased the most in number, in the Netherlands. These nationalities are the Turkish, Moroccan, Surinamese and Antillean and Aruban nationalities. Hence, elderly participants from amongst these groups of nationalities will be invited to complete the questionnaire. To find out which age groups the questionnaires will target, the number of deaths by age for the common ethnic groups, will be looked at. Appendix A1 shows a list with these numbers. However, the table does not show the percentage for each group. Hence, this data is imported into excel in order to calculate the percentages.

The following graphs are made from the results seen in appendix A.1. These graphs look at men and women between the ages of 50 and 75+. They show the ages at which, the most number of people

from the different population groups, passed away. The graphs also differentiate between men and women.

Figure 23, shows clearly that native men live to a much older age, in comparison to men from the other population groups. The Turkish and Moroccan men pass away at earlier ages. The groups score relatively the same in every age category. Perhaps, this has to do with the immigrants in the 1960s, who took part in heavy manual work. Furthermore, figure 24 shows that the women have relatively similar scores.

Figure 25, shows the ages at which, the people from the above ethnic groups, pass away on average. It is clear to see that most Moroccans and Turkish people died younger, in comparison to the Native, Surinamese and the Antilles/Aruban populations. For the questionnaire, this is an important factor. From the results shown in the figures above, this research

will look at the elderly ages 60 and above. The following age groups will be looked at separately: 60-64, 65-69, 70-74 and 75+.

The different age groups will be an important factor in the design. For each age group, the requirements of visual and thermal comfort will differ. Hence, it is necessary for the first stages of the design, to know what factors to focus on.

The questionnaires will be completed anonymously and set up in three categories:

- [1] general information such as ethnic group, age and sex.
- [2] Visual comfort within sub-categories, such as ageing eye disease, glare, light levels and favorite places in their homes.
- [3] thermal comfort, such as clothing level, thermal adaptive behavior and favorite places in their homes.

Figure 23.
Percentage
of death by
age, Man.

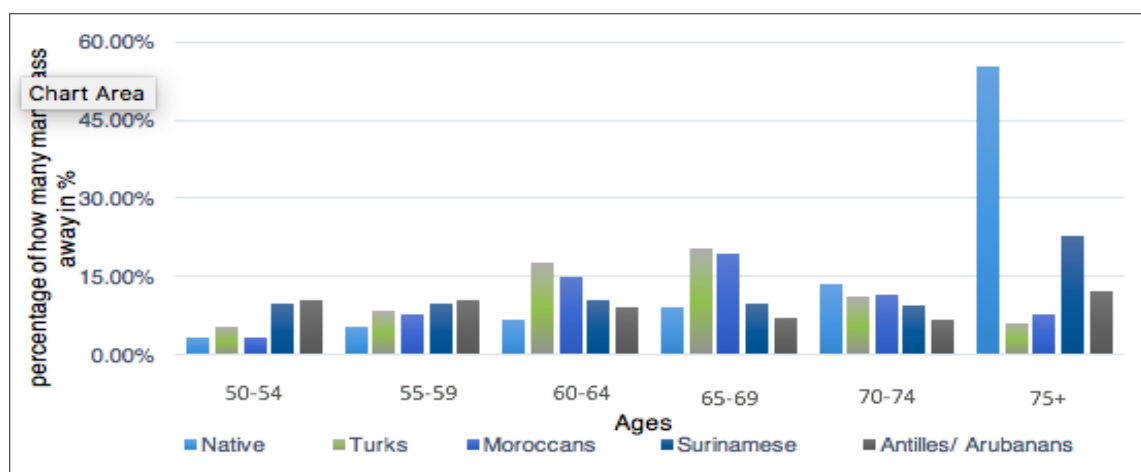


Figure 24
Percentage
of death by
age, woman.

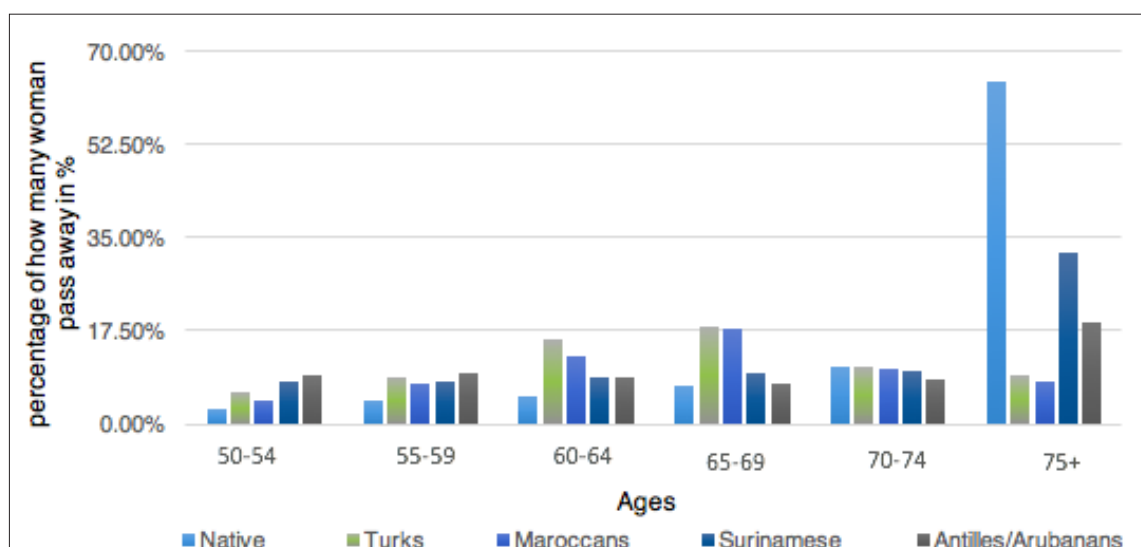
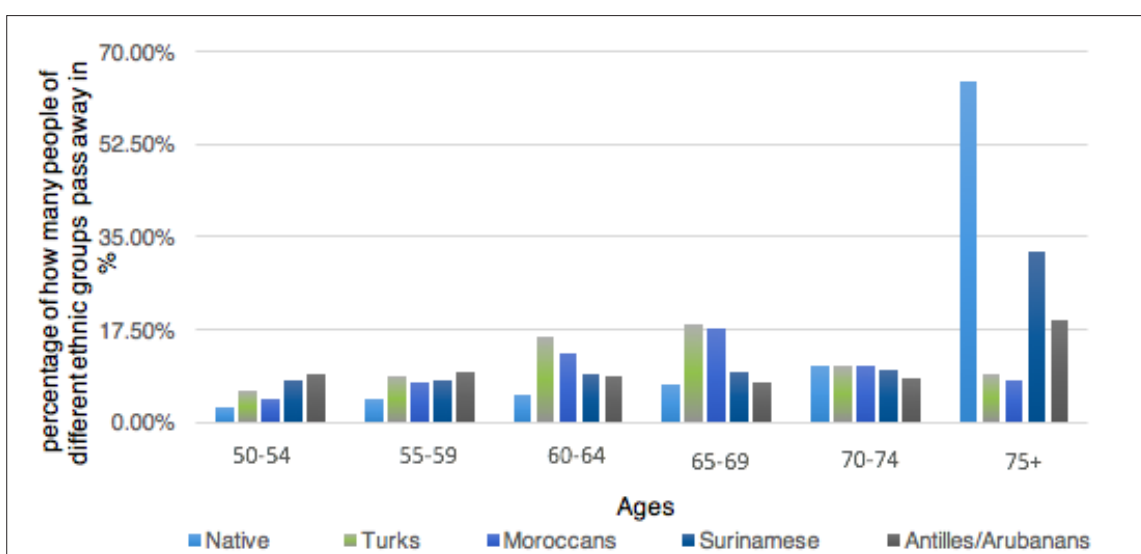


Figure 25
Number of
death by age
for different
ethnic groups
in the period
2002-2006.



5.2 Questionnaire

The elderly who will fill the questionnaire all live in the Netherlands. Most of the elderly of the above mentioned ethnic groups do not understand English. To make it easier for them, the questionnaire will be taken in Dutch. Appendix A.2 shows the questionnaire. In order to complete them, it is important to go to the houses of the elderly. The questions will be asked while I sit with the elderly subject. From the answers to the questionnaire and the story of how they live, conclusions can be drawn on the specific ways in which elderly people from the different nationalities live in the Netherlands.

The results of the questionnaires will be analyzed in three categories:

- [1] general information
- [2] visual comfort
- [3] thermal comfort.

For all of those categories there will be a conclusion which will be used later to compare the results of the measurements. The results of the questionnaire will be entered into Excel and plotted in graphs.

5.2.1 General information

For the completion of the questionnaires, it was difficult to find elderly people from different populations who were willing to participate. This is because it was difficult for people to let outsiders into their lives, even if they knew it was for the purposes of research. However, for this research, it was important to interview various elderly people who lived at different locations. With the help of friends, family, colleagues and neighbors, it was possible to gather 40 participants. Unfortunately, it was not possible to gather elderly participants of Antilles/Aruban background. Hence, results of this group will not be discussed. Table 9 shows how many men and women of different nationalities participated in the research.

The most number of person are in the age group of 60-64 years, followed by the group in the age group of 65-69 years. In both these groups, the number of Moroccans is high. In the age groups of 70-74 years and 75+ years, the number of Moroccans is the lowest. It was difficult to find participants over the age of 75+. During the completion of the

questionnaires, the elderly interviewed were asked if they knew people over the age of 75. Most did not know of any people past the age of 75. This was because most the elderly above that age choose to live in their countries of origin. Most of the elderly who were still able to travel spent approximately three months in their home countries every year. The elderly were also queried about their living arrangements. Figure 27 shows the different living situations of the elderly participants, grouped according to their different ages and nationalities. The graph below shows the following categories:

- [1] Living together with husband/wife.
- [2] Living together with husband/wife and child/children.
- [3] Living together with child/children.
- [4] Living alone.

Most of the elderly between the ages of 60-64 live only with a spouse and those older than 75+ live alone. This has to do with the death of a wife or husband.

Most of the elderly of different ethnic group live together with their husbands and wives. However, it seen that 12 out of the 21 Moroccans interviewed live together with husband and children. This has to do with the fact that Moroccans would marry at a young age in the past. This often resulted in large families. Hence, there are enough children to make it a high possibility that there will always be a child who lives with his or her parents. As a result of Moroccan cultural norms, it is natural for children to continue to live with their parents past the age of 18. This is especially true for women, who often only leave their parental homes when they get married. However, even though it is natural for generations to live together, privacy can be a necessity. Hence, the elderly were also asked about how much privacy they require. Figure 28 show how important privacy is for each group. The graph consists of five categories which refer to how important they find privacy to be

- [1] not at all important
- [2] not important
- [3] rather important
- [4] very important
- [5] extremely important

As is evident from Figure 28, there were no elderly

participants who did not find privacy important. Privacy was important to all elderly participants, with only a handful of Moroccans disagreeing. Six of the eight Native participants found privacy extremely important, while only seven out of the twenty-one Moroccan participants found privacy extremely important. We can conclude that privacy is much more important for Native people as opposed to the other groups interviewed. This could be attributed to the Dutch cultural, where independent lives are encouraged from a young age. On the other hand, privacy might be less

important to the other groups because of their cultural expectations of being taken care of by their children.

As evident in figure 29, most of the native people are more on the left side of the figure. While answering the questionnaires, they also mentioned that they did not want to be a burden on their children's busy lives. However, if an appropriate solution can be found that allows them to live near their children and be taken care of by their children without being a burden to them, they would take the opportunity.

Population	Female	Man	Total
<i>Moroccan</i>	12	9	21
<i>Turkish</i>	6	2	8
<i>Native</i>	3	5	8
<i>Suriname</i>	2	1	3

Table 9. Amount of people of each population that participated

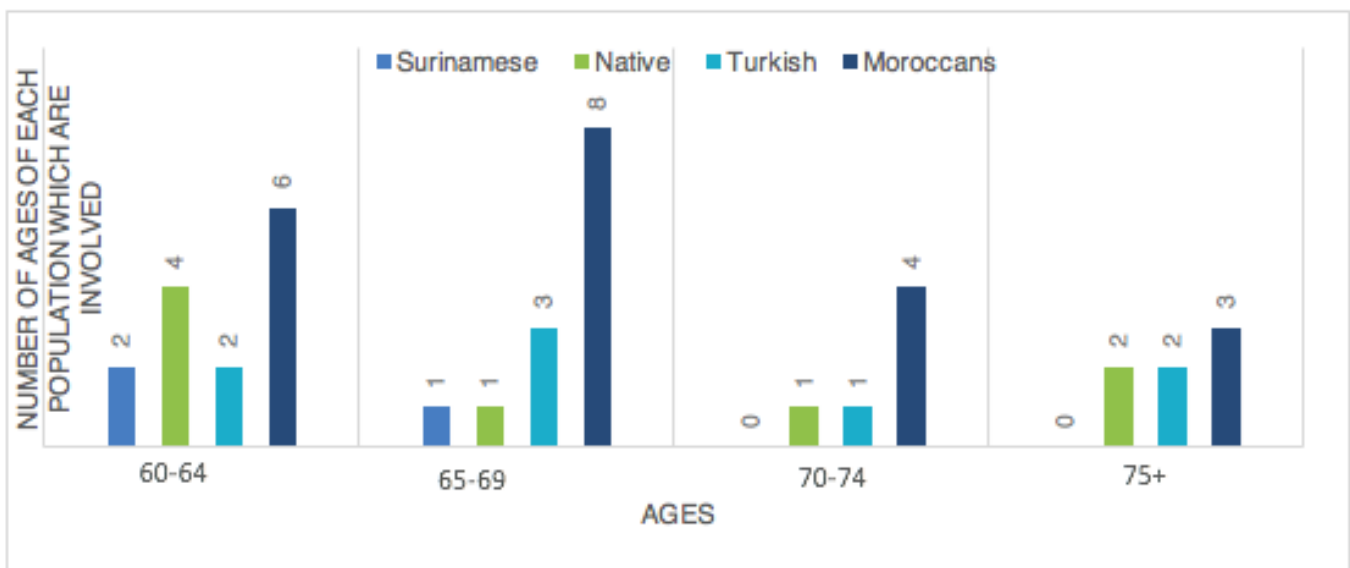


Figure 26 .Number of ages of each population which are involved.

Figure 27. Living situation for the different ethnic groups .

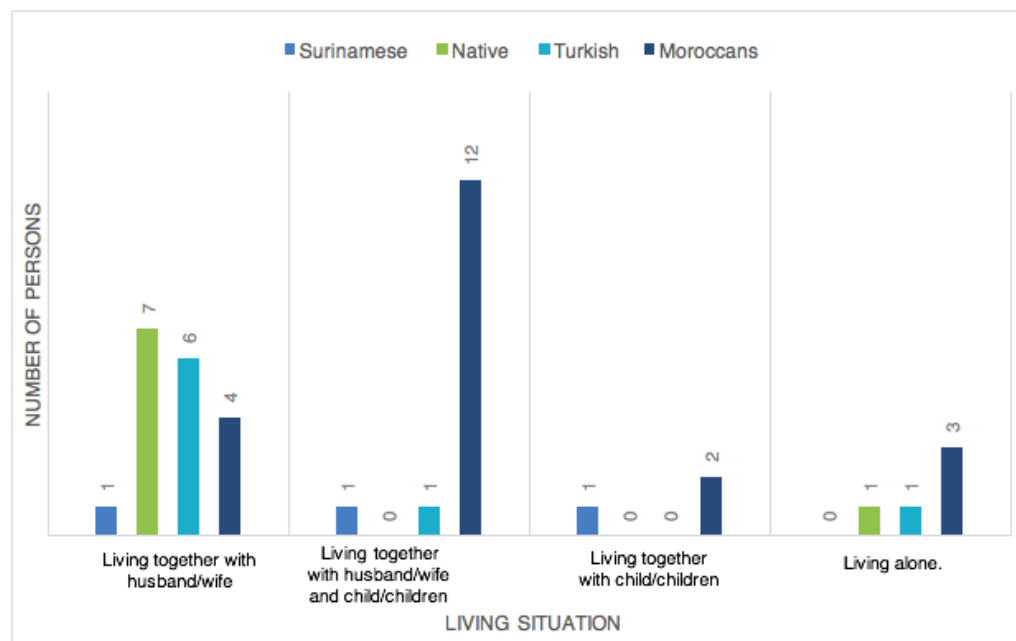


Figure 28. Privacy

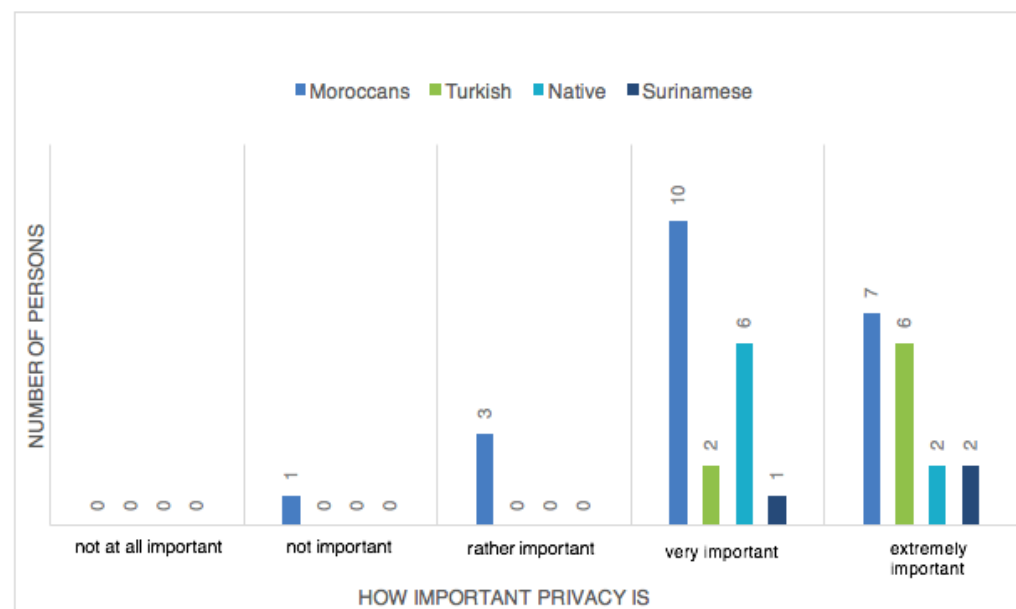
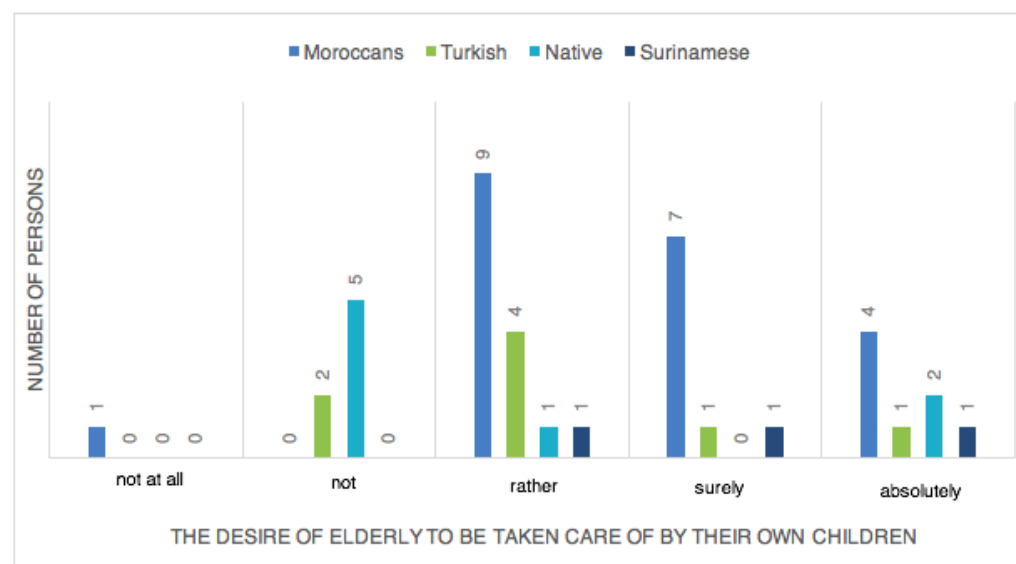


Figure 29. Desire to be taken care of by their own children



5.2.2 Weather

The questionnaire was taken in the period between the 30th of September and the 14th of October in the year 2017. The average, maximal and minimal temperatures as measured by the Koninklijke Nederlandse Meteorologisch Instituut (KNMI) are

plotted in figure 30, where the y-axis shows the temperature in degrees Celsius and the x-axis shows the dates. From this data, we can see that the average temperature in this period was approximately 10,8 degrees. At this time, the weather was mostly rainy, cloudy and sometimes dry. It was a brief period of autumnal weather.

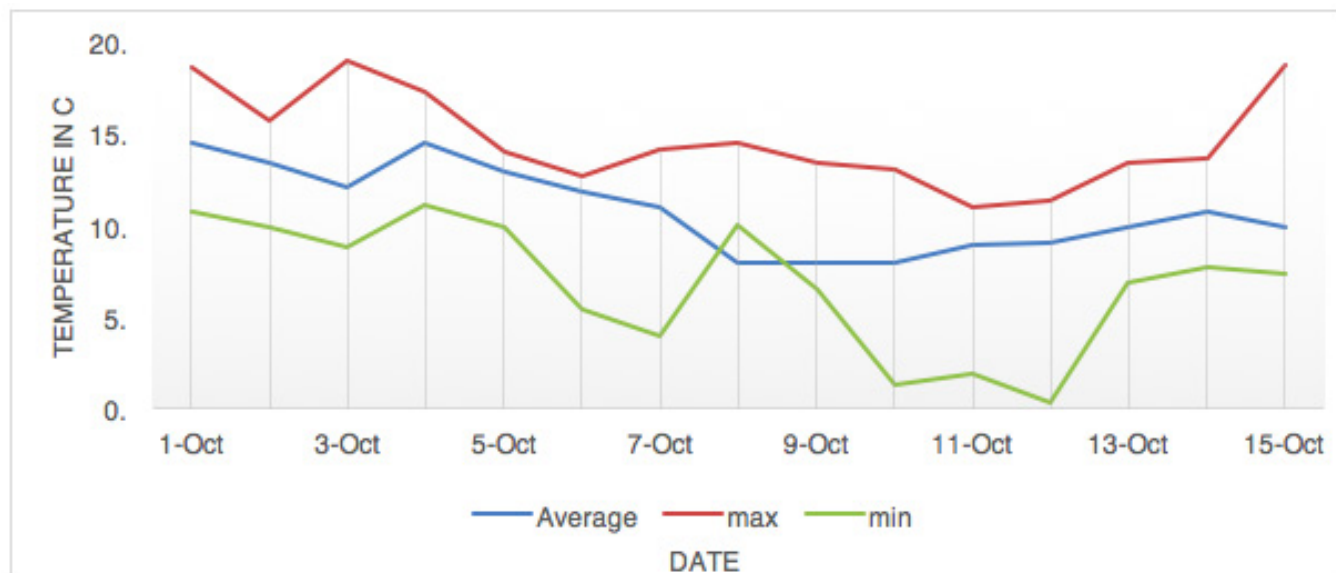


Figure 30. Weather data from the KNMI.

5.3 Results thermal comfort

As mentioned above, the buildings where the questionnaires were answered were situated at different locations and the they were answered on different dates and at different times. This means that the outside temperatures were different for each location. In addition, the buildings differed from each other in other factors, like the insulation rating of the building, its sun-orientation, the surface area of glass on its facade, and the age of the building. Despite these differences, the questionnaires attempted to understand how people felt in their homes and in the places where they spent the most time. The questionnaires were all taken in the living room with the elderly.

Most of the living room had a thermostat which gives the temperature of the building inside. Table 9 shows the average temperature for all ethnic groups. Moroccans and Turkish population had a higher average temperature compared with the Native and Surinamese. The native woman had a lower temperature inside then the man. However, this had to do with the woman herself. She liked to open most of the windows in the morning. The participants were also asked what their desired

temperature would be if they could manipulate the temperature as they wished. The results are shown in table 10. The table shows that the Moroccan and Turkish interviewed prefer a temperature 1 °C higher than the total average temperature inside and the Surinamese prefer a temperature 3 °C higher than the total average temperature inside. On the other hand, the Native prefer a temperature that is 2 °C lower. This shows that the Native elderly are the only group who feel that the temperature in their homes is higher than their ideal temperature.

The results of how the elderly feel in their respective living rooms will be compared with the average temperature shown by the thermostat in the living rooms and with the average temperature outside, as shown in figure 31.

Along with recording the temperature on the thermostat, the elderly were asked how thermally comfortable they felt inside their homes. They could choose from the following seven options:

- [1] hot
- [2] warm
- [3] comfortably warm

- [4] neutral
- [5] comfortably cool
- [6] cool
- [7] cold

As seen in figure 31, the Native participants were the most thermally comfortable in their homes, with 6 out of 8 participants thermally comfortable in their homes. This was followed by the Moroccans, with 12 out of 21 participants thermally comfortable in their homes. 4 out of the 8 Turkish participants were thermally comfortable in their homes and only 1 out of the 3 Surinamese participants was thermally comfortable at home. Most of the elderly from the Native population had the same level of thermal comfort with only slight differences of one scale. If we compare their

comfort levels with the average temperature of 19 °C, it seems that the native feel comfortable at a temperature of 19 degrees. However, if they could change the temperature, they would prefer a lower temperature. For the Moroccan and Turkish elderly, the temperature of 21 °C is comfortable. The rest of the elderly are more on the left side of the graph, which shows that they prefer it to be warmer as opposed to colder. If the Moroccan and Turkish elderly could change the temperature, they would prefer a higher temperature. This means that they have a preference for the warmer temperatures of their countries of origin. The Surinamese elderly had more varying levels of thermal comfort. Additionally, the different levels of thermal comfort between men and women of the different backgrounds was also compared.

Ethnic group	Average Female [°C]	Average Man [°C]	Average Total [°C]
Moroccans	21	21	21
Turkish	21	22	21
Native	17	20	19
Surinamese	19	19	19

Table 10. Average temperature of the building inside.

Ethnic group	Average Female [°C]	Average Man [°C]	Average Total [°C]
Moroccans	21	22	22
Turkish	22	21	22
Native	21	22	18
Surinamese	24	20	22

Table 11. Average temperature what the ethnic groups prefer.

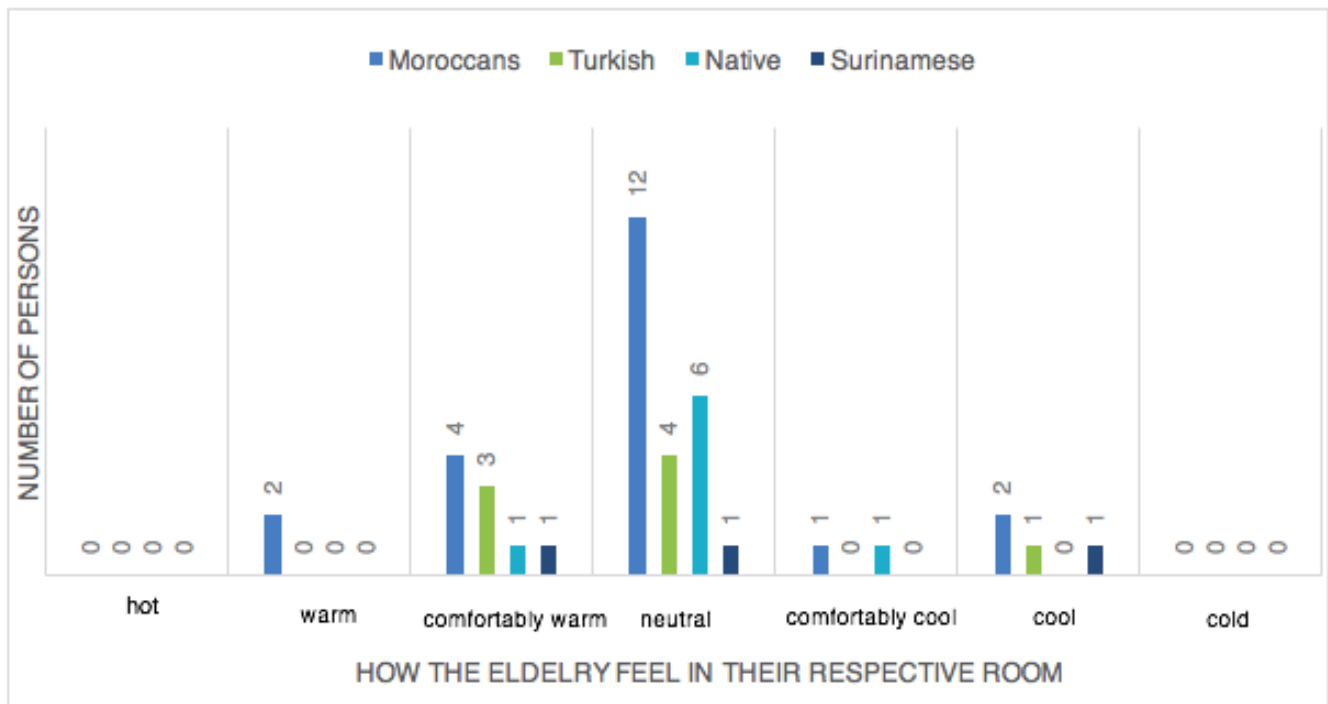


Figure 31 How the elderly feel in their respective room.

5.3.1 Moroccan elderly, women compared to men

Within the Moroccan elderly, the thermal comfort level is the the same for the women and the men. However, the thermal comfort levels of the women are more spread out in comparison to the thermal comfort levels of the men. As is the case with both male and female elderly within the Native population, the results show that Moroccan men

are thermally comfortable in their homes, feeling neither too hot nor too cold. The difference in thermal comfort levels between the men and the women within the Moroccan elderly could be attributed to the amount of time the women spend outside in comparison to the men. Participation in sports might also have an effect on these results. These two factors will be further analyzed later in this chapter.

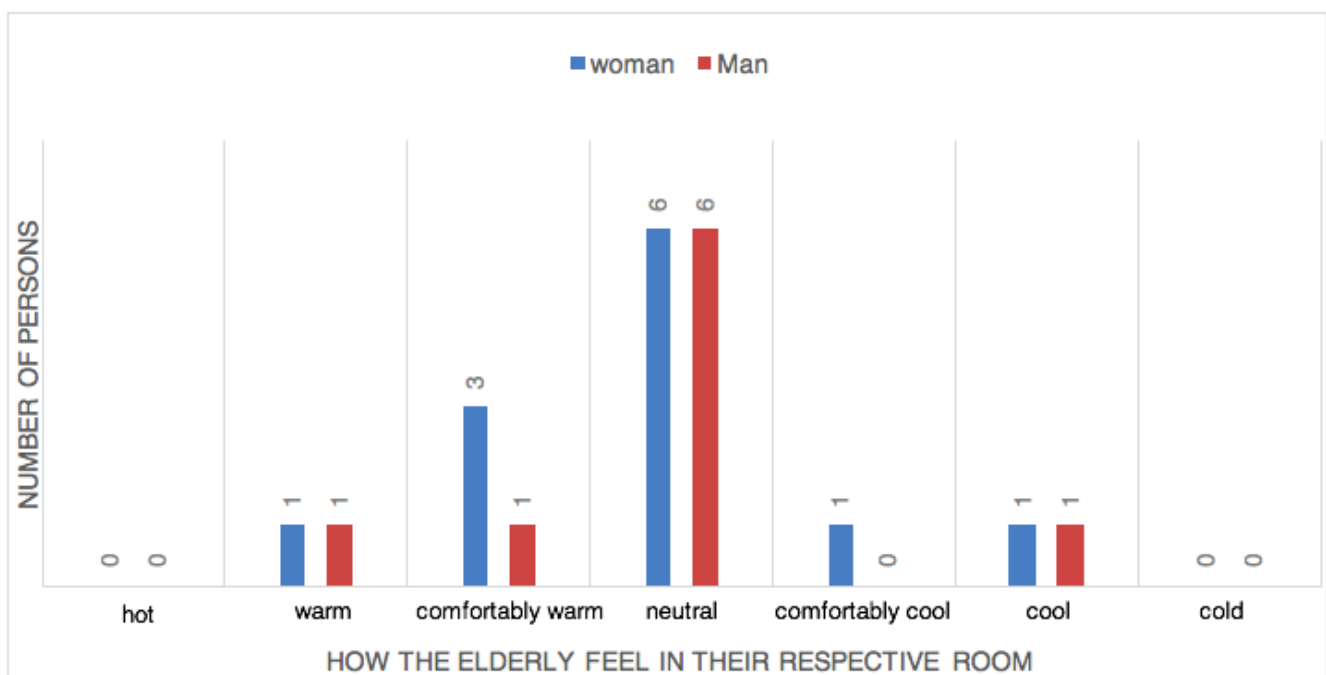


Figure 32 How the Moroccan elderly feel in their respective rooms, woman compared to men.

5.3.2 Turkish elderly, women compared to men

Figure 33, shows the results obtained from the Turkish elderly. As was the case with the Moroccan elderly, the Turkish men were much more thermally comfortable in comparison to the women. The thermal comfort levels of the Turkish men are comparable to the comfort levels of the Native elderly.

5.3.3 Surinamese elderly, women compared to men

The difference in thermal comfort levels between the Surinamese men and women interviewed is shown in figure 34. However, these results are not reliable as there was only one man who participated in this research, a sample size that is far too small to be produce reliable results. As a result, the figure shows that the thermal comfort of the women are far more spread out across the scale, as compared to the thermal comfort levels of the men.

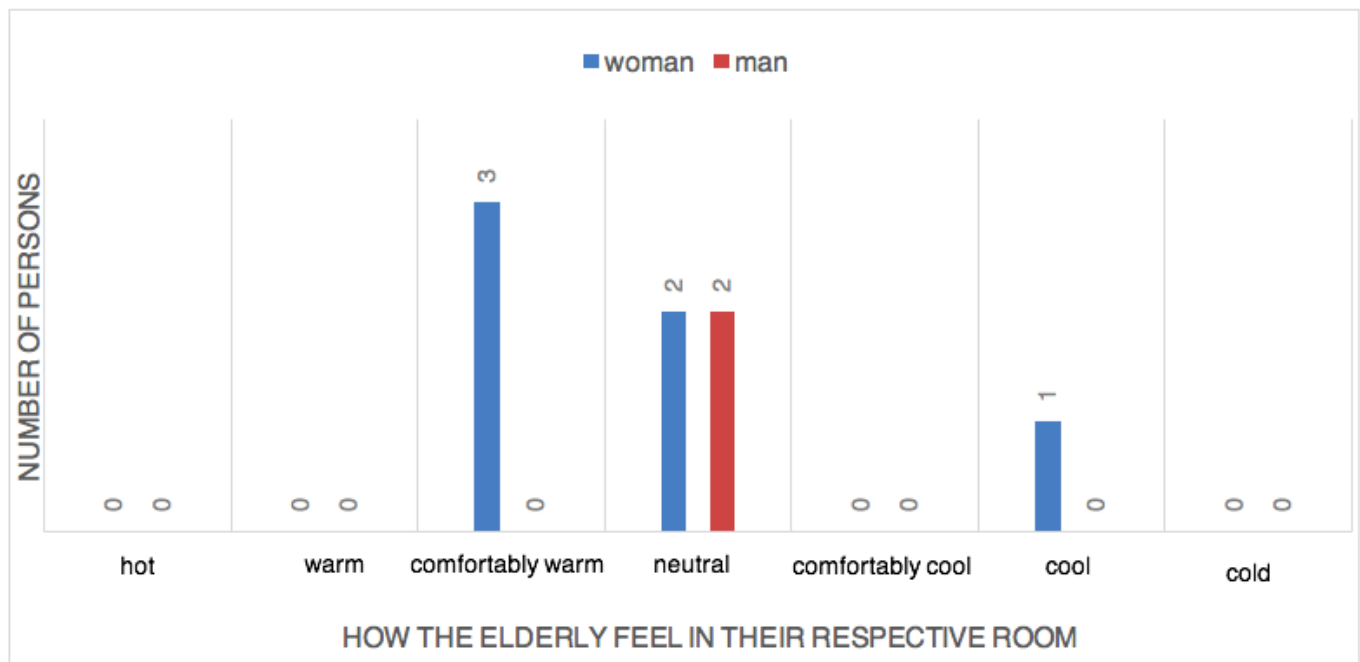


Figure 33. How the Turkish elderly feel in their respective rooms, woman compared to men

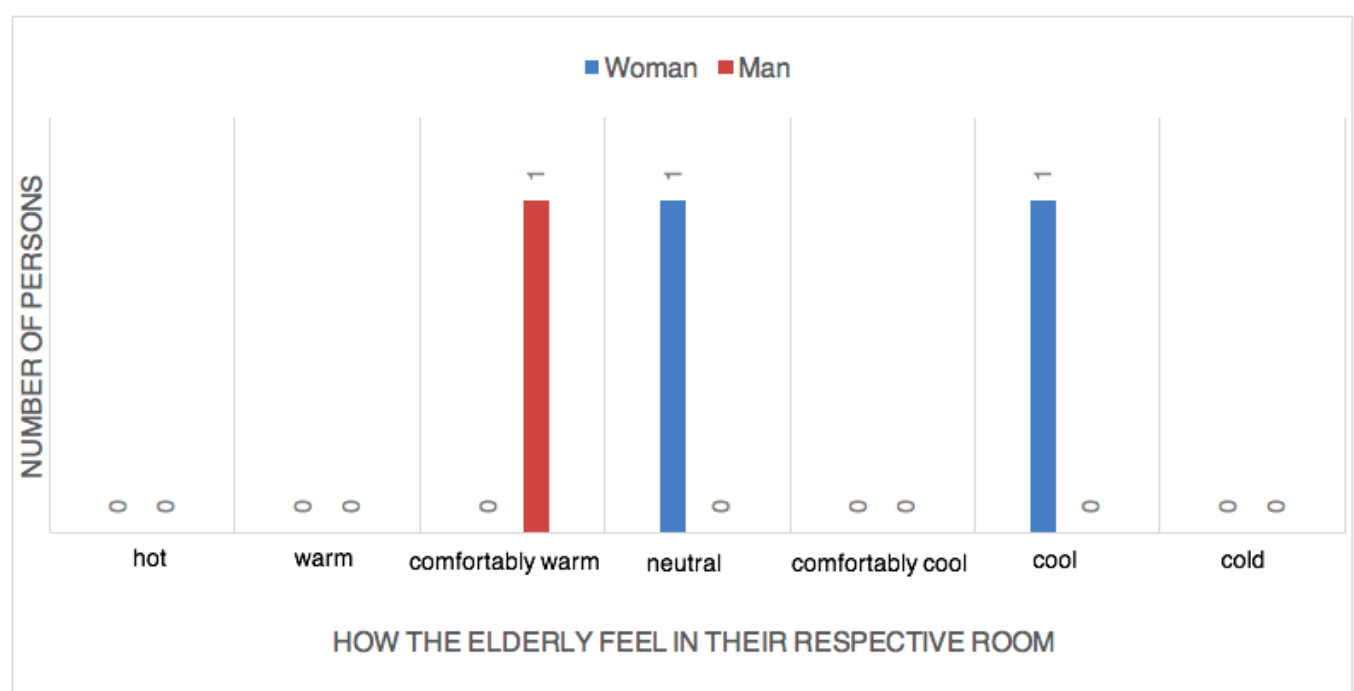


Figure 34 How the Surinamese elderly feel in their respective rooms, woman compared to men

5.3.4 Native elderly, women compared to men

Differences in thermal comfort levels between the elderly Native men and women is plotted in figure 35. It can be seen that the men are thermally comfortable and the results of the women are more spread out. However, compared with the results of the other ethnic groups, the thermal comfort levels of the Natives are not as spread out over the scales. This could have to do with the fact that these elderly live in their countries of origin.

5.3.5 Clothing package

A section of the questionnaire looked at what type of clothing the men and women were wearing inside the house. Women could choose between the following three options:

[1]: underwear, panty with light summer dress/pants, shoes.

[2]: underwear, panty with skirt or long pants, long sleeve sweater, thick socks and shoes.

[3]: underwear, panty with skirt or long pants, long sleeve sweater, thick socks, shoes and a headscarf.

The package options for the men differed slightly from that of the women. Men could choose between the following two options:

[1] underwear, light long pants/shorts, open-top shirt, short sleeves, thin socks and shoes.

[2] underwear, long pants, long sleeve long sleeved

shirt, thick socks and shoes.

The results of the choices made by the women are plotted in figure 36. It is clear from the figure that the elderly women of Moroccan and Turkish descent mostly chose option 3. The options for women also included one with a headscarf. The Turkish and Moroccan women involved in this research have an Islamic background and many Muslims consider a headscarf to be an obligatory requirement for women. However, a headscarf is not considered to be mandatory around other women and specific male family members (i.e: husbands, fathers, brothers etc). Hence, a headscarf is often not necessary inside one's home. When asked about this, the women claimed that they would often wear one even when it was not mandatory, as it helped to moderate their thermal comfort levels inside their homes. They also mentioned that when in their home countries, they often forsook headscarves altogether in summer, when temperatures were too high.

The results of the choices made by the men are plotted in figure 37. Most of the Moroccan men chose Package 2. This included clothing which covered the entire body. Hence, the elderly men find it comfortable to be well covered. The results for the other groups are similar, with differences found only in the results of a single person. It is therefore difficult to draw conclusions from these results.

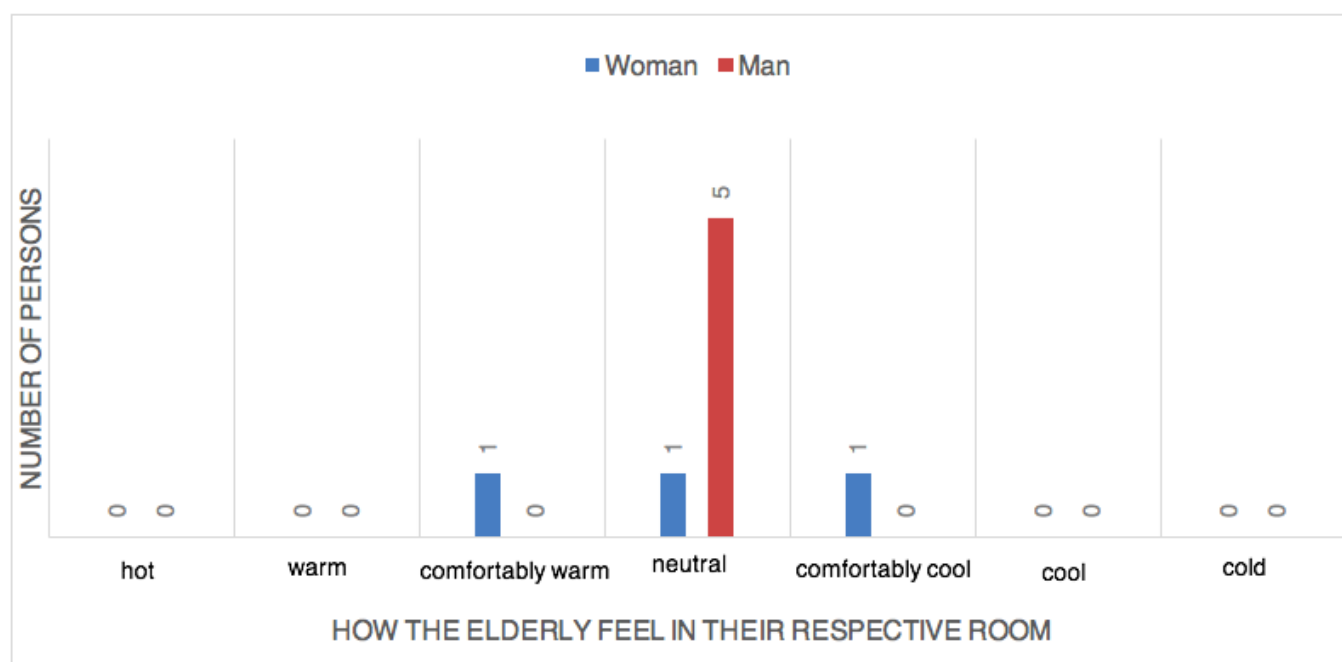


Figure 35 How the Native elderly feel in their respective rooms, woman compared to men

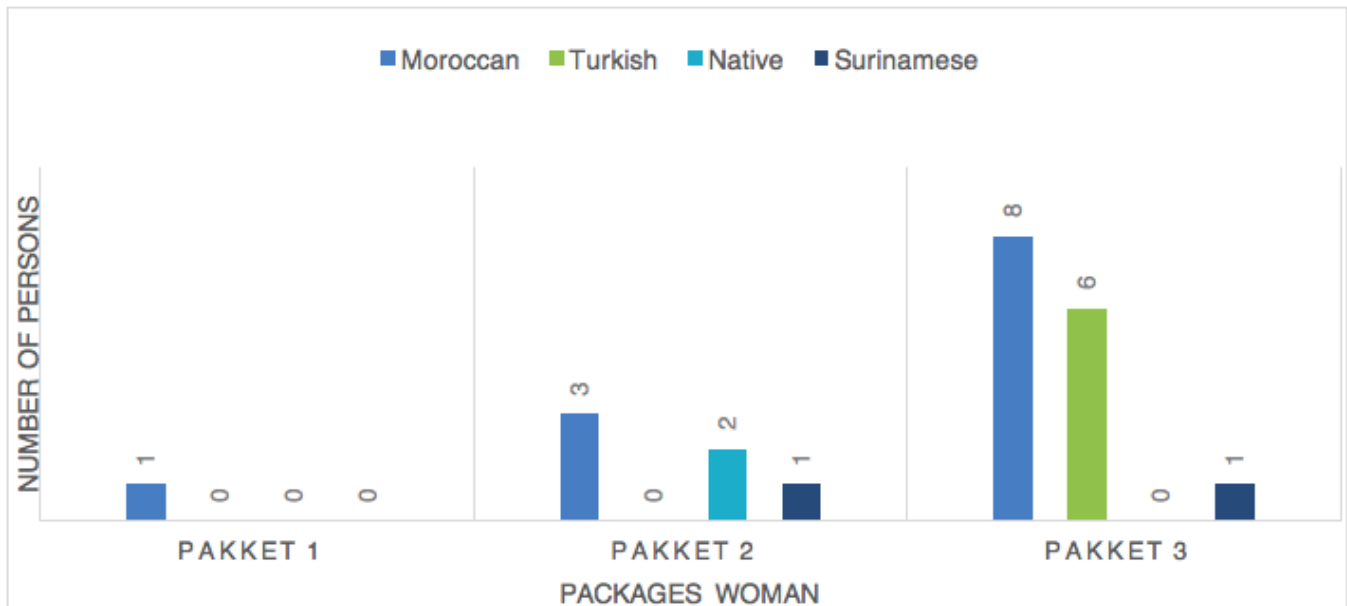


Figure 36. Package woman

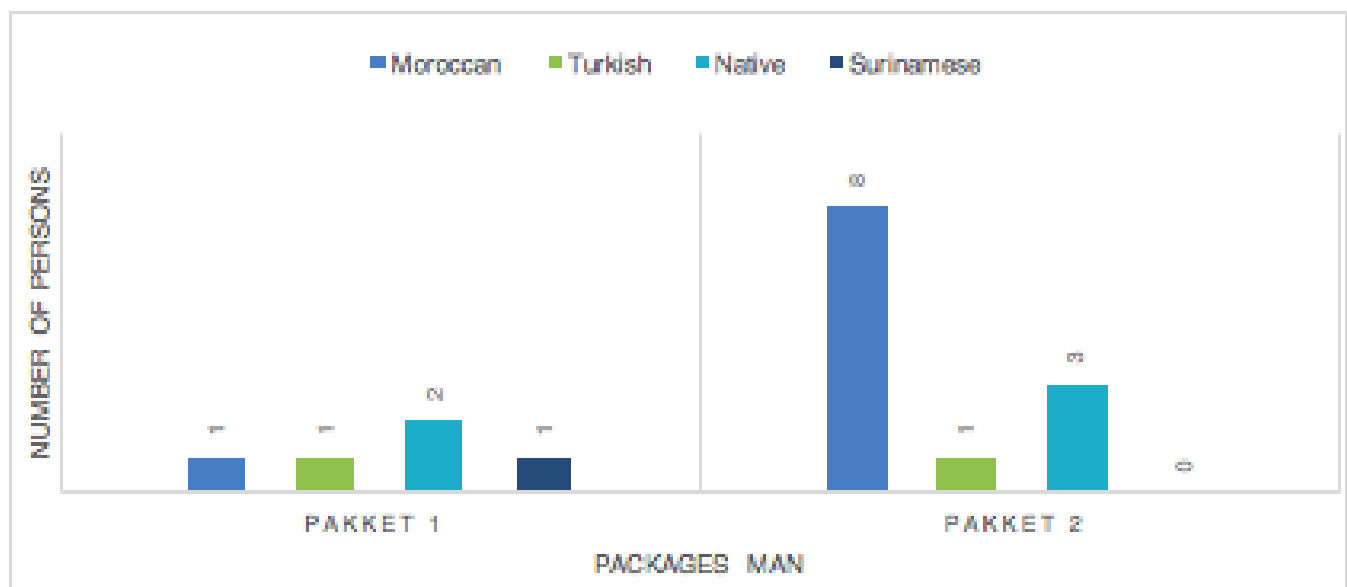


Figure 37 Packages man

5.3.6 Movement

As mentioned above, the thermal comfort levels of the elderly have to do with different factors. One of these factors is the movement of the body. This can take the form of physically intense activities like sports or less intense activities like walking outside for some fresh air. The elderly were asked how much time they spend outside on a weekly basis. The results are shown in figure 38. 9 out of 21 amongst the Moroccan elderly spend 4-8 hours outside weekly and 10 out of 21 spend between 12 and 16 hours outside weekly. However, in the process of completing the questionnaire, it became clear that when the participants talked about

spending time ‘outside’, they referred to spending time beyond the grounds of their house. They did not consider spending time in the balcony or garden to be the equivalent of spending time ‘outside’. Hence, the amount of time the elderly participants spend in the outside air is not clear from the results of the questionnaire. Amongst the Turkish elderly, 3 out of 8 spend 4 to 8 hours outside weekly and 5 out of 8 spend between 12 and 16 hours outside. However, what is striking amongst these groups, is that there are those who are spend between 0 and 4 hours outside weekly. This is a very low level of activity for a person. The Surinamese and the Native spend more then 4 hours outside weekly. However, for all the groups of elderly, it would

be beneficial to increase the amount of physical activity.

The results of those of Moroccan and Turkish descent is looked at more closely because there are those who spend less than 4 hours weekly outside. These results can be seen in Figures 39 and 40. The figures show that the elderly men of Moroccan and Turkish descent are outside more often than the elderly women. This has to do with the culture of the first generation immigrants from Morocco and Turkey. In their respective cultures, women are expected to take care of the children and the household. In contrast, the men are supposed to take care of things outside the house, like doing the groceries and going to work. This manner of living stayed with them when they moved to the Netherlands. While answering the questionnaires, many of the participants expressed interest in returning to their countries of origin, an indication of their attachment to the cultural practices of their home countries. However, their children who grew up in the Netherlands have grown up with different values, making it problematic if they were to relocate to their countries of origin.

The regular movement of the muscles is important both for the health of people, and also for their thermal comfort. Figure 41 shows the average amount of time people of the different nationalities spend on sports. The Native are the most active in sports, with 5 of 8 people that participate in sport more than 2 times a week. The other groups spend less time on sporting activities, with 16 out of 21 Moroccan elderly and 6 out of 8 Turkish elderly participating in sports more than 2 times a week. While answering the questionnaire, the Native elderly mentioned that they were encouraged to play sports while growing up. Their parents registered them sports clubs at a young age. These include swimming, football or hockey clubs, amongst others. Those elderly understood that sports was important both for the reduction of stress and to keep the body healthy. However, even though the Turkish and Moroccan elderly of the first generation did not grow up with sports, they do make regular movements with their bodies. During the questionnaire, some of the elderly laughed and mentioned that they do partake in sport five times a day and during the month of Ramadan even more times. Most of them were raised as Muslims and as part of their religious practices, pray five times

a day, bending and prostrating in the direction of Mecca. However, the intensity of this bending and prostrating motion has never been studied.

In the design of facade, it is necessary to know if the elderly are able to open and close the windows, operate the thermostat, control the sunshades by pulling them up or dragging them down, or control the ventilation system by turning it on or off. The results of enquiries made on these are plotted in figure 42. The figure shows that most of the elderly are able to control the temperature by themselves in all stages. However, for the ventilation system, there were a few elderly participants who were unable to operate it by themselves. As part of the questionnaire, the participants were asked about how they regulate temperatures during cold and warm weather. The results are shown in figure 43 and 44. During warm weather, the elderly opens the windows or reduce the amount of clothing. While those of Native descent prefer to reduce the amount of clothing, the Moroccan elderly prefer to open the windows instead as they find that the clothing they wear during summer periods are thin enough. In addition, they grew up in a culture where they were encouraged to be modestly covered. Another factor is that summer in their home countries is different from that of the Netherlands. It is much hotter in their home countries, making them used to warmer temperatures. However, summer in the Netherlands is much more humid, which creates difficulty. For example, they experience more headaches during warm days in the Netherlands, as opposed to warm days in their respective home countries.

Figure 38. Average amount of time spent outside weekly by elderly of the different nationalities

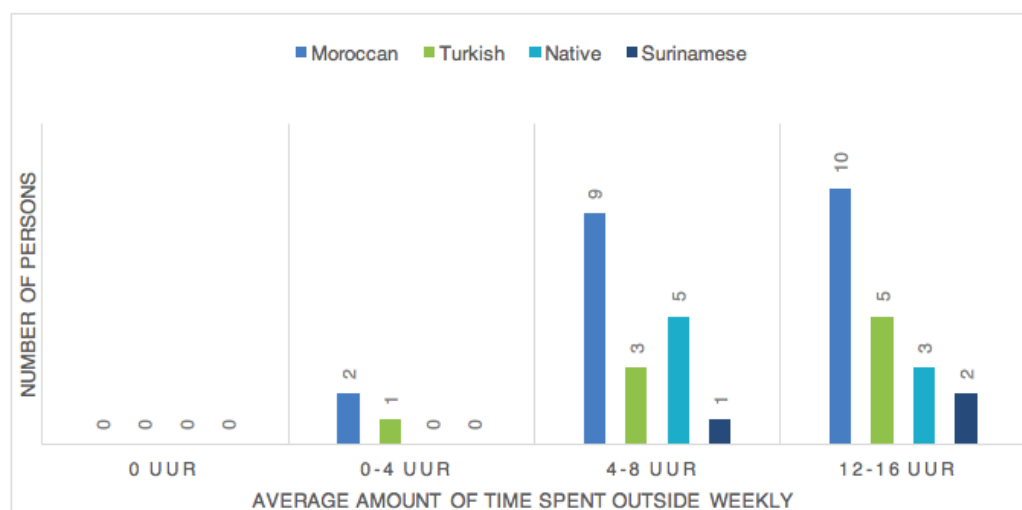


Figure 39. Average amount of time spent outside weekly by the Moroccan elderly.

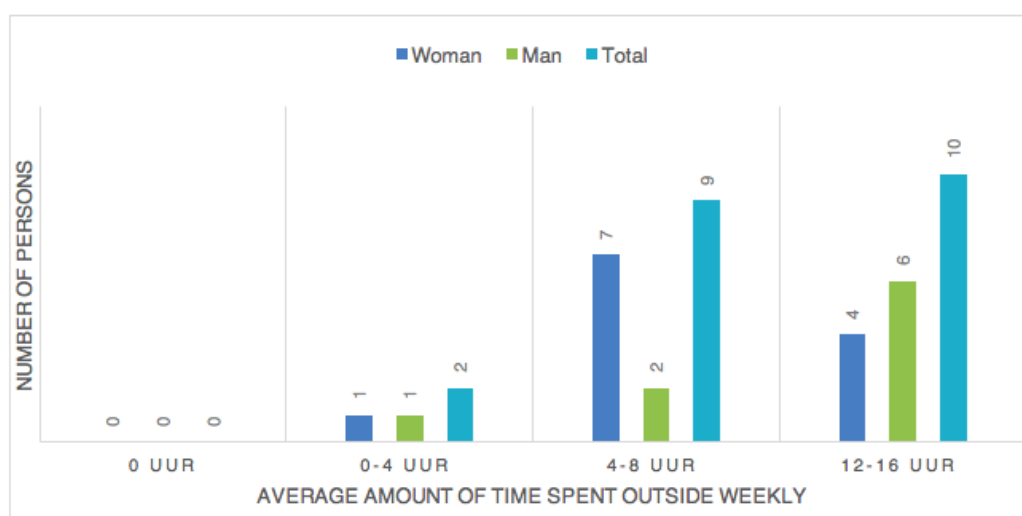


Figure 40. Average amount of time spent outside weekly by the Turkish elderly

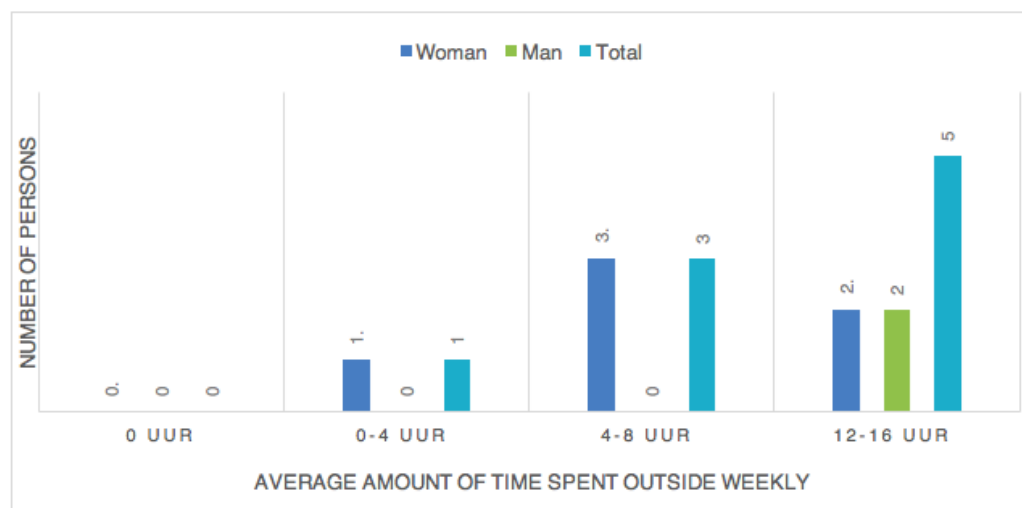


Figure 41. Average amount of time spent playing sports weekly by elderly of the different nationalities.

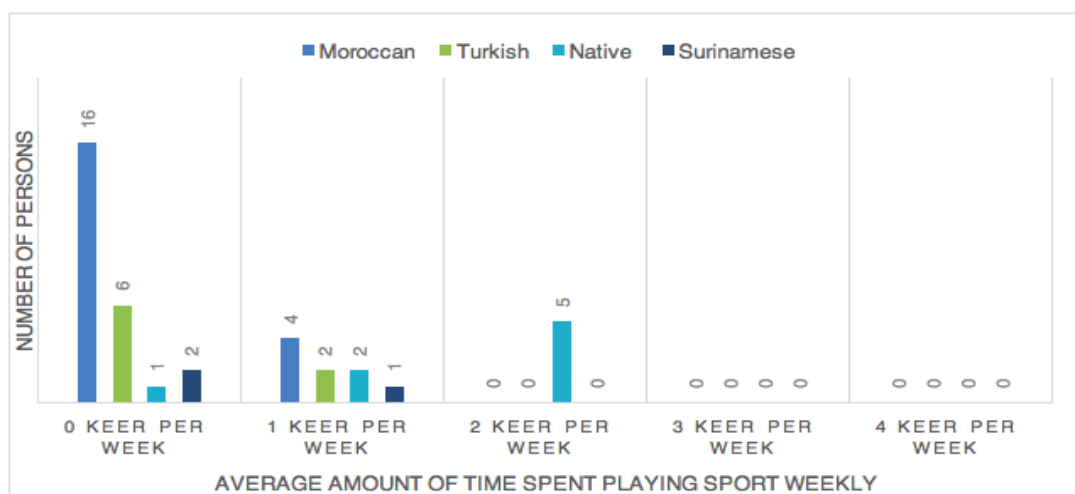
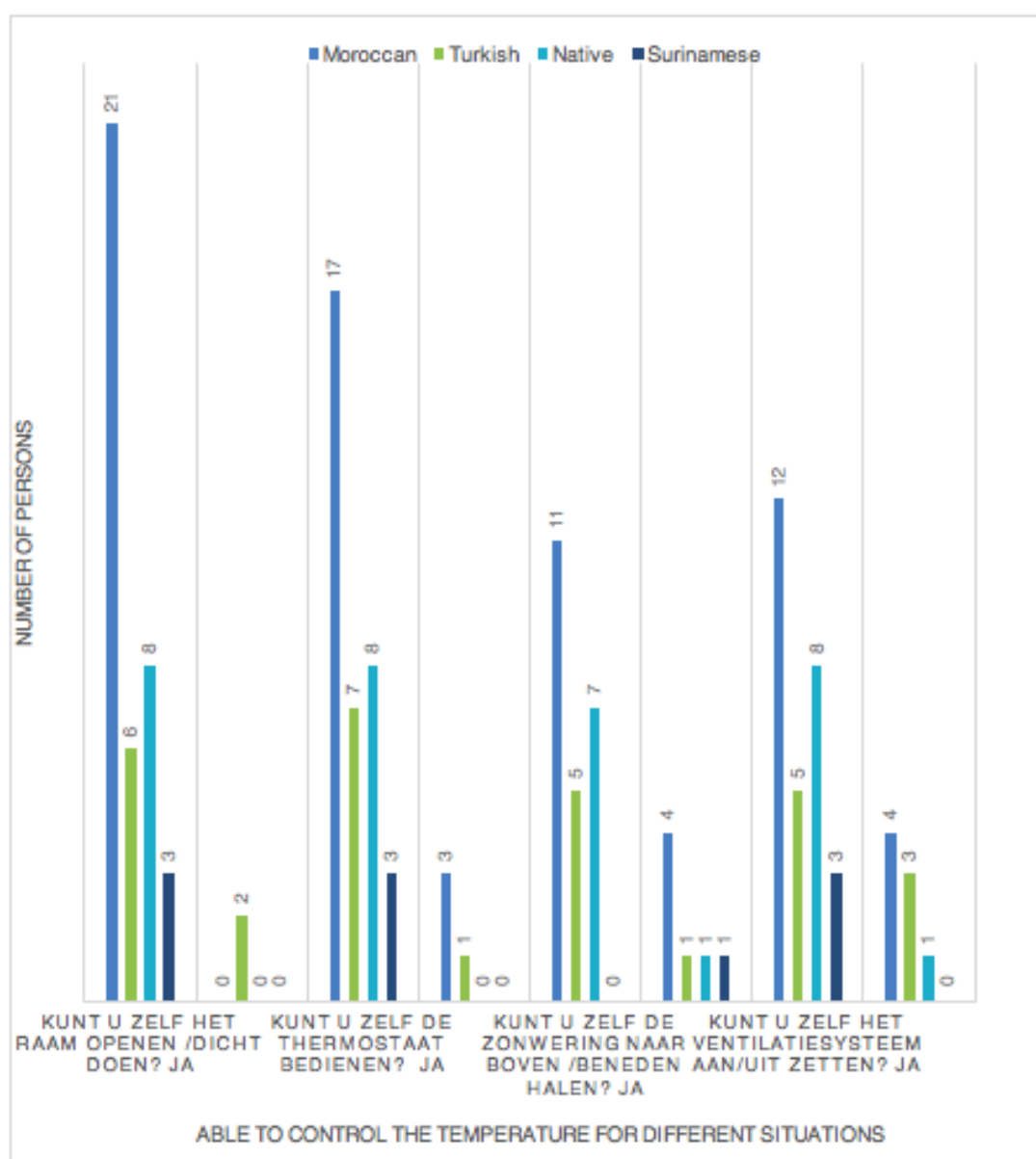


Figure 42. Able to control the temperature.



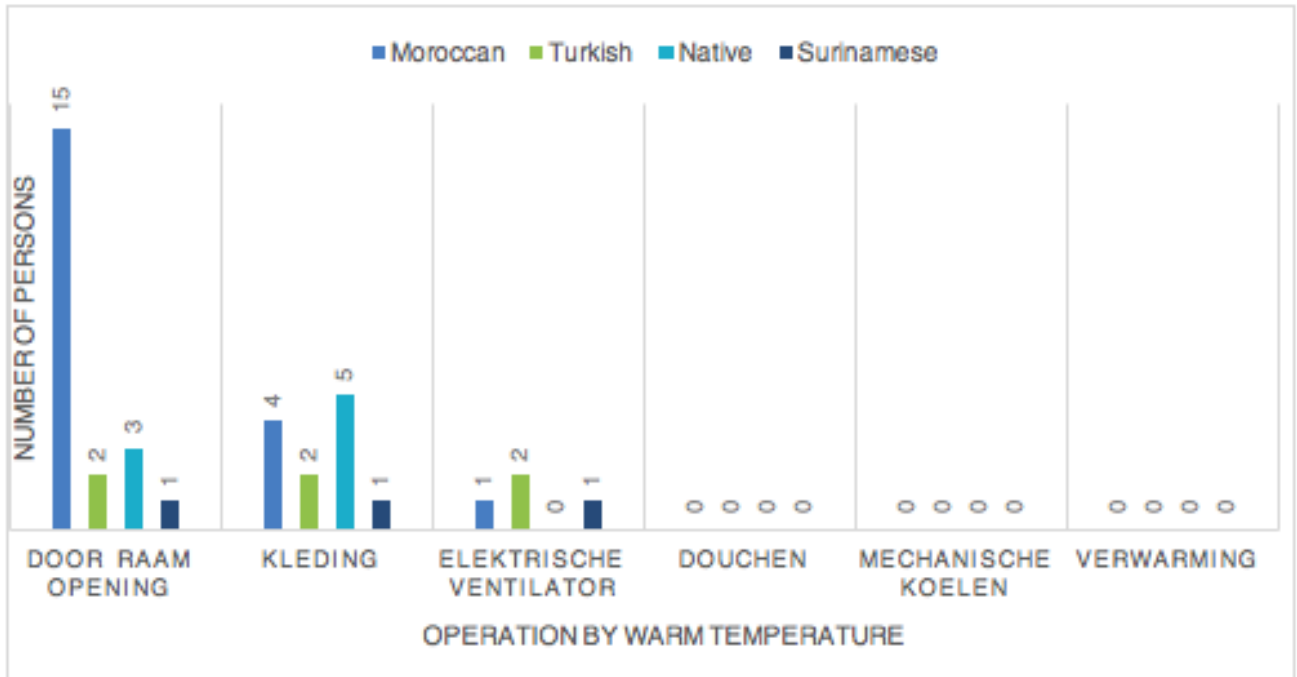


Figure 43. Operation by warm temperature

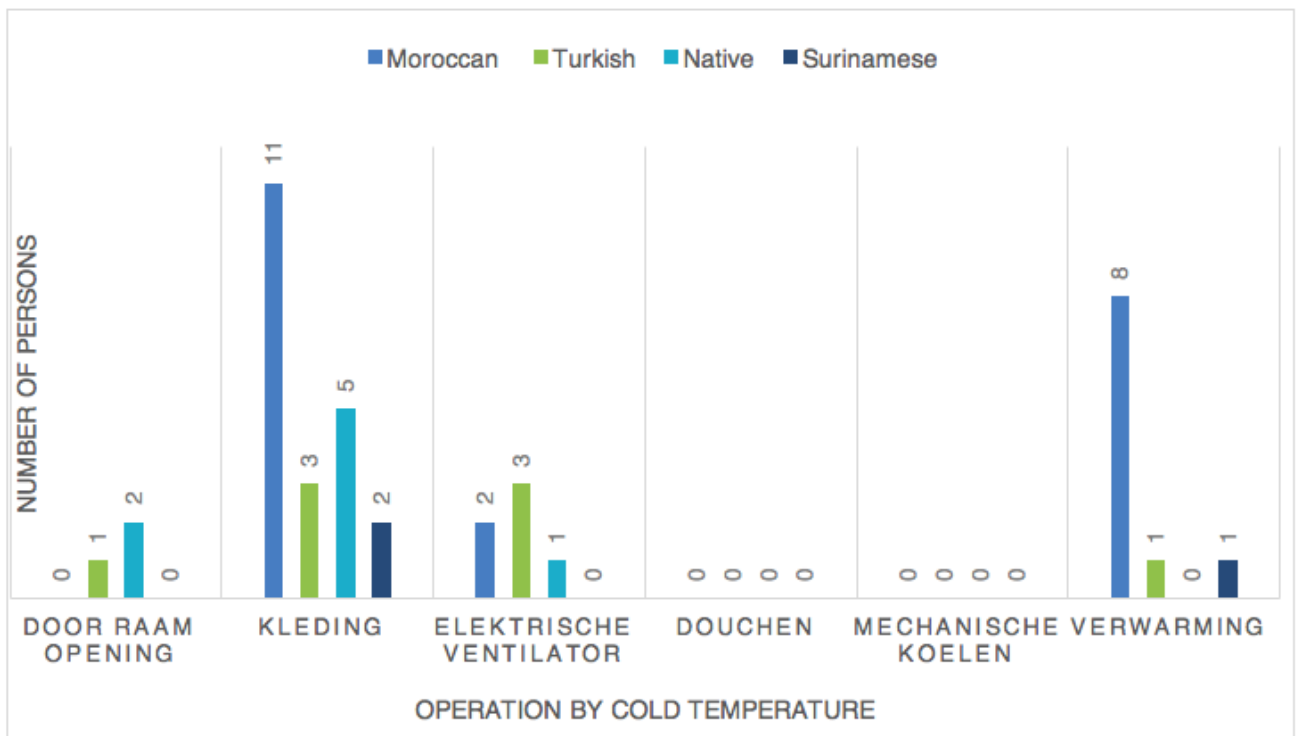


Figure 44. Operation by cold temperature

5.4 Results visual comfort

In addition to thermal comfort, the visual comfort of the elderly was also looked at. In order to understand this, it was important to know which part of their homes the elderly spent the most time in. This will help in designing the plans, as understanding where the elderly spend more time in their homes will help highlight their preferences and this can be used as a design strategy. During

the questionnaire, the elderly were asked where they spend the most time in their homes. Figure 45 shows which part of the house the elderly of different nationalities spend the most time in. From this, we understand that most of the elderly spend their time in the living room. An explanation for this might be the functional suitability of the living room in conducting their daily activities. Another reason could be the amount of daylight which enters this room. However, there are a few amongst

the Moroccan elderly that spend their time in the kitchen and amongst the Natives, one of the elderly spent his time in the dining room and another, in the garden. The native elderly found the garden to be a calming place where one could be with nature.

During the questionnaire, the elderly were also asked where they spend the least time in their homes. Those results are plotted in figure 46. The bathroom and bedroom are the places where the participants spent the least amount of time during the day.

This may have to do with the function of the room or with the thermal and visual comfort. Hence, they were also asked where the most and least daylight entered the house. The results are seen in figure 47 and 48. Most of the daylight that enters through the house, enters the living room, followed by the kitchen. Less light enters the bathroom, as the quality of these spaces are of less import when compared to the other rooms of the house. Additionally, most bathrooms in the Netherlands are mechanically ventilated and do not require window openings.

In addition to the bathroom, a few of the elderly interviewed also had less daylight entering their bedrooms and kitchens. For a sufficient amount of daylight to enter the home, one has to consider

factors like building orientation, window size, street profile and the volume of the individual rooms.

The research also looked at whether the rooms that the elderly spent the most time in, would sometimes have too much sunlight or glare coming in. The average amount of glare coming into the room is shown in figure 49 and clearly shows that there is sometimes too much sunlight in the rooms the elderly spend their time in. While answering the questionnaires, the elderly mentioned that there was sometimes glare reflecting into their eyes from their screens and tables. Some from the Moroccan and Turkish elderly interviewed expressed that the amount of daylight in the rooms they stayed in was not comfortable.

The elderly interviews were also asked if the room was too dark or too bright. The results are shown in figures 50 and 51. However, these results are not very clear as they are spread out all over the scale. While filling out the questionnaires, the elderly also found it difficult to answer this question. In addition, while I was sitting in the room, I sometimes disagreed with their responses on whether the room was too dark or too bright. This question will be more clearly answered in the following chapter where the plans of the houses measured are studied.

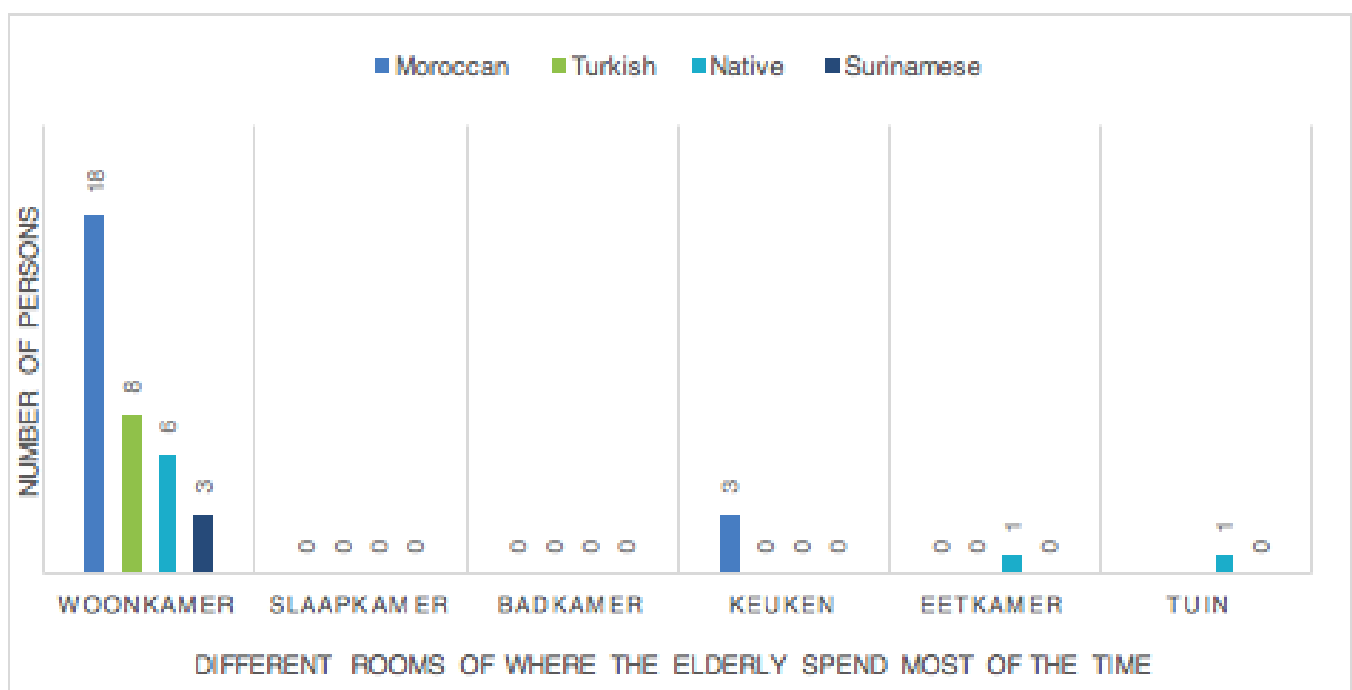


Figure 45 Where the elderly spends the most amount of time in their homes.

Figure 46 Where the elderly spends the least amount of time in their homes.

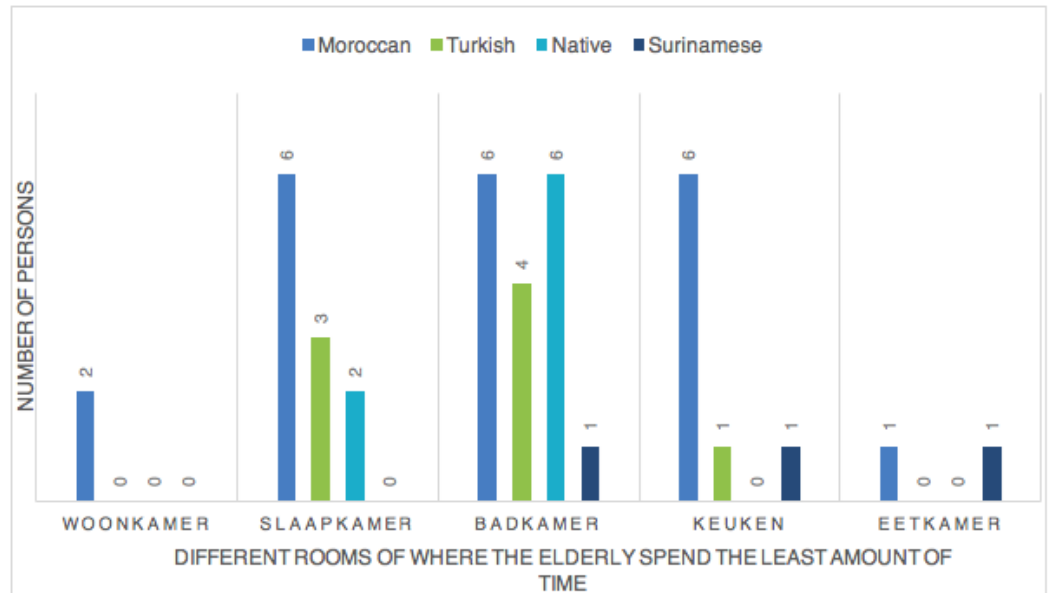


Figure 47. Most sunlight.

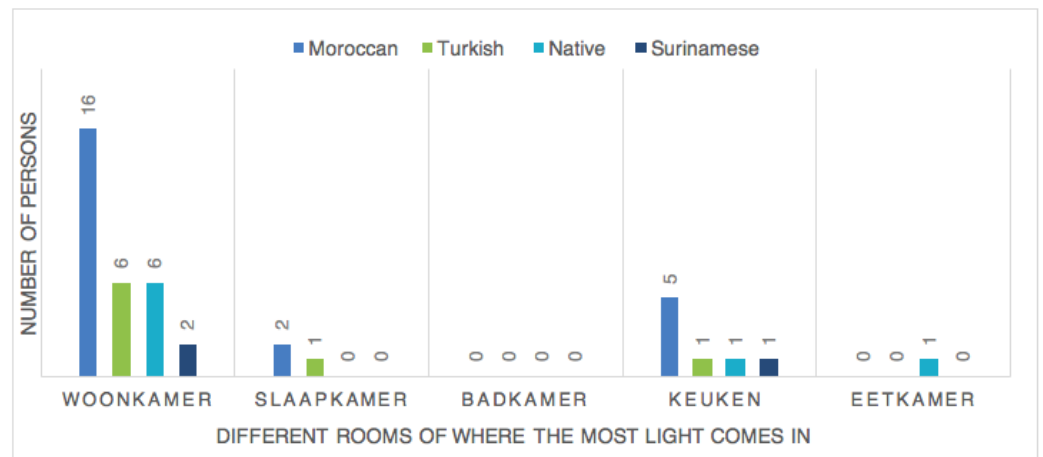


Figure 48. Less sunlight.

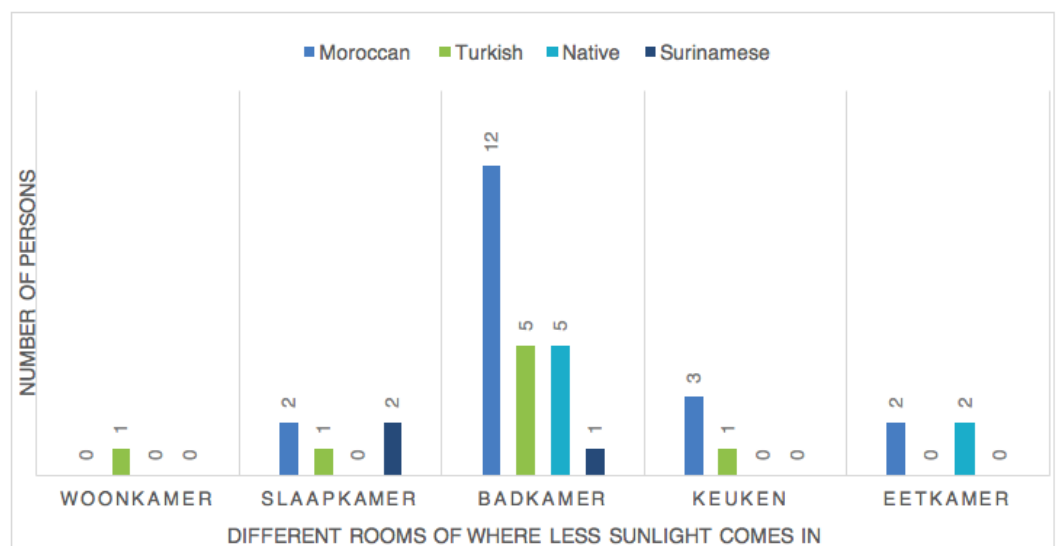


Figure 49 Glare which comes into the room.

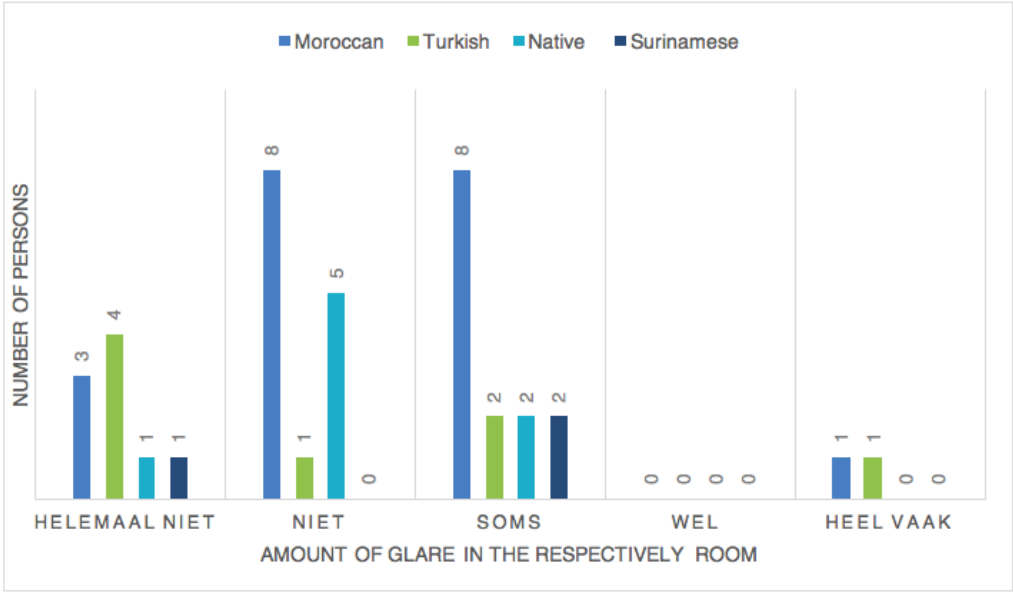


Figure 50 Light places in the room.

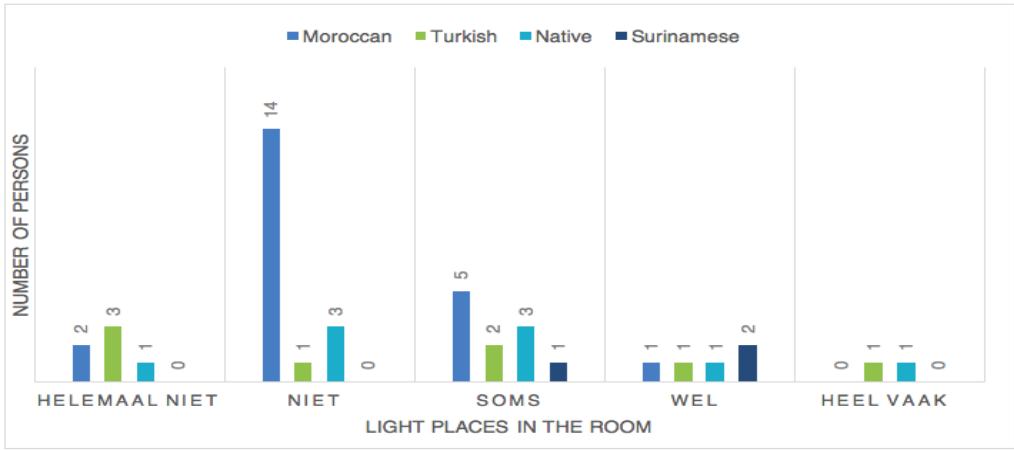
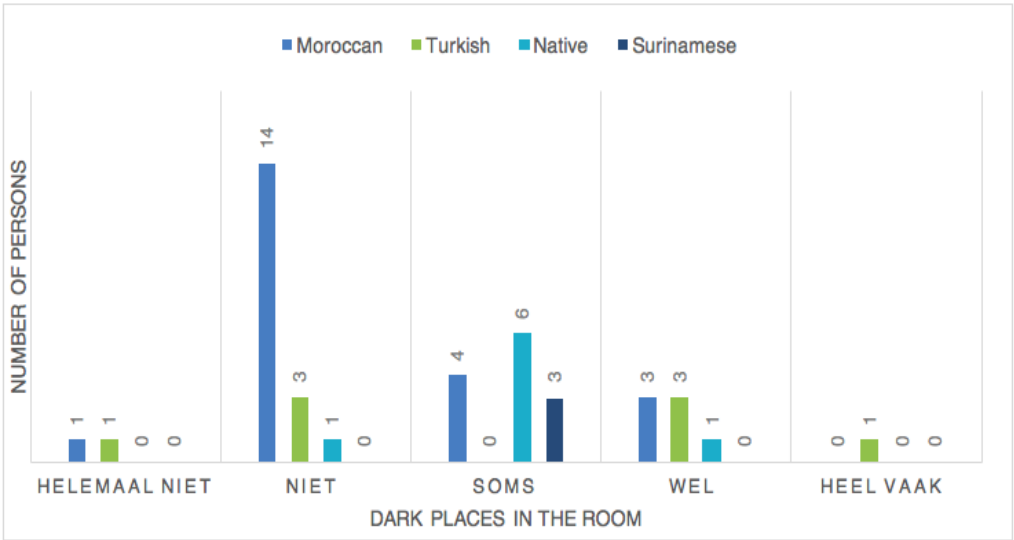


Figure 51 Dark place in the room



5.4.1 Plans highlighting the preferred places in the house

In addition to the results of thermal comfort levels, it is necessary to understand through drawings the favorite places the elderly have in their homes. The plans drawn up will be ordered by ethnic group. Each plan will have a short description which can be utilized further on in the report when drawing conclusions.

The favorite places are indicated with a red cross. The following plans of the rooms are not measured drawings, but sketches that give an indication of what the rooms look like. For each plan there will be a short description of the room, and the elderly who live there, and their favorite places within the room. Some of the elderly have a different favorite place in summer and this will also be noted. Brief descriptions of these places will aim to explain they are favorites. The arrows on all the drawings below point North and the asterisks indicate that a measured drawing of the plan will be shown in chapter 6.

5.4.1.1 Moroccan elderly men and women

Firstly, we will start with the Moroccan men.

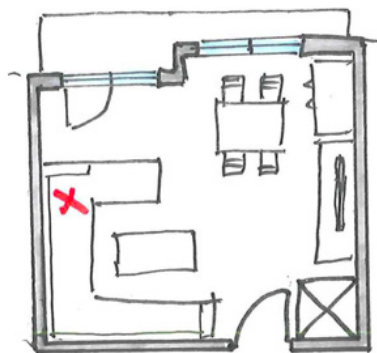


Figure 52. Plan 1 seen in questionnaire 1 appendix A.3.1

- Male, 65-69 years old
- Gallery building
- Second floor
- Living room with door leading to the balcony .
- Small balcony with a view of an outside playground for children.
- A lot of light enters through the window in summer.
- His favorite place is in the corner because it is in front of the television screen. Additionally, in summer, the door can be opened to let fresh air in.

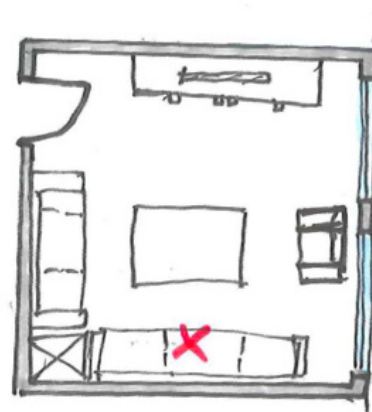


Figure 53. Plan 2 seen in questionnaire 2 appendix A.3.2

- Male, 65-69 years old
- Apartment complex
- Ground floor
- Living room
- His favorite place is in the middle of the sofa because it is in front of the television screen. When family comes over, the favorite place is the single seat, because the television is then turned off.

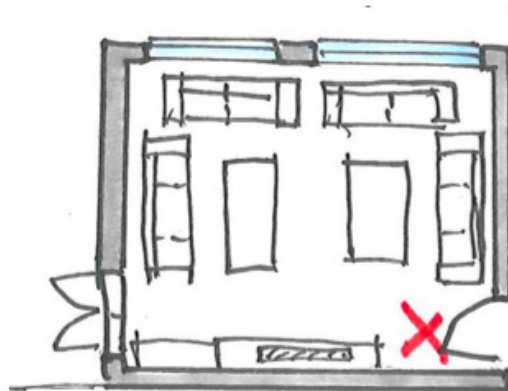


Figure 54. Plan 3 seen in questionnaire 3 appendix A.3.3

- Male, 75+ years old
- Corner of an apartment complex
- Ground floor
- Living room with door leading to the garden
- This man has a special favorite place next to the door. This is because he mostly feels too warm inside the house. Since his wife is sick and always feels cold, the temperature inside the house has to be higher than he prefers it to be. In summer, the door to the garden will be opened.

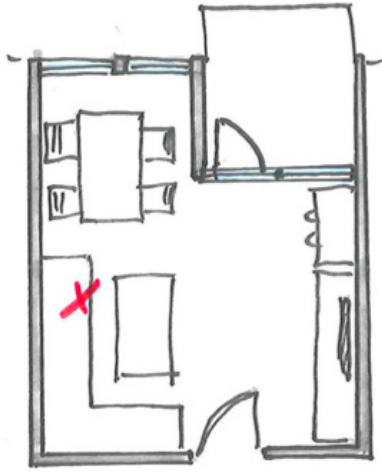


Figure 55. Plan 4 seen in questionnaire 4 appendix A.3.4

- Male, 60-64 years old
- Gallery building
- Third floor
- Living room with door leading to the balcony.
- His favorite place is in front of the television. In summer, he sits in the chair next to the door of the balcony. From this position, he can enjoy the sunlight and still watch tv.

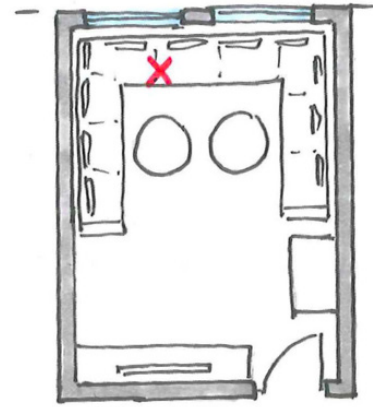


Figure 57. Plan 6 seen in questionnaire 6 appendix A.3.6

- Male, 70-74 years old
- Apartment complex
- First floor
- Living room
- His favorite place is next to the window, because its in front of the television. In winter, it is the warmest place as the heating is behind the seat

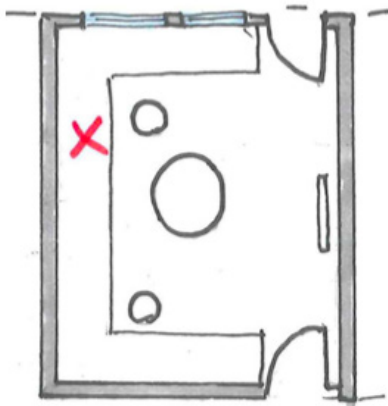


Figure 56. Plan 5 seen in questionnaire 5 appendix A.3.5

- Male, 65-69 years old
- Terraced house
- Ground floor
- Living room with door that enters the house
- This house has two living rooms. This is the living room the man spends most of his time in. This is because he smokes and can easily go outside and smoke from this living room.
- His favorite place is in the corner where he can lay down and watch tv

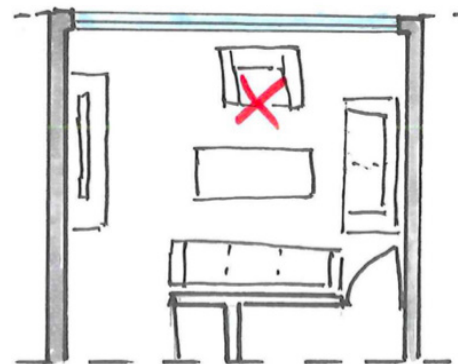


Figure 58. Plan 7 seen in questionnaire 7 appendix A.3.7

- Male, 60-64 years old.
- Terraced house
- Ground floor
- Living room
- His favorite place is in front of the window because he cannot see well in the dark and needs more light for activities like reading.

Plans showing the favorite places of the Moroccan women interviewed.

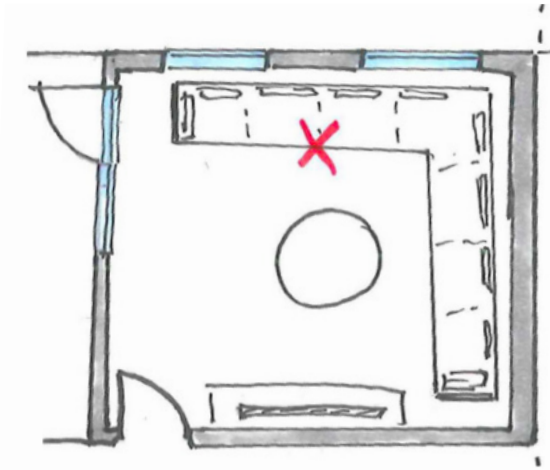


Figure 59. Plan 8 seen in questionnaire 8 appendix A.3.8

- Male, 70-74 years old.
- Apartment complex
- First floor
- Living room with door leading the balcony
- His favorite place is in front of the television and in summer, in the corner of the sofa, near the door to the balcony. This is because of the fresh air that comes in through the door.

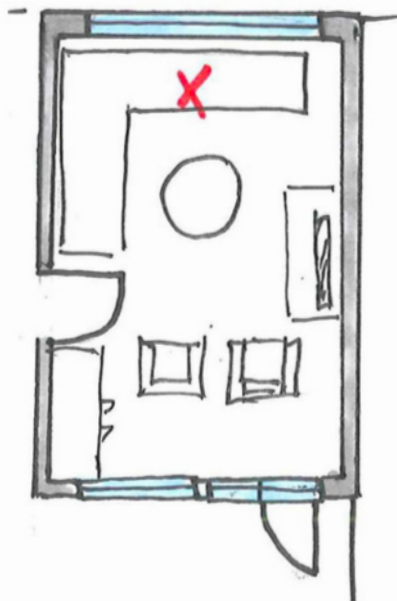


Figure 60. Plan 9 seen in questionnaire 9 appendix A.3.9

- Male, 70-74 years old
- Terraced house
- Ground floor
- Living room with door leading to the garden
- His favorite place is in front of the window because of the view to the garden and the light that enters through the window.

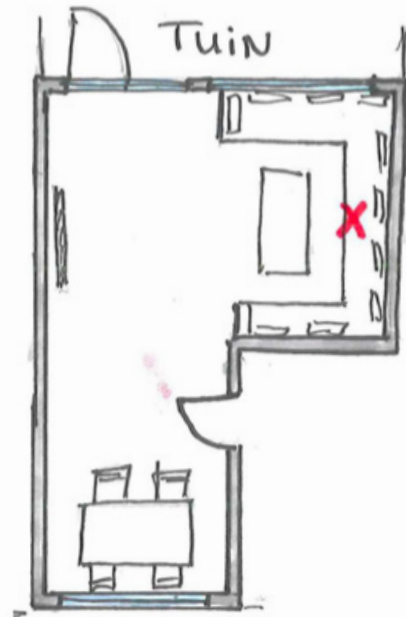


Figure 61. Plan 10 seen in questionnaire 10 appendix A.3.10

- Female, 65-69 years old
- Terraced house
- Ground floor
- Living room with door leading to the garden
- Her favorite place in front of the television screen.

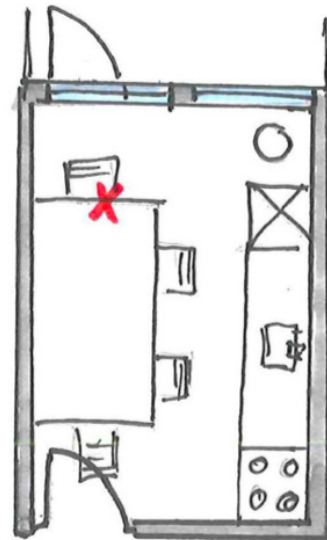


Figure 62. Plan 11 seen in questionnaire 11 appendix A.3.11

- Female, 60-64 years old
- Terraced house
- Second floor
- Kitchen with door leading to the balcony
- Her favorite place is next to the door of the balcony. This is because of the the light entering the room at that corner. In summer and spring, the door is opened and she likes to sit in the early morning sun.

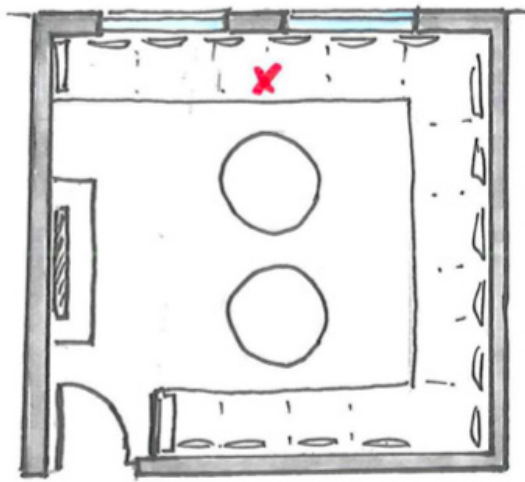


Figure 63. Plan 12 seen in questionnaire 12 appendix A.3.12

- Female, 70-74 years old
- Gallery house
- Second floor
- Living room
- Although she lives alone, her living room is full with seats because her children often come over with her grandchildren.
- Her favorite place is in front of the window. This is because it is next to the heater.

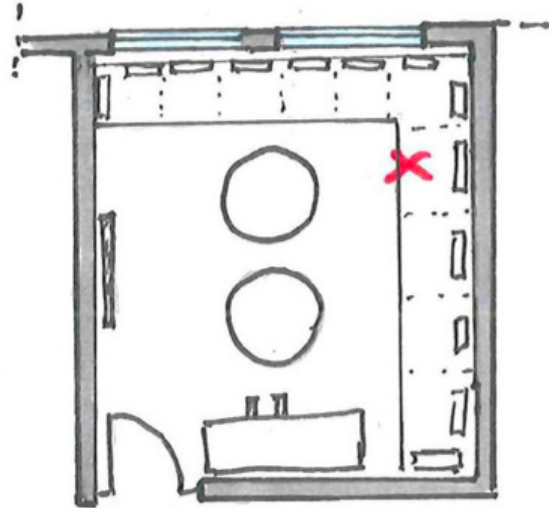


Figure 65. Plan 14 seen in questionnaire 14 appendix A.3.14

- Female, 65-69 years old
- Gallery building
- Second floor
- Living room
- Her favorite place is in the corner of the sofa. She likes the place because she has an overview of the room and can see who comes in and out of the room. In summer, the window is opened to let in air.

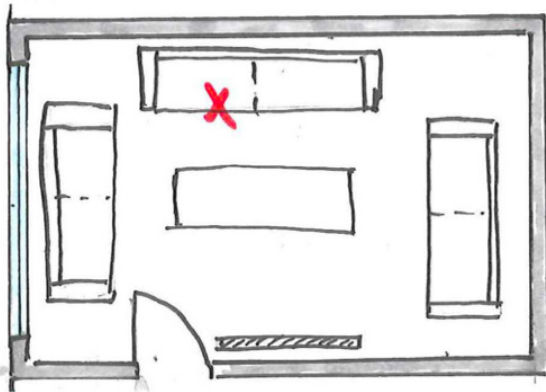


Figure 64. Plan 13 seen in questionnaire 13 appendix A.3.13

- Female, 65-69 years old
- Apartment complex
- First floor
- Living room
- Her favorite place is on front of the television. Because of her difficulties walking, her daughter takes care of her and she spends most of her time watching television or reading the Koran.

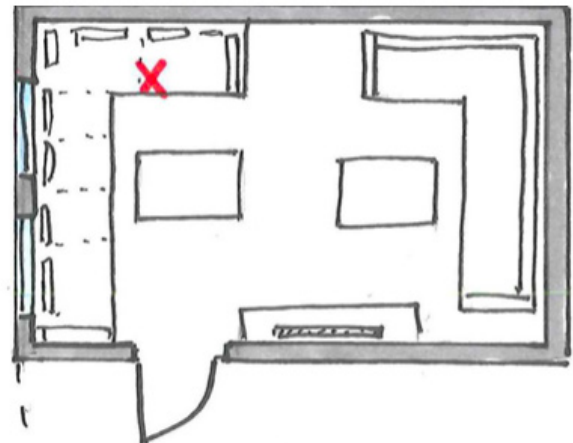


Figure 66. Plan 15 seen in questionnaire 15 appendix A.3.15

- Female, 60-64 years old.
- Terraced house
- Ground floor
- Living room
- Her favorite place is near the window because she likes to look through the window and watch people walk by. She also prefers that seat more than the other, because it is darker in the other side of the room where there are no windows.

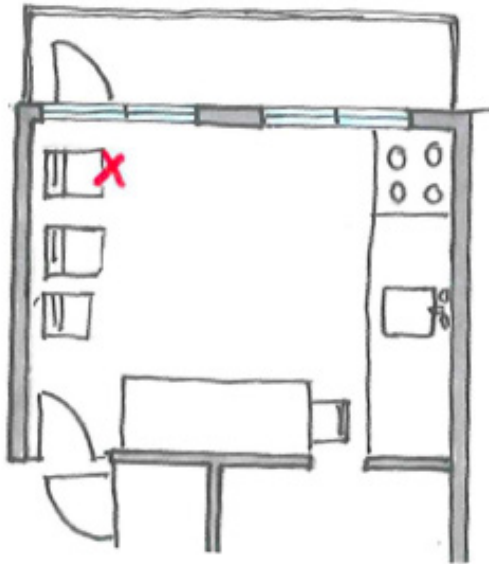


Figure 67. Plan 16 seen in questionnaire 16 appendix A.3.16

- Female, 60-64 years old
- Apartment complex
- First floor
- Kitchen with door leading to the balcony
- The woman likes to have breakfast next to the door of the balcony. There is no curtain in front of the door and in summer, she likes to open the door to get fresh air into the kitchen and sit next to the open door.

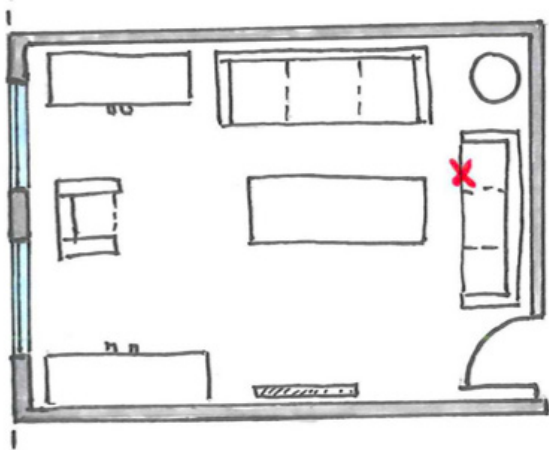


Figure 68. Plan 17 seen in questionnaire 17 appendix A.3.17

- Female, 60-64 years old.
- Apartment complex
- Third floor
- Living room
- Her favorite place is the corner of the sofa. She could not provide any reasons as to why it is her favorite place.

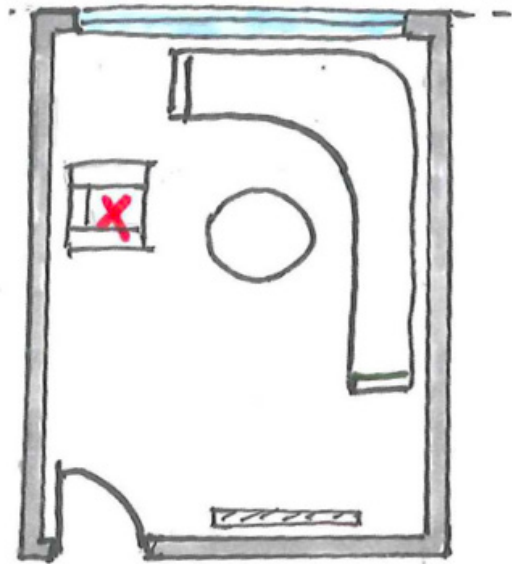


Figure 69. Plan 18 seen in questionnaire 18 appendix A.3.18

- Female, 75+ years old
- Apartment complex
- Ground floor
- Living room
- Her favorite place is the single seat, because it is comfortable to sit in.

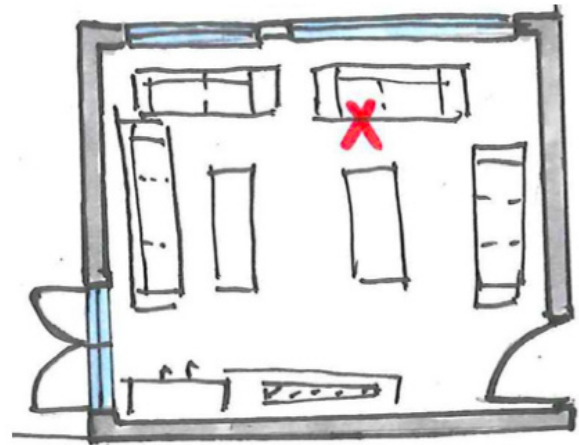


Figure 70. Plan 19 seen in questionnaire 19 appendix A.3.19

- Female, 75+ years old
- Corner of an apartment complex
- Ground floor
- Living room with door leading to the garden
- Her favorite place is in front of the window, because it is near the heater. Furthermore, it is in front of the television.

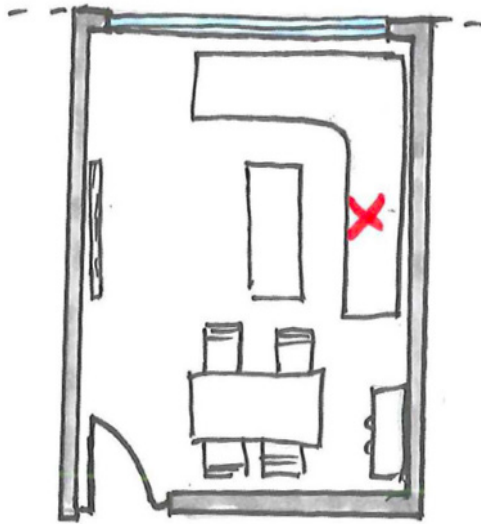


Figure 71. Plan 20 seen in questionnaire 20 appendix A.3.20

- Female, 65-69 years old
- Apartment complex
- Fourth floor
- Living room
- Her favorite place is on the sofa, in front of the television. Although there is a dining table in the room, she does not like its position at the back of the room, and prefers to have her dinner on the sofa.

5.5.1.2 Turkish elderly men and woman

Plans showing the favorite places of the Turkish men interviewed.

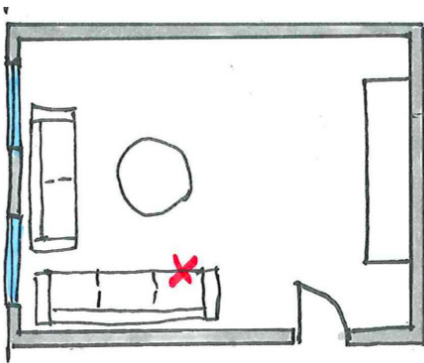


Figure 72. Plan 21 seen in questionnaire 21 appendix A.3.21

- Male, 60-64 years old
- Terraced house
- Ground floor
- Living room
- His favorite place is in front of the television and next to the door. He likes to sit at the corner of the sofa and have a view of everyone when they come to visit and sit with him.

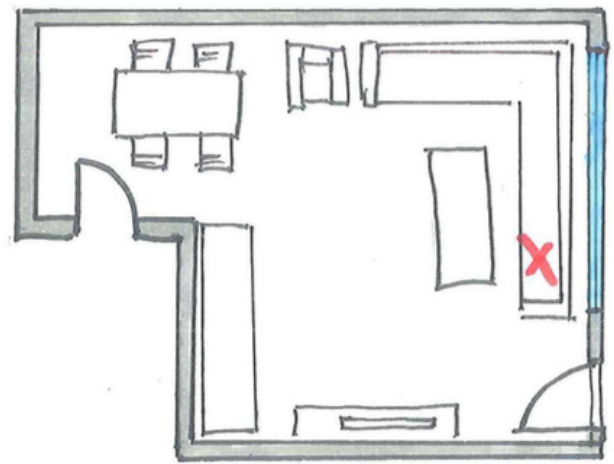


Figure 73. Plan 22 seen in questionnaire 22 appendix A.3.22

- Male, 65-69 years old
- Terraced house
- Ground floor
- Living room with the door to enter the house.
- His favorite place is in front of the window and next to the entry door. This is because he feels too warm in the house. When people walk in through the door, he feels the fresh air. In summer, the door is open most of the time.

Plans showing the favorite places of the Turkish women interviewed.

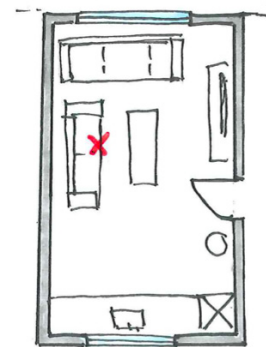


Figure 74. Plan 23 seen in questionnaire 23 appendix A.3.23

- Female, 75+ years old
- Terraced house
- Ground floor
- Living room and kitchen
- Her favourite place is in front of the door because she is close to the kitchen and it takes less effort to walk to it.

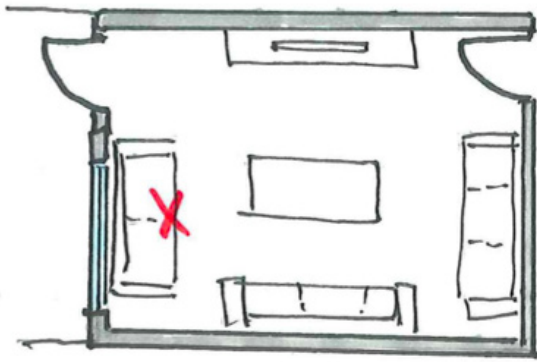


Figure 75. Plan 24 seen in questionnaire 24 appendix A.3.24

- Female, 75+ years old
- Terraced house
- Ground floor
- Living room of the house
- Her favorite place is near the door to the garden. This is especially so in summer.

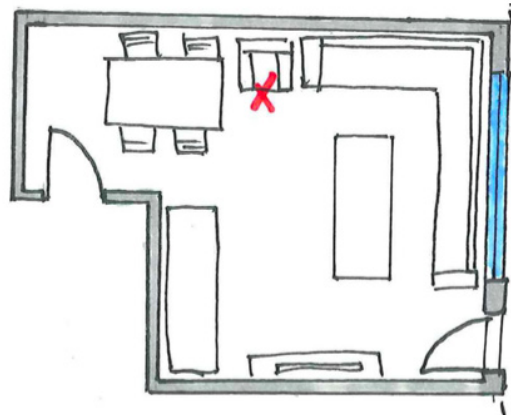


Figure 77. Plan 26 seen in questionnaire 26 appendix A.3.26

- Female, 65-69 years old
- Terraced house
- Ground floor
- Living room with door to enter the house
- Her favorite place is in the corner, far from the entry door. She feels that it is colder near the door.

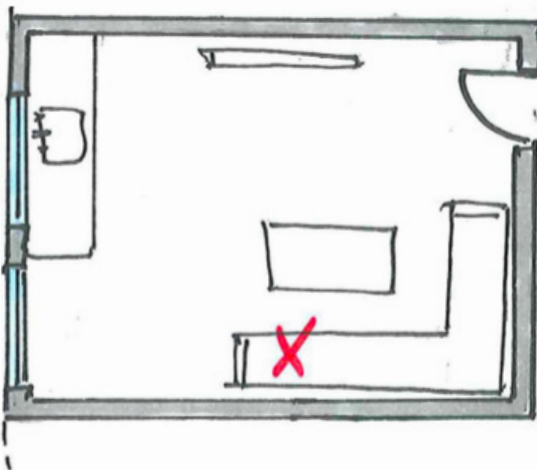


Figure 76. Plan 25 seen in questionnaire 25 appendix A.3.25

- Female, 65-69 years old
- Apartment complex
- First floor
- Living room and kitchen
- Her favorite place is in front of the television. Additionally, it is close to the kitchen so it takes less effort to reach the kitchen.

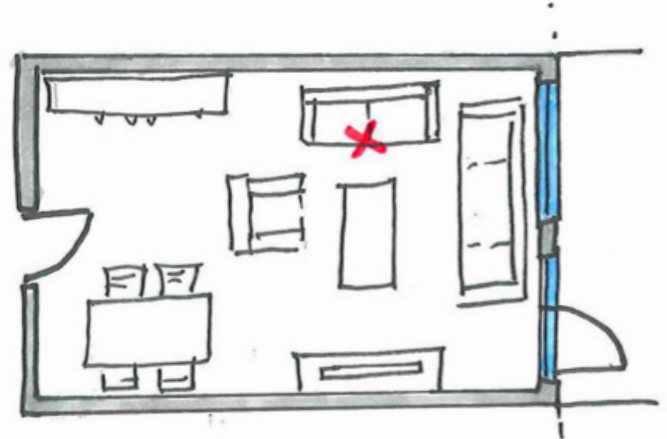


Figure 78. Plan 27 seen in questionnaire 27 appendix A.3.27

- Female, 70-74 years old
- Terraced house
- Ground floor
- Living room with door leading to garden
- Her favorite place is near the window but she also wants to watch television comfortably. When the family is over, she sits in front of the window, as the television is turned off.

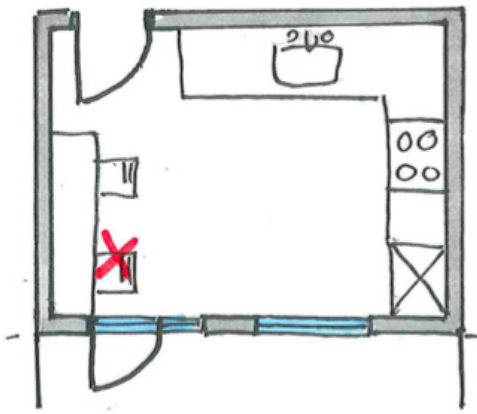


Figure 79. Plan 28 seen in questionnaire 28 appendix A.3.28

- Female, 60-64 years old
- Terraced house
- Ground floor
- Kitchen
- Her favorite place is near the door to the garden because she likes to look through the glass door. In summer, the door is opened to let fresh air into the room. She likes to have breakfast early in the morning while listening to the birds.

5.4.1.3 Surinamese elderly men and women

Plans showing the favorite places of the Surinamese men interviewed.

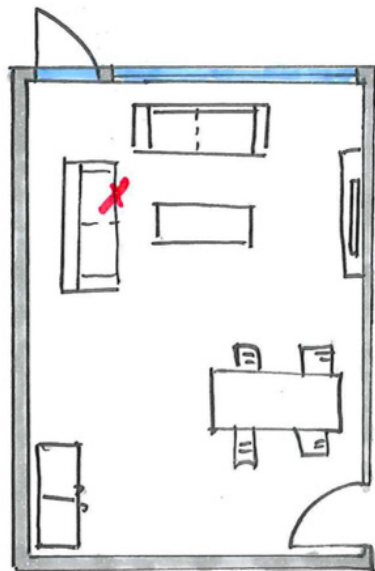


Figure 80. Plan 29 seen in questionnaire 29 appendix A.3.29

- Male, 65-69 years old
- Terraced house
- Ground floor
- Living room
- His favorite place is near the window and the door leading to the garden. The seat is also in front of the heater

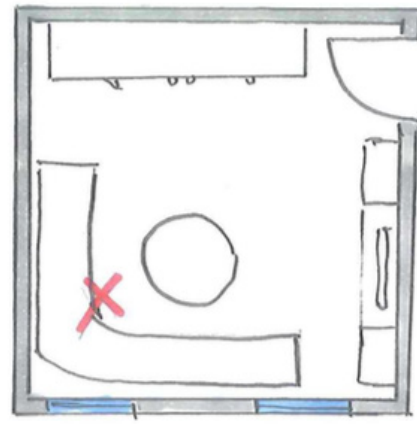


Figure 81. Plan 30 seen in questionnaire 30 appendix A.3.30

- Female, 60-64 years old
- Gallery house
- First floor
- Livingroom
- Her favorite place is in front of the television

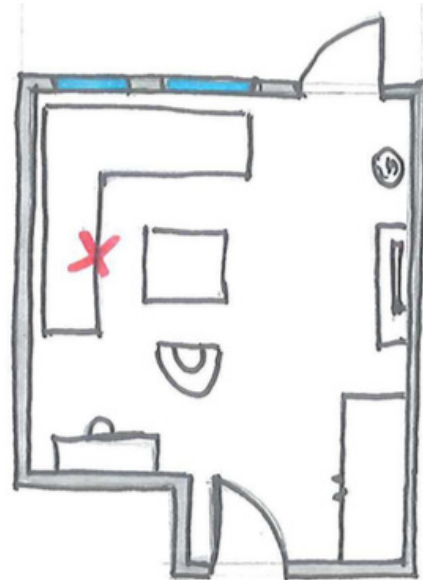


Figure 82. Plan 31 seen in questionnaire 31 appendix A.3.31

- Female, 60-64 years old
- Appartement
- first floor
- Livingroom
- Her favorite place is in front of the television

5.4.1.4 Native elderly men and women

Plans showing the favorite places of the Native men interviewed.

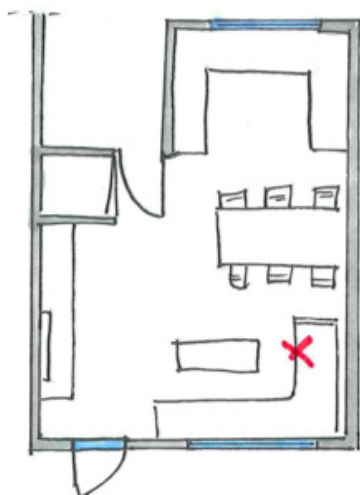


Figure 83. Plan 32 seen in questionnaire 32 appendix A.3.32

- Male, 60-64 years old
- Terraced house in the corner
- Ground floor
- Living room and kitchen with door leading to the garden.
- His favorite place is in the corner of the sofa. It is near the kitchen and he can comfortably watch football on the television.

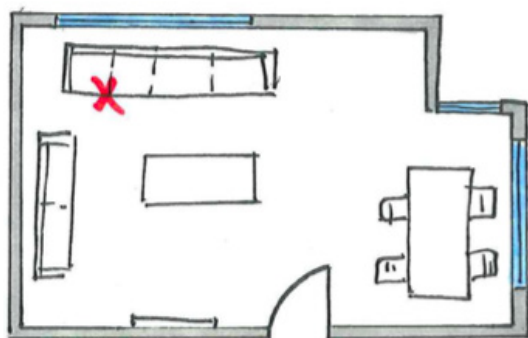


Figure 84. Plan 33 seen in questionnaire 33 appendix A.3.33

- Male, 60-64 years old
- Terraced house
- Ground floor
- Living room
- His favorite place is in the corner room, in front of the television. The window behind the seat also lets in the most light into the room.

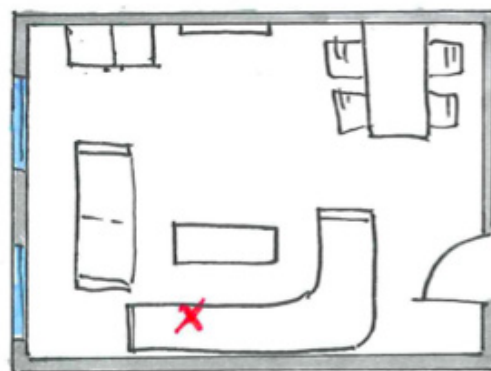


Figure 85. Plan 34 seen in questionnaire 34 appendix A.3.34

- Male, 60-64 years old
- Terraced house
- Ground floor
- Living room
- His favorite place is in front of the television, from where he also has a view of the garden.

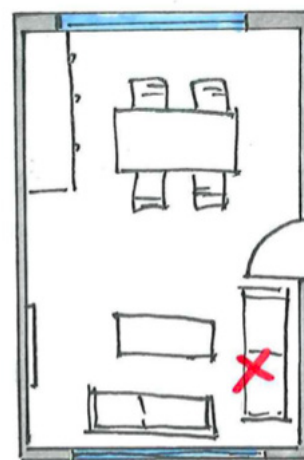


Figure 86. Plan 35 seen in questionnaire 35 appendix A.3.35

- Male, 60-64 years old
- Terraced house
- Ground floor
- Living room
- His favorite place is in front of the television, from where he also has a view of the garden.
- Male, 75+ years old
- Detached house
- Ground floor
- Living room
- In winter, his favorite place is in front of the window. However, in summer, he like to be outside in the garden.

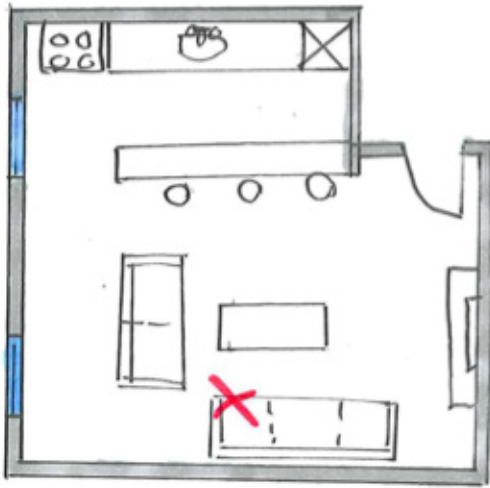


Figure 87. Plan 36 seen in questionnaire 36 appendix A.2.36

- Male, 65-69 years old
- Apartment complex
- First floor
- Living room
- His favorite place is in the corner of the sofa, from where he has a view of the kitchen. In this way, he can talk to his wife while she is cooking.

Plans with the favorite place for the Native woman



Figure 88. Plan 37 seen in questionnaire 37 appendix A.2.37

- Female, 75+ years old
- Apartment complex
- Ground floor
- Living room and kitchen
- Her favorite place is in front of the window where there is the most light. She finds the kitchen much darker.

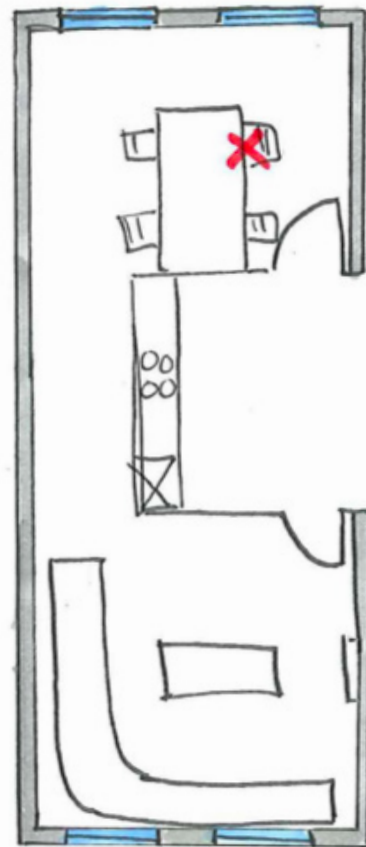


Figure 89. Plan 38 seen in questionnaire 38 appendix A.2.38

- Female, 60-64 years old
- Terraced house
- First floor
- Living room and kitchen
- Her favorite place is in the dining area This is because there is more light there and she likes to work on creative projects on the table.

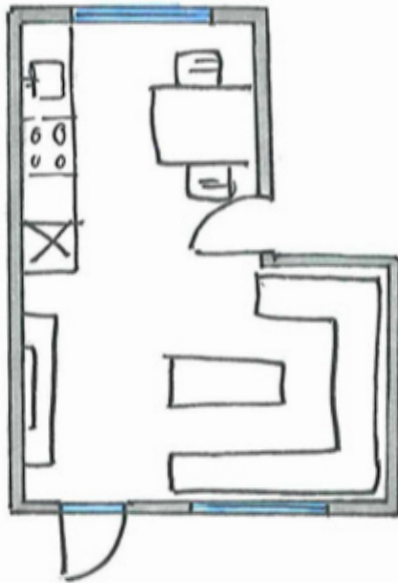


Figure 90. Plan 39 seen in questionnaire 39 appendix A.2.39

- Female, 70-74 years old
- Terraced house
- Ground floor
- Living room and kitchen
- Her favorite place is the dining table in the kitchen. She likes the light that comes into the kitchen more than the light that comes into the living room.

5.5 Conclusion on the questionnaire

In the conclusion, the sub-question that was introduced in the beginning of the chapter will be answered:

“What are the different standards for the thermal and visual comfort in different societies?”

This question will be answered in two parts. The first part will look at thermal comfort and the second part will look at visual comfort.

i. Thermal comfort

The ethnic groups analyzed were the Moroccans, the Turkish, the Natives and the Surinamese. The preferred temperatures of the elderly from the different ethnic groups were looked at. Since the questionnaires were taken in the respective homes of each elderly participant, they were taken in various locations around the Netherlands. During the period the questionnaire was taken, the average outside temperature across the different locations was 10,8°C. The questionnaires were all filled in the living rooms of the respective houses where

the elderly participants lived and the temperature of the rooms were also recorded. It was found that the average temperature across the various living rooms was 20°C. The Moroccan and Turkish participants had living room temperatures that were 1°C above the average. The Native and Surinamese participants had living room temperatures that were 1°C below the average temperature. The Moroccan, Turkish and Surinamese participants all preferred a temperature of 22°C, 2°C above the average.

On the other hand, the Native participants found their living room temperatures too high and preferred a temperature of 18°C, 2°C below the average. The participants were also asked to rank their thermal comfort on a scale ranging from 1 to 7. Across all the ethnic groups, the men were more thermally comfortable in comparison to the women. The scale was the most spread out amongst the Moroccan participants, and the least spread out amongst the participants from the Native group.

	Most comfortable			Average temp. inside		Average temp. prefer
Native	6/8	75%	→	19°C	→	18°C ↓
Moroccan	12/21	57%	→	21°C	→	22°C ↑
Turkish	4/8	50%	→	21°C	→	22°C ↑
Surinamese	1/3	0,33%	→	19°C	→	22°C ↑

Figure 91. Conclusion of what the elderly prefer as temperature .

Hence, the Moroccan, Turkish and Surinamese elderly participants preferred a higher temperature, as illustrated in figure X. One reason could be that they are used to the higher temperatures of their home towns. Another reason could be that the Native participants are more active, since they engage in sports twice as often as participants from the other ethnic groups. However, this is something that might change in the future, as the offspring of the Moroccan, Turkish and Surinamese immigrants have grown up in the Netherlands, where they are used to lower temperatures and a sporting culture. The questionnaire also looked to how often the elderly participants go outside. The results showed that a few of the participants only spent 0-4 hours outside, in a week. These participants were Turkish and Moroccan women. A reason for this could be prevailing cultural norms from their home countries, where women are encouraged to stay indoors. However, this is also something that will

possibly change in future generations that grew up in the Netherlands, with different cultural norms and standards of education.

The questionnaire also looked at what the elderly participants chose to wear at home. The Turkish, Surinamese and Moroccan women mostly chose package 3, which includes a headscarf. They chose to wear one even when it was not mandatory, as it helped them feel more thermally comfortable. Most of the native women and most of the male participants chose package 2, which included clothing that covered the entire body. Hence, it can be said that most the elderly participants preferred to be well covered. As the results across all the groups are similar, with differences found only in the results of a single person, it is difficult to draw definite conclusions from the results.

The questionnaire also looked at where the elderly participants were able to regulate their thermal comfort by themselves. The results showed that most of them were able to do so. In winter, the participants would increase the amount of clothing, close the windows and use mechanical heating. Conversely, in summer, participants would reduce the amount of clothing, open the windows, and use mechanical cooling when necessary. Amongst the participants, the Native participants have a greater preference for reducing the amount of clothing in order to moderate their thermal comfort levels in summer. The lower preference amongst the other participants might have to do with their Islamic background, where they are encouraged to wear clothing that covers the body more fully.

ii. Visual comfort

The questionnaire also looked at the visual comfort in the rooms the elderly participants spent the most time in every day. Most of the participants spend most of their time in the living room, some spent the most time in the kitchen and all of them spent the least amount of time in the bathroom and the shower. The preference for the living room could be because of the amount of natural light entering the room, and also because the room facilitates a large range of activities. Sketch plans were drawn showing the favorite place of each elderly participant, in order to better understand the similarities and differences between them.

The plans showed that the Moroccan elderly preferred to sit near the window and in front of the television. Hence, they chose a place that would allow for both. The preferred place would sometimes change between summer and winter. This had to do with thermal comfort. On warmer days, the preference was to sit near openings, where the wind could cool one down. Some of the Moroccan women preferred to sit in the kitchen, instead of the living room. Their preference was still for places that received the most daylight. In cases where there was no access to the television, they liked to sit near the opening to a balcony or garden, if this was an option. The male and female participants from the other ethnic groups preferred to sit near the window and in front of the television. Hence, when it comes to visual comfort, the difference in behavior does not vary much between the different ethnic groups. The elderly participants from the different groups all preferred a room which has a lot of natural light entering it.

These findings on thermal and visual comfort help to better define the differences and similarities in thermal and visual comfort requirements between elderly people of different ethnicities. This information is necessary in order to arrive at a design which is able to be thermally and visually comfortable to elderly occupants of various different ethnic backgrounds.

Chapter 6

Measurement and results

For the design of the facade, it is important to understand, through the use of detailed measurements, how much daylight already gets into their homes, and whether it is enough for their daily activities. These activities differ between the elderly interviewed. For example, some of the elderly read books, watch television or cook, while others sit with their families. With the results of the theoretical part of how much daylight the elderly needs and the results of the measurement and the results of the favorite places which is discussed in chapter 5.5.1.1 a conclusion can be drawn. At the end of the chapter, there will be a conclusion that will aim to answer the following question: “To what extent do the elderly feel visually comfortable in their existing homes?” and “To what extent do the elderly feel thermally comfortable in their existing homes?”

6.1 Measurement for thermal comfort

The thermal comfort of six different rooms will also be measured. The rooms that will be measured are the plans of figure 52, 55, 56, 57, and 71. This will be also the same rooms in which where the measurement of the visual comfort took place. However, the thermal comfort measurement will be taken at different time and day of from the visual comfort measurement. Measurements will be taken with the i-button shown in figure 91. This i-button will be placed in the rooms for five days. The rooms where be measured from 27 December 2017 till 1 January 2018. After a few days the results captured by the i-button will be read using the program Maxim's 1-Wire. These results will be analyzed and compared with the results obtained from the questionnaire.



Figure 92. i-button

6.1.1 Outside temperature from 27 December 2017 till 1 January 2018

The average, maximal and minimal temperatures as measured by the Koninklijke Nederlandse Meteorologisch Instituut (KNMI) are plotted in figure 92, where the y-axis shows the temperature in degrees Celsius and the x-axis shows the dates. From this data, we can see that the average outside temperature in this period was approximately 6,3 °C.

6.2 Results for thermal comfort

The average maximal and minimal temperatures, as measured by the i-buttons, are plotted in figure 93, where the y-axis shows the temperature in degrees Celsius and the x-axis shows the time. Table 12 shows which figure refers to.

Figure	Room
52	6
57	1
56	3
71	5
55	4

Table 12. Figure refers to room.

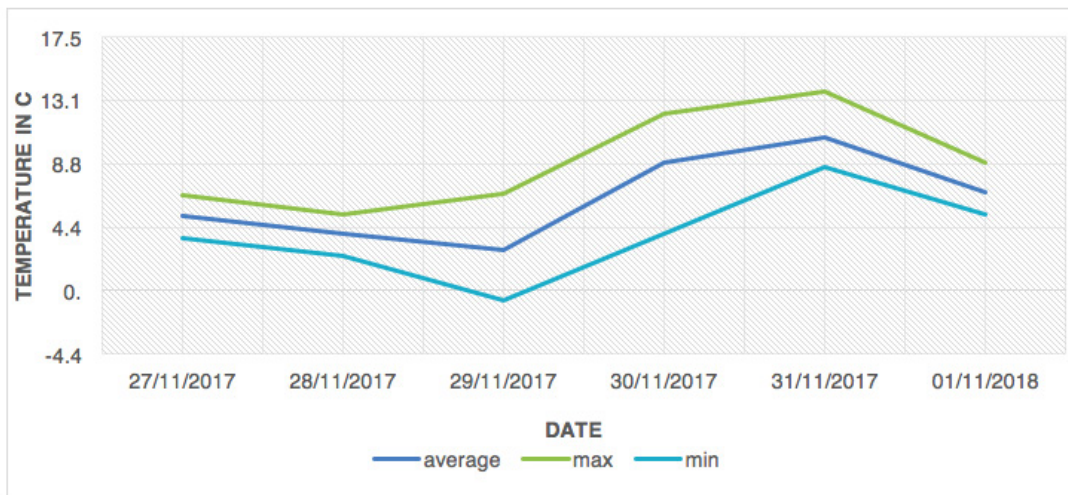


Figure 93. Weather data from the KNMI between 27 December 2017 till 1 January 2018.

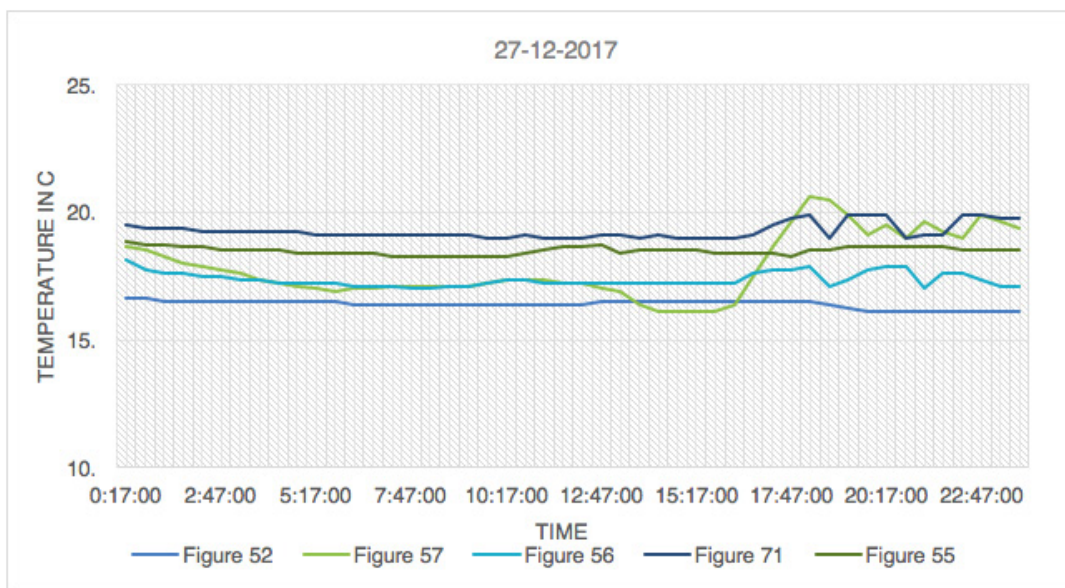


Figure 94. Graph thermal results of the measurement on 27 December 2017.

Figure 95. Graph thermal results of the measurement on 28 December 2017

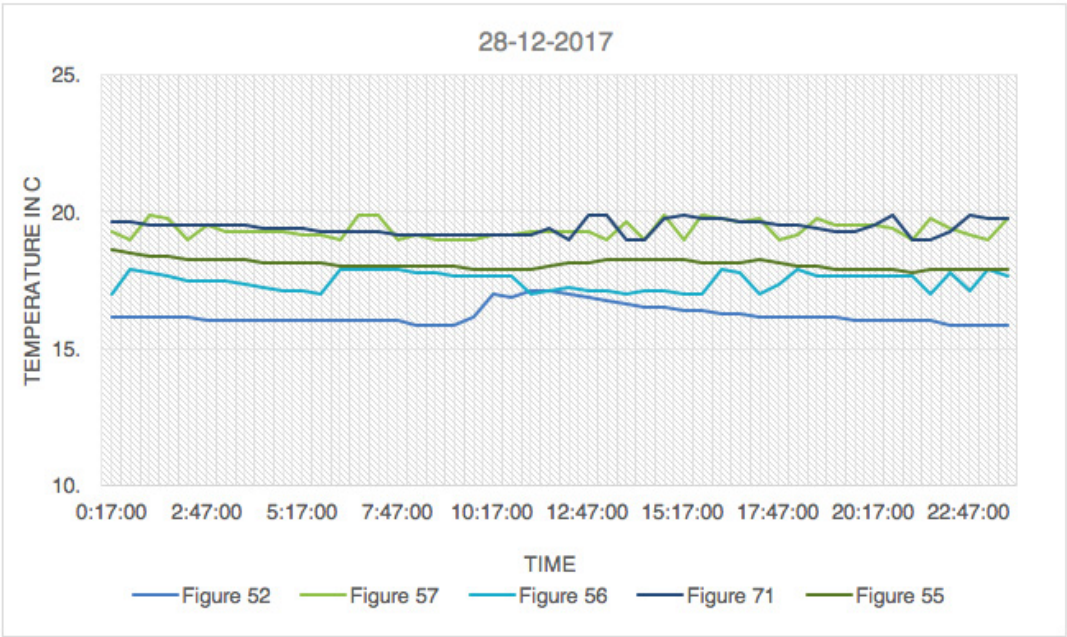


Figure 96. Graph thermal results of the measurement on 29 December 2017

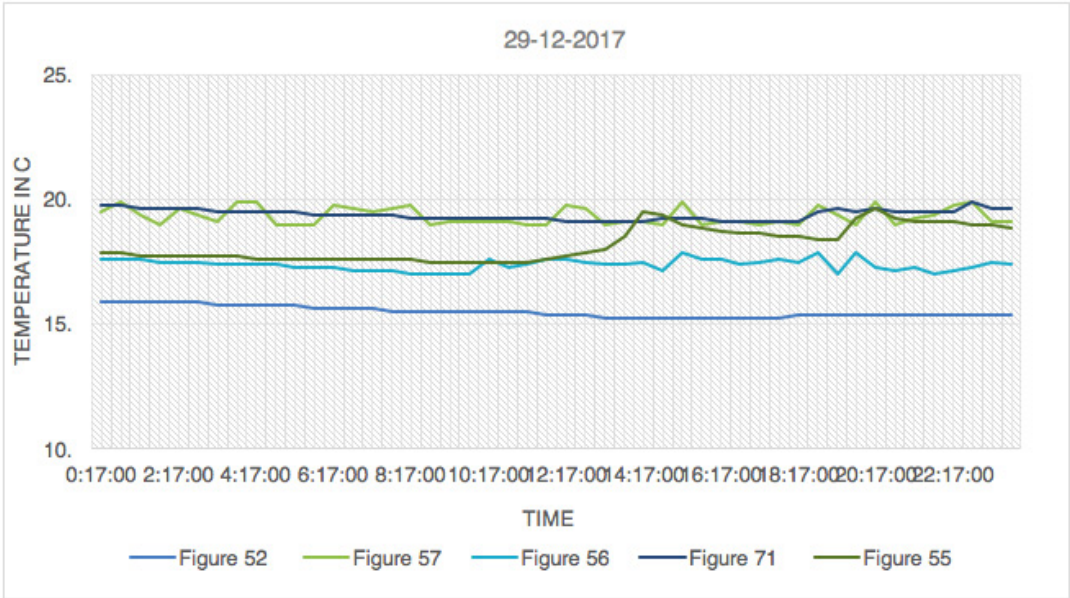


Figure 97. Graph thermal results of the measurement on 30 December 2017

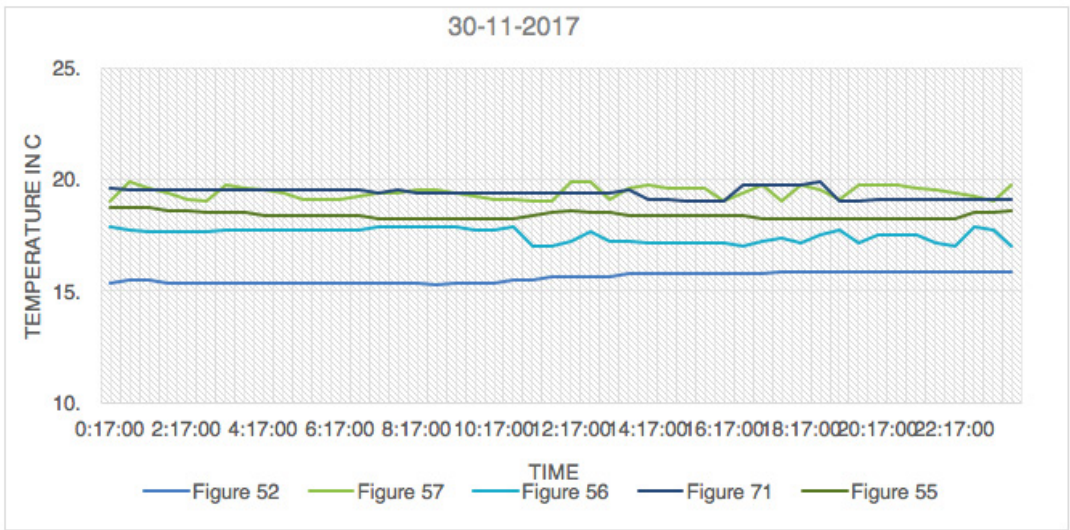


Figure 98. Graph thermal results of the measurement on 31 December 2017

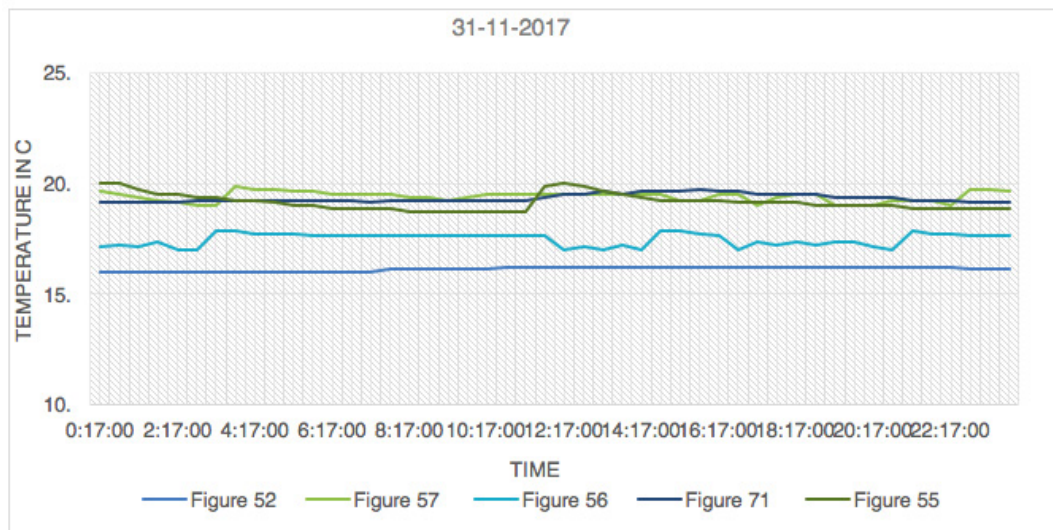


Figure 99. Graph thermal results of the measurement on 1 January 2018

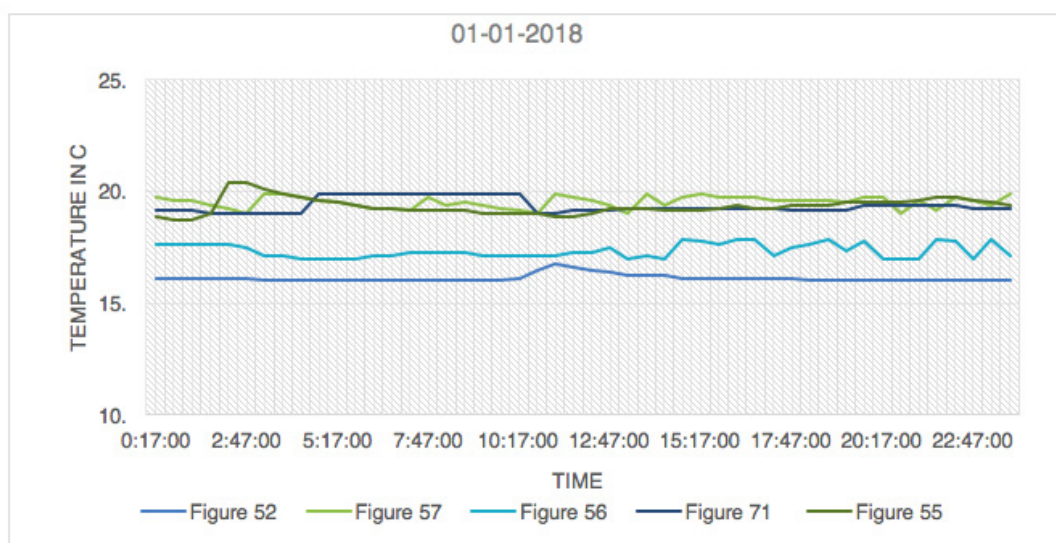
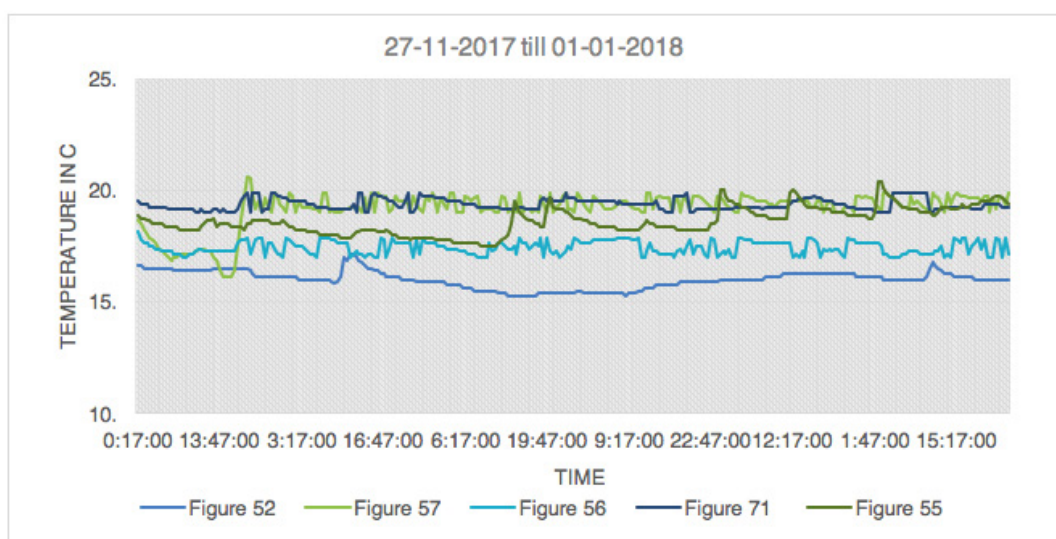


Figure 100. Graph thermal results of the measurement from 27 December 2017 till 1 January 2018



6.3 Measurement for visual comfort

In order to have accurate data, the time and weather at the time of the measurement will be recorded and considered in the analysis of the data. This information is recorded in table 13 below.

6.3.1 Horizontal measurement

For the measurements of visual comfort, the horizontal and vertical illumination intensity will be measured. The horizontal measurements will be taken first. For this measurement, the activities of the elderly will be analyzed. This will be taken at eye level. The answers to the questionnaires show that the elderly mostly sit with their families or read books. One set of horizontal measurements will be taken at the places where the elderly sit for the longest periods of time, and another set will be taken from the places they never sit in. There will be also a measurement with the lamp switch on. Measurements will be taken with the lux meter of the Konica Minolta T-10 which is shown in figure 101. Before beginning the measurements, the size of the room, the windows and other openings in the room will be measured and drawn.



Figure 101. Konica Minolta T-10

6.3.2 Vertical measurement

The vertical measurements will be taken at eye level and the illumination will be recorded. The results will be analyzed together with the data on how many hours the elderly spent outside in a week.

The daylight factor is the ratio of illumination intensity at a point inside the room, divided by the total daylight which comes through the façade. In equation it will be:

Room	Date	Time	Weather
Nr.1	15/11/2017	12:30h	• Clear sky • No rain
Nr.2	15/11/2017	13:05h	• Clear sky • No rain
Nr.3	16/11/2017	11:10h	• Clear sky • No rain
Nr.4	17/11/2017	12:05h	• Clear sky • No rain
Nr.5	23/11/2017	12:03h	• Clear sky • Strong wind
Nr.6	25/11/2017	12:30h	• Cloudy • Drizzling rain

Table 13. measurement of the room with time and weather.

$$\text{Daylight level} = \frac{\text{Illuminance inside}}{\text{Illuminance in free field}} \times 100\%$$

The Konica Minolta T-10 will be used in the measurement of the amount of daylight entering through the facade. This device will be stuck onto the window at a height of 85cm. For each point, the illuminance outside will be measured at the same time as the illumination intensity inside. The illuminance in free field in the Netherlands varies from 10.000 lux in December and 30.000 lux in July (Melet, 2006).

Results of the daylight level reveal information on the quality of the daylight entering a space. Table 14 shows what the different values of daylight level indicate.

6.4 Results of the visual measurement in the rooms

The following measurements were taken in different rooms and each house will be analyzed separately. It will be explained what kind of house the measured room is situated in. To explain clearly the volume of each room, the dimensioned plan will be shown alongside the dimensioned section. Furthermore, all the plans and dimensions consists of a measurement grid. During measurement, these points were marked with pieces of tape. Hence,

that the measurement with the lamp switch off and switch on are at the same places.

6.4.1 Results of room number 1

The first house is an apartment unit located in a building along a side street that has branched off a heavily trafficked main street. This side street is mostly lined with apartments blocks no taller than four floors high. Along this street, in front of the apartment blocks are a few trees with heights that do not go past the first floor of the apartment blocks. At the time of measurement, most of the leaves are fallen off these trees. The elderly participants live with their three children in an apartment on the first floor. Unique to this house is that the measurement of two rooms were taken. This is because the elderly couple had different favorite places in their home.

The living room is located at the eastern side of the apartment. The living room is 4 meter by 7 meter rectangle with a height of 2,5 meter. Figure 102 shows the plan of this room. Both windows had thin white lace curtains drawn over them at the time of measurement. Figure 103 shows the section of the room. As shown in the section, the window starts 0.7m above the floor and has a height of 2,1m. However, the ceiling overlaps the top of the window by 300mm. In the niche this overlap makes in front of the window, is space for the installation of the curtain rod.

Daylight level (DL)	Quality of the daylight
DL > 5%	Abundant daylight
3% < DL < 5%	Good daylight
2% < DL < 3%	Rational daylight
1% < DL < 2%	On the gloomy side
DL < 1%	Too little for a living space

Table 14. Daylight levels retrivied from <http://daglichtontwerp.nl/daglichtfactor/>

Figure 102. Plan room 1.

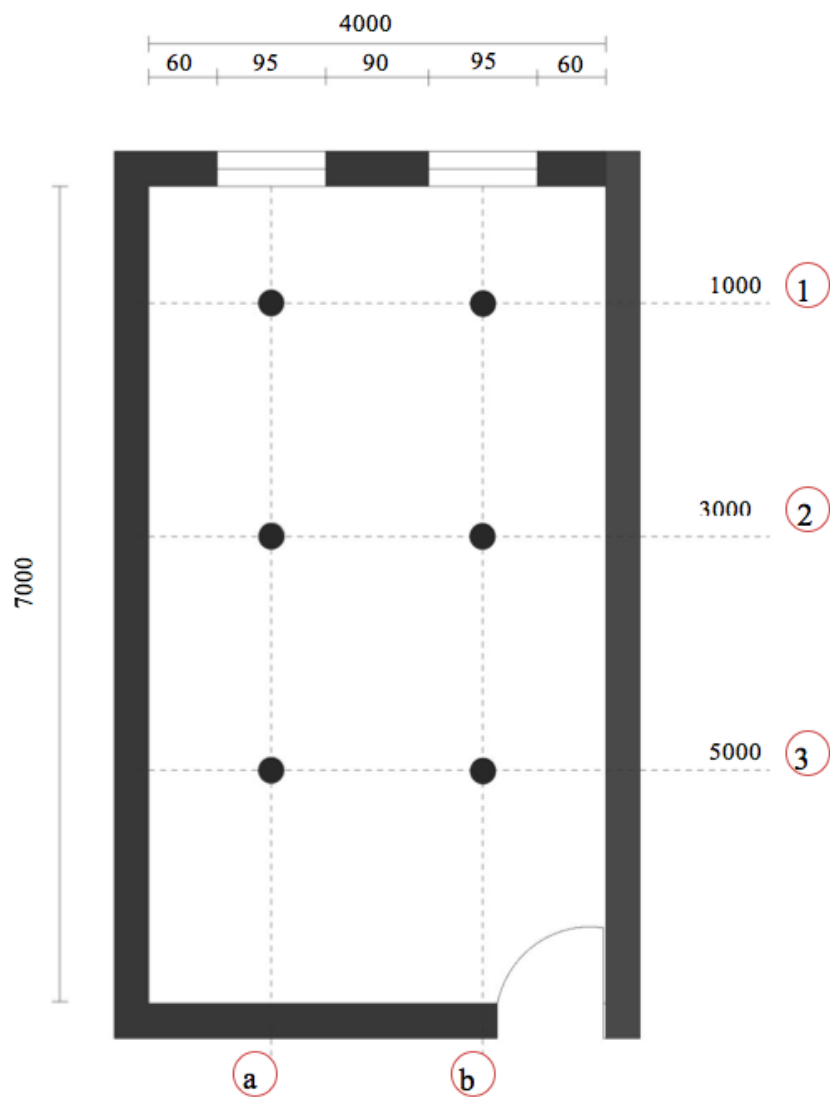
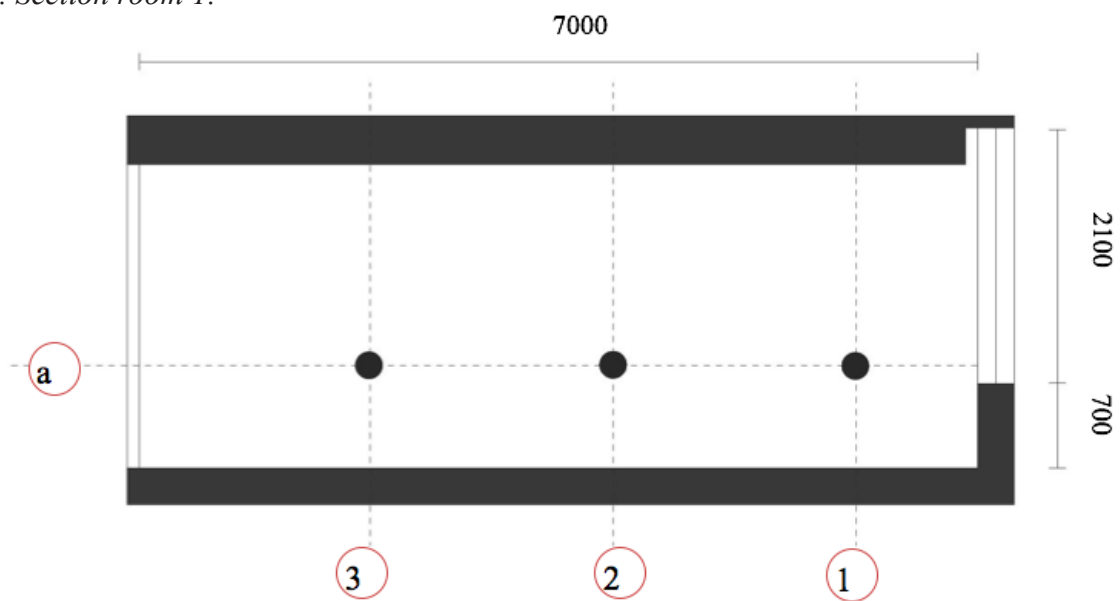


Figure 103. Section room 1.



Results of the horizontal measurements of room number 1 are plotted in table 15. The room contained two halogen lamps. One of the lamps hung approximately 1 meter from the window and the other hung 5 meters from the window. When taking the set of measurements with the lamps turned on, both of the lamps were turned on.

For the vertical measurements, the daylight level for each point in the room is measured. These results will be compared with the results in table 14 and the answers to the questionnaires in order to understand the quality of the daylight which enters the room through the windows.

Lamp off				Lamp on			
<i>Points</i>		<i>Grid (lux)</i>	<i>Daylight (lux)</i>	<i>Points</i>		<i>Grid (lux)</i>	<i>Daylight (lux)</i>
1	a	77,1	982	1	a	97,2	1140
	b	94,4	1066		b	164,9	1061
2	a	44,1	1047	2	a	65,2	1062
	b	54,8	1148		b	65,0	1080
3	a	16,9	1053	3	a	42,5	1026
	b	18,9	1359		b	40,0	1105

Table 15. results of the horizontal measurements.

Lamp off			Lamp on		
<i>Points</i>		<i>Daylight level</i>	<i>Points</i>		<i>Daylight level</i>
1	a	0.9	1	a	0.9
	b	1		b	1.7
2	a	0.5	2	a	0.7
	b	0.5		b	0.7
3	a	0.2	3	a	0.4
	b	0.2		b	0.4

Table 16. Results of the daylight level.

6.4.2 Results of room number 2

The second room measured in the same house as room number 1. Room number 2 is the kitchen. While the previous room was on the eastern end of the house, the kitchen is located at the opposite western end of the house. The shape of the living room is almost a square with a size of 4 meters by 3 meters and a height of 2,5 meters. Figure 104

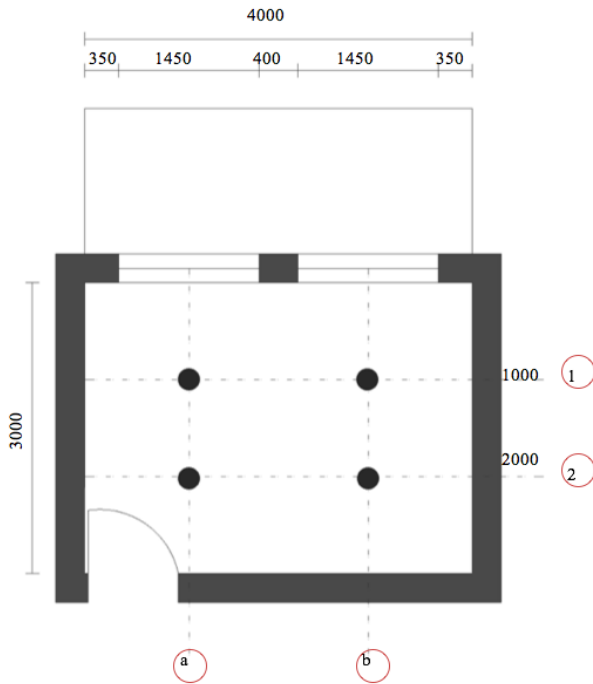


Figure 104. plan room 2

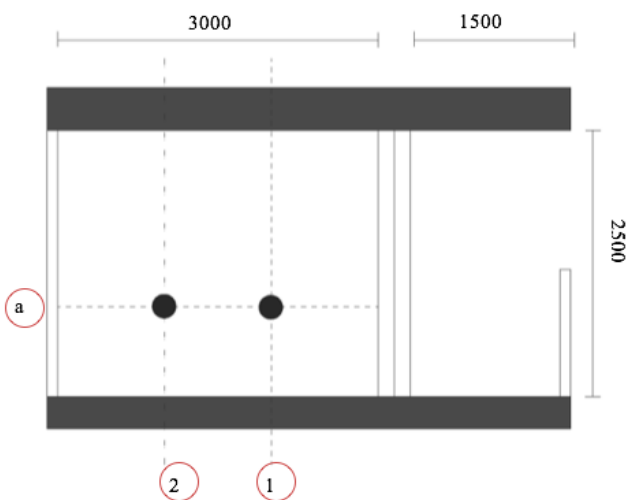


Figure 105. Section room 2 grid a

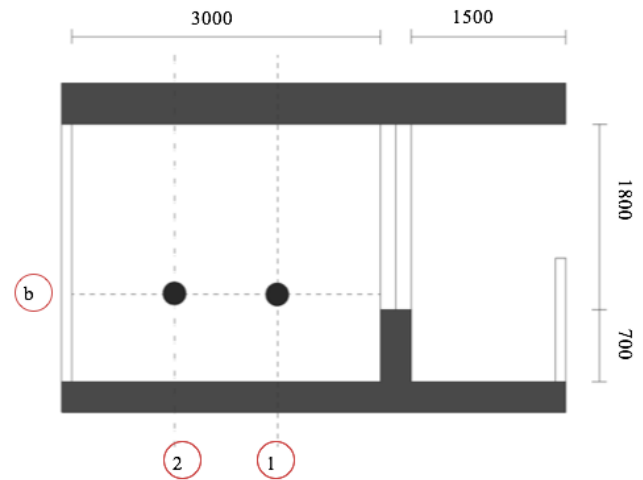


Figure 106. Section room 2 grid b

From the plan of the kitchen, it seems that the windows let in a generous amount of light into the room. However, the sections show that the windows are recessed into the facade. The overhang over the windows shade them and reduce the amount of light entering the kitchen. In addition, there is a tree directly in front of the windows, providing shade when the tree is full with leaves. During summer the tree ensure shade for cooling. Results from the measurements are recorded in table 17. The room contained one energy saving lamp. The lamp was placed 1,5 meter form the window. When taking the set of measurements with the lamps turned on, this single lamp was turned on.

For the vertical measurements, the daylight level for each point in the room is measured. These results will be compared with the results in table 14 and the answers to the questionnaires in order to understand the quality of the daylight which enters the room through the windows.

Lamp off				Lamp on			
<i>Points</i>		<i>Grid (lux)</i>	<i>Daylight (lux)</i>	<i>Points</i>		<i>Grid (lux)</i>	<i>Daylight (lux)</i>
1	a	121,5	535,6	1	a	238,9	480
	b	163,7	407		b	114,5	434
2	a	55,1	586,9	2	a	122,7	425
	b	81,9	437		b	127,5	448

Table 17. Results of the horizontal measurements.

Lamp off			Lamp on		
<i>Points</i>		<i>Daylight level</i>	<i>Points</i>		<i>Daylight level</i>
1	a	1.1	1	a	2.3
	b	2		b	1.2
2	a	0.5	2	a	1.3
	b	1		b	1.3

Table 18. results of the daylight level.

6.4.3 Results of room number 3

The third house is located on is two streets away from the heavily trafficked main street. The building is a row house. This building has a square in front of it. Children play at this square and the elderly sit there. The street the building is on has a number of trees with heights that reach the third floor or higher of the apartment blocks. At the time of measurement, most of the leaves had fallen off the trees. This elderly couple lives in a house with four children. The room measured was the living room located on the ground floor of the house.

of the house. The shape is almost a square, with a size of 4,5 meters by 5 meters, and a height of 2.7 meters. Figure 107 shows the plan of the living room. The room contains two windows and the main door which is used to enter the house. The other end of the living room holds the stairs that lead up to the second floor. The windows both had thin white lace curtains drawn over them at the time of measurement. The door is opaque and this means that daylight only enters the room through the windows. Figure 108 shows the section of the room. As shown in the section, the windows have heights of 2 meters.

The living room is located at the north-western side

Figure 107. Plan
room 3.

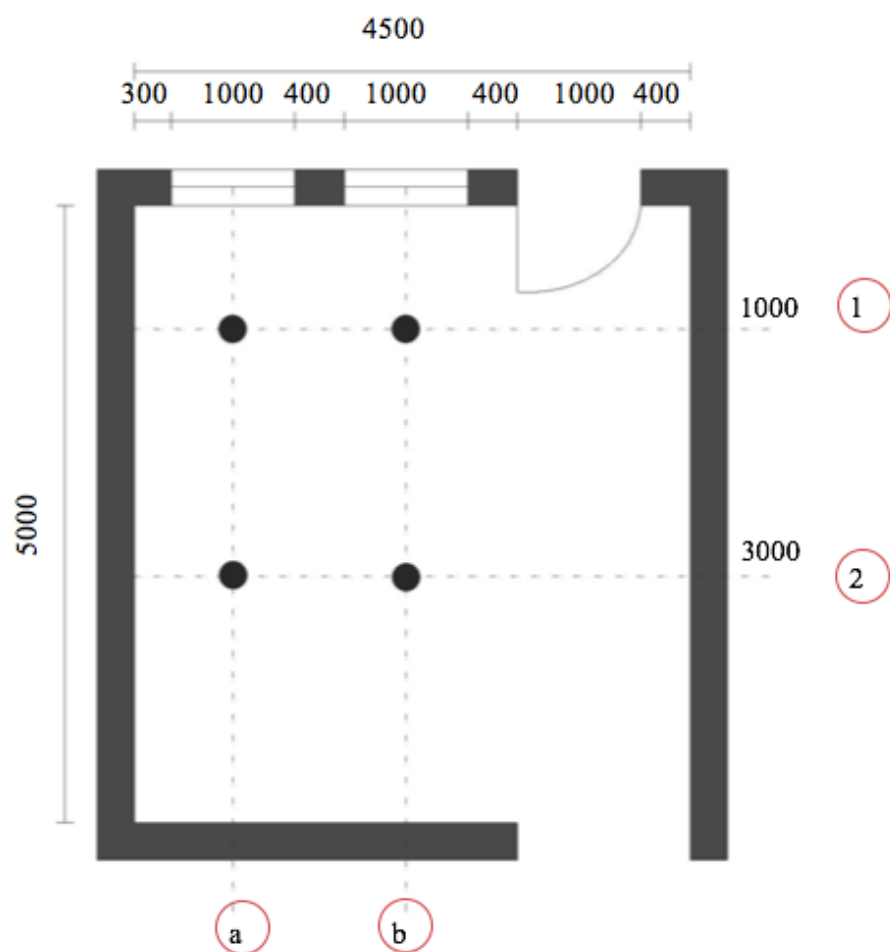
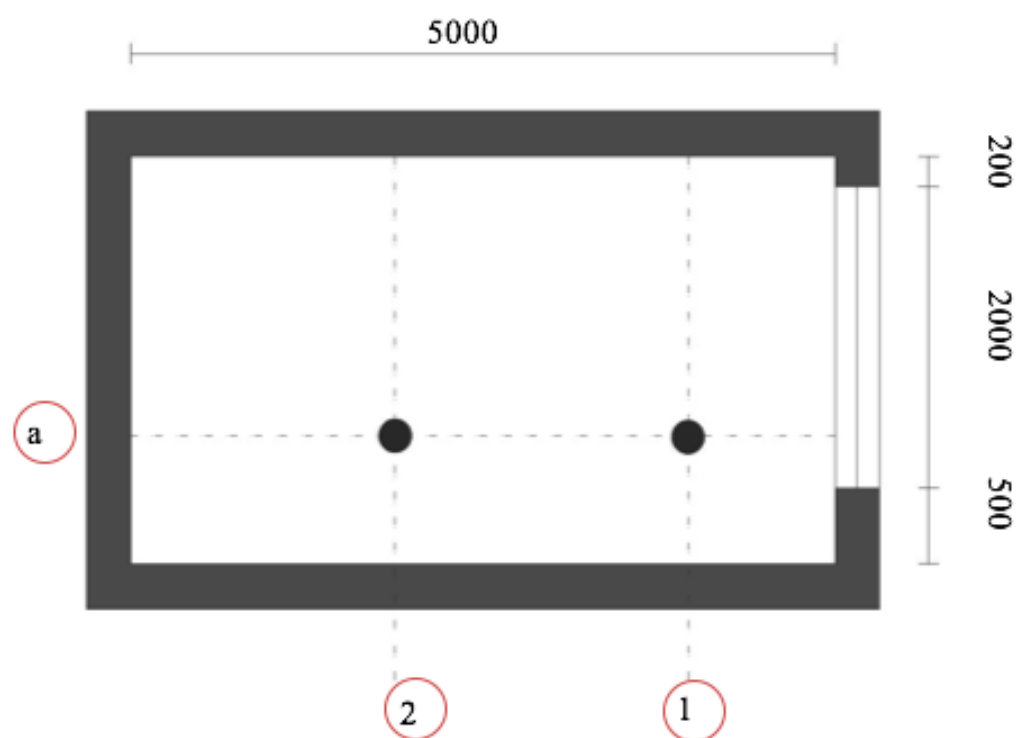


Figure 108. section
room 3.



For the vertical measurements, the daylight level for each point in the room is measured. These results will be compared with the results in table 14 and the answers to the questionnaires in order to understand the quality of the daylight which enters the room through the windows.

Lamp off				Lamp on			
<i>Points</i>		<i>Grid (lux)</i>	<i>Daylight (lux)</i>	<i>Points</i>		<i>Grid (lux)</i>	<i>Daylight (lux)</i>
1	a	28,5	364,9	1	a	53,1	391,8
	b	14,86	280,9		b	20,0	403,6
2	a	52,5	375,5	2	a	66,3	373,7
	b	15,02	374,9		b	30,2	461,8

Table 19. results of the horizontal measurement

Lamp off			Lamp on		
<i>Points</i>		<i>Daylight level</i>	<i>Points</i>		<i>Daylight level</i>
1	a	0.3	1	a	0.5
	b	0.2		b	0.2
2	a	0.5	2	a	0.6
	b	0.2		b	0.2

Table 20. Results of the daylight level

6.4.4 Results of room number 4

The fourth house is a four story gallery building located along a side street that has branched off a heavily trafficked main street. This side street has no trees. The elderly couple living there live with their two children on the third floor. In this house, the living room is measured. The living room is located at the north-western side of the house. The room is 6,6 meters by 4 meters with a height of 2,7 meters. Figure 109 shows the plan of the living room. The plan shows a balcony at the right hand

corner of the room. The room has three windows and one glass door which leads to the balcony. The windows and the door all have thin champagne colored lace curtains drawn over them at the time of measurement. Figure 110 shows that the window opening is 0,6m above the floor. The glass door is 1700 cm high. The room contained two blue LED lamps. When taking the set of measurements with the lamps turned on, both lamps were turned on.

Figure 109. plan
room 4

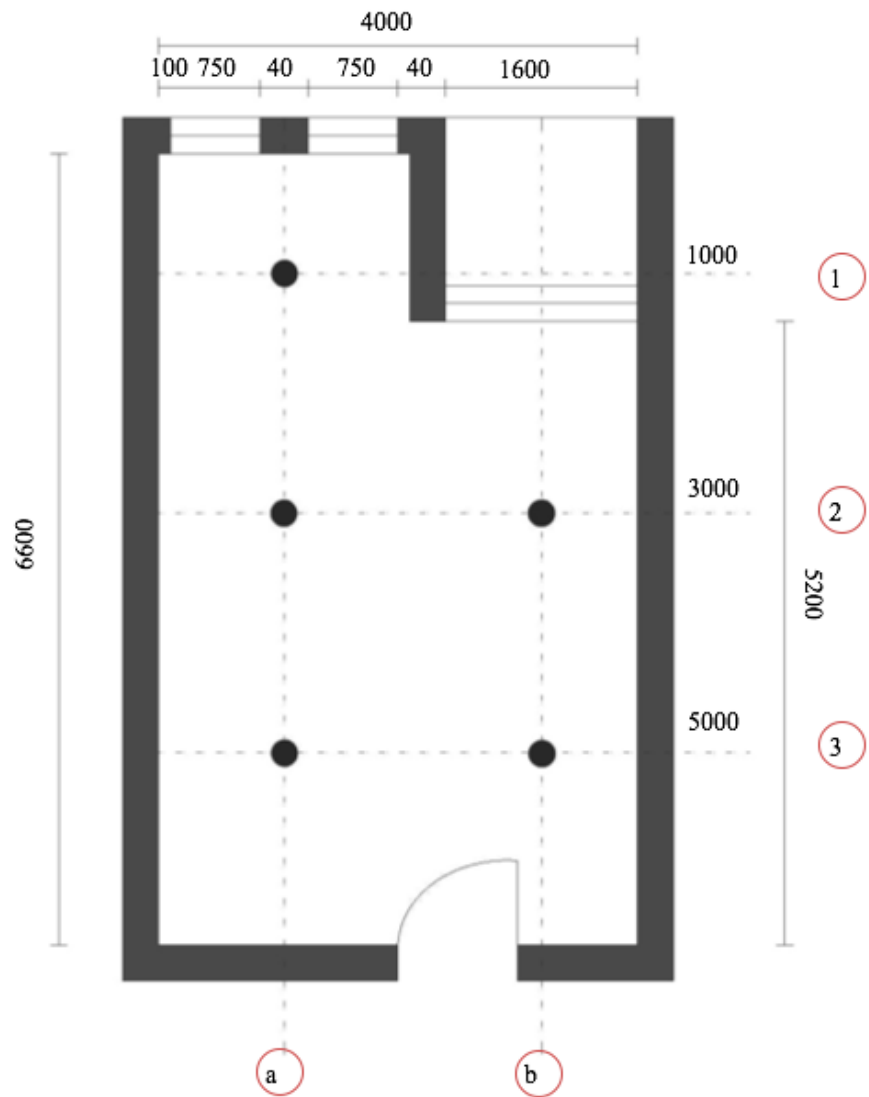
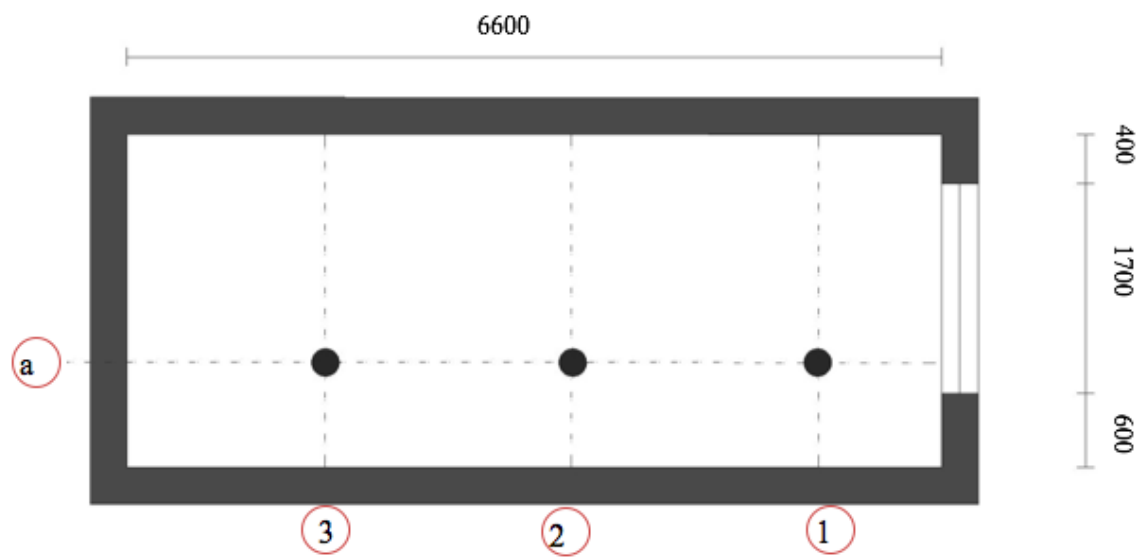


Figure 110.
section room 4.



Lamp off				Lamp on			
<i>Points</i>		<i>Grid (lux)</i>	<i>Daylight (lux)</i>	<i>Points</i>		<i>Grid (lux)</i>	<i>Daylight (lux)</i>
1	a	376,1	1389	1	a	486,7	1871
2	a	127,4	1483	2	a	140,5	2085
	b	138,6	1539		b	163,9	2045
3	a	58,7	1667	3	a	74,8	2273
	b	55,8	1903		b	82,3	2228

Table 21. results of the horizontal measurements

For the vertical measurements, the daylight level for each point in the room is measured. These results will be compared with the results in table 14 and the answers to the questionnaires in order to understand the quality of the daylight which enters the room through the windows.

Lamp off			Lamp on		
<i>Points</i>		<i>Daylight level</i>	<i>Points</i>		<i>Daylight level</i>
1	a	5.7	1	a	4
2	a	1.9	2	a	1
	b	1.9		b	1.3
3	a	0.7	3	a	0,5
	b	0.6		b	0.6

Table 22. results of the daylight.

6.4.5 Results of room number 5

The fifth house is an apartment complex located along a side street that has branched off a heavily trafficked main street. In this house the, the living room is measured. The living room is located at the north-western side of the house. The room is 6 meters by 4,5 meters with a height of 2,5 meters. Figure 111 shows the plan of the living room. The room has one big window at the side of the street. The windows have thin champagne colored lace curtain drawn over them at the time of the measurement. Figure 112 shows the window opening is 0,8 m above the floor and 2,5 m height. The room contained two halogen lamps. When taking the set of measurements with the lamps turned on, both lamps were turned on.

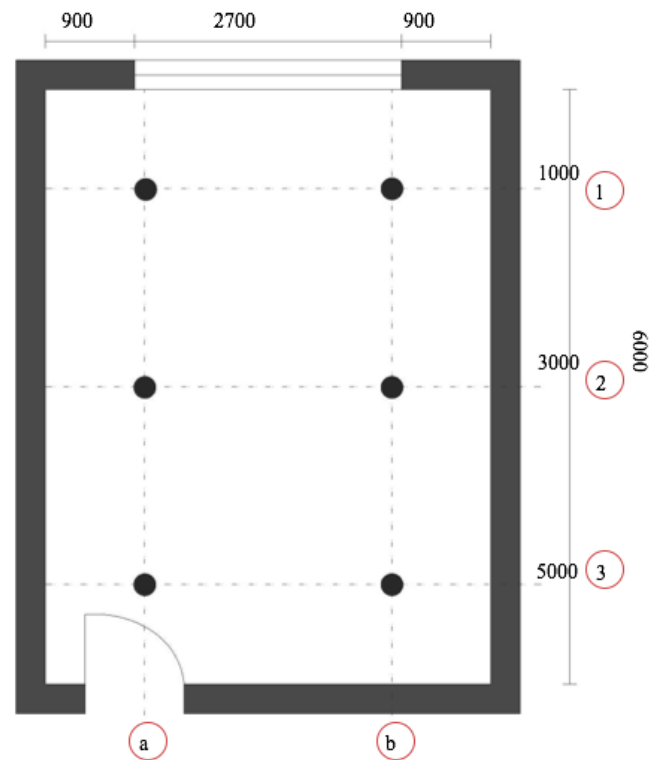


Figure 111. Plan room 5.

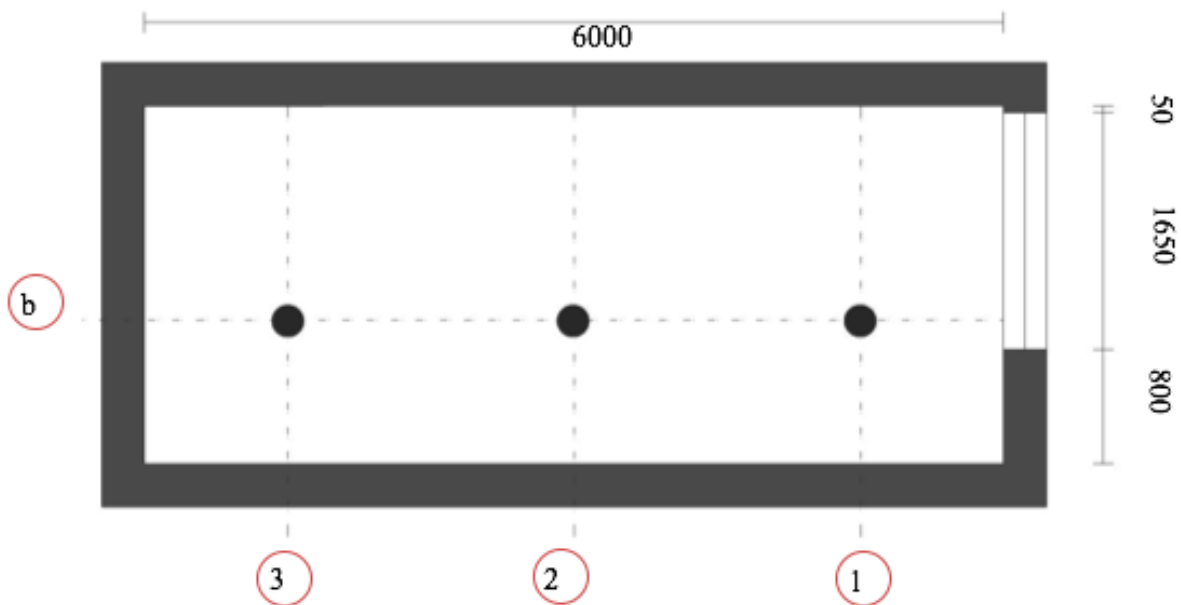


Figure 112. Section room 5

Lamp off				Lamp on			
<i>Points</i>		<i>Grid (lux)</i>	<i>Daylight (lux)</i>	<i>Points</i>		<i>Grid (lux)</i>	<i>Daylight (lux)</i>
1	a	168,9	2240	1	a	292,7	2882
	b	291,1	1813		b	439,0	2083
2	a	51,8	1828	2	a	77,6	2115
	b	59,4	2350		b	88,6	2060
3	a	24,3	2582	3	a	61,3	2017
	b	21,5	2734		b	231,0	2230

Table 23. results of the horizontal measurements.

For the vertical measurements, the daylight level for each point in the room is measured. These results will be compared with the results in table 14 and the answers to the questionnaires in order to understand the quality of the daylight which enters the room through the windows.

Lamp off			Lamp on		
<i>Points</i>		<i>Daylight level</i>	<i>Points</i>		<i>Daylight level</i>
1	a	2.3	1	a	1.9
	b	4.7		b	4
2	a	0.8	2	a	0.7
	b	1		b	0.6
3	a	0.7	3	a	0.2
	b	2.3		b	0.2

Table 24. results of the daylight level

6.4.6 Results of room number 6

The sixth house is a gallery building located in a street with a playground for children. In this house the, living room is measured. The room is approximately 5 meters by 5,5 meters with a height of 2,5 meters. The room has a door leading to the balcony. Furthermore, the room has a two big windows. Figure 114 shows the window openings is 0,7 m above the floor and 1,75 m height. The room contained two light bulbs. When taking the set of measurement with the lamps turned on, both lamps were turned on.

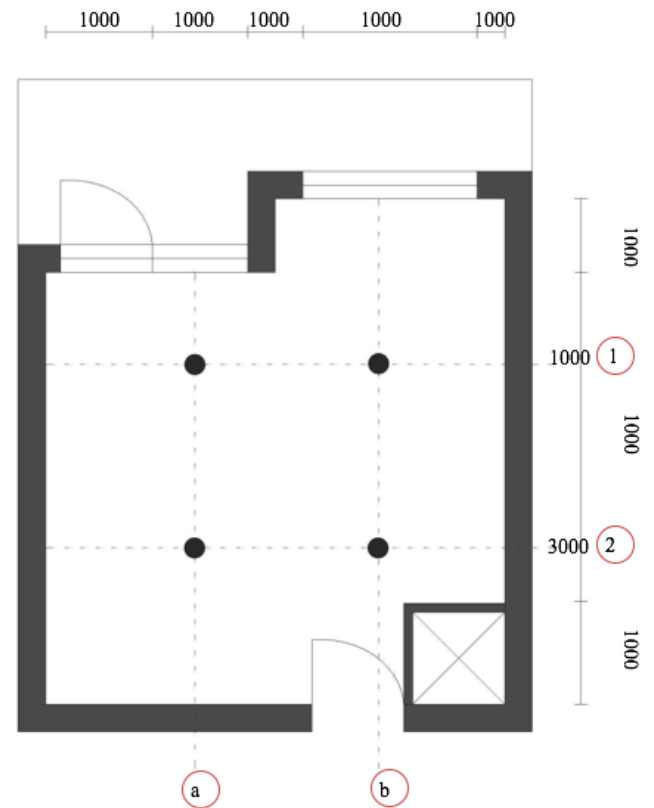


Figure 113. Plan room 6

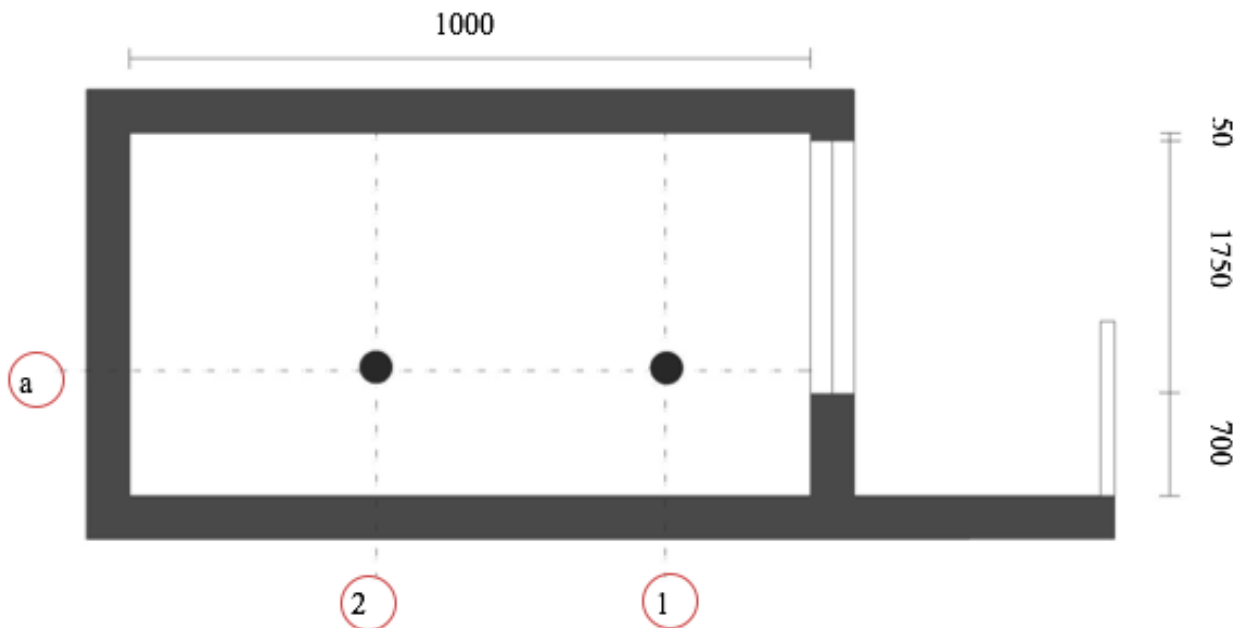


Figure 114. section room 6

For the vertical measurements, the daylight level for each point in the room is measured. These results will be compared with the results in table 14 and the answers to the questionnaires in order to understand the quality of the daylight which enters the room through the windows.

Lamp off				Lamp on			
<i>Points</i>		<i>Grid (lux)</i>	<i>Daylight (lux)</i>	<i>Points</i>		<i>Grid (lux)</i>	<i>Daylight (lux)</i>
1	a	39,8	184,4	1	a	78,5	136,6
	b	22,4	160,9		b	58,2	136,9
2	a	9,9	150,7	2	a	104,1	138,6
	b	10,7	143,7		b	68,0	144,0

Table 25. results of the horizontal measurements

Lamp off			Lamp on		
<i>Points</i>		<i>Daylight level</i>	<i>Points</i>		<i>Daylight level</i>
1	a	0.3	1	a	0.8
	b	0.2		b	0.6
2	a	0.1	2	a	1
	b	0.1		b	0.7

Table 26. results of the daylight level.

6.5 Discussion and conclusion of the measurement

In the conclusion, the following sub-question that was introduced in the beginning of the chapter will be answered:

“To what extent do the elderly feel thermally comfortable in their existing homes?”

The results in Figures 93 to 98 show that the elderly had a higher temperature inside around midday. They might feel colder in the morning because the windows are often opened to let fresh air in upon waking up. The evenings might feel colder because the elderly are less active in the evening. During the day, they work inside the home or take part in activities outside.

Comparing the results of the measurements with the answers of the questionnaire:

The man in Room 6 is warm most of the time and does not want to change the indoor temperature of 16 degrees Celsius. From the results of the questionnaire, it is clear that the man is active and engages in sports twice a week. This might indicate that he has a higher metabolic rate than the other elderly participants. Hence, he does not desire a higher indoor temperature.

The man in Room 1 inhabits a room with a higher indoor temperature than the rooms of the other participants. This room has a temperature between 19 and 21 degrees Celsius. This might be attributed to the fact that, the day the measurements were taken, the man had family over. Hence, the higher number of bodies in the room might have increased the temperature in the room. This participant does not engage in sports and he is often sitting with friends and going to the mosque. However, he does engage in physical activity when he walks approximately 10 minutes from his home to reach the mosque.

The man in Room 3 feels cold most of the time and wants the temperature in the room to be higher. From the graph, it seems that the indoor temperature is around 8 degrees. Even when the heating is turned on, there is a thermal bridge from the mailbox which is attached to the door. The room he is in also adjoins to the void of the stair,

which also makes it difficult to heat up the room. Hence, even the man turns up the heating, it does little to increase the temperature of the room. Additionally, he does not like to wear many layers of clothing in the house as he finds it uncomfortable.

The woman in Room 5 feels cold most of the time in a room which has an average indoor temperature of 19 degrees Celsius. This can be attributed to the fact that he does not engage in sports and does not wear many layers of clothing indoors. Hence, even when the temperature is not that low, she feels cold.

The man in Room 4 mostly feels comfortable in his room. The temperature of the room is usually between 18 and 20 degrees Celsius, with some increases in temperature about midday.

From the analysis above, we can conclude that the elderly women usually feel colder than the men. Additionally, people who are more active feel more comfortable with a lower indoor temperature. In general, the results of the questionnaire and the measurements show that most of the elderly participants would like the indoor temperature of the rooms they inhabit to be higher.

“To what extent do the elderly feel visually comfortable in their existing homes?”

In order to derive clear conclusions on the visual comfort of the elderly participants, the quality of daylight and the lux value for each measured room, will have to be looked at. These results have been summarized in table 27. The level of the daylight was calculated by dividing the ‘illuminance inside’ by the ‘illuminance in the free field’. The ‘illuminance in free field’ varies from 10.000 lux in December, to 35.000 lux in July, in the Netherlands. The measurements were taken in November, and since the weather in November does not differ much from the weather in December, the ‘illuminance in free field’ for December, 10.000 lux, was used in the calculations. For example, the average daylight in room 1 is approximately 1109 lux. Hence, 10.000 lux divided by 1109 lux gives a factor of 9. This method of calculation was applied to all the rooms. Hence, the daylight level will be divided by this factor.

Room 1			Room 2			Room 3		
<i>points</i>	Lamp off	Lamp on	<i>Points</i>	Lamp off	Lamp on	<i>Points</i>	Lamp off	Lamp on
<i>1a</i>	0.9	0.9	<i>1a</i>	1.1	2.3	<i>1a</i>	0.3	0.5
<i>1b</i>	1	1.7	<i>1b</i>	2	1.2	<i>1b</i>	0.2	0.2
<i>2a</i>	0.5	0.7	<i>2a</i>	0.5	1.3	<i>2a</i>	0.5	0.6
<i>2b</i>	0.5	0.7	<i>2b</i>	1	1.3	<i>2b</i>	0.2	0.2
<i>3a</i>	0.2	0.4						
<i>3b</i>	0.2	0.4						

Room 4			Room 5			Room 6		
<i>points</i>	Lamp off	Lamp on	<i>Points</i>	Lamp off	Lamp on	<i>Points</i>	Lamp off	Lamp on
<i>1a</i>	4	5.7	<i>1a</i>	1.9	2.3	<i>1a</i>	0.3	0.8
<i>2a</i>	1	1.9	<i>1b</i>	4	4.7	<i>1b</i>	0.2	0.6
<i>2b</i>	1.3	1.9	<i>2a</i>	0.7	0.8	<i>2a</i>	0.1	1
<i>3a</i>	0.5	0.7	<i>2b</i>	0.6	1	<i>2b</i>	0.1	0.7
<i>3b</i>	0.6	0.6	<i>3a</i>	0.2	0.7			
			<i>3b</i>	0.2	2.3			

Daylight level (DL)	Quality of the daylight
	Abundant daylight
	Good daylight
	Rational daylight
	On the gloomy side
	Too little for a living space.

Table 27. summarization visual results.

Table 27 shows that every room has areas that receive insufficient daylight. This is especially true for Rooms 1, 3, 6 and one half of Room 5. This has to do with the poor orientation of the buildings, and also because there are not enough windows in comparison to the size of the rooms.

Comparing the results of the measurements with the answers of the questionnaire:

Rooms 1 and 2 are in the same house. However, the orientation of the rooms are in opposite directions to each other. The results of the questionnaire show that the man in Room 1 finds that there are not many well lit areas in the room. Despite this, he chooses to sit there because it is the living room. His favorite spot in the room is near the window and far from the television set.

Room 2, where the elderly woman likes to spend her time, is the kitchen. The results from the questionnaire show that the kitchen has a mix of well-lit and dark spaces. The room has a lot of windows which are able to let in daylight. Her favorite spot is near point 1a, where it is darker than other parts of the room.

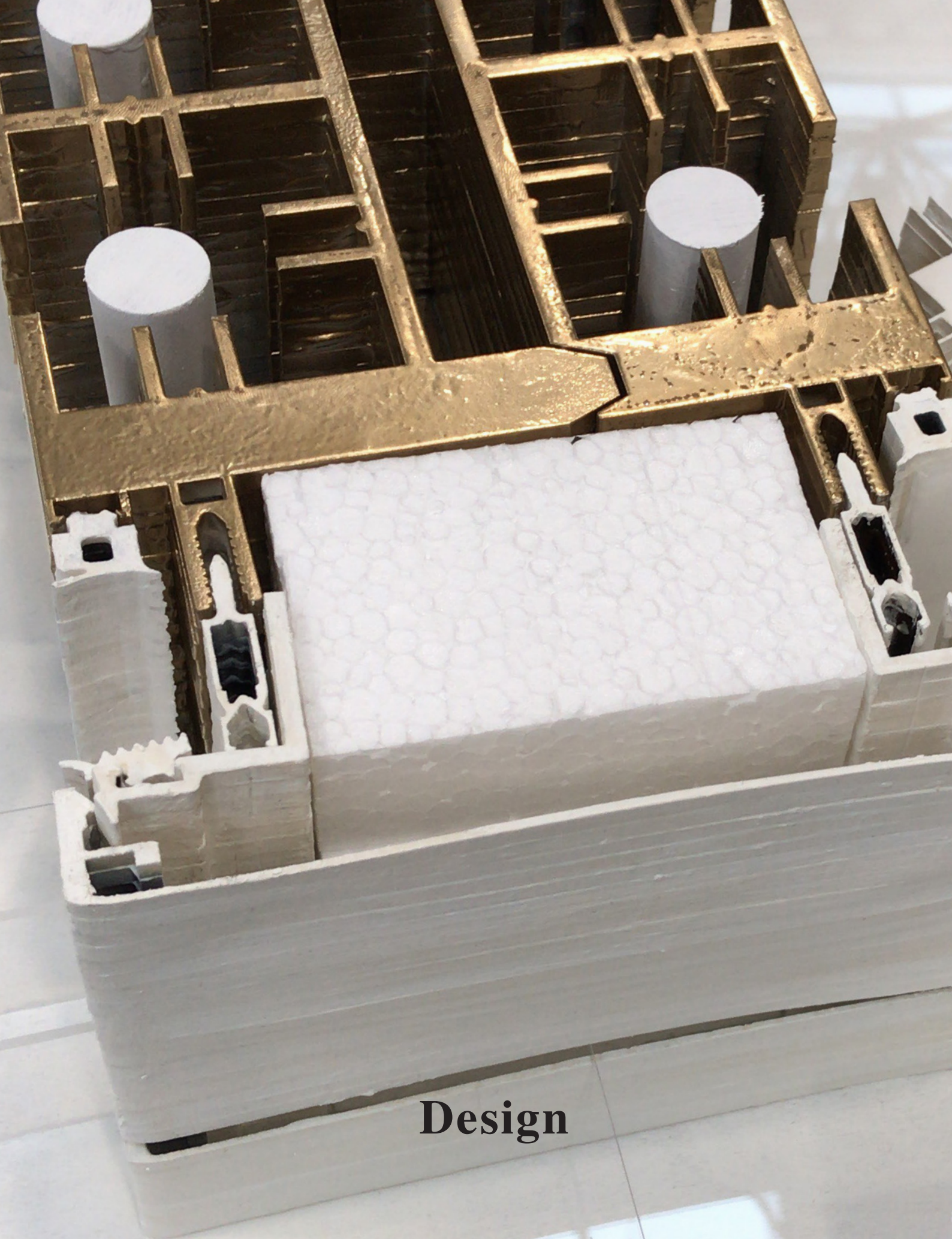
Room 3 is one of the worst rooms as it has a lot of dark spaces. The room is only sometimes lit up with daylight. For example, the area near the window is well-lit in the mornings. This is where the elderly man likes to spend most of his time. Past morning, even the area around the window is dark, because of the poor orientation of the room and the small windows.

Room 4 is one of the best rooms. The level of daylight in the room decreases only after moving 3 meters away from the window. It could not be concluded from the questionnaire if the room has more well-lit or more dark spaces, as the elderly man found it difficult to answer. His favourite place is in the corner of the seat where the level of daylight is still high. However, the seat is not positioned in the most ideal part of the room and it seems that the furniture in the room could be rearranged in order for the elderly man to profit more from the good daylight conditions in the room.

Room 5 has sufficient daylighting up to one meter from the window. The answers to the questionnaire showed that the room was often too bright.

Room 6 is one of the worse rooms. The measurements might have come out especially poor because they were taken in rainy and cloudy weather. Hence, there was not much daylight entering the room. The elderly man's favorite place is near Point 2a, where the daylight levels are low.

From the above analysis, we can conclude that none of the rooms have good daylight levels. According to European norm NEN-EN 12464 in 2003, living rooms should have a general lux value of 100 lux in order to be sufficiently well lit. Going by that standard, the rooms above can be said to be sufficiently well-lit. However, if we take a standard of 500 lux (NEN-EN 12641) to be necessary for activities like reading, writing and typing, none of the above rooms can be considered to be sufficiently well-lit or visually comfortable.



Design

Chapter 7

Design Concept

For the design of the house, it is necessary to have a list of requirements. These requirements will be discussed in this chapter. The design concept consists of different components such as floor, roof, and interior. As this research is primarily on thermal and visual comfort, the focus of the design will be on the façade. The other components will not be designed, but only discussed. To aid in this design and discussion. At the end of the chapter, there will be a conclusion that will aim to answer the following question: “What are the possibilities for designing a façade?”

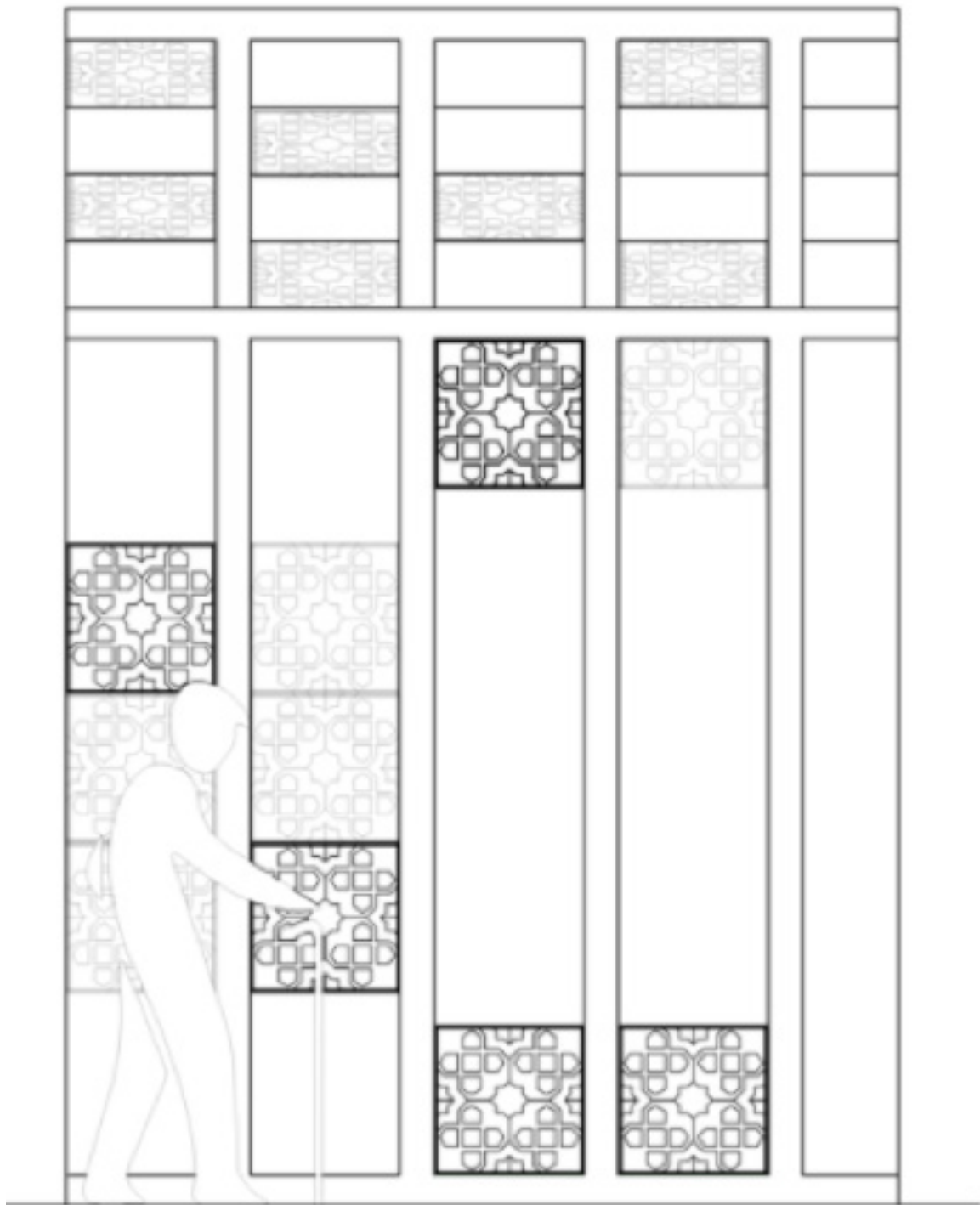


Figure 115. First sketch of the design.

7.1 Requirements

The requirements of the house will be in three categories. Namely, [1] customization, [2] construction and [3] climate.

7.1.1 Customization

The proposed design needs to have the opportunity to be flexible when it comes to customization and leasing. The way that IKEA offers options for various types of customization for people with various requirements, is an important example to consider and be inspired by. Each client will have a different set of requirements for visual and thermal comfort.

An important property of the design is that it can be made larger or smaller, as desired. In the case in which the house becomes empty, it has to have possibility of being converted into another function or returned to the factory. For example, when the house is empty, it should be possible to add a few parts together to create a storage or hobby room.

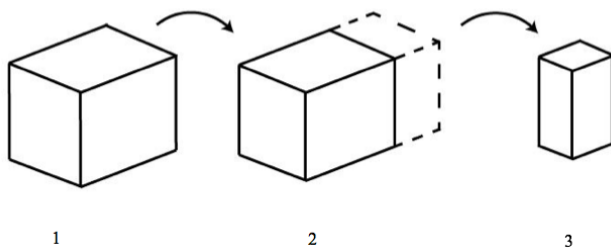


Figure 116. Possibility of the size of the house .

Point 1: The minimum size of the box where an elderly person can live.

Point 2: In case more space is needed, it can be added.

Point 3: Give the house another function when the inhabitant has passed away.

7.1.2 Construction

The construction of the entire building has to be composed of parts of the same size. This will make it easy for it to be customized into bigger or smaller sizes. In addition, part of the façade has to be made in the factory. This will make it easier to lease, and in the case of damage, the whole façade can be exchanged for another one.

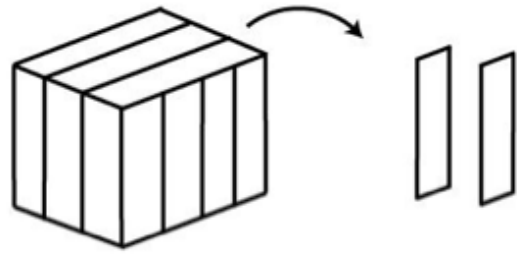


Figure 117. Construction strategy .

7.1.3 Climate

The design stage will begin with understanding the requirements for thermal and visual comfort that each individual client will have. In this way, the climatic conditions of the house can be decided on by the client before they receive the house.



Figure 118. Climate strategy.

7.2 Building design

The theoretical research has shown that people are more comfortable in a house which they refer to as their own place. This could be the place where they come from, or the place of their younger years. However, this is an important part in the design of the façade. This will be included in the design strategy.

7.2.1 Shape

For the shape of the design, the report looks at what kind of shape would receive the most daylight and which facade system would be the easiest for the elderly to understand. A round shape would received the most daylight during the day. However, a round shape can only be assembled in facets, giving the shape many different angles. The height of the building will also be too low to make optimal use of the interior spaces.

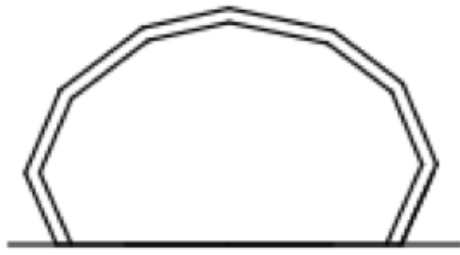


Figure 119. Option shape 1 .

The second option is a continuation from the first option. As figure 2 shows, the second option has a height which is useful to walk in. However, the overall height of the building will be too high as it might obstruct the views from the main house and the daylight entering it.

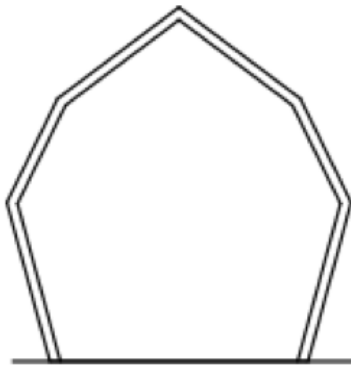


Figure 120. Option shape 2.

The third option is a combination of the first and second options. This shape still has an angle at the corners to maximize the entry of daylight and gives the possibility of having solar panels on the roof. However, in this shape the floor space cannot be use optimally because the angles in the shape create unusably low ceiling heights at the edges of the building. To optimize floor use space, it will be better if the “legs” of the shape are straight.

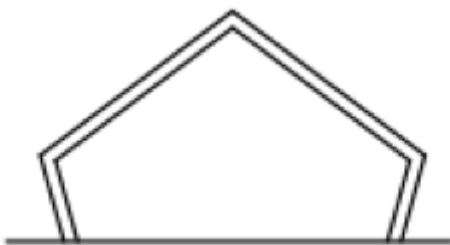


Figure 121. Option shape 3

Option 4 is the decided upon shape of the proposed building. The shape is simple compared with the other ones. In this shape the floor can be used optimally. With a simple shape, the façade can be a strategy to make the design interesting.

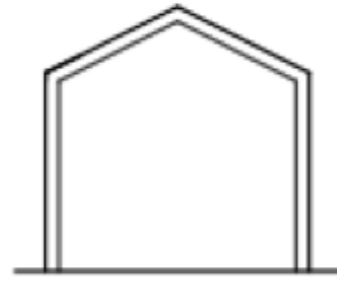


Figure 122. Option shape 4.

7.2.2 Floor system

The floor will also have a modular system which work with the other parts of the building. The floor size also depends on the space available in the garden and the site preferences of the elderly. The floor should have modular dimensions, and it should be possible to easily add one floor component to another. However, this report will not go into further study or design of the floor system.

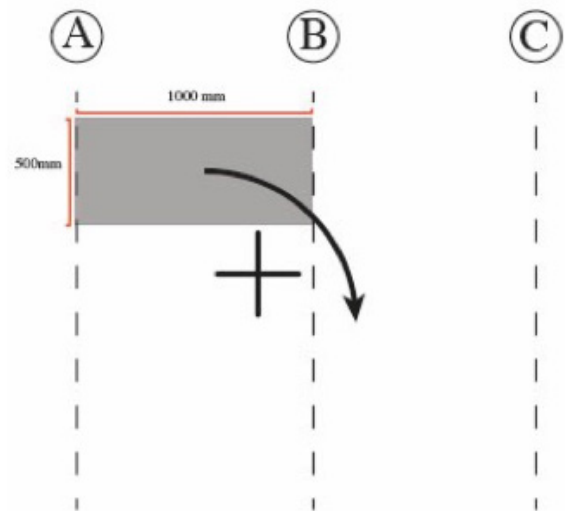


Figure 123. Floor system strategy.

7.2.3 Façade system

The main part of the building is the façade and what this report will focus on. The facade should provide enough daylight, but also allow for thermal comfort. The Netherlands has four different seasons. In winter, the days are short and making optimal use of daylight is a necessity. In summer, the days are longer and sun shading is necessary, along with the cooling of the building.

7.3 Façade design

Looking at the theoretical conclusions of thermal and visual comfort, it can be concluded that the elderly

need three times more light than younger people. In addition, the thermal comfort requirements of the elderly differ from those of younger people. This means that the elderly requires more light to come in through the façade. However, too much glass in the façade will result in the unwanted heating up of the building in summer and will have a big influence in the reduction of energy consumption in winter. Looking at the multicultural generation, each population group has its own requirements for thermal and visual comfort. These considerations have to be integrated into the construction and façade system of the building. In order for the façade to let in an optimal amount of daylight, a sliding system will be designed.

The sliding needs to move in a vertical direction. One example of such a system is the mechanism of the chalkboard. This is an old system which is still common in educational settings. This mechanism uses a system of hidden lead counter weights which are suspended by steel aircraft cables from a steel ball bearing pulley system. This system allows for the effortless manual operation of the sliding panels. The system is very well hidden and offers no clues from the exterior on how it operates. In terms of the design, this is desirable for aesthetic reasons. The diagrams in figure 124 show how this chalkboard system works.

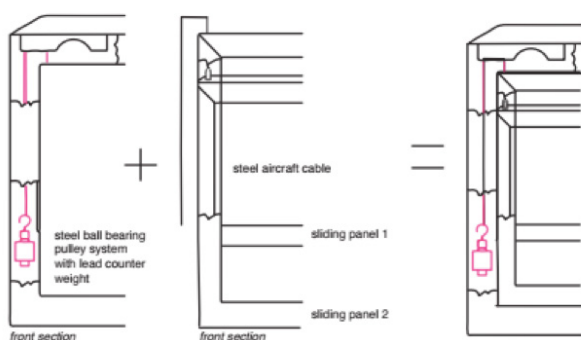


Figure 124. Explanation of the chalkboard system.

The system of the chalkboard works manually. The results of the questionnaires in chapter 5 showed that most of the elderly are able to control the sunshades, ventilation system and windows. However, as the elderly continue to, they have indicated that their muscles and joints begin to hurt after a while. Hence, the façade will be divided in sub facades that can be slid over each other mechanically by the elderly themselves. The façade will have the flexibility of being re-used or changed when leased by a new person. This is an important requirement for this project, because the requirements of visual

and thermal comfort will differ from project to project. The elements will always have the same system of construction. However, the elements can look different from each. This will be done through use of the sliding panels. The panels will be set up according to the requirements of the location, size, thermal comfort, visual comfort and requirements of the elderly person living in the building.

The façade system should be easy to set up on location. Therefore, a facade composed of elements is a good solution. The modular façade is a facade which consists of prefabricated elements that only need to be mounted on the building site. Assembly of the individual modules will take place at the factory. The modules will then be transported to the site.

7.3.1 Sliding panel

The design of the sliding panels will be chosen and designed by the elderly in the first stages of leasing. For the design of the sliding panel in this report, a pattern is chosen which refers to the cultural background of a majority of the elderly participants of the questionnaires and is my own cultural background as well. The architectural patterns present in Moroccan culture has a strong Islamic influence. These include geometric patterns and ornamental Islamic calligraphy. Hence, the design of the panels will incorporate these geometric patterns. The pattern of the sliding panels will play a role in contributing to the thermal and visual comfort of the elderly. Figure 125 shows the main pattern of the panel. The figure shows that the panel is a square of 500 x 500 mm with some openings which relate to each other (Peters, 2016).

As mentioned before, the panels can be slid over each other. Figure 126 shows how they will look in three different stages. The first stage shows when the panels do not overlap, and hence cover the entire height of the façade. The second image shows what happens when the panels begin to slide over each other and overlap. The third option shows the panels completely overlapping each other.

However, the pattern of the screen changed slightly during the model making process. Making the model showed that the pattern allowed too much light into the interior and the panels did not work well together. Hence, the pattern was edited. As

seen in figure 127, the panels now work together and there are options where the panels are partially or completely overlapped and do not allow much sunlight into the interior.

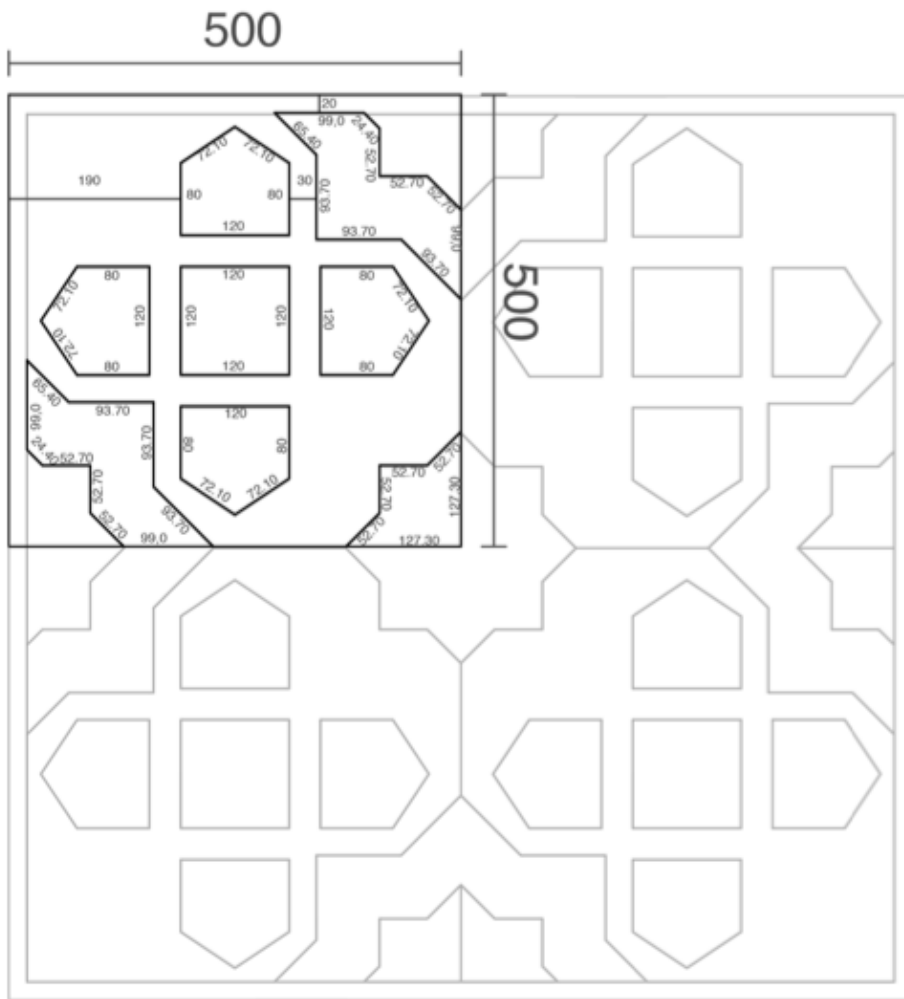


Figure 125. Main pattern.

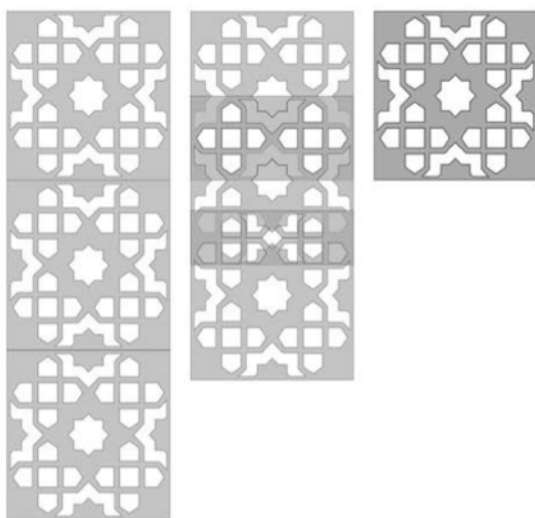


Figure 126. Different stages of the sliding panel with first pattern.

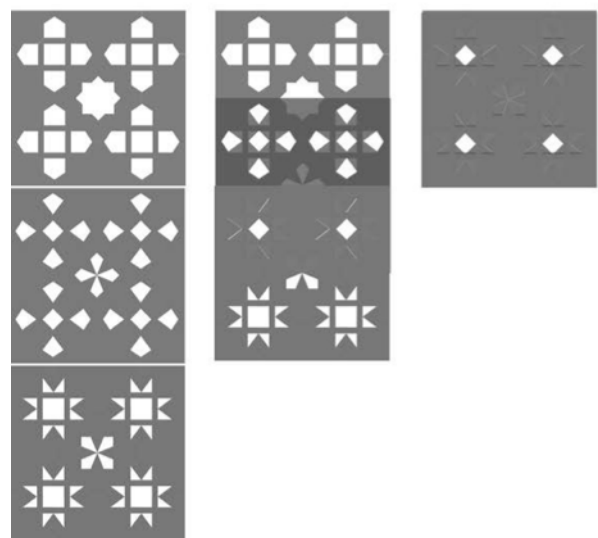


Figure 127. Different stages of the sliding panel with final pattern.

7.3.2 Design with HEA profiles

In the first design strategy, we assume a façade which consists of sliding panels which are set up in different layers both on the inside and the outside. Before looking to a mechanically operated solution we will look to a manually operated solution. The panels on the outside have to be slid manually from the inside using a crank. Each sliding panel will have its own pulley. In this way, they can be moved individually. For this example, we will start with two sliding panels on the outside of the facade, a glass panel in between and one sliding panel on the inside.

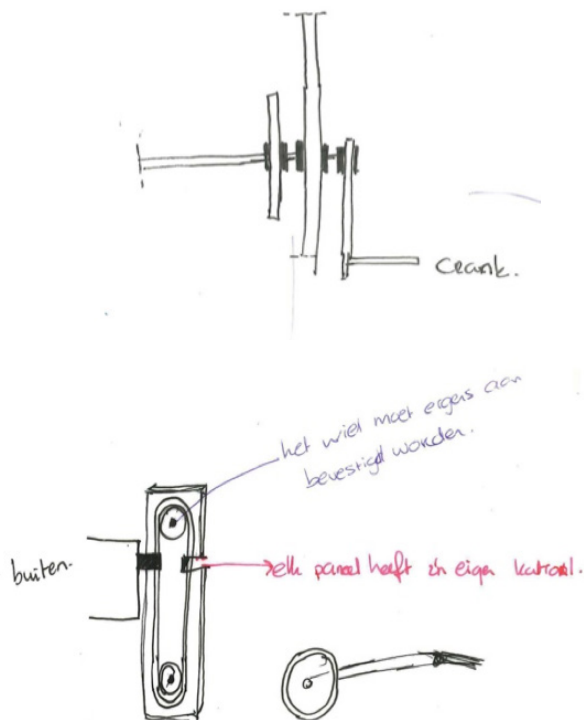


Figure 128. Crank sketch .

Firstly, the construction of the house will be composed of steel HEA profiles. The profiles will be the main construction of the house and the system of panels will be installed in between or against the profiles. Sketches 129 and 130 shows the first steps taken in designing the crank and assembling the window against the steel HEA profile. The transition zone will be difficult to design as the outside panel has to be slid manually from the inside. The crank attached to the outside panel might be problematic if it forms a cold bridge, known in Dutch as the 'Koude brug'.

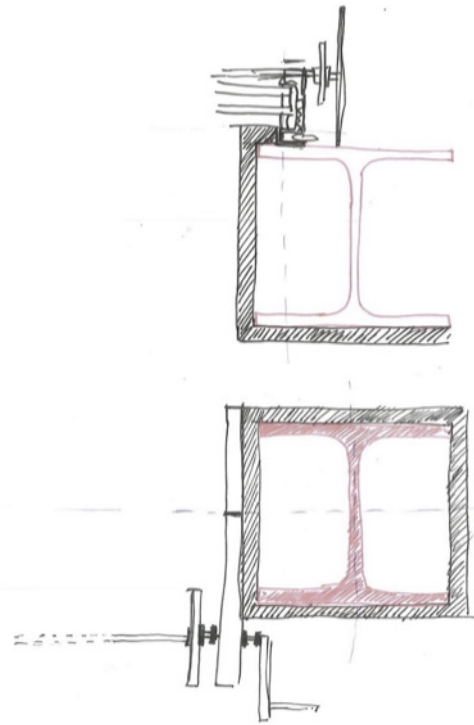


Figure 129. Sketch crank assembling to HEA profile.

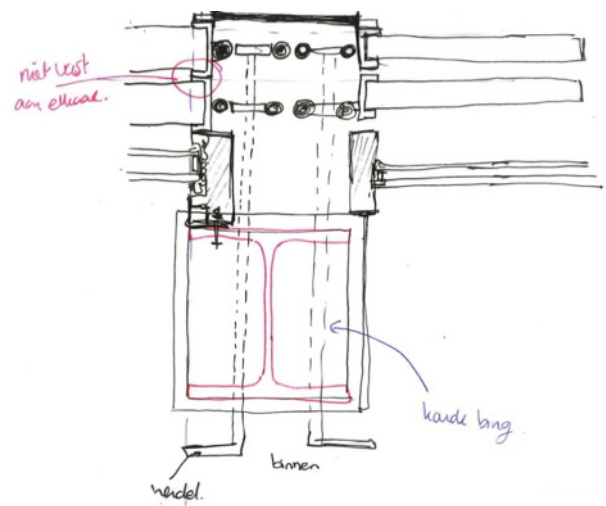


Figure 130. sketch crank assembling to HEA profile .

For the pulley, it is important to know how the crank can be rotated. The pulley can be installed either horizontally or vertically. This has to do with the crank. If the pulley is installed horizontally, the crank can be connected directly without any extra construction. Figure 131 shows the difference in horizontal and vertical installation of the pulley. The red construction suggests a construction that will be connected to the steel HEA profile. The component with the panels is a single component that will arrive at the site preassembled from the factory. This component then only has to be slid in. A disadvantage of this is that from the outside (above the profile), there will be thick closed parts. This is contradictory with the large quantities of light required for the visual comfort of the elderly.

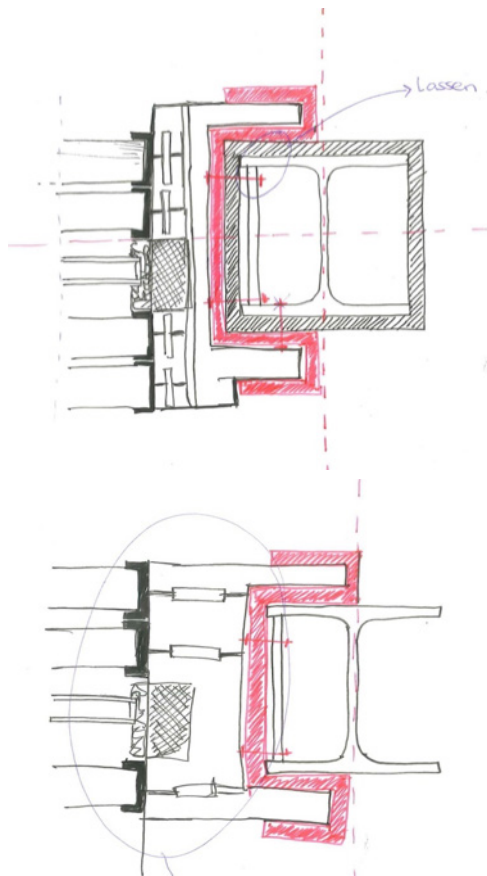


Figure 131. Difference in horizontal and vertical installation of the pulley

A sketch is made by looking only at the facade component, and disregarding the installation of the steel HEA profile. The outside and inside panels are separated from each other by the window and by the insulation in between them. Figure 133 shows two components that are installed together.

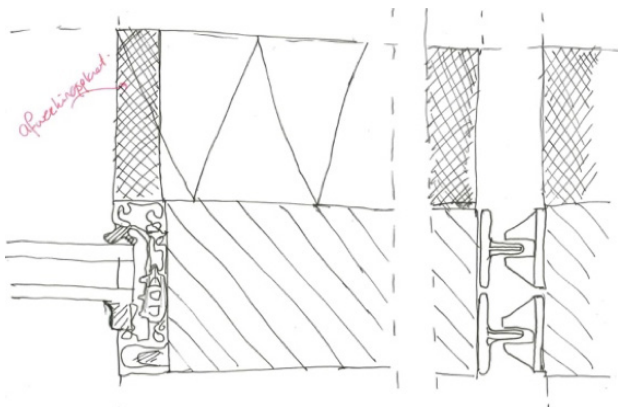


Figure 132. Horizontal sketch.

From the sketches, it is evident that it is difficult to attach the facade panels to the HEA profile. Hence, the first option of designing the house with steel HEA profiles is reconsidered. A new strategy is to design a single element which can function as a construction element and the panels can be attached to it. A material which can be freely designed and produced into custom forms, while retaining its structural capacity, is aluminum.

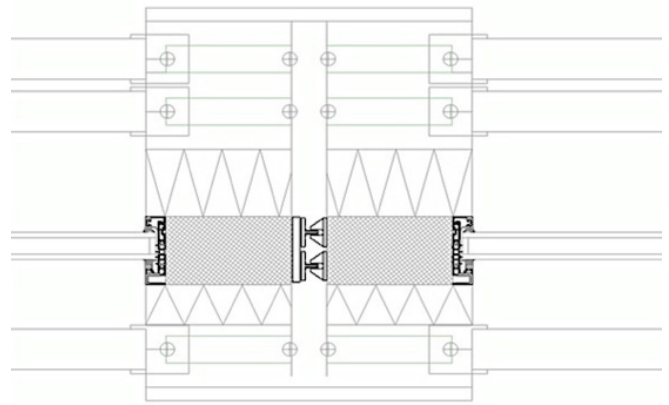


Figure 133. Components that will install together.

7.3.3 Aluminium

Through the analysis of the sketches above, it was decided that the component has to be a single element, in order to prevent the cold bridge. A material that can be formed easily into custom forms while retaining its structural capacity, is aluminum. It is only since 1886 that aluminum has been used as a serious industrial metal. This was because of the invention of the smelting process. However, pure aluminum is too weak for structural use. It has a tensile strength ranging from 90 to 140 N/mm². Hence, for structural use it has to be strengthened by alloying (Dwight, 1999).

The form can be produced through extrusion and rolling. Aluminum has a low melting temperature and is therefore excellent in molding. Apart from freedom in producing different forms, aluminum has many more positive characteristics:

- [1] Light in weight, with a density of $2.7 \cdot 10^3$ kg/m. This is one third of the weight of steel.
- [2] Strong, depending on the type of alloy and its strength.
- [3] Weatherproof, as aluminum naturally has a protective oxide layer.
- [4] Sustainable, as it can be easily recycled. The melting required to recycle it only uses 5% of the energy that is required to produce primary aluminum.
- [5] Decorative, as it can be decorated with anodizing or lacquer treatment.
- [6] Easy to work on, as there are many machine techniques which are applicable for aluminum.
- [7] Good conductive material for conducting electricity and heat. (Aluminium Centrum, 2010)

However, there are also the following negative aspects to consider:

- [1] Cost, as aluminum is about 1.5 times more expensive per volume, in comparison to structural steel.
- [2] Buckling, as the failure load for an aluminum component due to buckling is lower than for steel when comparing components of the same thickness.
- [3] Temperature, as some alloys begin to lose strength above 100°C.
- [4] Aluminum components are more prone to failure by fatigue than steel components.
- [5] Thermal expansion, as aluminum expands and contracts with temperature twice as much as steel.
- [6] Corrosion may occur at joints with other materials, unless correct precautions are taken.
- [7] Deflection, as there is much more deflection in aluminum as compared to steel. (Dwight, 1999)

For the design process, is it important to know how the components will be produced in practice. The production of the designed component can be done through [1] extrusion profiles or through the [2] liquid shaping of aluminum.

[1] In the case of the extrusion profiles, a round aluminum foil will be pre-heated by pressing a mold. It is often a discontinuous process. The mold consists of one or more complex shaped holes which form the final molded bar material, the extrusion profile. This can be a solid or a hollow profile. Through this process, it is easy to connect profiles through click connections, by welding or by screwing the elements to each other. This process can be used for window frames where a polyamide ladder or a plastic insulator is molded in between. In this way, the inside temperature is separated from the outside temperature (Aluminium Centrum, 2010).

[2] For the liquid shaping of aluminum, the final shape produced can be made very accurately, to be very close to the design. Casting gives the most freedom in designing a product. The freedom of design makes it possible to reduce the parts of a product. The casting can be done by lost-mold casting or a permanent molding method. The difference between lost mold casting and permanent molding method is shown in table 28.

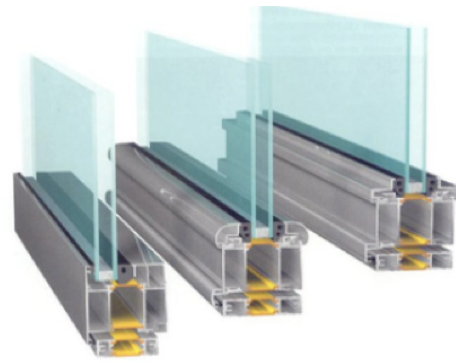


Figure 134. Example of aluminum window frame.

Lost molding casting
• Includes sand casting, lost wax casting, lost foam casting and vacuum casting. • Production of single pieces and small series to large series. • Investment for tools is low.
Permanent molding method
• A mold can be used several times • Possible for high pressure and low pressure.

Table 28. Differences between lost mold casting and permanent molding method.

For the design, it is important to know which alloy will be used for the beam and column. This has to do with the fact that aluminum in itself not strong enough. Aluminum always needs an alloy to make it suitable for structural use. To have an overview of the types of alloys, they are divided into seven groups. Each group of alloys can be used for different applications, as seen in table 29.

The group of alloys best suited to structural use is Group 6xxx. This group contains silicon and magnesium as alloying elements. Alloys from this group can be deformed by annealing and well deformability subsequently increases strength by hardening. This is also the alloy which will be used for the design.

Group	Strength	Deformability	Corrosion resistance	Welding ability	Applications
1xxx	low	very good	very good	very good	reflectors, heat exchangers, high voltage cable, welding wire, kitchen utensils, packaging, lighting, chemistry, foodstuffs
2xxx	high	rational	moderate	bad	aircraft and truck wheels, construction, transport, machine building, automatic turning
3xxx	low	good	good	good	beverage cans, cooking utensils, heat exchangers, storage tanks, furniture, roofing, shutters, partitions
4xxx	average	good	good	good	engine blocks, pump housings, cylinder buttons,
5xxx	average to high	good	good	good	shipbuilding, body panels, construction, cladding, window frames,
6xxx	average	good	good	good	electrical conductors, structures, shipbuilding, body panels, rolling doors, fences, decorative anodizing
7xxx	high	average to high	moderate to average	moderate to good	aviation, transport, dynamically loaded constructions.

Table 29. Each group of alloys which can be used for different applications.

7.3.3.1 Design with aluminum

As previously mentioned, aluminum allows for the freedom to design components in any shape. The façade will consist of different layers. Each layer will have an aluminum profile and the profiles can be added to each other. Firstly, we will consider a façade with two sliding panels, with taking windows into account. The mechanism of the façade is the same as that of the chalkboard. The panels are held by steel aircraft cables. Figure 135 shows the first sketch of such a system. As seen in the figure, there are two layers. Reading the image from the left, we see how it is installed, with the second aluminum profile attaching to the first. The aluminum profile is designed in such a way that many layers can be added to each other. This is shown in figure 136. The first aluminum profile is

indicated with a black fill. The second profile will be placed in the opposite direction in order to allow it to be connected to the first.

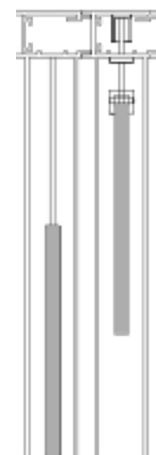


Figure 135. Design with aluminum.

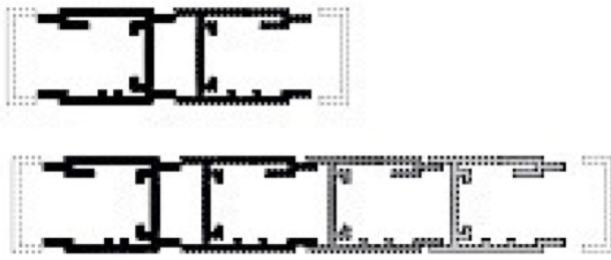


Figure 136. Adding aluminum profiles to each other.

However, the width of two layers is already 330 mm and adding more layers only increases the width. A facade with one layer on the outside and two layers on at the inside gives a width of 518 mm. Taking into account the facades on both ends, the floor space decreases by a meter. Another disadvantage is that the panels can be moved by the force of the wind, or the cable can break. In addition, working with counter weights makes the mechanism complex.

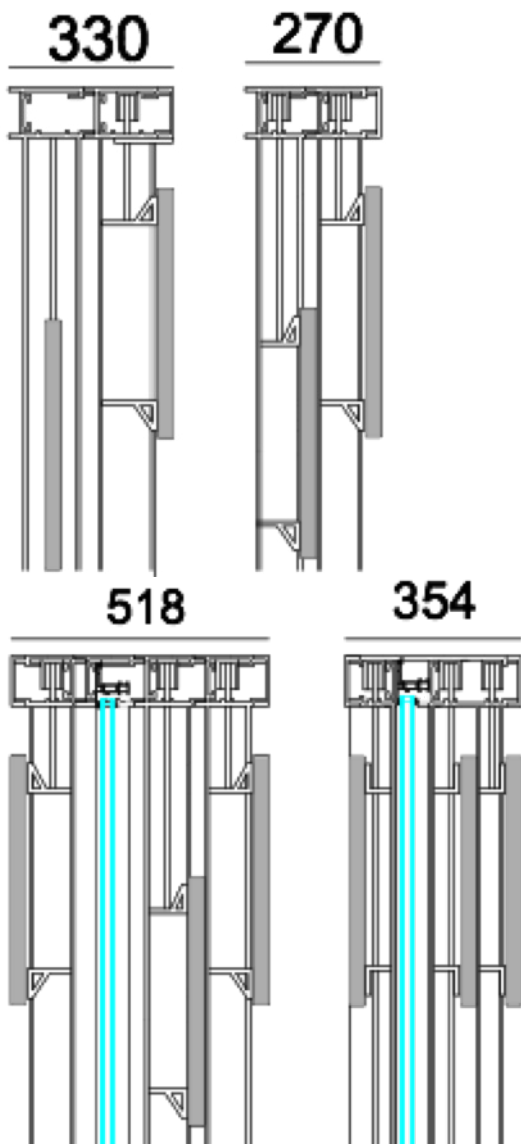


Figure 137. Examples of adding the profiles to each other.

Hence, a second mechanism is looked at, whereby the panels are moved using a spindle. Each panel will be attached to a spindle. The spindle will be rotated manually. There will also only be panels on the outside of the façade, to make the system clearer for the elderly. In the interior of the building, the elderly can choose to have a curtain if they need it. Another aspect is that the façade can now consist of only one aluminum profile as the window is now the last layer of the system. It is no longer sandwiched between panels, making it easy to replace if necessary. Furthermore, there is no longer a cold bridge in the system. A first sketch of the spindle is shown in figure 138.

As seen in the figure, the closed parts of the facade still take up a significant amount of space, of around 255mm. This is because the gear box will be installed in the top corner. To reduce the amount of space taken up by it, the gear box will be placed under the floor instead. This detail will be explored later on in the report.

This means that less of the facade will be obstructed. The aluminum profile will be made of one profile where the window will be installed at. The sliding panels are still assembled to the spindle. The gap between the two façade panels will be filled with insulation to keep the cold out. Zooming in, it can be seen that the window will be assembled from the inside. The main construction of working from inside to outside will be turned around. This is possible because there will be no other floor then the ground floor. In addition, the insulation line will be on the inside of the house, instead of the way it is usually on the exterior of a building.

In order to improve and optimize the design, different design options were drawn. The drawings show the attempts to integrate the window frame within the aluminum construction frame. The design options also looked at how adjacent frames can connect to each other when assembled. The first option looks at the possibility of the adjacent frames fitting together like a zipper. Through the process of model making, it was decided that this will not be a good idea as it will be too difficult to fit every part of one zipper to the one beside it. Hence, the second option explored a straight connection that uses a cam lock to connect to the adjacent frame. This is a system that is often used in IKEA furniture. However, this connection was also

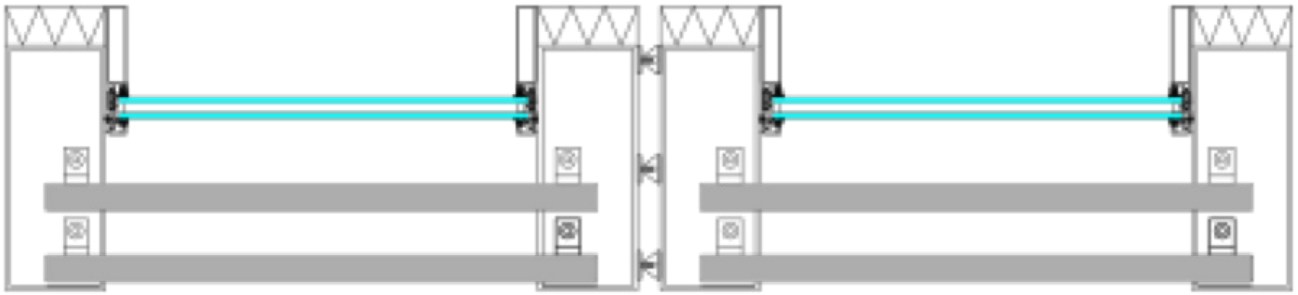


Figure 138. First horizontal sketch with the spindle integrated

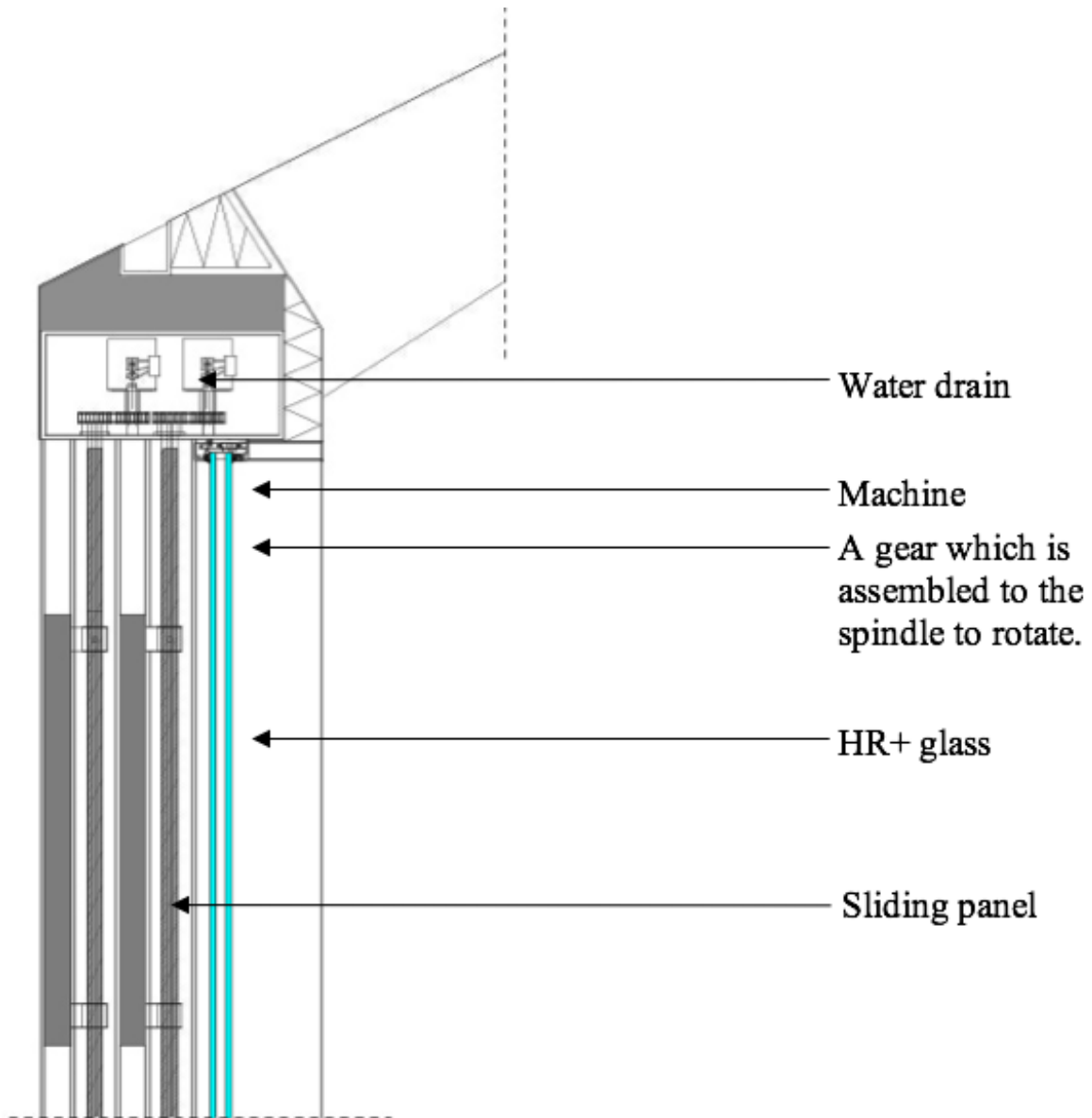


Figure 139. First vertical sketch with the spindle integrated.

deemed to be too difficult to assemble. Finally, the third option looked at a self-seeking system, where the aluminum frame will have openings that will allow for the adjacent aluminum frame to connect to it. This connection detail is also used for the other elements of the building and the conclusion of this chapter will show the final design.

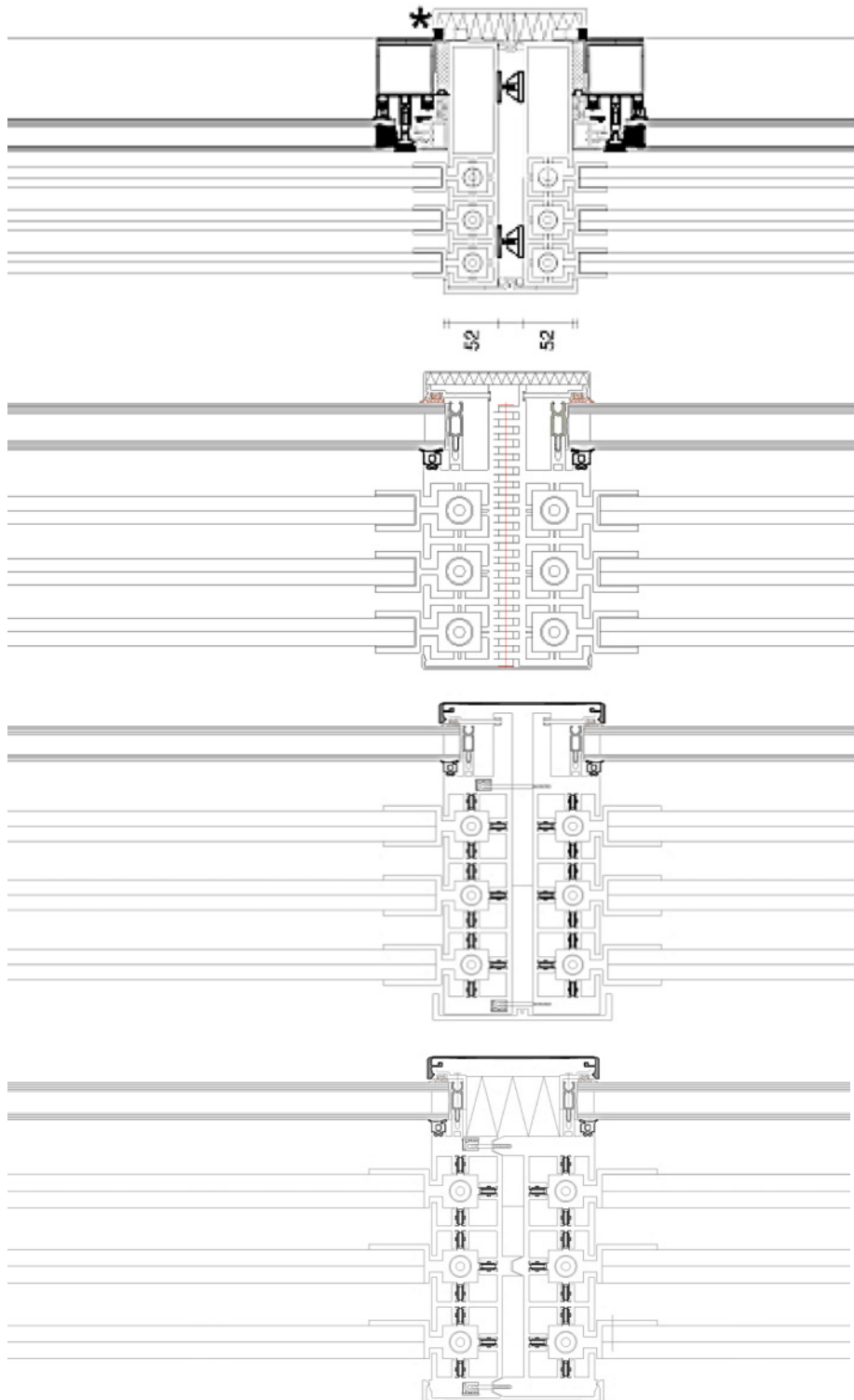


Figure 140. Optimizing the aluminum frame step by step (horizontal).

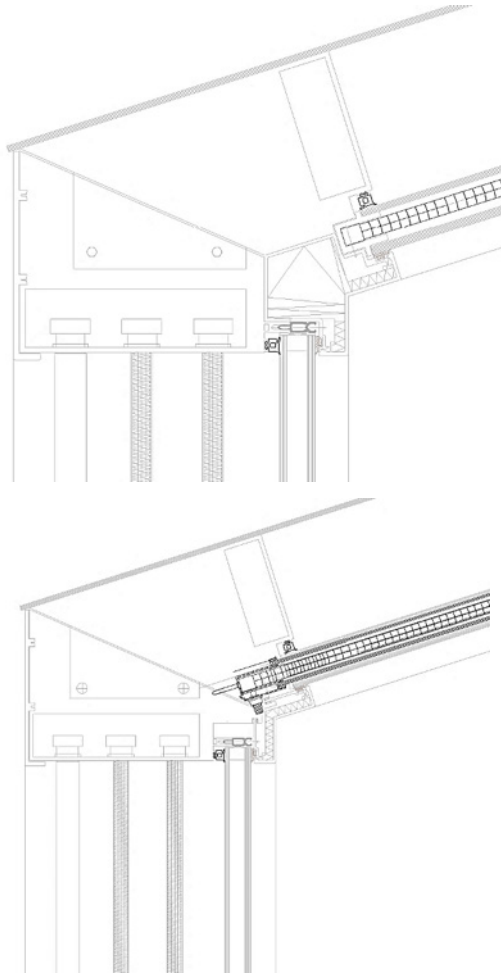


Figure 141. Optimizing the aluminum frame step by step (vertical).

7.4 Construction

The shape of the design gives the opportunity to use a three hinged construction. This construction is a buckle structure with two foot hinges and one top hinge which is usually at the center of the roof. The two foot hinges are both fixed hinges, while the top hinge is moveable. In this way, the construction elements can be transported in two parts. The construction ensures that the three hinges are less sensitive to movement and temperature change.

A hinged suspension has both vertical and horizontal forces acting on the construction. The connection exerts, on a beam, an unknown horizontal reaction force and an unknown vertical reaction force. The angle of the beam is not important. The reaction forces are always horizontal and vertical.

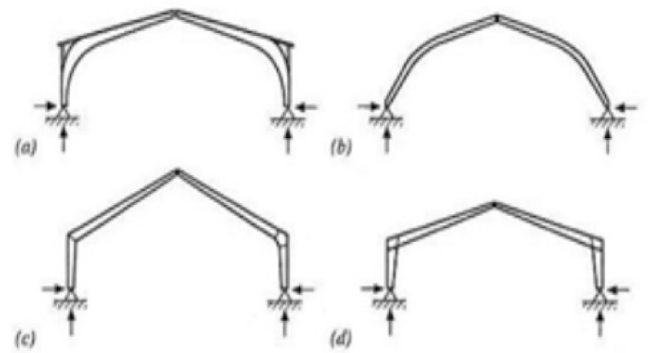


Figure 142. Three hinge construction retrieved from: <http://www.joostdevree.nl/shtmls/driescharnierspant.shtml>

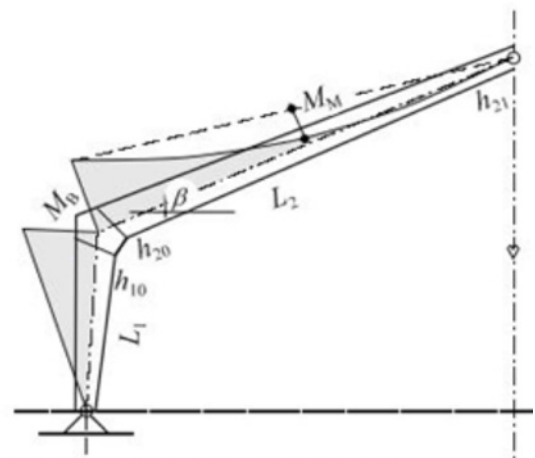


Figure 143. Three hinge construction retrieved from: <http://www.joostdevree.nl/shtmls/driescharnierspant.shtml>

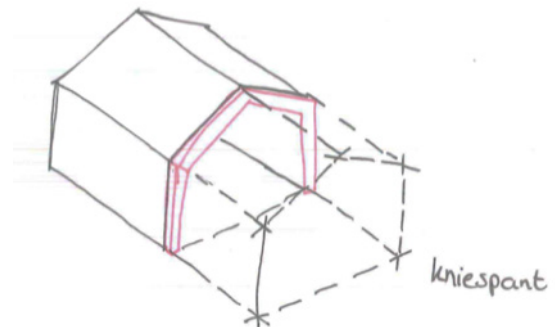


Figure 144. Building sketch of the construction

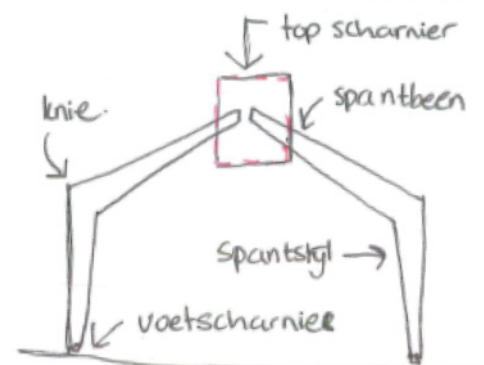


Figure 145.a Two construction options for the building

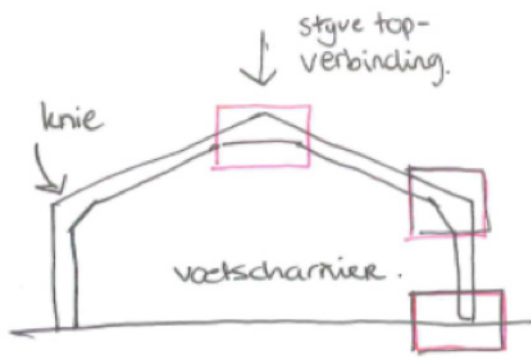


Figure 145.b Two construction options for the building.

As seen in figure 145a en b, the construction can be made as the first or the second option. The difference between the two options is that the first option is top hinged while the second option is stiff. The benefit of the first option is that it can be transported in two parts with a smaller truck and assembled on site. The size of a truck required is 2.55m with a maximum height of 4m and a maximum length of 12.0m. To maximize the space in the truck, the first option will be divided into four parts. Figure 146 shows the size which will use for the design of this report.

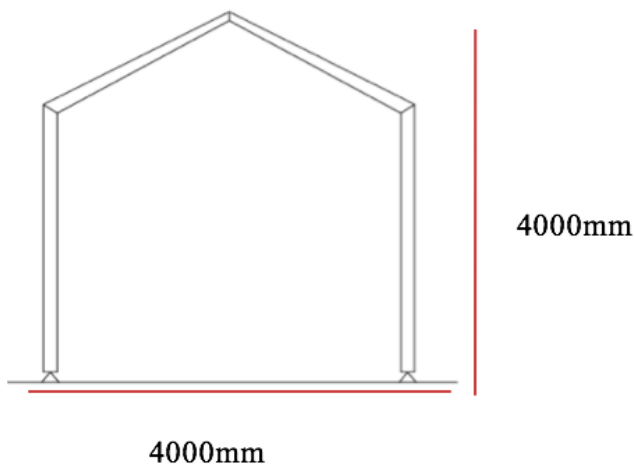


Figure 146. Size of the building for this report.

7.4.1 Calculation

The choice of alloy of the aluminum is important here. The alloy that we will use for the construction and the design will be from group 6xxx which contains silicon and magnesium as alloying elements. For the beam, it is important to know if it can carry weight of the roof and support its own weight. Therefore, a calculation is needed to see if the beam is satisfactory.

Before beginning the calculation, a statistic schedule, construction plan and the load on the beam of the roof will be shown in figure 147 and 148. The load on the roof is divided in three categories:

- BG1 the own weight
- BG2 resting load
- BG3 variable load

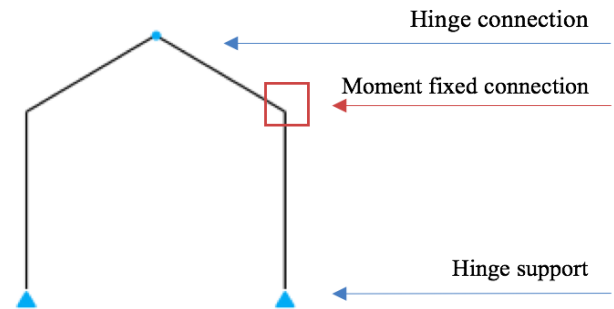


Figure 147. Static schedule.

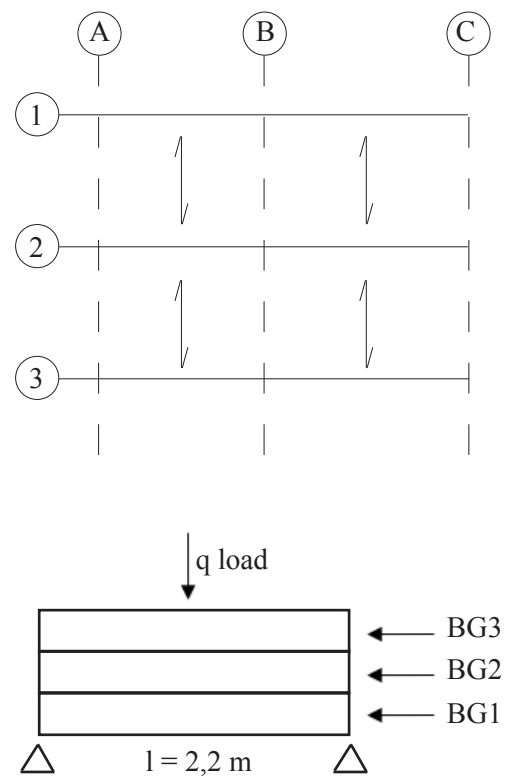


Figure 148. Construction plan and load on the beam

For the calculation of the strength of the beam, we will look at the column which stands at grid A2. The distance between the columns are consistent. Hence, the distance between grid A1 and A2 is 1000 mm and the distance between A1 and C1 is 4000 mm. The data necessary for the calculation is shown in table 30. For the calculation the size of the beam and column are the same, as shown in figure 149 below.

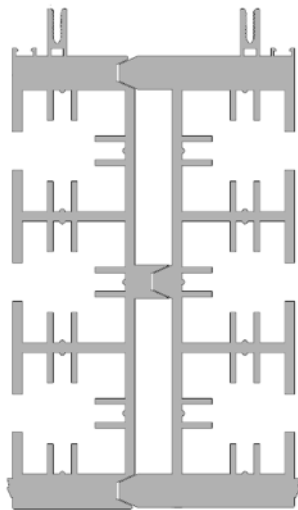


Figure 149. Size of the beam.

DATA BEAM A2 ALUMINIUM					
h floor beam	Weight [kN/m]	Wy [mm ³]	Iy [mm ⁴]	E-modulus [N/mm ²]	Strength (max)
235	0.93	436869	502777792	69 x 10 ³	280

Table 30. Data beam A2 aluminum

Weight [kN/m]:

The weight is not always given per linear meter. In order to determine this, we first need to know the area of the cross section and this must be multiplied by the density, ρ (kg/m³). Secondly, the result must be multiplied by the acceleration of gravity. The density of aluminum is 2702 kg/m³. Hence, the weight will be:

$$\text{Weight} = b \times h \times \rho \times (10/1000)$$

$$\text{Weight} = 0,146 \times 0,235 \times 2702 \times (10/1000) \longrightarrow 0,927 \text{ kN/m} \longrightarrow \text{BG1} = 0,93 \text{ kN/m}$$

Moment of resistance W_y [mm³]

The moment of resistance is easy to calculate for a rectangular beam. However, for the proposed design, this value will be complicated to calculate. Hence, this will be calculated in the program AutoCAD by making a polyline of the aluminum profile and look at the mass properties. The mass properties shows:

$$W_y = 436869 \text{ mm}^3$$
$$I_y = 502777792 \text{ mm}^4$$

E-modulus

The E-Modules is different for each material. It is defined as the slope of its stress-strain curve in the elastic deformation. The E-modulus for aluminum is:

$$69 \times 10^3 \text{ N/mm}^2$$

BG2 Resting load

For the calculation of BG2, it is important to look at the construction plan and to know the layers of the roof. This is shown in figure 150 below.

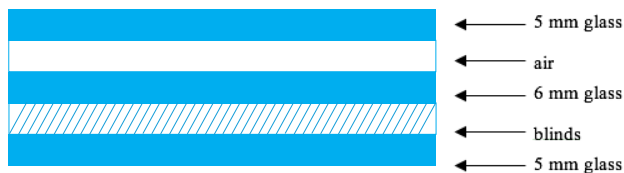


Figure 150. Layer roof.

To calculate the q-loads the volumetric weight should be multiplied by the layer thickness. The thickness of the layers is seen above. The area of the roof is 2,5 m². For glass, the specific volumetric weight is 2500kg/m³. For two layers of glass of 5 mm thickness each, the load will be:

$$0,005 \times 0,01 \times 2500 \times 2 \rightarrow 0,25 \text{ kN/m}^2$$

For the two layers of glass of 6 mm thickness each, the load will be:

$$0,006 \times 0,01 \times 2500 \rightarrow 0,15 \text{ kN/m}^2$$

The total load of the glass will be:

$$0,40 \text{ kN/m}^2$$

The calculation does not take the blinds into account. Therefore, we use a specific weight of 45kg/m³ that includes the blinds, some lighting fixtures and a finishing layer which will be used in some instances. Assuming a layer thickness of 2mm, the load will be:

$$0,002 \times 0,01 \times 45 \rightarrow 0,009 \text{ kN/m}^2$$

Hence, the total resting load is:

$$(1+1) / 2 \times 0,41 \rightarrow 0,82 \text{ kN/m}^2$$

$$\text{BG2} = 0,82 \text{ kN/m}^2$$

BG3 Variable load

The variable load depends on the function of the building and the total weight of the floor. In Europe, Eurocodes are standards and guidelines for the construction industry. For our project, “Eurocode 9: Design of aluminium structures” and “Eurocode 1: Opgelegde belasting” is applicable. Eurocode 1 give a list with use classes for a residential building and associated values for the vertical imposed load. This is showed in table 31.

Use class		q_k [kN/m ²]				Q_k [kN]
residential building	Floor	2,0				2,0
	Stair	3,0				2,0
	Balcony	4,0				2,0
Inaccessible roofs, unless for maintenance		$A < 20 \text{ m}^2$	$A \geq 20 \text{ m}^2$	$A \geq 40 \text{ m}^2$	$A \geq 60 \text{ m}^2$	
Flat and weakly sloping roofs ($\alpha < 30^\circ$)		0,8	0,6	0,4	0,2	1,5
sloping roofs ($\alpha \geq 30^\circ$)		0,6	0,5	0,3	0,2	1,5
sloping roofs ($\alpha \geq 40^\circ$)		0,4	0,3	0,2	0,1	1,5
sloping roofs ($\alpha \geq 60^\circ$)		0	0	0	0	1,5

Table 31. Eurocode 1 retrieved from <http://www.wtcb.be/homepage/index.cfm?cat=publications&sub=bbri-contact&pag=Contact8&art=124>

Hence, for each of the façades, we have a roof with an angle of approximately 22,6 degrees and an area of 2,2 m². From the table, we can use the load of 0,8 kN/m² in the calculations. This gives the following BG3:

$$\begin{array}{c}
 \downarrow \\
 (1+1) / 2 \times 0,8 \longrightarrow \boxed{1,6 \text{ kN/m}^2} \\
 \downarrow \\
 \boxed{\text{BG3} = 1,6 \text{ kN/m}^2}
 \end{array}$$

For the safety factor of permanent load, the factor 1,2 and 1,5 are used. This gives the following equation:

$$q = 1,2 \times q_{pb} + 1,5 \times q_{vb} \longrightarrow q = 1,2 \times (\text{BG1} + \text{BG2}) + 1,5 \times \text{BG3}$$

This gives a q-load of:

$$\begin{array}{c}
 \downarrow \\
 q = 1,2 \times (0,63 + 0,82) + 1,5 \times 1,6 \rightarrow \boxed{4.14 \text{ kN/m}}
 \end{array}$$

To determine the deflection of the beam, the stiffness of the beam need to be calculated. This can be done with the equation of the “Vergeet me nietjes”. The deflection of the beam can be calculated with

$$w = \frac{5}{384} \times \frac{q l^4}{E I}$$

and the unity check with

$$\text{U.C} = \frac{w_{bij}}{w_{norm}} \leq 1$$

For the w_{norm} , the regular rule is: $w_{norm} = 0,0034 \times l$. Hence, for our beam, the deflection is:

$$w = \frac{5}{384} \times \frac{4.14 \times 2200^4}{69 \times 10^3 \times 50,20 \times 10^7}$$

$$0.035 \text{ mm}$$

$$U.C = \frac{0,035}{6,6} \leq 1$$

So, the beam satisfies

Compressive strength column

To determine the compressive strength, the following equation can be used:

$$\sigma = \frac{F_d}{A} \leq f_{c;d}$$

In reality, the column will collapse earlier than calculated. This is because the load on the column will never be completely straight. In order to be able to make a global calculation, a reduction factor “Eurocode 3 – EN 1993-1-1” will be used. Depending on the shape of the cross-section, a specific value can be maintained. The Eurocode offers five different possibilities for the form of the knickcurves. For the calculation of the column in our design, we will use a value of 0,49. Before we start the calculation, we need the data of the column. The size of the column is the same as that of the beam. Table 32 shows the data of the column.

For the total load of UGT: $(1,2 \times 5,1) + (1,5 \times 2,2) = 9,42 \text{ kN}$.

$$\sigma = \frac{F_d}{A} \leq f_{c;d}$$

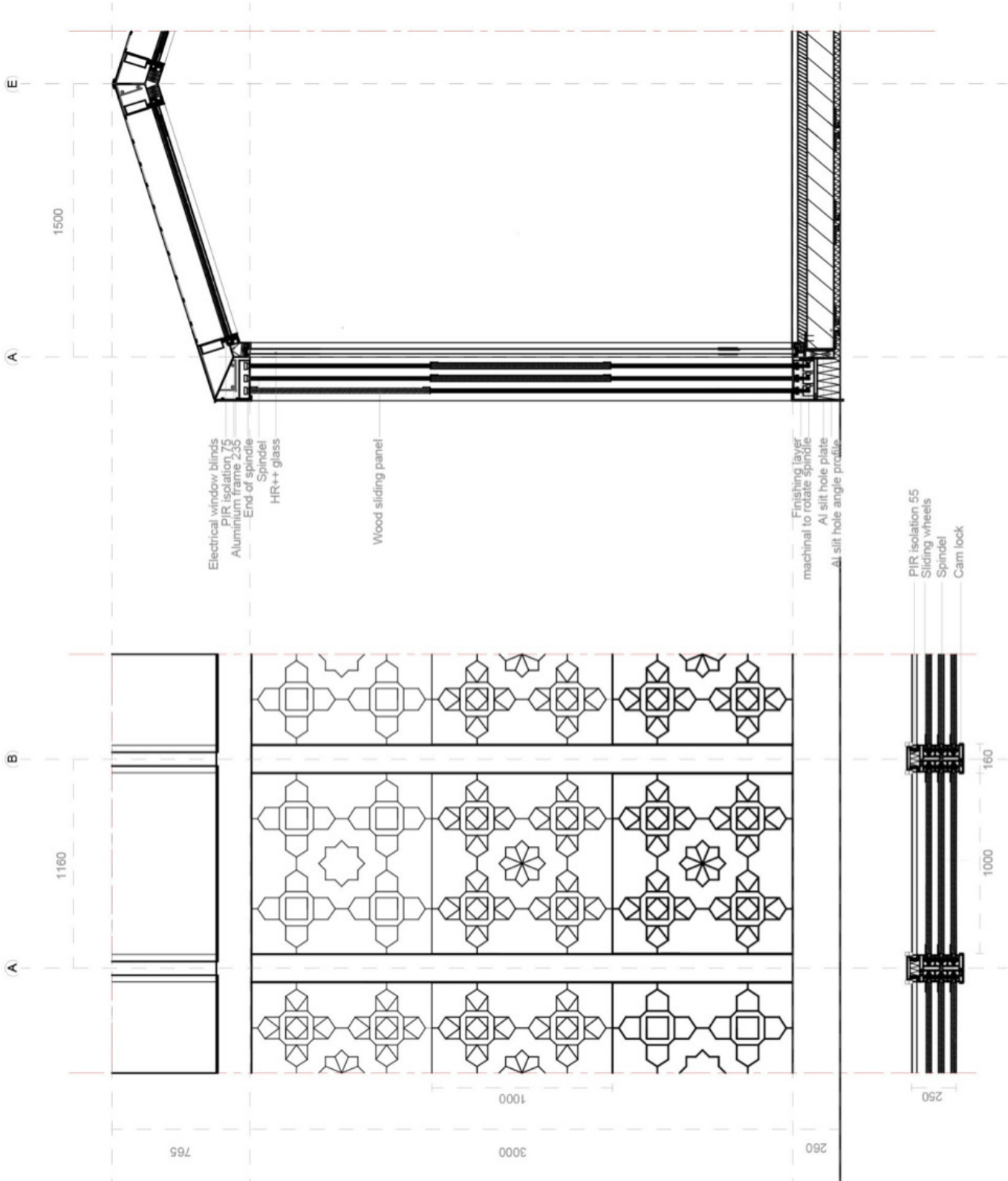
$$\sigma = \frac{9,42 \times 10^3}{2200} = 4.28 \text{ kN/mm}^2$$

So, the column satisfies

	Length (height) [m]	Width (height) [m]	Load. /m ²	Perma nent load	Total per. load	Variable load [kN]	Fact.	Cal. Variable load
Variable load	2,2 x	1 x	1			2,2	0 =	2,2
Weight roof construction	2,2 x	1 x	0,82	1,8				
Weight beam	2,2 x		0,63	1.4				
Weight column	3 x		0,63	1.9				
					5,1			
Total in kN			Permanent load = G:		5,1	Variable load	2,2	

Table 32. Data of the column.

7.5 Final design



Chapter 8

Testing Model

This chapter will look at the tests done on a physical model of the proposed design. These tests will show if the visual comfort requirements from the previous chapter are realized in the design. For the thermal comfort requirements, we will look at the adaptability of the building facade and how effectively it can block the sun. At the end of the chapter the following question will be answered: “What are the possibilities for the design of a facade?”



8.1 Visualization of the model

The model is built on a scale of 1:10 and primarily made out of MDF board, with the glass in the windows represented by Perspex.

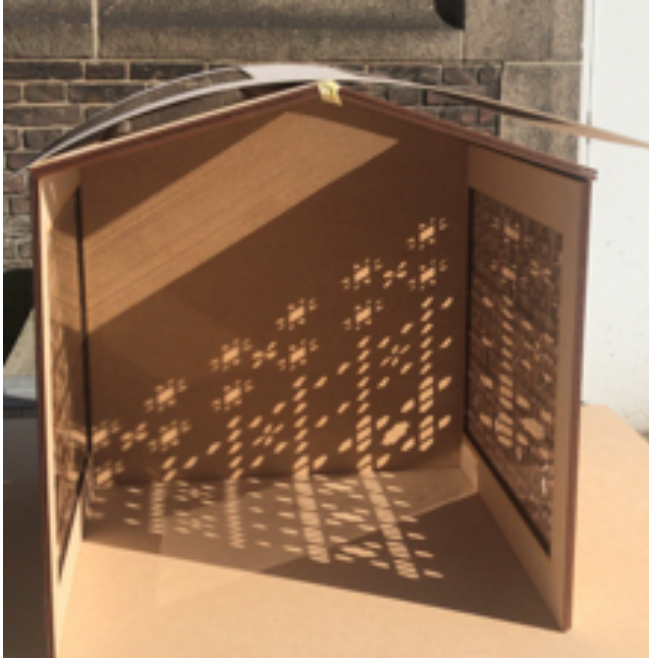


Figure 151. The model.

8.2 Testing the model

A lux meter is used in the physical model in order to test for visual comfort. The lux meter is placed in the middle of the floor of the model. The model is then placed outdoors, in the city of Delft, next to the Faculty of Architecture at TU Delft. The time of measurement was 12:05pm. The weather that day was sunny.

The facade of the physical model is configured in 3 different ways and measurements are taken for each configuration. In the first configuration, the facade panels do not overlap at all. In the

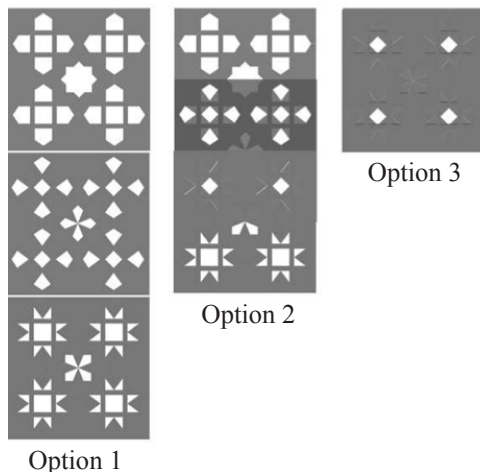


Figure 152. Configurations

Configuration	Lux inside	Daylight level
1	380	4
2	430	4
3	615	6

Table 33. Results of the measurements in the model

second, they overlap partially and in the third, they overlap completely. The roof of the model and two of the four walls were removed for all of the measurements. Hence, in total, the model had 3 completely open faces. The lux meter was always placed at the center of the floor of the physical model. The results of the measurements can be seen in Table 33.

Additional measurements were taken using the model, in order to understand if there was a significant difference when the model had two completely open faces instead of three. Hence, measurements were taken with the roof of the model and one wall removed. For configuration 1, this resulted in 300 lux inside and for configuration 3, it resulted in 500 lux inside. There was not a significant difference from the previous set of results. The results were more dependent on the orientation of the physical model than on the number of open faces it had.

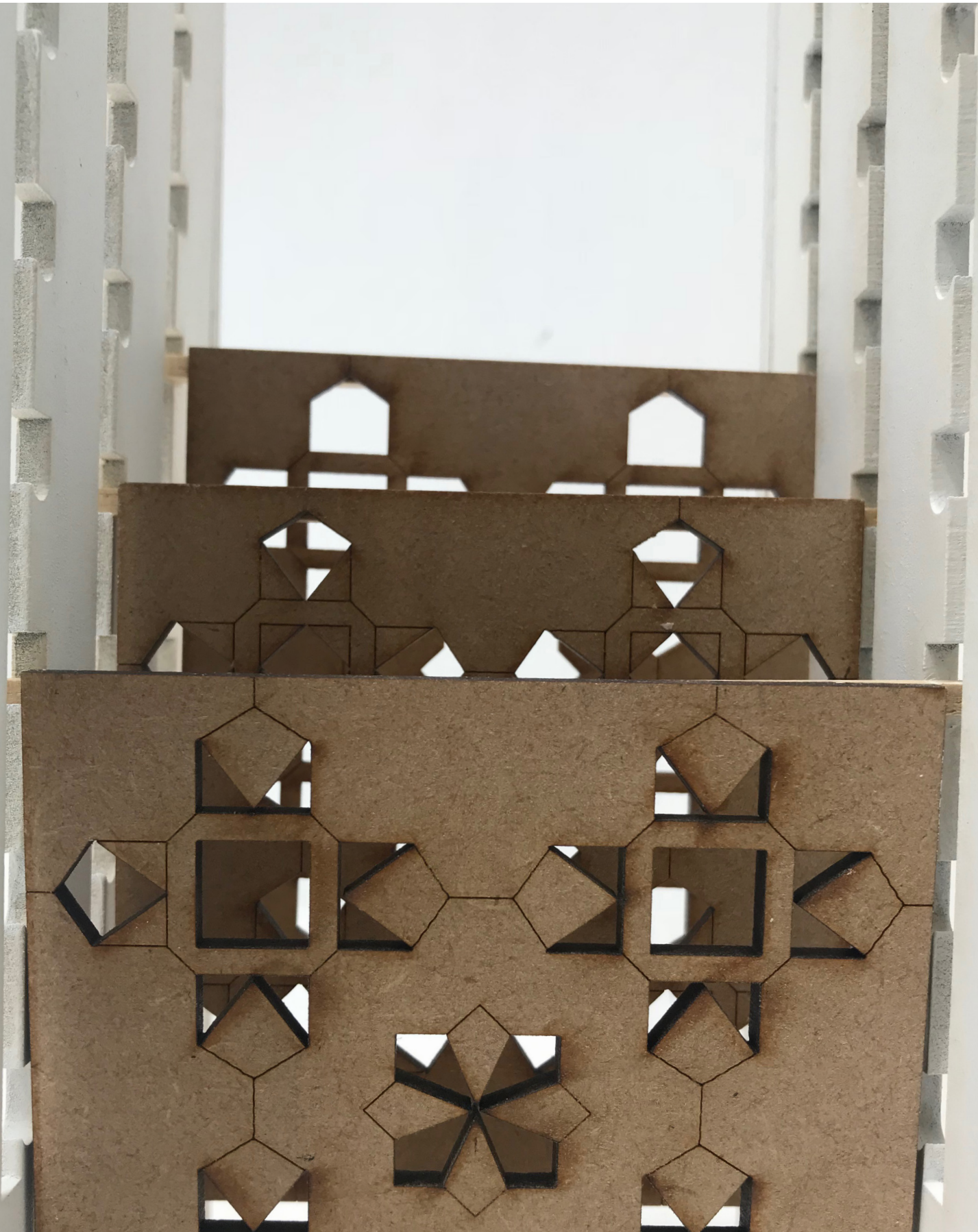
8.3 Conclusion

In the conclusion, the sub-question that was introduced in the beginning of the chapter will be answered:

“What are the possibilities for the design of a facade?”

The design of a facade consisting of panels that are able to move vertically, allows for flexibility when it comes to controlling the amount of daylight entering the interior. In summer, the panels can be shifted to reduce the amount of light entering the interior. This will help to lower the temperature of the interior. At the same time, the facade will still allow sufficient levels of daylight in even when the panels are fully overlapped. The panels can also be shifted such that the openings can allow fresh air into the building, while the shadow from the panels provide shade and help to keep the interior cool. In winter, the panels can be shifted to allow

the maximum amount of sunlight in. This will keep to increase the temperature of the interior. Additionally, the panels function as a second skin that will help to reduce heat loss and gain. In other to further optimize the facade, the panels could also incorporate a layer of insulation. However, this will have to be tested in order to understand if it is a viable and efficient solution.



Chapter 9 Discussion & Conclusion

In this final discussion and conclusion, the sub-question that was introduced in the beginning of this report will be answered:

“How can a façade be designed for a house for elderly people, where their children can take care for them in close proximity, while being flexible enough to customize for the thermal and visual comfort of a multicultural population?”

In the Netherlands, it was once common for families to live together in multi-generational homes. The Kangaroo Huis is an example of a such a house that allows for multi-generational living. A disadvantage of the Kangaroo Huis is that it is expensive, making it inaccessible to many. With an increase in the population of the aged in the Netherlands, it is beneficial to think of ways to reduce the cost of multi-generational living. A way to make multi-generational living accessible, is to introduce the option of leasing a building and returning it when it is no longer required. This buildings can be placed in the garden of an existing house and can be inhabited by one or both elderly parents. In this way, people are able to live in close proximity to their elderly parents while maintaining a desirable level of privacy.

For such a building to be comfortable, it needs to address requirements for thermal and visual comfort. The elderly have different requirements for thermal and visual comfort, when compared to those who are younger. Additionally, individuals also have different personal preferences for thermal and visual comfort. This makes it difficult to propose a design that is able to satisfy every potential occupant. However, to understand better the trends and patterns in thermal and visual comfort requirements, the elderly population can be better understood through groupings based on living conditions, gender, and ethnic background. As there are more than 200 ethnic groups in the Netherlands, it is difficult to study every group. Hence, the ethnic groups with the highest population were chosen to be studied. These ethnic groups are the Turkish, the Moroccans, the Surinamese and the Antillean and Aruban. This report looks at the thermal and visual comfort requirements of the elderly of these ethnic backgrounds. However, it was first necessary to

understand what thermal and visual comfort is, and the factors that positively and negatively affect these comfort levels.

Thermal comfort consists of five categories:

- (1) mean radiation temperature
- (2) relative air velocity
- (3) humidity
- (4) activity level
- (5) thermal resistance of clothing

Additionally, psychology can also influence thermal comfort. To be thermally comfortable, the internal heat gain must be equal to the external heat loss. This depends on metabolism and the thermal insulation of the skin. Hence, even if Turkish people prefer a warmer temperature in general, there might be Turkish individuals who prefer a lower temperature. These individuals may have higher fat reserves, or they might be more physically active than the average elderly person. The questionnaire showed that the elderly also prefer to regulate their thermal comfort manually, instead of through mechanical systems, and most of them are capable of doing so. This was an important point to consider for a successful design. Hence, the facade of the proposed design incorporated panels that can be moved vertically in order to control the amount of sunlight that enters the interior of the building. The theoretical part of the report found that the elderly, in general, prefer a temperature between 25.4 and 25.7 degrees Celsius. However, the questionnaire found that all the participants from every ethnic group preferred temperatures lower than the average. It is was also found that the Native participants are the only ones who preferred a temperature lower than the current temperature in their homes. This can be attributed to the higher activity levels of the Native elderly. They engage in sports twice as often as participants from the other groups. However, this is something that might change for the future generations of the other ethnic groups.

Visual comfort is a term that is related to lighting performance and human psychology. Light, in general, is an important basic requirement for the human body. It has an effect on physical and physiological behaviors. Because of its wide

spectrum, daylight is considered to be the best type of light for health. Daylight is the natural light that comes from the sun and its strength changes during the day. One of the hormones for which daylight is important, is the hormone melatonin. This hormone influences the sleep-wake rhythm. To have a positive effect on this hormone, people should spend more time outside, in daylight. However, the results of the questionnaire showed that the elderly do not spend much time outside and this is detrimental to their health. Hence, it was important for the facade to allow enough daylight into the interior. According to NEN-EN 12641, a person with normal vision requires 500 lux to complete visual tasks such as writing or reading. This lighting level has to be three times higher for the elderly, as compared to younger people. From the measurements taken of the rooms of the elderly participants, it was seen that none of those rooms were able to meet this requirement. Hence, it was important for the proposed design to allow a lot of daylight into the interior. To achieve this, the facade is composed largely of glass and this glass can be shielded by panels that have patterned openings in them. The panels can be moved, and they work together to shield or expose the building as desired. The desire for privacy, which was apparent from the results of the questionnaire, can also be met through the use of these patterned panels.

In the design of the building, the focus was on the facade. The facade is designed such that it is composed of parts that can be individually customized. Depending on the site and context, different permutations of facade components can be added together to create a customized whole. Each facade component is one meter wide. This dimension comes from the standard width of a door. Hence, doors can easily be set into the individual facade segments, as necessary. The facade also consists of panels that are able to move vertically and this allows for flexibility in controlling the amount of daylight entering the interior. The pattern on the panel can be changed not only according to the thermal and visual comfort requirements of the client, but also according to their aesthetic preferences and the specific requirements of the site. In summer, the panels can be shifted and overlapped to reduce the amount of light entering the interior. This will help to lower the temperature of the interior. At the same time, the facade will still allow sufficient levels of daylight in even when the

panels are fully overlapped. The panels can also be shifted such that the openings can allow fresh air into the building, while the shadow from the panels provide shade and help to keep the interior cool. However, for this report, the facade is not designed in such a way that the glass windows can be opened. In winter, the panels can be shifted to allow the maximum amount of sunlight into the interior. This will help to increase the temperature of the interior. Additionally, the panels function as a second skin that will help to reduce heat loss and gain. In order to further optimize the facade, the panels could also incorporate a layer of insulation. However, this will have to be tested in order to understand if it is a viable and efficient solution.

Chapter 10 Reflection

The reflection will have a short, substantiated explanation to account for the preliminary results of the research and design phases. The aim of the reflection is to look back on the methodology in order to understand where it was successful, and in which ways it was lacking.

10.1 The relationship between research and design

The relationship between research and design was clearly expressed at the beginning of the report. The research methodology diagram (Figure 4) showed that, following the literature study, the research and design phases would run concurrently. However, during the preparation of the research questionnaire, it was often difficult to focus on the design phase. This was because the preparation and execution of the questionnaire was very time consuming. Additionally, many parts of the design were dependent on the results of the questionnaire. The part of the design that was not dependent on the questionnaire, was worked on concurrently while the questionnaire was being prepared and executed. This was the design question of how the building can be made flexible enough, such that parts can easily be added or taken out to create a house that was able to accommodate a wide range of thermal and visual comfort requirements. Upon completion of the questionnaire, and an analysis of the results, the various requirements for thermal and visual comfort became clear. However, at this stage, there was not enough time to design every aspect of the house. Hence, a decision was made to focus on the façade of the house. The façade was chosen because it is a crucial factor in influencing thermal and visual comfort. During the design process, it was also beneficial to have both thermal and visual comfort to consider. When the design process got stuck in either visual or thermal comfort, it was useful to switch to the other factor in order to regain a fresh perspective on the design. In order to test the design for visual comfort, a model was made and tested outdoors. This will be done in a separate research which will be continued in the AE Master track. Hence, this report focuses on how a façade can be optimised in order to cater to the thermal and visual comforts of different groups of elderly users.

10.2 The relationship between the theme of the graduation lab and the subject/case study chosen by the student within this framework (location/object)

The Netherlands was chosen as the location for this report. This is because there is a sharp rise in ageing in the Netherlands and there also elderly people from various ethnic groups within this one country. Hence, while the report was located in one country, it was able to include participants from various racial and religious backgrounds. Results from the questionnaire conducted was analysed for each ethnic group and the results were compared between the different groups. In order for the results to be more accurate, it would be better to have a larger sample size, and also to have the same number of participants from each ethnic group. However, this was difficult to achieve in reality. Additionally, questioning the participants was often difficult as many of them were unable to comprehend the questions and the purpose behind them. This was especially true for the elderly of Moroccan and Turkish origin.

The resulting façade design can easily be replicated in other countries, because of the in-built flexibility of the façade. The façade can be modified to adapt to different levels of sunlight and temperature.

10.3 The relationship between the methodical line of approach of the graduation lab and the method chosen by the student in this framework

The chosen method of interviewing individual elderly participants and taking measurements of the rooms they inhabited was time consuming, but significant for the study. The results of the questionnaire, together with the measurements, results in a large amount of data. In hindsight, sufficient time was not allotted to this process. Additionally, the sample size was too small to draw

firm conclusions, and the period of the research only covered a short period of time in the year. A larger sample size, and multiple measurements taken at different times of the year would have led to more accurate conclusions. Additionally, a lot more time was needed for the design, than previously anticipated. This could have been overcome by applying changes to a pre-existing design instead of starting the design process from scratch. However, this would have deprived me of some of the satisfaction gained from the results of the design.

10.4 The relationship between the project and the wider social context

Currently, there is insufficient research in the field of Building Physics, on how the needs of the elderly differ from those who are younger and do not suffer from the typical ailments that afflict the elderly. With the rapidly ageing population of the Netherlands, the need for care centres and suitable housing for the elderly will increase. In order to reduce the burden of care on the state, there should be affordable options for those who wish to take care of their aged parents within their homes. The proposed design is able to accommodate this, as the buildings can be leased out, transformed or taken when necessary, and reused in a sustainable manner.

10.5 Recommendations for a follow-up study

- A model of the entire proposed building should be made and tested for thermal and visual comfort in the programme 'Design Builder'.
- A site could be chosen in order to fully develop the design, from its exterior relationship to the context, to its interior manifestation. This report began this process by looking at the strategies for construction that would allow the building to be flexible.
- The questionnaires should be conducted with a larger sample size, with equal participants in the various ethnic groups. The measurements can also be taken at different times of the year, so that various weather conditions are captured. This will allow for firmer conclusions to be drawn.

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