



# Design of a power nap facility for night shift workers

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## Chapter 0. Executive summary

The number of people working night shifts has been steadily increasing over the past 20 years. Although shift workers have known this for a long time already from first-hand experience, the Dutch national institute for public health and the environment has recently published advice to minimize night (shift) work, as it is detrimental to the physical- and mental health of shift workers. Furthermore, night shifts increase the risk of workplace accidents and put a lot of stress on the social lives of shift workers.

Over the years, multiple strategies to combat the negative effects of working night shifts have been developed and used. One method that has recently been gaining popularity in healthcare and industry is power napping. When utilizing power naps to combat the negative effects of night shift work, shift workers take a brief nap during their shift. Power napping during night shifts has been proven to be an effective method for reducing many of the common problems caused by working night shifts.

In this graduation project, a new power napping solution, called Asper, has been developed for the company NEWAS B.V.. Asper is the result of an extensive design process with multiple iterations. The process started with an analysis phase, followed by ideation and concept development. During the last phase, product development, the Asper was optimized for manufacturing and assembly.

The main goal of the design process was to develop a lay-down power nap solution that enabled night shift workers to take an optimal power nap. Through the integration of multiple design aspects, such as ergonomics, aesthetics, usability and manufacturability, this goal was achieved. The final result is a well-developed design that is ready for its 0<sup>th</sup> production series.



# Chapter 1. Introduction

In recent years, awareness for the negative effects of working night shifts has been growing. Negative effects of working night shifts include sleep disorders, reduced physical- and mental health and increased work-related accidents. One method to combat these negative effects is to take power naps during night shifts. This thesis describes the process and final results of the design process that led to the Asper, a power napping facility that has been developed for the company NEWAS B.V..

This chapter contains an overview of the design process' starting point. In chapter 2, the main result of the design process is shown. In chapter 3, the analysis phase of the design process is described. In chapter 4, the ideation method and results are presented. Chapter 5 outlines the concept development containing the first two iterations. Chapter 6 describes the product development, containing the third and fourth iteration. In chapter 7, the final design is described in great detail. Chapter 8 is the conclusion.

## 1.1 The design brief: a napping solution for night shift workers

The original design brief for this project was to develop a power napping solution in which night shift workers could take a power nap while laying down. Privacy and comfort were two of the main aspects that were considered relevant before the project started. Another relevant aspect was costs, the design had to be sold for between €4000,- and €7000,-. Other considerations included the need for users to not have claustrophobic feelings inside the product, being easy to store or even foldable and being easy to manufacture in small batches. For the original TU Delft design brief, see appendix A.

During the project, multiple adjustments were made to both the brief and requirements of the final design. The final design brief was: *'Design a power napping bed, in which healthcare and industry night shift workers can take an optimal power nap. The design must cost less than €1500,- excl. VAT. to manufacture and should not require upfront investments of over €5000,- excl. VAT. The design should be comfortable, ergonomic and add value to the power nap besides the included FPS technology.'* With this design brief in mind, the Asper was developed.

## 1.2 The client: NEWAS B.V.

The client of this graduation project is NEWAS B.V. NEWAS is a small company that was established in 2011 in Buren, the Netherlands. During the initial years, NEWAS developed their proprietary frequency physio support technology, FPS technology in short. After development, the FPS technology was integrated into three different chairs sold under the label VITA Sentation. The chairs are: model LOUNGE, model LUXURY and model COMFORT (see figure 1.1). Model LOUNGE is a fixed recliner chair. Model LUXURY is a motorised recliner chair. The model COMFORT is a lift chair, most commonly sold to the elderly. These chairs were initially sold as luxurious and comfortable chairs that helped the user to relax with its FPS technology. In recent years, the shift to power napping during night shifts was



made. The LOUNGE and LUXURY model are now the large majority of chairs sold. The main target markets are healthcare and industry, as HR and managers in these industries are becoming increasingly aware of the issues surrounding night shift work. With competitors introducing lay-down power nap solutions, NEWAS wanted to develop their own.



Figure 1.1 - Vita sensation chairs

### 1.3 The technology: FPS

FPS technology, or Frequency Physio Support, is a proprietary technology developed by NEWAS B.V. Through special 'bass shaker' speakers, vibrations with a frequency between 20 and 100Hz are created. Because multiple speakers are added to each FPS system, the software can create waves of vibrations with different frequencies, intensities, wave amplitudes, wave speeds and wave direction. Through the variations of these variables, multiple FPS programs can be made. Currently, five categories of programs exist: power nap, rest, empowerment, physical focus and wellness. A maximum of 12 programs can be programmed on a single system, the programs are selected based on the clients wishes. Because the technology is proprietary, no further detailed information can be given on the inner workings of the technology. Through its vibrations, FPS technology can aid in the reduction of muscle tension and stress and increase blood flow (Wilder-Smith, Horstik, Giezen, Nijenhuis, & Heijink, 2015). These characteristics allow FPS technology to aid users in relaxation and falling asleep.

### 1.4 The project scope

To set boundaries for the project, a project scope was defined at the beginning of this graduation. Activities included in a typical design process that lead to a well-developed design ready for its 0<sup>th</sup> production run are within the scope. These activities include: conducting user-, market-, literature- and context research; ideation through sketching, brainstorming and mood boards; concept development with 3D modelling and multiple iterations; product development through refining aesthetics, features and manufacturability. Activities and goals that are excluded from the project scope are: development past a 0<sup>th</sup> production run, further development of the FPS technology and creating promotional material for NEWAS. During the development of the Asper, the relaxation

guidance feature was considered out of scope as it's development could be an entire graduation project on its own.

## 1.5 Recommended reading order

Because this thesis is rather extensive, recommended reading orders are provided. These recommendations differ based on the goal and intent of the reader. Recommendations are made for three different types of readers:

1. **Interested in both the design process and end result.** If you are interested in the entire process, all consideration made during the process and final result of the design process, it is recommended that you read the thesis in its original order.
2. **Interested in the end result.** If you are just interested in the final result and not necessarily in the process or reasoning behind the final result, first read chapter 2 followed by chapter 7. These two chapters will most likely satisfy your needs. If you have any questions about the concepts development, read chapter 5 and 6. If any questions about the research or early development pop-up while reading, read chapter 3 or 4. Read chapter 8 last.
3. **Interested in the design process.** If you are interested in the design process and do not want to be spoiled with the final design before reading about the process, start with chapter 3 and move on from there. After chapter 6 either pick chapter 2 or 7, depending on the desired level of detail. Read chapter 8 last.

## Chapter 2. Asper design overview

This chapter provides a brief overview of the main aspects that have been considered during the design process of the Asper. These aspects are: functionality and features; aesthetics and shape; dimensions and ergonomics; manufacturing and assembly. For more details on the design of the Asper and every aspect, see chapter 7.



Figure 2.1 - Asper design

### 2.1 Functionality and features

The main functionality of the Asper is to provide a suitable facility to power nap on during night shifts. The Asper is designed to provide the optimal power napping environment for users. Its shape and features are designed to help the user relax and take an effective power nap.

The basic model of the Asper comes with a set of standard features. To reduce the base cost, some additional features are optional. These can be added to the Asper when a customer's context requires said feature.

#### 2.1.1 Standard features

##### FPS technology

FPS technology aids the user in reducing stress and quickly falling asleep. This works through the reduction of muscle tension and increase of blood flow. The Asper has an FPS system integrated into its mattress with programs optimized for power naps.

### **LED lighting**

The Asper comes with integrated lighting (see figure 2.2). This lighting has a dual purpose. The first purpose of the lights is wayfinding. When placed in a dark room, users no longer have to use their phone as a light source after turning off the room lights or when the nap has finished. The second purpose is discussed in the next paragraph.

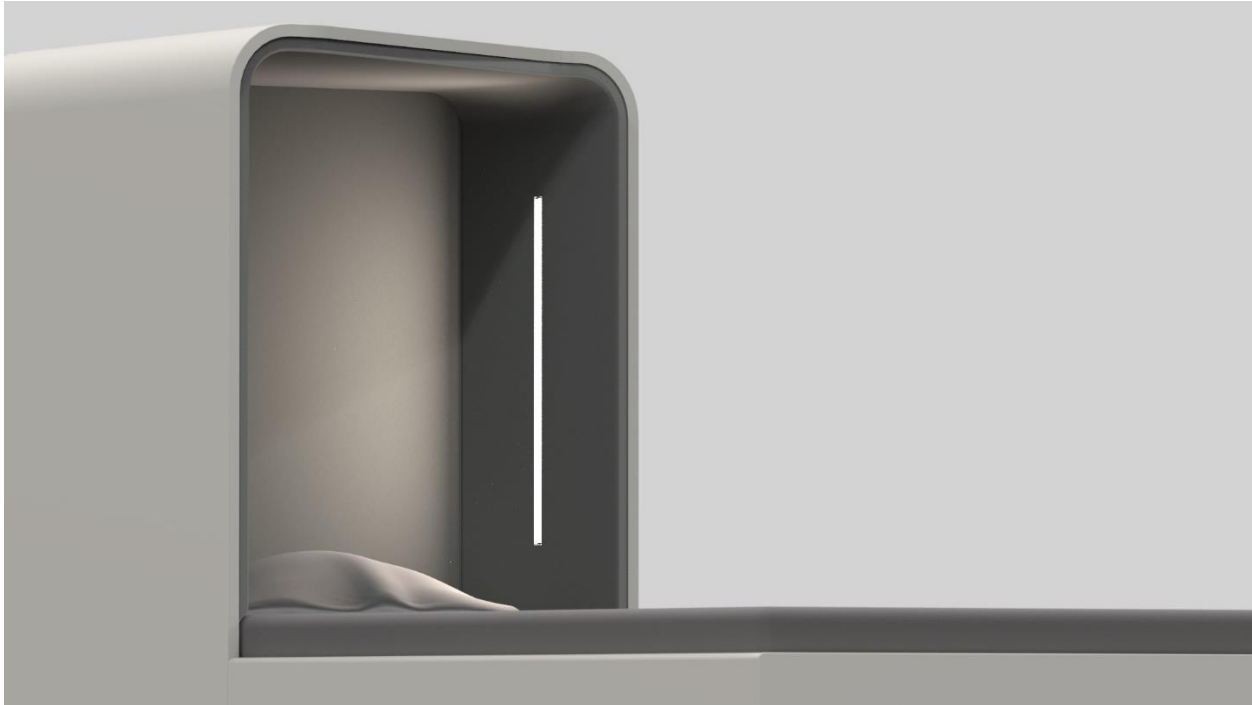


Figure 2.2 - integrated LED's

### **Waking assistance.**

The Asper has an integrated waking assistance system. A concern of both experienced- and inexperienced nappers is the inability to wake up after a power nap and going into deep sleep. The waking assistance prevents this by slowly increasing intensity of the light at the end of the power nap. This is combined with a significant boost of FPS intensity at the end of the power nap program, ensuring the user wakes up.

### **Privacy structure**

The Asper's shape provides the user with sufficient privacy to relax and take a power nap. It blocks the lines of sight to the user's upper torso and head from about 200 degrees. The Asper is not fully closed off, as the intended placement for the Asper is in power napping rooms.

### **Integrated storage space**

To store clean bedlinen and blankets, the Asper comes with integrated storage. This storage can also be used to store information pamphlets about the FPS programs and small personal items like glasses, phones, pagers and tools.

### **Sound absorption**

Because noise is a common disturbance when power napping, the Asper's head capsule is upholstered with foam and water resistant fabric. Although this upholstery does not fully eliminate sounds, it does prevent reverberation inside the capsule.

## **2.1.2 Optional features**

### **Casters**

The feet of the Asper can be replaced by casters (see figure 2.3). This feature is expected to be of great value in healthcare contexts, as it makes cleaning in and around the concept significantly easier.

### **Electric blankets**

A common issue in night shift workers is being cold. The Asper can be equipped to support electric (under) blankets to provide additional warmth to the user.

### **Relaxation guidance**

Relaxation guidance can be added to the Asper to further aid users in relaxing and falling asleep. The current version of this feature utilizes breathing exercises visualised through the LED lights.

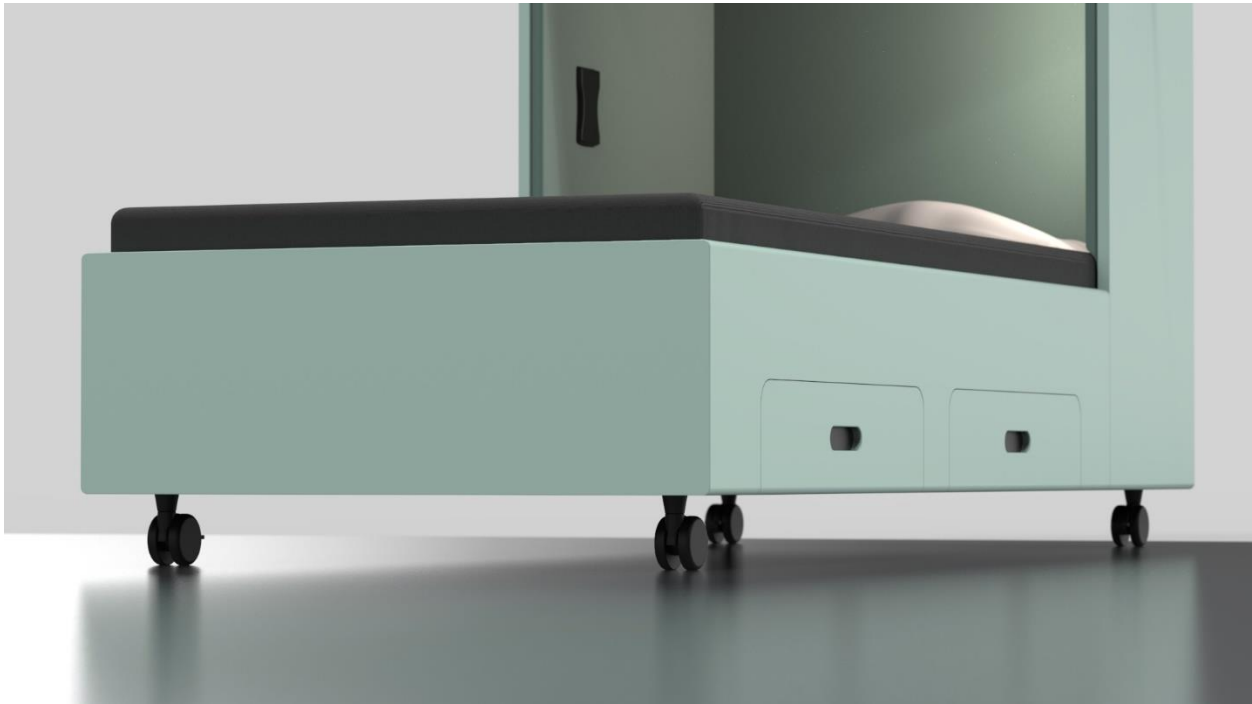


Figure 2.3 - Asper with casters

## 2.2 Aesthetics and shape

Four aesthetic goals were set for the Asper. The Asper has to look: comfortable, inviting, calming or relaxing and soft. To achieve these goals, the Asper has large round shapes on the head capsule, rounded edges on the frame, rounded feet and rounded drawer corners. Furthermore, the surface finish is low-gloss, making the shapes look even softer. Another aspect that aids in the perceived comfort and softness is the soft fabric used for the upholstery. To be inviting, the concept is semi open. This lowers the barrier to enter and try the Asper out.

The Asper will be available in four different colour schemes. These are called: natural nap, sweet dreams, cloud sleeper and nights rest. See figure 2.4 for the colour combinations.

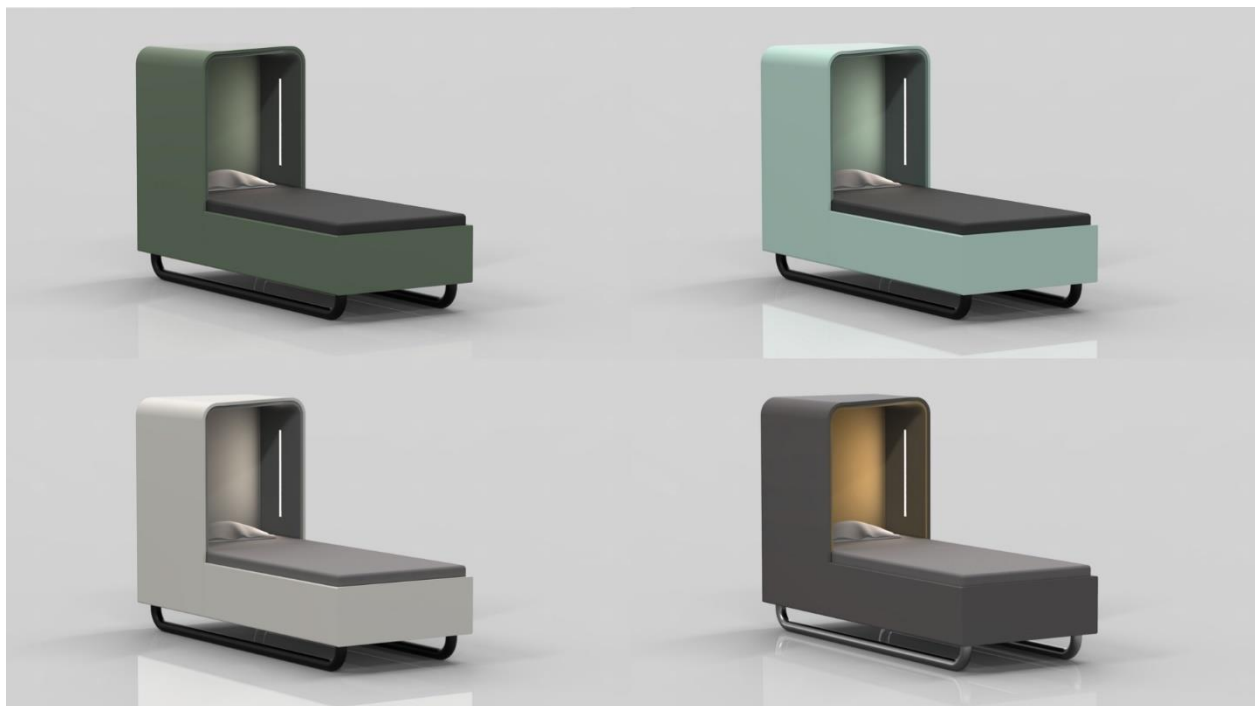


Figure 2.4 - Different colour schemes

## 2.3 Dimensions and ergonomics

The Asper is 2046mm long, 846mm wide and 1348mm tall. With these dimensions, the Asper fits through most Dutch doors. The mattress in the Asper is 2000mm long by 800mm wide, ensure that the user has plenty of space to move around. Both ingress and egress are easy, as the short sidewall of 440 mm does not obstruct the user's motion when entering the bed. The internal height of the head capsule is 800mm to prevent anyone from hitting their head while going to lay down or sit back up. The bottom of the Asper is raised 147mm above the floor, allowing for easy access when vacuuming or mopping the floor. Fully assembled, the Asper weighs approximately 90 kg. See figure 2.5 and 2.6 for a visualisation of the dimensions.

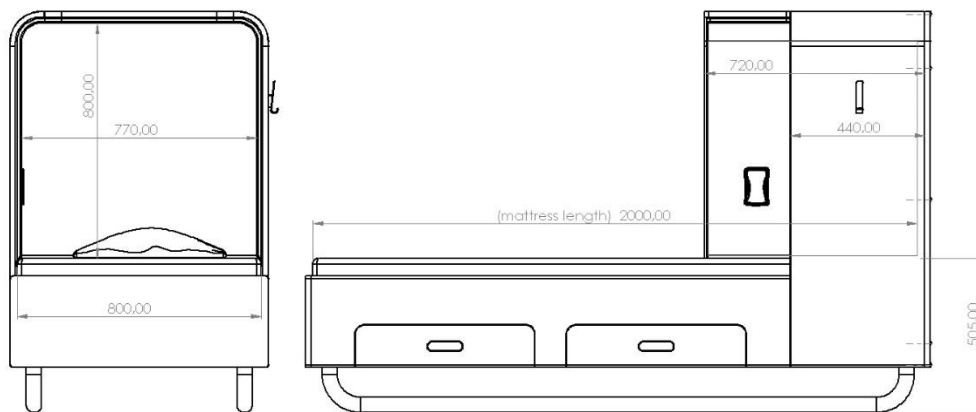


Figure 2.5 - Inner dimensions Asper

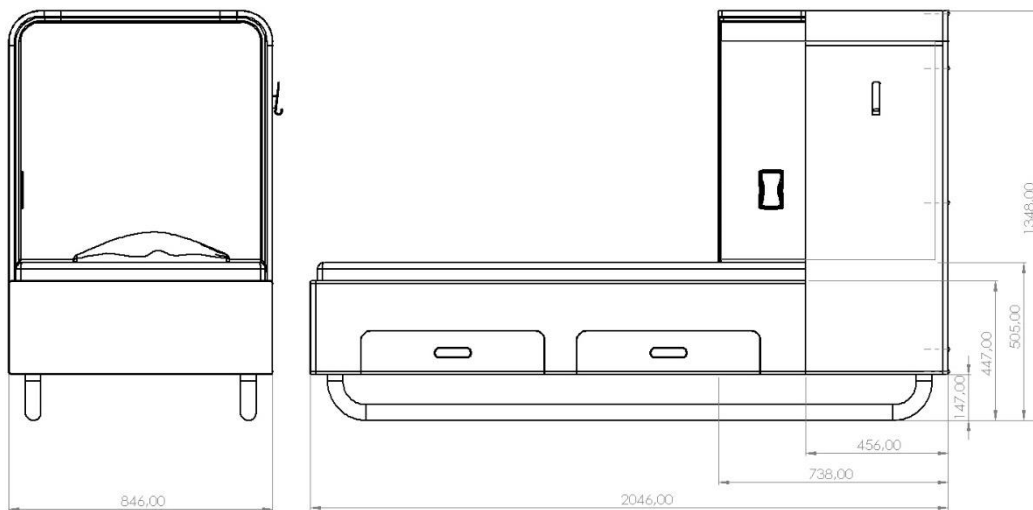


Figure 2.6 Outer dimensions Asper

## 2.4 Manufacturing and assembly

An important consideration in the design of the Asper has been the manufacturability and assembly of the final product. Because the expected production volume is low, especially in the first years of manufacturing, manufacturing methods with high initial investment requirements were excluded. This led the Asper to being almost exclusively made out of poplar plywood, as it is light, strong and relatively cheap. Multiple iterations were made to improve the manufacturability. The end result is a product that can easily be manufactured by any larger furniture manufacturer.

To be able to easily transport the Asper, a final assembly step is required on site. The head capsule needs to be attached to the base frame. Brackets are installed on the head capsule to make this process simpler (see figure 2.7).



Figure 2.7 - Steel brackets for assembly



## Chapter 3. Analysis

Many of the decisions that led to the design of the Asper are based on research. Like most design projects, the design process of the Asper started with an extensive research phase. This chapter contains a description, the main findings and requirements that stem from the research for each activity in this phase. Although easy for some activities, pointing out the influence on the design is almost impossible for others, as some activities provide general background information.

Nevertheless, all activities were important in shaping the design. Activities included in this phase are: a literature review; a competitor- and stakeholder analysis; user-, facility management- and context researches.

### 3.1 Literature overview

In this sub-chapter an overview of the conducted literature research regarding sleep, shift work and power napping is presented. The literature search started with defining relevant questions to answer and topics to cover within the three categories. Throughout the research, new knowledge and insights were gathered, resulting in additional questions and topics. To answer the questions and cover the defined topics, literature was searched. This was done with ScienceDirect, PubMed and Google scholar.

#### 3.1.1 Sleep

Understanding the basics of sleep is a necessity to understand power naps, as a power nap is a brief period of sleep. The following sections provide background information on sleep. Answers to questions such as: Why do humans sleep? How does sleep work? And what types of sleep exist? are given to provide a basic foundation of knowledge for the research on power naps.

##### 3.1.1.1 Need for sleep

On average, humans need between 7 and 9 hours of sleep each day (M. Carskadon, Dement, Kryger, Roth & Roehrs, 2005). The exact and complete purpose of sleep is still a subject of discussion in the scientific community (Brinkman, Vamsi & Sharma, 2018). Despite not knowing the exact purpose of sleeping, there are many indications as to why sleeping is useful. Sleep is needed for processing the information and stimuli that individuals receive during a day (Pearlman, 1979). Another process that only occurs during sleep is brain plasticity, a process in which the structure and organization of the brain changes. This is considered to be critical in learning and memory (Caverzasio et al., 2018). Many negative effects of sleep deprivation have also been discovered and proven, further illustrating the need for sleep. These negative effects include: diabetes, cardiovascular diseases, hypertension, reduced immune function, high blood pressure, reduced cognitive functioning and poor moods (Amira et al., 2016). Sleep deprivation also results in increased rates of errors and accidents in work

environments (Gold et al., 1992; Hope, Øverland, Brun, & Matthiesen, 2010). According to Worley (2018), good sleep is a requirement for good health, both physically and mentally.

### **3.1.1.2 Sleep regulation**

Sleep is regulated by two internal mechanisms; Process C, which promotes wakefulness and process S, which promotes sleep.

Process C is regulated by the circadian rhythm which follows the day-night cycle and repeats roughly every 24 hours. The circadian rhythm is also responsible for regulating the day-night cycle of other bodily cycles like body temperature and blood pressure (Oosterhuis, Smid & Hulshof, 2020). Through a process called entrainment, external stimuli called zeitgebers (German: 'time givers') calibrate the circadian rhythm to match the day-night cycle (Waterhouse, Fukuda & Morita, 2012). This allows the human biological clock to shift and synchronise with the context. Clear examples of this are the ability to adjust to local time after long-distance flights across different time-zones and being able to adjust to seasonal changes. Important zeitgebers are: the light-dark cycle and temperature (Waterhouse et al., 2012), social activities and meals (Grandin, Alloy & Abramson, 2006) and physical activity (E. J. W. Van Someren & Riemersma-Van Der Lek, 2007).

An abnormal deviation in the circadian rhythm is called circadian rhythm disorder, which is relatively common in night shift workers (James, Honn, Gaddameedhi & Van Dongen, 2017). Circadian rhythm disorder can increase the risk of a weakened immune system, cardiovascular diseases, gastrointestinal disorders and cognitive and behavioural disorders. The last of which may lead to reduced productivity and workplace safety (National Heart Lung and Blood Institute, 2019).

Process S, or the sleep-wake homeostasis is responsible for controlling the need for sleep. This need for sleep increases with every woken hour and peaks just before going to sleep (Borbély, Daan, Wirz-Justice, & De boer, 2016). During a normal night of sleep, the need for sleep reduces or even disappears and starts building up again when waking up. When awake for longer, like when working night shifts, the need for sleep increases resulting in sleepiness and drowsiness (Khan, Duan, Yao & Hou, 2018).

### **3.1.1.3 Sleep types**

Human sleep consists of two types of sleep: non-rapid eye movement sleep (NREM) and rapid eye movement sleep (REM). During normal sleep these two types of sleep alternate cyclically. Sleep starts with NREM sleep and is followed by REM sleep, after which sleep cycles back to NREM followed by REM sleep and so forth (M. Carskadon & Dement, 2017). The first cycle of NREM sleep followed by REM sleep lasts between 70 and 100 minutes, subsequent cycles last between 90 to 120 minutes (Colten & Altevogt, 2006).

NREM sleep has three different stages, named stage N1 to N3 respectively (Berry et al., 2020). Each stage has distinctive properties like variations in eye movement and brain waves. Stage N1 is the

transitional stage, from being awake to falling asleep. This stage lasts between 1 and 7 minutes and is easily interrupted by external stimuli (Colten & Altevogt, 2006). Stage N2 is a period of light sleep before entering deeper sleep in stage N3 (National Institute of Neurological Disorders and Stroke, 2016). The duration of stage N2 is usually between 10 and 25 minutes during the first cycle, and then increases with each subsequent cycle. Stage N2 plays an important role in learning and memory formation (Gais, Mölle, Helms & Born, 2002). The last stage of NREM sleep is N3, often called the slow-wave-sleep (SWS). During N3 sleep, it is very difficult to be awoken, as many environmental stimuli no longer produce any reactions. For power naps to be effective and to prevent sleep inertia, it is advised to terminate sleep before entering slow-wave-sleep (see section 3.1.3.3). Slow-wave-sleep is thought to be the most restful form of sleep, the phase which most relieves subjective feelings of sleepiness and restores the body (Waterhouse et al., 2012), due to the production of growth hormones (Coenen, 2006).

REM sleep, or stage R, is characterized by rapid eye movement and is often linked to dreaming. During REM sleep, reflexes and muscle tone are suppressed to prevent sleepers from physically reacting to their dreams (Bader, Gillberg, Johnson, Kadesjö & Rasmussen, 2003). REM sleep initially lasts 1 to 5 minutes, but like stage 2 of NREM sleep, becomes progressively longer during the subsequent cycles (M. Carskadon et al., 2005).

### **3.1.2 Night shift work**

The intended context and use of the Asper is to enable power naps during night shifts. The following sections provide general information about night shifts, the effects of night shift work on employees and existing (partial) remedies to fight the negative effects of night shift work.

#### **3.1.2.1 Night shift work definition**

Although no agreement on the definition of shift work exists in literature, it is generally considered to encompass all workhours outside regular working hours (Bøggild & Knutsson, 1999). I.e. shift work refers to all work schedules that fall between the hours of 18:00 (6 pm) until 07:00 (7 am). This includes evening-, night- and morning shifts. Night shifts have been inconsistently defined across multiple studies (F. Wang et al., 2013). The definition used in this thesis is: *working the fulltime period between 24:00 (12 pm) and 05:00 (5 am)* (Pesch et al., 2010).

Shift work is used to provide 24/7 labour coverage. Traditionally, working in shifts occurred in sectors where either start-up- and shut-down costs are steep like in some industrial processes (e.g. steel, oil and gas production) or in sectors where constant availability and the ability to intervene is required, like healthcare and energy. Nowadays, shift-work is more common in other sectors like hospitality, public utilities, telecommunications and security. With the rise of online-shopping and next-day delivery, shift work has become common in logistics as well (Gezondheidsraad, 2017).

Over the past 15 years, the number of Dutch shift workers has increased by 264.000 people, from 533.000 in 2005 to 797.000 in 2020, which is an increase of almost 50% (CBS, 2020). Over 15% of the total working population occasionally to regularly works during the night. The European average is slightly higher at almost 20% of people working night shifts (Malleret, 2018). Recent events have increased the pressure on- and need for- shift workers in both healthcare and logistics, resulting in further expected growth of these numbers.

### **3.1.2.2 The effects of night shift work**

Although necessary for certain industries, working night shifts has been proven to have a negative impact on the lives of shift workers in multiple aspects like:

*(a) Physical health:* Working night shifts has been proven to correlate with a reduction in both sleep quality and quantity, causing an increased risk to multiple disorders and diseases. This includes an increased risk of cardiovascular- and gastrointestinal disorders (Harrington, 2001).

*(b) Mental health:* Shift work and night shifts are likely to be correlated with increased levels of anxiety (Thun et al., 2014). Furthermore, night-time shift work also increases the risk of depression (Angerer, Schmook, Elfantel & Li, 2017).

*(c) Family and social life:* Night shift workers, are reported to experience substantial disruption of social and family activities (Harrington, 2001). As most social- and family activities take place during the day and weekends, (night) shift work limits the ability to attend these activities.

*(d) Safety:* Night shift work has been proven to reduce cognitive functioning and increase reaction times (Sumińska, Nowak, Łukomska & Cygan, 2020). Fatigue and sleepiness during night shifts increase the risk of work-place incidents (Dinges, 1995). Furthermore, the risk of road accidents happening during the commute after a night shift increased significantly (M. L. Lee et al., 2016). In the following paragraphs these four factors are further elaborated on.

#### **The effects of night shifts on physical health (a)**

It is generally agreed upon in scientific publications that shift work, and especially night shifts, have a negative effect on sleep. Night shift workers are estimated to be 1.5 to 2 times more likely to experience sleeping problems than regular day-workers (Yong, Li & Calvert, 2017). Working either early morning- or night shifts results, on average, in a loss of sleep of between 1 and 4 hours during the following day's sleep (in respect to normal nocturnal sleep). The quality of sleep is also affected by working night shifts, as both stage N2 and REM sleep are reduced (Akerstedt, 1990). The reduction in sleep quality and quantity as a result of shift work is called shift work disorder (Sateia, 2014). With the reduced time and quality of sleep, sleep deficits can emerge. Sleep deficits can result in alterations in the immune system and an increased risk of obesity, diabetes and metabolic syndrome (M. A. Carskadon, 2004).

Working night shifts has also been found to increase the risk of cardiovascular disorders. The most common health outcomes are chest pain (angina pectoris), high blood pressure (hypertension) and

heart attacks (myocardial infarction) (Harrington, 2001). This risk increases with the years spent working in night shifts. The Gezondheidsraad (2017) (Health council of the Netherlands) estimates, based on two large retrospective cohort studies, that 4 out of 100 cases of cardiovascular disorders in night shift workers are caused by working in night shifts for 5 years. This number rises to 23 out of 100 after 40 years of night shifts. This means an 8 percentage-point risk increase after 40 years.

Another area of health issues related to night shifts are gastrointestinal disorders. It is widely reported that night workers experience more digestive disorders than their day-job counterparts (Harrington, 2001). According to multiple studies, 20% to 75% of night shift workers report disturbances of appetite, dyspepsia, heartburn, abdominal pains, grumbling and flatulence whereas only 10% to 25% of day-job workers experience these disorders (Costa, 1996). Furthermore, a significant relation between night shift work and the risk of the metabolic syndrome was found. The increased risk correlates with the number of years working night shifts (F. Wang et al., 2014).

According to the Gezondheidsraad (2017), working in night shifts is strongly correlated with diabetes mellitus. Research on the effects of rotating night shift work on the risk of diabetes mellitus in women concludes that nightwork modestly increases the risk of diabetes mellitus (Pan, Schernhammer, Sun & Hu, 2011). Like cardiovascular- and gastrointestinal disorders, the risk of diabetes mellitus increases with the years spent working night shifts. The Gezondheidsraad estimates that 3 out of 100 cases of diabetes mellitus among shift workers is caused by their work after 5 years. This number rises to 21 out of 100 cases after 40 years. This means a 7 percentage-point risk increase after 40 years (Gezondheidsraad, 2017).

The effects of working in night shifts on issues like reproductive health and cancer have been studied, however current evidence is inconclusive. The main issues in the research conducted on these topics, are the poor definition of nightwork and the lack of records of exposure to nightwork (Chau, West & Mapedzahama, 2014; Gezondheidsraad, 2017).

### **The effects of night shifts on mental health (b)**

Besides the physical health risks, multiple studies showed that night shift work is also associated with an increased risk of several mental illnesses like anxiety and depression. In a meta-analysis of these studies, Lee et al. (2017) concluded that night shift work is indeed associated with an increased risk of depression independent of subgroups like gender, night shift duration, type of occupation, continent and type of publication. Lee et al. (2017) quantitatively estimated that night shift workers have a 40% higher risk of depression than their day-job counterparts. Night shift workers who change from night-shifts to day-shifts report a significant decrease in symptoms of both anxiety and depression. However, shift workers who change from day-shifts to night-shifts do not show a significant increase in symptoms during their first two years, suggesting that these symptoms might only occur when working night shifts for a longer period of time (Thun et al., 2014).

### **The effects of night shifts on family and social life (c)**

Another effect of working (night) shifts is the misalignment of recreational time of shift workers and regular social events. Although hard to quantify, the impact of (night) shift work on the social lives of the (night) shift workers is often reported (Costa, 1996). Shift work is reported to negatively impact marital relations, child care and social contacts. The former can lead to social marginalisation (Harrington, 2001).

### **The effects of night shifts on safety (d)**

Lastly, the effects of working night shifts on safety. It has been widely accepted that working night shifts causes fatigue, reduced reaction times and cognitive functioning (Akerstedt, 1990; Dawson, Ian Noy, Härmä, Akerstedt & Belenky, 2011; Marquié, Tucker, Folkard, Gentil & Ansiau, 2015; Meijman, de Vries-Griever & Kampman, 1989). These negative effects of night shifts affect the quantity, quality and safety of night shift labour (Folkard & Tucker, 2003; Sumińska et al., 2020). Productivity is reported to be reduced by between 11 and 17% when compared to day-work (Hanna, Chang, Sullivan, & Lackney, 2008). Furthermore, fatigue and sleepiness during night shifts increase the risk of work-place incidents. Although the increased risk is highly dependent on industry, environment and context, night shift work is reported to increase the risk of work-place incidents by between 2% and 40% (Dinges, 1995). Another problem related to night shifts occurs during the commute back home after a shift. Fatigue and drowsiness causes a high risk of motor accidents in night shift workers (Lee et al., 2016). Recently published Dutch guidelines by the NVAB (Dutch association for occupational physicians) for night shift work now recommend resting before commuting back home (Oosterhuis et al., 2020).

### **3.1.2.3 Existing solutions and suggestions to improve the night shift**

In an attempt to reduce, or even eliminate, the negative effects that night shifts have on workers, a plethora of different solutions and suggestions has been developed. These include sleep hygiene recommendations, dietary changes, light filtering, scheduling adjustments and power naps. In this subsection an overview of the suggestions for reduction or mitigation of negative effects of night shifts is given.

#### **Sleep hygiene**

Sleep hygiene is a set of recommendations that is intended to aid people with achieving good and healthy sleep. The effectiveness for treating insomnia, sleep hygiene's original purpose, as a monotherapy is considered to be limited (Morgenthaler et al., 2006). Nevertheless, the implementation of sleep hygiene is confirmed to be strongly related to sleep quality and modestly related to perception of daytime sleepiness (Mastin, Bryson & Corwyn, 2006).

With an increasing portion of the population spending less time asleep than the recommended minimum of 7 hours (Spoormaker, 2006), sleep hygiene recommendations have found their way outside the clinical settings where the recommendations are used to improve the sleep quality and quantity of the general public. Sleep hygiene recommendations have also found their way into suggested solutions for night shift workers. The NVAB (2020) included sleep hygiene recommendations as a potential solution in their report on night shift work.

Sleep hygiene provides both behavioural and environmental recommendations for healthy sleep. Behavioural topics covered by sleep hygiene are things like exercise, sleep scheduling, stress management, timing of/limited usage of caffeine, nicotine, alcohol, (sleep) medication and many more (Irish, Kline, Gunn, Buysse & Hall, 2014). Environmental recommendations include temperature, darkness and noise level in the bedroom and general comfort of the sleeping environment including a comfortable bed and bedding (Irish et al., 2014). The recommended temperature lies between 16 and 18 °C, for light levels and noise levels no such quantitative recommendations exist. Rather, the recommendations just advise to minimize light and noise. In the design of the Asper, the environmental recommendations play a significant role as the design is easily able to influence these aspects. A complete list of recommendations for sleep hygiene can be found in Appendix B.

### **Dietary changes**

Another aspect that has been gaining a lot of attention in recent years is the focus on consuming healthier foods during night shifts. Eating healthier is often included in seminars and talks about healthy shift work (Fedele, 2019). The guidelines from the NVAB (2020) also include a healthy diet as part of the preventative measures against shift work related diseases. Tips to improve eating habits during night shifts include; make healthy choices and avoid unhealthy foods; get into a routine with food intake (i.e. consume at set times); prepare both meals and snacks to lower the bar for making healthy choices; limit caffeine intake; and be sure to stay hydrated (Rimmer, 2019). Despite the widespread recommendations on healthy food during night shift, insufficient research has been conducted to draw firm conclusions on the effectiveness of these recommendations (Phoi & Keogh, 2019).

### **Light filtering**

A relatively new solution that has entered the market are tinted glasses for shift workers. These glasses work on the basis that light, which enters the human eye, influences the circadian rhythm (Phillips et al., 2019). Both the colour and intensity of this light play a large role in the size of the effect (Esaki et al., 2016). The filtering of light with short wavelengths (e.g. blue light) has been proven to reduce sleep disruption and improve performance in rotating-shift workers (Rahman et al., 2013). To effectively filter short wavelength light, sunglasses are equipped with specially developed orange, or amber lenses (Somnoblue.nl, 2020). The companies that produce such products do however not

claim that this is a complete solution, instead they claim that it should be part of an integral solution for night shift related problems.

### **Scheduling adjustments**

Scheduling and adjusting night shift schedules is another topic that has received a lot of attention over the years. In Dutch healthcare, shifts tend to be irregular (van de Ven, 2017). Employees often are able to influence their schedule by indicating their preferred shifts. In Dutch industry, where constant capacity is required, shifts tend to be regular and rotating forward, meaning that employees first work two or three mornings, followed by two or three afternoon shifts and then two or three night shift, followed by three to four days off (Gezondheidsraad, 2017). The NVAB (2020) recommends adjusting the work-schedule and implementing a degree of control over the work-schedule for employees experiencing problems due to shift work.

### **Power naps**

Another solution that is becoming more and more prevalent in night shifts, especially in healthcare and industry, is taking power naps. An effective power nap is a break in which an employee can rest for up to 25 minutes. This is best done in a designated room or space equipped with a comfortable chair or bed as this eases falling asleep (Janssen, 2018) Taking naps increases alertness and performance while reducing the risk of making mistakes (Ficca, Axelsson, Mollicone, Muto & Vitiello, 2010) Because this topic is integral to the project, power napping is discussed in more detail in section 3.1.3.

## **3.1.3 Power naps**

To be able to design a good power napping facility, it is critical to understand what a power nap is, what the benefits of power naps are and most importantly, what makes a power nap good. The following sections provide answers to these topics.

### **3.1.3.1 Power naps; the basics**

A power nap is a brief sleep that is terminated before entering sleep stage N3, deep- or slow wave sleep. The goal of power napping is to quickly regain energy, attention and focus (Janssen, 2018). By briefly entering sleep and exiting it before stage N3, subjects gain the benefits of sleep without experiencing the negative effects of exiting sleep in stage N3. Exiting sleep in stage N3 can cause sleep inertia, which is associated with feeling dazed, uncomfortable and tired (Tassi & Muzet, 2000). Entering stage N3 usually takes between 12 and 32 minutes after falling asleep (Colten & Altevogt, 2006). It is however important to reach stage N2, to benefit from the recuperative effects of a power nap. Hayashi, Motoyoshi, & Hori (2005) found that a short nap containing 3 minutes of N2 sleep has recuperative effects, whereas those effects are limited following sleep only containing stage 1.



Janssen (2018) recommends a power nap duration between 10 and 25 minutes, depending on how quickly an employee falls asleep and how long their stage N1 and N2 sleep last. McKenna & Wilkes (2018) suggest a maximum power nap duration of up to 30 minutes.

### **3.1.3.2 The benefits of a power nap**

Research on the benefits of power naps does not always conform to the maximum recommended duration of 30 minutes. Especially in older work (e.g. Bonnet & Arand, 1994; Dinges, Orne, Whitehouse & Orne, 1987; Mednick, Nakayama & Stickgold, 2003) naps up to 90 minutes are still categorized as power naps. For the purpose of this project, power naps over 30 minutes are considered regular naps. The focus will be on 20-30 minute power naps, as these naps fit better in the intended context and use of the final design (powernapping at work in healthcare and industry). A significant portion of research on the effects of power naps (e.g. Barthe, Tirilly, Gentil & Toupin, 2016; Lovato, Lack, Furguson & Tremaine, 2009; Rotenberg, Silva-Costa, Vasconcellos-Silva & Griep, 2016)) is focussed on night shifts, which describes benefits of power naps taken by shift workers like; increased- performance and alertness and reduced- fatigue and sleepiness. Research on day-time power napping yields similar results in areas like performance and alertness (Takahashi & Arito, 2000).

Takahashi (2003) concluded that naps are a reliable and inexpensive way to alleviate night shift problems such as reduced vigilance performance and alertness, increased sleepiness, fatigue and risk of accidents or errors. Research on the health effects of power naps during night shifts, especially related to alleviating health issues stemming from night shift work is limited and inconclusive. A 20-minute nap has been shown to significantly improve the vigilance performance of shift workers during their night shift (Purnell, Feyer & Herbison, 2002). Research carried out by Sallinen, Härmä, Akerstedt, Rosa, & Lillqvist (1998) shows that a 30-minute power nap during night shifts also positively affects response times and both objective- and subjective sleepiness. Smith, Kilby, Jorgensen and Douglas (2007) confirmed these findings and added that reaction times, and both subjective- and objective alertness are also positively affected by a 30-minute nap. A short nap has also been proven to improve memory performance (Lahl, Wispel, Willigens, & Pietrowsky, 2008). Furthermore, a 30-minute power nap was also shown to decrease fatigue and improve performance in a simulated driving task, indicating that a power nap might also reduce motor accident risk (Kennedy, Howard, Pierce & Radford, 2001). According to Halm (2018), the improved cognitive functions like vigilance performance, alertness and reduced sleepiness leads to fewer errors during night shifts.

During the user research (see subchapter 3.4), some night shift workers expressed the concern that power naps affect subsequent sleep. However, power naps taken during a night shift have limited or no effects on subsequent (main) sleep during the day (Ruggiero & Redeker, 2014).

### **3.1.3.3 Effective power naps**

Multiple studies (e.g. Halm, 2018; Takeyama, Kubo & Itani, 2005) have noted that more research is required to determine both the optimal nap characteristics like duration, frequency and timing and the optimal environmental and contextual factors like location, noise, light, etc. to maximize the positive effects of power napping. This section covers and supplements the information on nap characteristics given in the previous section, but is mainly focussed on the environmental and contextual factors, as these factors can be implemented in the design of a power nap solution. However, research on environmental factors influencing power naps is very limited. Some general guidelines do exist, but they are rarely grounded in science. For the purpose of making informed design decisions, it is deemed possible to extrapolate research on normal, full-night sleep and falling asleep onto power naps, provided that the research applies to the first two stages of sleep.

#### **Nap characteristics**

As discussed in section 3.1.3.1, the ideal power nap lasts less than 30 minutes. During a regular night shift of 8, up to a maximum of 12 hours, employees should not power nap more than once, as taking multiple naps can reduce sleep quality of subsequent daytime sleep (Janssen, 2018). During longer shifts, like a 16 hour shift, a second nap or a longer nap between shifts could be beneficial, but this depends on the individual and their napping habits (Takahashi, 1999). The optimal timing of a power nap is hard to research and depends on many factors including shift starting times and duration, varying work pressure during the shift, sharing facilities with colleagues, individual sleep and nap habits. As a rule of thumb, employees should try to power nap between 00:00 (12:00 AM) and 04:00 (04:00 AM) (Halm, 2018; Takeyama et al., 2005).

#### **Sound**

It is well known and documented that falling asleep in an environment with irregular, loud noise is significantly more difficult than in an environment with limited, constant noise (WHO Regional Office for Europe, 2009). Noise tends to be most disruptive during the light stages of sleep, or stage N1 and N2 (Perri, 2021). However, noise does not only impair the process of falling asleep, but also disturbs sleep (Meng, Zhang, Kang, & Wu, 2020). To combat the negative effects of sound on sleep a few strategies have been developed. The first one is fairly obvious; reducing the intensity of noise at the source. Attempts to implement this strategy in intensive care units have had mixed results (Delaney, Litton, & Van Haren, 2019). Although generally still considered worth pursuing, the high-stakes environment of ICU's have made implementing this strategy difficult and definitive evidence of improved patient outcomes is lacking (Delaney et al., 2019). Another strategy is to absorb or redirect noise. This strategy has been proven to be more successful in ICUs (Tseng, 2016), but is also used in a plethora of other applications like aircraft (Sadeghian & Gorji Bandpy, 2020) and homes (Residential Acoustics, 2018). Sound absorption and redirection can be achieved by applying specific materials and geometry such as fibrous materials and split-surfaces facing in different directions. The third strategy

is masking noise to ease sleeping. Masking noise is usually done with white or pink noise. Although widespread in use, its effectiveness has not been proven (Riedy et al., 2021). According to Cajochen, as quoted by Geddes (2020), white noise might be effective for night shift workers to 'drown out' the noisy day-time environment, but should be used carefully for regular sleeping in a relatively quiet environment. For the purpose of developing a power nap solution, absorbing and redirecting noise is most practical and should be considered.

### **Light**

Light, or perhaps more accurate, darkness is an important aspect when it comes to falling asleep and sleeping. Janssen (2018) also recommends a dark room or space for power naps. Darkness triggers the production of melatonin, an important hormone that influences the ability to fall asleep and sleep (Masters-Israilov et al., 2014). Light exposure on the other hand, disrupts sleep and reduces sleep quality (Amira et al., 2016). Both the intensity and colour of the light affect the severity of disruption and quality reduction. Higher light intensities coincide with increased disruption of sleep and reduced sleep quality. The colour, or wavelength, of light also influences the severity of the effects of light. Shorter wavelengths (e.g. on the blue side of the spectrum), have a significantly larger effect on sleep quality and disruption than longer wavelengths (e.g. on the red side of the spectrum) (Lockley, Brainard, & Czeisler, 2003). In the development of a power nap solution, light and darkness should be considered. The product can potentially shield users from light sources, but can also use light as a waking mechanism. If lights are used in the product, the right intensity and wavelength (colour) should be selected to minimize the negative impact of the light.

### **Temperature**

The effects of temperature on the onset of sleep and sleep are well known. For the general public, the optimal bedroom temperature is between 15.5°C and 19.5°C depending on personal preferences and context (Y. Wang, Liu, Song & Liu, 2015). Temperatures both below and above this range negatively affect sleep quality, however the effect is greater for temperatures above the range (McHill, Smith & Wright, 2014). In normal sleep, body temperature starts to fall as a result of the circadian rhythm. A reduced core body temperature plays a large role in falling asleep (van Someren, 2000). The loss of body heat, appears to be a necessary function for the onset of sleep (Okamoto-Mizuno & Mizuno, 2012). While lower ambient and core body temperatures improve sleep onset, research found that warm feet help with falling asleep (Kräuchi, Cajochen, Werth & Wirz-Justice, 1999). Within the microclimate under a blanket, temperatures need to be higher to prevent cooling down too much. The temperature of this microclimate is naturally maintained at between 32°C and 34°C (Okamoto, Iizuka, & Okudaira, 1997). For the purpose of developing a power nap solution, temperature regulation should be considered as it plays an important role in sleep onset. A difficulty however, is the inability to influence the ambient temperature. Solutions would need to affect the core temperature without having to change the ambient temperature of the room which is very difficult. Therefore, temperature control should be considered on a smaller scale. During the development of

the concept(s), ways to affect the microclimate should be considered instead (e.g. heating/cooling blankets).

### **Privacy**

Privacy is a contextual factor that has hardly been researched in relation to taking power naps. A study on the napping behaviour of nurses did however reveal the importance of having a private area that is exclusive to staff members (Fallis, McMillan, & Edwards, 2011). This knowledge gap is filled with user research, see chapter 3.4. Although little is known about the exact privacy requirements during a power nap, the power nap solution should take privacy into account. The required level of privacy offered by the product, largely depends on the context of the product and its placement.

### **Air quality and ventilation**

Another environmental factor that influences sleep quality, is air quality. Strøm-Tejsen, Zukowska, Wargocki, and Wyon (2016) found that sleep quality improved significantly when CO<sub>2</sub> levels were lower. Lower CO<sub>2</sub> levels were found to increase sleep efficiency and reduced the number of times participants woke up (Mishra, van Ruitenbeek, Loomans & Kort, 2018). A later study conducted by Liao and Laverge (2019) however, concluded that the effects of CO<sub>2</sub> levels on sleep quality were insignificant. More research is required to determine the effects of CO<sub>2</sub> levels on sleep. Other pollutants like volatile organic compounds and formaldehyde may reach high levels in sleeping environments, but research on the effects of these pollutants on sleep has yet to be conducted (Canha, Lage, Candeias, Alves, & Almeida, 2017). The implications of this research on a power nap solution are limited as the air quality is highly dependent on the context. Air quality inside a power nap room cannot effectively be changed by a power nap solution, but instead relies on ventilation of the space. Allowing for passive airflow in or through the power nap solution should ensure the air quality inside the solution matches the air quality in the room.

### **Aromatics**

The smell of the environment and bedding plays a large role in the ability to fall asleep. Scents associated with calmness and relaxation can be beneficial to relax before sleeping (The Sleep Foundation, n.d.). Inhaling essential oils during sleep has been reported to positively effect sleep onset and sleep quality (Lillehei & Halcon, 2014). In elderly, aromatherapy significantly increased sleep duration (Takeda, Watanuki & Koyama, 2017). Yamagishi et al. (2010) found that the aromatic compound heliotropin significantly reduced the time it took participants to fall asleep. Despite the promising improvements in sleep, aromatics or aromatherapy will not be applied in the power nap solution. The application of oils containing the aromatic compounds is not practical in breaks or short power nap periods.

### **Relaxation methods**

Although relaxation might be more of a behavioural factor, the ability to relax is highly influenced by environmental and contextual factors. Multiple power napping guidelines stress the importance of relaxing and provide recommendations on how to do this effectively. Janssen (2018) recommends breathing exercises and mindfulness, whereas Headspace (n.d.) recommends (guided) meditation. Despite there being no conclusive research on the effectiveness of these recommendations for power napping purposes, all three have been proven to reduce stress and aid in relaxing (Khoury et al., 2013; Mohan, Sharma, & Bijlani, 2011; Perciavalle et al., 2017). Aiding users to apply these techniques should be considered in the design of a power nap solution.

### **Other factors**

Other factors, such as humidity, the ability to change posture, the bedding system, microclimate and caffeine intake may also influence the quality of sleep and a power nap. Due to time limitations, these factors have not been fully researched. Because humidity and caffeine intake cannot effectively be influenced by the design, these factors are not included in the design process. The ability to change posture is included in the concepts as it makes sense from a user perspective. Bedding system and microclimate depend on the context in which the concept is placed.

## **3.1.4 Literature review conclusions**

Sleep is a critical part of human life, as sleep enables a plethora of essential and healthy processes to take place in the human body that do not occur when awake. Normal sleep consists of multiple cycles between four stages, N1, N2, N3 and REM sleep. Sleep is regulated by two internal mechanisms; Process C, which promotes wakefulness and process S, which promotes sleep.

A lack, or shortage, of sleep is correlated with many negative health consequences. Such shortages and disturbed sleep are common in night shift workers. Besides the negative consequences on both physical- and mental health, shift workers also experience problems in social settings, as their schedules often inhibit attending social activities. Furthermore, night shift work has been proven to reduce safety and increase accident risks. To combat these negative effects, a wide array of (partial) solutions has been developed and tested. Some of these solutions or the underlying theories as to why the solution works, have been (partially) implemented in the Asper.

Power napping is one of the (partial) solutions to aid night shift workers. A power nap is a brief period of sleep, that is terminated early to prevent sleep inertia. Power naps have been proven to provide a large number of benefits, including increased- performance and alertness and reduced- fatigue and sleepiness. Research on the health benefits of power naps however has been inconclusive. Little research has been conducted on the requirements and context for an optimal power nap. Because power napping is closely related to the first stages of regular sleep, research on several aspects that influence sleep have been extrapolated to aid in the design of the concepts.

### **3.1.4.1 Recommendations for future research**

During the literature review, a large gap in research has been identified. Little is known about the effects of contextual- and environmental factors on the effectiveness of power naps. These factors include sound or noise, light, temperature, privacy, air quality, aromatics, relaxation methods, humidity, ability to change posture, bedding system and microclimate. Future research should attempt to fill these knowledge gaps. By filling these gaps, improved power nap facilities can be created to further reduce the issues caused by night shift work. Furthermore, a widely accepted definition of power naps and a standardized way to measure their effectiveness should be developed.

### **3.1.5 Requirements derived from the literature review**

The literature review led to requirements that were used during the design process. This section covers the requirements derived from the literature review.

#### **Power nap characteristics**

The following requirement stems from the research that shows power naps should not last longer than 30 minutes to prevent entering and waking during SWS.

- The concept should not facilitate power naps longer than 30 minutes.

#### **Contextual power nap influences**

The next requirements stem from research on the effect of environmental aspects such as light, noise and temperature on falling asleep. These factors are also considered to be important zeitgebers.

- The concept should try to minimize noise from outside a power nap- or resting room through absorption or redirection of sound.
- The concept should minimize light exposure from windows and ceiling-mounted lighting.
- The concept should allow for passive airflow to ensure the air quality inside the concept is similar to the room air quality.

#### **Power nap features**

The following requirements come from the research about aspects that can improve the process of falling asleep or improve power nap quality.

- The concept should provide privacy to the user. The level of privacy should match the need for privacy which stems from its context.

- The concept should use warm (between 2400 and 2700K), soft (<800 lumen) light if it integrates light as a function.
- The concept should be able to provide some form of relaxation other than the FPS technology.

## 3.2 Competitor analysis

To be able to design a concept that can compete with other power napping products, it is critical to know and understand the competition. This subchapter covers the products of NEWAS' main competitors, their place in the current market of nap- and recovery solutions for night shift work in industry and healthcare and their respective strengths and weaknesses. For more details and a complete overview of features for each product, see appendix C.

### 3.2.1 Ahrend – Loungescape power nap

The Loungescape power nap from Ahrend (See figure 3.1) is one of NEWAS' main two competitors in the Dutch market. Ahrend is the preferred furniture supplier of most Dutch hospitals, usually having long term contracts for supplying all office and non-medical furniture. With this strong foothold in healthcare, Ahrend has been successfully selling its power napping solution to hospitals. According to G.Djontono, interior manager for the Erasmus hospital, multiple large Dutch hospitals have invested in the Loungescape power nap. The solution is priced at roughly €7000,- excl. VAT. The Loungescape power nap is fairly simplistic, yet elegant in design. Its large radii and geometric features result in a calm, soft and relatively timeless aesthetic. Ingress and egress are easy as a result of the open side. The head cover provides some privacy as well as light- and noise reduction. The Loungescape comes with a 'whole body vibration' mattress developed by Neurosonic. This technology is similar to the FPS technology from NEWAS. The standard version of the Loungescape power nap comes with a noise cancelling headset. Due to hygiene concerns, this feature is rarely used or even allowed, especially in healthcare. Another drawback is the use of an app to control the product. Keeping the app up to date is costly, resulting in either repeating costs for Ahrend or a degrading interaction as new software or hardware mess with the app.



Figure 3.1 – Ahrend Loungescape power nap



### 3.2.2 BOOZTR – Flatbed and recliner pods

BOOZTR, with its flatbed and recliner pods (See figure 3.2) is NEWAS' other main competitor. Despite not being as established in the Dutch healthcare market as Ahrend, BOOZTR has been successfully selling their pods to many hospitals. According to NEWAS, this is a result of the aggressive yet effective sales tactics of BOOZTR and their early entrance in the market when few competitors existed. BOOZTR now also offers a flatbed version with FPS technology. The flatbed and recliner pods are sold for approximately €5950,- excl. VAT. and €7450,- excl. VAT. respectively. The flatbeds with FPS technology cost approximately €7950,-. The pods are fairly simple in design and construction. The shells that provide privacy and light reduction, can be stickered to show the customers logo. Thanks to the fully closable capsule, BOOZTR's pods provide significantly more privacy and light reduction than the Ahrend Loungescape. This enclosed design comes from the pods original purpose. The Pods are designed to provide a sleeping space for long distance travellers waiting on airports between flights. A drawback of the Pods design is the difficult ingress and egress. By having to enter from the feet end of the bed, the user is forced to crawl into position. Another issue is the manual cover that has to be pulled from the head side to the foot of the bed, forcing the user in a difficult position. This cover also reduces air circulation, negatively affecting the air quality when users are inside the pod for prolonged periods of time. The overall shape and design also make accessing the interior for cleaning more difficult. According to BOOZTR, the pods can be placed in hallways because the pods can be fully closed. However, users from the user research (see chapter 3.4) expressed that the placement in (busy) hallways inhibits good power napping. According to the client, for this same reason, the Radboud UMC Amalia kindziekenhuis removed BOOZTR pods after trying them for 6 months.



Figure 3.2 – BOOZTR flatbed and recliner pods (closed and open)

### 3.2.3 BOOZTR – Igloo pods

Another product sold by BOOZTR, is the Igloo pod (See figure 3.3). This product is relatively new in their product portfolio and currently not a main threat to NEWAS. Unlike the recliner pod, this version is not available with FPS technology. The Igloo pods are sold for around €10000 excl. VAT. The Igloo pods are larger than the regular pods, and are therefore sold as small spaces or rooms that can be placed anywhere. BOOZTR claims that the Igloo pod can even be used for work that requires high, solo concentration as the Igloo has a table that supports a laptop. With similar intended placement of the Igloo pods, the igloo is expected to face the same issues as regular pods. The Igloo is unbalanced in design and the contradicting design language results in an overall unimpressive aesthetic.



Figure 3.3 – BOOZTR Igloo pod

### 3.2.4 Metawake – Power nap pod

The power nap pod from Metawake (see figure 3.4) is another product sold on the Dutch market. This solution is a low-tech, low-cost solution for power napping. The relatively low price of €1750,- excl. VAT. is the only real unique selling point. Both in design and features this solution lacks far behind its competition. It does not have FPS or another similar technology. The power nap pod from Metawake uses electric roller blinds to provide privacy and darkness to the user. Because the product is made from birch plywood, sound absorption or reduction is extremely limited.



Figure 3.4 – Metawake Power nap pod

### 3.2.5 Sleepwing LTD – Podtime

Podtime from Sleepwing LTD (see figure 3.5) is a power nap solution that is currently not being sold on the Dutch market. In the UK, a potential future market NEWAS wants to enter, Podtime costs an equivalent of around €6500,- excl. VAT. Podtime provides an additional perspective on what the power nap solution could look like. The design is round and simple, yet looks well developed. Podtime manages to catch the eye thanks to the colour use. The sliding door with vibrant mattress causes the Podtime to look inviting. The Podtime is also available as a stackable solution. One issue with Podtime is the ingress and egress. Because the opening is fairly small, users have to pull up their knees, turn and then get into the pod. The sliding door and shell provide a lot of privacy as the pod can be fully closed off. Because of the semi-opaque plastic, light is hardly reduced. No additional features, like FPS technology, are included in the Podtime.



Figure 3.5 – Sleepwing LTD Podtime

### 3.2.6 Metronaps – EnergyPod

The EnergyPod from Metronaps (see figure 3.6) is a futuristic recliner chair with many features that aid in power napping. Despite its plethora of features, the EnergyPod is not a serious competitor in the Dutch market. The main reason for this is the price of the EnergyPod. The EnergyPod costs approximately €12000,- excl. VAT.. When compared to the other options, the EnergyPod is excessively expensive. Only one Dutch hospital owns an EnergyPod, which was gifted by Metronaps. Although it is hard to say how many EnergyPods are sold on the Dutch market, the number is expected to be very low. Over the past few years, NEWAS has never heard of the EnergyPod being seriously considered. Despite not being a serious competitor, the EnergyPod can still offer insights in good design and features. The EnergyPod is sleek and clean, and emits a futuristic feeling. Its aesthetics invite the user and clearly show its purpose. The EnergyPod aids the user in waking after a power nap through gentle vibrations. Furthermore, privacy and light reduction are provided by the swivelling visor.



Figure 3.6 – Metronaps EnergyPod

### 3.2.7 Look industries – N.A.P.

The N.A.P. from Look industries is another solution that is hardly sold on the Dutch market. With a price of around €16000,- excl. VAT, the solution is simply too expensive for hospitals and industry, especially since other solutions offer similar features and value at a significantly lower price. Like the Ahrend Loungescape power nap, the N.A.P. comes with Neurosonic's whole body vibration technology. A strength of the N.A.P is that it has casters. This makes transporting the N.A.P. within a facility easier. It also allows a cleaning crew to move the N.A.P. to make vacuuming or mopping the floor easier. Another strength is the simplistic, yet elegant design. The rounded, upholstered case looks comforting and inviting. Weaknesses of the N.A.P. include its lack of adjustability, tablet control and overall size. Because the product is quite large, it is hard to place in a small room.



Figure 3.7 – Look industries N.A.P.

### 3.2.8 Conclusions of the competitor analysis

Although more power napping solutions exist, only two products are considered real competitors for NEWAS in the Dutch market; the pods from BOOZTR and the Ahrend Loungescape power nap. With its strong sales, BOOZTR has carved out a space for itself in the power napping market. However, BOOZTR’s mismatch in intended use and context of the design (sleeping on airports) and actual use and context (power napping in healthcare and in industry) has led to some problems. Placing the power nap facility in hallways and public spaces, which the closed off design enables, limits effective power napping. Ahrend with its Loungescape power nap is NEWAS second serious competitor. With its sleek design and foothold in healthcare, the Loungescape power nap is in a prime position to dominate the healthcare power nap market. Although other competitors all have their own strengths, they are currently not a concern for NEWAS within the Dutch market. The strengths and weaknesses of all competitors, of which an overview can be seen below in table 3.1, were used in the design and decision making process of the Asper.

Manufacturer	Model	Features					Price (in Euro's, excl. VAT)	USP (Unique Selling Point)	Main competitive advantage (strength)	Main competitive disadvantage (weakness)
		FPS or similar	Completely closable	Sound absorption	Adjustable	Relaxation tech (other than FPS)				
Ahrend	Ahrend – Loungescape power nap	•		•		•	7.000	Sleek design	Well established as hospital supplier	Originally designed as part of an office furniture line. Does not match actual context needs
BOOZTR	Flatbed pod	•	•	•			5.950	Customizable sides	Early market entrance, large market cap	Originally designed as sleep pods for airports, does not match actual context need
BOOZTR	Recliner pod		•	•		•	7.450	Customizable sides	Early market entrance, large market cap	Originally designed as sleep pods for airports, does not match actual context need
BOOZTR	Igloo pods		•	•		•	10.000	Multipurpose, power nap, pumping breast milk and working.	Different purposes than the other available solution, could be a niche solution	Ugly design
Metawake	Power nap pod		•				1.750	Low price	Low price	Low tech and basic design. Does not speak to the imagination
Sleepwing LTD	Podtime		•			•	6.500	Sliding door, sleek design	Stackable	Not yet available in the EU
Metronaps	EnergyPod			•		•	12.000	Futuristic design	Used by google, large online presence	Expensive
Look industries	N.A.P	•		•		•	16.000	Casters	-	Expensive

\*available with FPS, additional costs approx. €2000

Table 3.1 - Overview competitors

### 3.2.9 Requirements derived from the competitor analysis

Some of the strengths and weaknesses in the competitor's designs led to requirements in the design process. This section covers the requirements derived from the competitor analysis.

#### Price

The first requirement stems from the price point of NEWAS's two main competitors. NEWAS wants to price their concept under the concept of Ahrend and BOOZTR's flatbed with FPS.

- The concept should cost around €6500,- excl. VAT. This means that the maximum manufacturing and assembly costs should be €1500,- excluding V.A.T. and FPS mattress.

#### Ease of ingress and egress

The following two requirements stem from the design mistakes made in the BOOZTR pods and Podtime. Entering and exiting the solution should be easy and require little effort. These two requirements are aimed at ensuring this is true for the concept.

- The concept should be easy to enter (ingress) and exit (egress). It should take a healthy person with no prior experience no longer than 15 seconds.
- The user should be able to enter and exit the concept from the long side of the mattress.

#### Haptic controls

The next requirement stem from the usage of tablets, apps and screens for the control in the Ahrend Loungescape and Look industries N.A.P.. As discussed in the previous sections, using an app requires regular updating to keep up with software and hardware updates, increasing costs. Furthermore, using a light emitting source like a tablet, to control the concept goes against sleep hygiene recommendations. Touchscreens also lack haptic feedback, reducing feedback quality and performance (Vitense, Jacko, & Emery, 2003).

- The concept should have haptic or manual controls (referring to physical buttons etc.).

#### Placement restrictions

The following requirement comes from the (mis)placement of the BOOZTR pods. The concept should not be placed in hallways or public spaces. Therefore the Asper should not let people to believe that it is intended for this use through its design.

- The concept should not be fully closed off and should have at least 1 open side on the side of the concept.

**Ability to convey purpose/use**

The requirement to be able to convey the concept's purpose through its design comes from the large discrepancies in ability to do so between products. Products like the Metawake power nap pod and BOOZTR Igloo don't clearly show their purpose while other products like the EnergyPod and Loungescape power nap do a great job in showing their purpose.

- The concept should be able to convey its purpose through implementing sufficient use-cues and visual cues.

**Aesthetics**

The following requirements come from the, subjectively good, designs of the Loungescape, Podtime and N.A.P. The concept should strive to match these products in aesthetic qualities.

- The concept should look comfortable to use.
- The concept should look inviting.
- The concept should look calming or relaxing.
- The concept should look soft.

### 3.3 Stakeholder analysis

Because power nap products are a part of the workspace furniture, multiple stakeholders are involved during the lifespan of the product. The stakeholder purchasing the product is different from the stakeholder using the product, who is in turn different from the stakeholder cleaning and maintaining the product. The owner (management or department of the company) is yet another stakeholder. Although stakeholders have differing levels of influence on the commercial success of the product, all stakeholders should be considered in the design. Each stakeholder has their own requirements, wishes and interaction with the product during its lifespan.

To uncover all relevant stakeholders, two facility managers that were involved in the purchase of NEWAS chairs were interviewed about the purchasing process and the people involved during its lifespan. One facility manager worked in healthcare (Erasmus hospital), the other in industry (Port of Rotterdam).

#### 3.3.1 Purchasing process in the healthcare context

During the purchasing process of power nap facilities in healthcare, multiple stakeholders are involved. The entire process is illustrated in figure 3.8. First, employees or team managers request a power nap facility. The department that will pay for the facility will then inform the interior and furniture management about the request. This group will then inquire for suitable options by suppliers. The interior and furniture management will also invite multiple stakeholders to share their requirements. The stakeholders involved in this process are: power napping users (e.g. nurses, doctors), the unit infection prevention, the cleaning crew and building management. With the requirements from these stakeholders, the interior group selects and proposes a solution to the department that is providing funding. This proposition either is accepted or rejected, resulting in either a purchase or another proposal after reconsidering the available options.

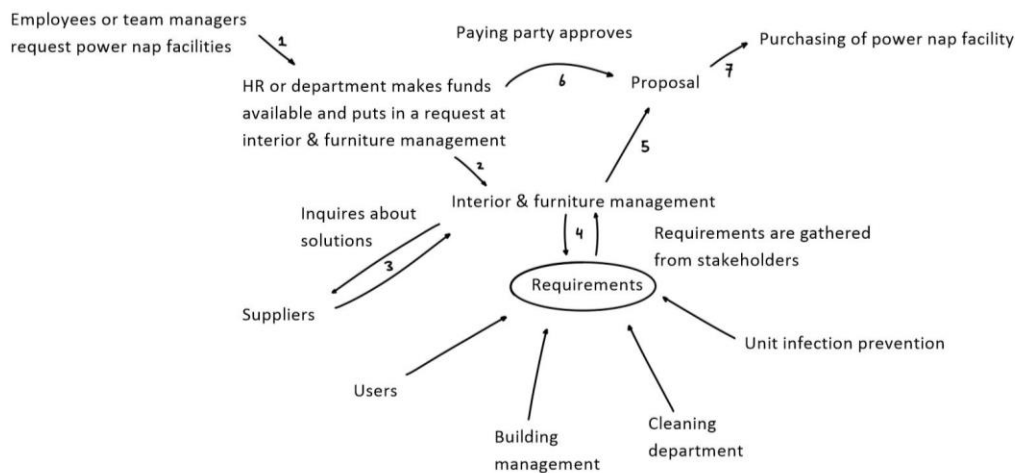


Figure 3.8 – Purchasing process in healthcare



### **3.3.2 Stakeholders in healthcare**

The stakeholders that are involved during the purchasing process, and thus during the lifespan of the product are:

#### **Power napping users**

Power napping users are the stakeholders that interact most often with the product. Because of this, users are both important stakeholders and sources of information for the design process. The users in this context are nurses, doctors and other healthcare staff. By making the product comply with the needs and wishes of the users, the chance of successful implementation increases. To find the needs and wishes of the users, a user research was conducted. Concluding from this research, the main requirements from users are: the concept needs to be positioned in a dark and quiet room, be hygienic and comfortable. More information on this research can be found in chapter 3.4.

#### **Cleaning crew**

The cleaning crew is another stakeholder that regularly interacts with the product. Aspects that are important for cleaning crew are:

1. The concept should be easily cleaned with a detergent and wet cloth.
2. The concept should provide easy access to the floor for vacuuming and mopping the floor.
3. The concept should not have hard to reach places that require frequent cleaning.
4. The concept should not have any spots/corners that collect dust and dirt easily.

#### **Unit infection prevention**

The unit infection prevention (UIP) rarely interacts with the product, yet is quite influential in the purchasing process. Because the risk for infections is quite high in hospitals, furniture must comply with certain guidelines defined by the UIP. These guidelines include that materials should not be porous or permeable. Therefore, the upholstery in the concept should either be leather or pleather. Other materials require reviewing. Another requirement from the UIP is that the mattress should easily come out of the concept for deep cleaning and disinfection.

#### **Department of interior and furniture**

This department is responsible for the interior of the hospital. Important aspects for this department are the durability and long term maintenance of the product. In this specific case, the hospital requires a maintenance contract with supplier to ensure the purchased goods remain in good condition for a long period. Being able to easily move and manoeuvre the product is a plus, but not a hard requirement for this department as power nap facilities have dedicated rooms that do not change frequently. This department is critical in the purchasing process, as they do all the purchasing

and supplier contracts. Price however is not their main concern, they just have to stay within the budget of HR or the department that requested the purchase. Budgets can vary greatly.

### Human resources and department heads

For HR and the department heads, the effectiveness of the solution matters. Although they rarely interact with the product itself, it is vital to this stakeholder that users actually benefit from the facility. Therefore it is important to not only have a functional product, but also one that can convince HR and department heads of the benefits of the product during the purchasing process.

### Building management

The building management is responsible for providing a space to place the concept. Current solutions often require the lights to be changed so they can be dimmed. This additional cost is covered by the building management.

## 3.3.3 Purchasing process in industry context

The purchasing process for power nap facilities in the industry context is considerably less complex than in the healthcare sector. The process generally starts by either employees or team leads requesting a facility from HR. This request is processed by the health and safety officer. During this processing period, the health and safety officer researches the potential solutions and requests quotes from different companies, evaluating their offers. The best options are then forwarded to facility management which does a final evaluation. One solution is selected and the purchase is made. Facility management places the product and is responsible for its context. No other stakeholders, like users or maintenance and cleaning are involved during the purchasing process. See figure 3.9 for an overview of the process.

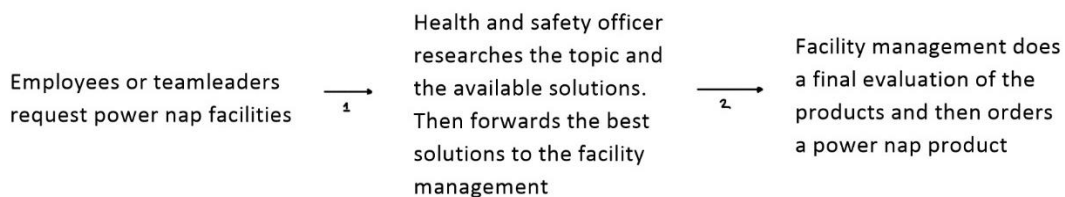


Figure 3.9 – Purchasing process in industry

### **3.3.4 Stakeholders in industry context**

Although few stakeholders are involved during the purchasing process, the facility manager did express his consideration towards other stakeholders during the purchasing process. The stakeholders that are either involved in the purchasing process or considered during the process are:

#### **Power napping users**

Users of the concept in the industry context are process operators, mooring workers and many more. The users of the concept in industry context are similar to the users of the concept in healthcare in terms of requirements and wishes. Concluding from the user research, the main requirements from users are: the concept needs to be positioned in a dark and quiet room, be hygienic and comfortable. More information on this research can be found in chapter 3.4. Although most needs were similar, the industry users explicitly mentioned the need for sturdy and durable products, as they thought their tools and rugged clothing would easily damage the upholstery.

#### **Facility management**

Facility management receives several options for a power nap facility from HR and evaluates these to select the best one. This product is then purchased. The main considerations for facility management are:

1. Is the product within budget?
2. Is the product durable, does it last at least 5 years?
3. Is it easily maintained and cleaned?
4. Does it fit in the relax/power nap space?

When these four criteria are met, a solution is deemed viable.

#### **Human Resources**

HR is mainly interested in the effectiveness of power naps for their employees wellbeing, productivity and alertness. Because it is close to impossible to estimate the exact effectiveness of a solution, HR makes an educated guess about solutions that should work. The concept should show and convince HR of its effectiveness.

#### **Cleaning crew**

Although the cleaning crew is not involved in the purchasing process, they are another stakeholder that is kept in consideration by facility management during the purchasing process as the cleaning crew regularly interacts with the product. Like in healthcare, hygiene is considered an important aspect of power nap facilities. Similar requirements, like being able to easily clean the product and vacuum around the product apply. A difference between these contexts is the rigor with which

cleaning is done. In healthcare, the required level of hygiene and disinfection is higher as they work with vulnerable patients.

### **3.3.5 Conclusions of the stakeholder analyses**

Although the purchasing process in both contexts is vastly different, a lot of similarities between stakeholders were found. Power napping users in both contexts have similar needs and wishes (See chapter 3.4), as do HR and facility management. According to HR, the product should be effective while facility management requires a sturdy or long-lasting product. Two main differences exist between the stakeholders in healthcare and industry that influence the design. In Healthcare, cleaning and hygiene is a higher priority than in industry, resulting in requiring certain material properties and exclusions by the unit infection prevention. In industry, the need for wear resistant upholstery is larger than in healthcare, because of the tougher materials used in clothing and tools people wear on them during their shift.

### **3.3.6 Requirements derived from the stakeholder analyses**

The desires, needs and requirements from the stakeholders that are either involved during the purchasing process or lifespan of the product influenced the design. This section covers the requirements derived from the stakeholder analyses.

#### **Hygiene**

The requirements affecting hygiene, stem from the needs of the cleaning crew and the unit infection prevention.

- The concept should be easily cleaned with cleaning detergent and a wet cloth.
- The concept should not have hard to reach parts that require frequent cleaning.
- The concept should not have corners, ridges or other geometry that easily collect dust and dirt.
- The concept should provide easy access to the floor for vacuuming and mopping the floor, potentially through the use of casters.
- The mattress should be easily removed from the concept for deep cleaning and disinfection.

#### **Material use**

The requirements that influence the material use in the concept come from the needs of the cleaning crew, unit infection prevention and users.

- The concept should use materials that are easily cleaned and don't absorb dirt or liquids.

- The concept should avoid having porous or permeable surfaces on the outside of the product.
- The concept should have wear-resistant upholstery on parts that the user is frequently in contact with (e.g. the mattress).
- The concept should avoid the use of regular, permeable textiles for the mattress upholstery. Artificial leather or regular leather is preferred in healthcare.

### **Perceived effectiveness of the facility**

The next requirement stems from HR's or team leader's desire to select the best power nap solution for the employees, thus maximizing benefits of power napping. Because it is virtually impossible to determine the exact effectiveness, the concept should be able to convey its effectiveness to HR or the team leader.

- The concept should be able to convey its purpose and effectiveness to HR or team leaders during the purchasing process through implementing sufficient use-cues and visual cues.

### **Product life-span, reliability and maintenance**

The requirements on the product life-span, reliability and maintenance originate from the facility managers. For these stakeholders, the concept needs to be reliable and have a long life to be able to recoup the investment costs through the benefits of power napping. Facility management also tries to minimize the required maintenance and repairs to reduce costs.

- The concept should minimize the use of moving parts, as these tend to be more susceptible to wear.
- The 'high traffic' parts of the concept (e.g. mattress, FPS interface and other parts users physically interact with) should last at least 5 years without major maintenance, repairs or replacement parts.
- The 'low traffic' parts of the concept (e.g. structural parts and parts users don't interact with) should last at least 8 years without major maintenance, repairs or replacement parts.
- The maintenance of the concept should be easy, and require no specialized skills or tools.
- Parts that are prone to wear should be easily accessible and disassemble to make repairing or replacing parts require little time.

### **User requirements**

Because users are the stakeholders that interact with the product the most, a separate user research has been conducted. Requirements from this research can be found in section 3.4.5.

## 3.4 User research

During the analysis phase, a user research was conducted. This research was intended to achieve the following three goals:

1. To gain a better general understanding of the context and shift worker's perception of shift work and power napping.
2. To find and confirm the relative importance of five environmental and contextual factors; privacy, comfort, silence, darkness and temperature. These factors were expected to be important for power napping based on the literature review.
3. To find the perceived user value and importance of multiple potential features that have been considered during the initial ideation phase.

The information and insights gathered from this research were used to make informed design decisions.

### 3.4.1 Research set-up

To be able to dig deeper in the answers and underlying reasoning by the participants, interviews were the selected method for this research. A set of questions was prepared, tested in a pilot with two non-shift working participants, adjusted and then used during the interviews (see appendix D). The interviews lasted between 35 and 60 minutes and were conducted online through Microsoft teams. Because all participants were Dutch, the interviews were conducted in Dutch.

### 3.4.2 Participants

In total eleven (n=11) participants were interviewed. 5 males and 6 females aged between 24 and 48 participated. 1 participant had children too young for school, 5 participants had children in primary school, 1 participant had children in secondary school, the others did either not have children or were at an age where they no longer required frequent care. 7 participants worked in healthcare, 4 participants worked in industry. All participants worked in shifts and regularly worked night shifts. Schedules and shift times varied widely. Five participants already had power nap facilities at their disposal, the other six did not.

### 3.4.3 Results

Five of the six participants that did not have power nap facilities in their work environment expected that such a facility would be beneficial for them; one participant did not feel like they needed or would benefit from a power nap facility. Similarly, one participant from the group that have a facility available, did not use it as they did not see the need for a power nap during their (night)shift.

When asked about the conditions needed for a good power nap, a quiet space, darkness and being able to briefly withdraw were the most common responses. Other responses included: a comfortable temperature, power naps being normalized in the work culture and being alone. When discussing the conditions for a good power nap, two concerns were brought up by multiple participants; fear of falling in deep sleep and not waking up in time and not being able to take a power nap during the shift because of high workloads.

Besides the questions that corresponded with the first goal, participants were also asked to rate the importance of five contextual and environmental factors on a Likert scale ranging from 1 to 7 (1 corresponding with very unimportant and 7 corresponding with very important, see figure 3.10). The contextual and environmental factors asked for were: privacy, comfort, silence, darkness and temperature. After each rating, participants were asked to elaborate on their rating.

o Hoe belangrijk is privacy voor u tijdens een rustmoment of powernap?

Zeer onbelangrijk	1	2	3	4	5	6	7	Zeer belangrijk
	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	

Figure 3.10 – Example question contextual factor

*(Translates to: How important is privacy for u during a break or power nap?  
Very unimportant (1) Very important (7))*

On average, all factors were found to be important. Privacy, comfort and silence, with an average score of 6.18, 6.05 and 5.91 respectively, are considered to be slightly more important than darkness and temperature with an average score of 5.14 and 5.45 respectively (see figure 3.11). The elaboration on the ratings resulted in some interesting insights. Whilst important, privacy was often considered to be a result of the power nap products location and room and not determined by the design of the power nap product itself. One participant commented on an experience with the BOOZTR nap pod that was situated in a hallway: *“No matter how far you can close the product, if it is in an open hallway, it is not private.”* Participants expressed that they instead prefer a product that provides some visual privacy upon entering the power nap space or room. Similar remarks were made about silence. Participants expressed that this would be highly dependent on the context of the product, but that they preferred a silent room over a sound blocking product in a noisy room. Comfort was found to be important by all participants, however nearly all participants found it difficult to describe what they desired to be comfortable. Responses were limited to the hardness and texture of the mattress and pillow for most participants. Two participants described the need for warmth to be comfortable. Later during the interviews, six more participants described the need for warmth and often being cold during night shifts. Like comfort, participants found describing the desired light levels difficult. Participants wanted the facility to either be completely dark or dimly lit. Another factor mentioned by multiple participants was the need for a clean and hygienic solution where bedlinen is

regularly replaced and the overall concept is regularly cleaned. *“The product must look and feel clean for me to comfortably sleep in it”.*

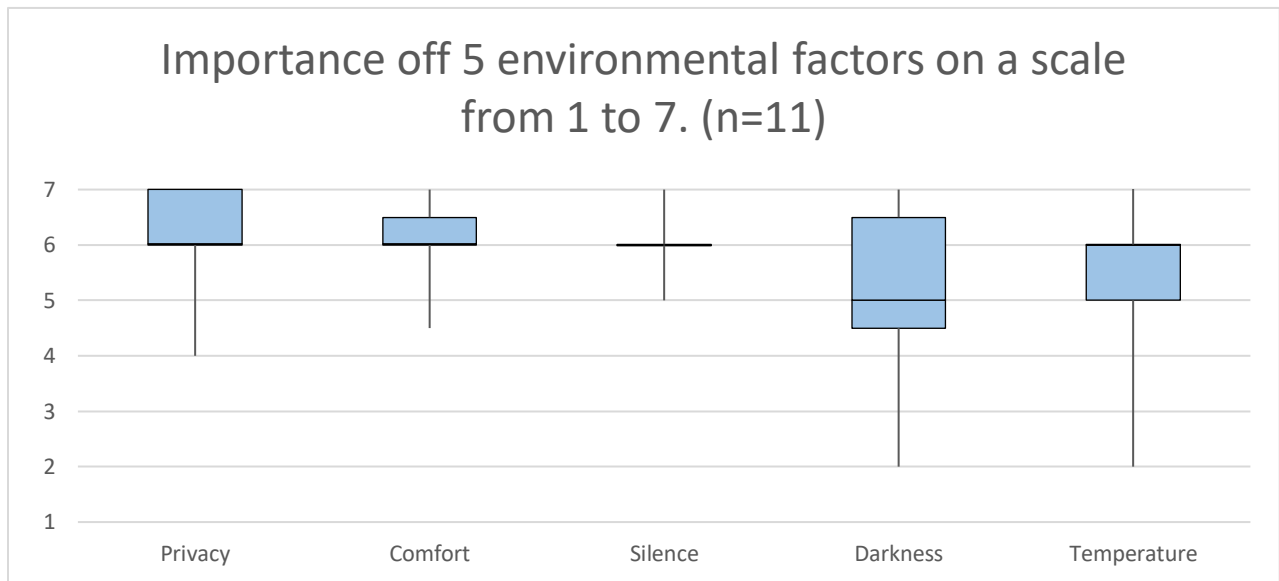


Figure 3.11 – Results of contextual and environmental factors

Lastly, participants were asked whether or not certain product features would add value to the concept for them. The results of these questions can be seen in figure 3.12. The perceived user value is one of the aspects that determines whether or not a feature is implemented. The binary questions on perceived value were followed up with requests for elaboration. Although interesting, very few of the elaborations led to new insights. One interesting insight gathered from these questions is that casters are highly appreciated by healthcare workers, as this is more or less the standard for hospital furniture. Furthermore, some healthcare workers without current access to power nap facilities, worried about not being able to be found or alerted by their colleagues in case of an emergency. Healthcare workers with power nap facilities however expressed that those problems do not occur, as the team adapts and culture changes to enable uninterrupted power naps. An alarm at the end of the program to prevent deep sleep was found to be a valuable feature for all participants.



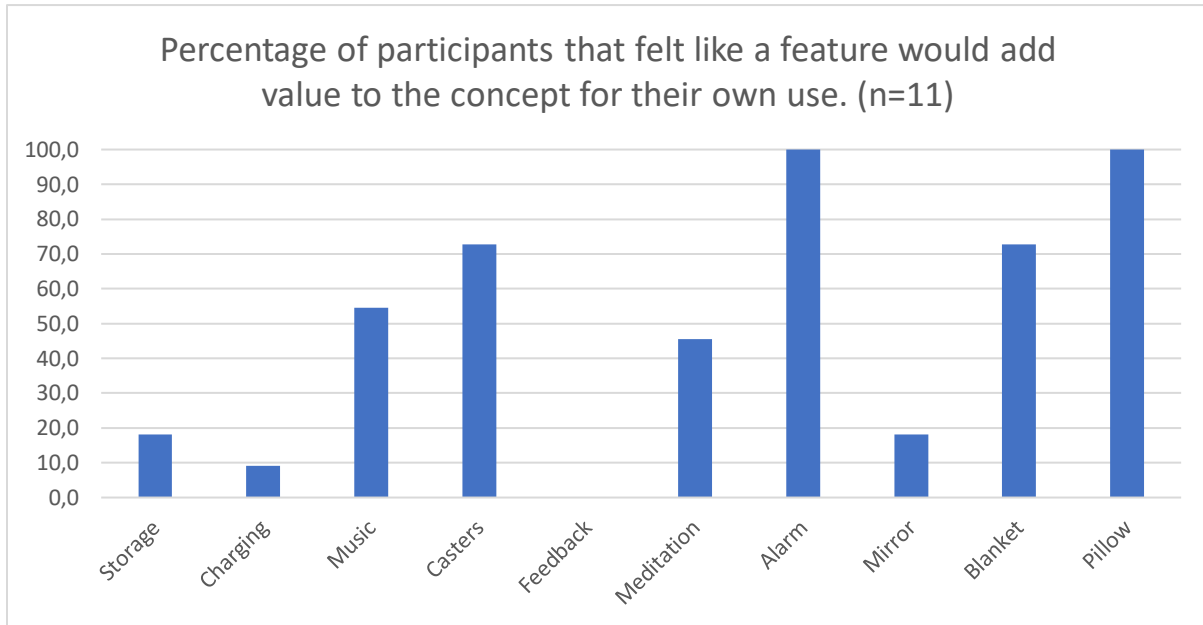


Figure 3.12 – Results of feature questions

### 3.4.4 Conclusions from the user research

According to the participants, conditions needed for a good power nap include a quiet space, darkness, being able to briefly withdraw, a comfortable temperature, power naps being normalized in the work culture and being alone. All five environmental and contextual factors were found to be important to users when it comes to power napping. Despite being important to have a good power nap, participants expressed that not all factors can or should be fully dealt with by a power nap product. Instead, adjusting and improving the context of such a product should be considered as a partial solution for factors such as privacy, silence and temperature. Certain features like an alarm and pillow are unanimously found to add value to the concept. Other features like feedback on the power nap, being able to charge a phone or having a mirror are rarely valued.

The results of this user research played a significant role in the decisions that led to the design of the Asper. The conditions needed for a good power nap identified by the participants (a quiet space, darkness, the right temperature, being alone and being able to briefly withdraw) were continually being considered during the design process, especially in finding a balance between the product features and the context factors.

The same was done for the five environmental and contextual factors. With each design decision the impact on these five factors was considered. If a decision was detrimental to a factor it was reconsidered and attempts were made to reduce or eliminate the negative effect of the decision on the factor.

The questions on the product features had direct impact on the design. Features with a rating over 75% were considered required and therefore implemented unless a solid reason was found to not do

so. Features with a rating between 25% and 75% were individually considered and either implemented or not based on product fit, cost and added value. Features with a rating below 25% were not implemented unless a good reason to implement the feature came up.

### **3.4.5 Requirements derived from the user research**

The user research led to the following requirements in the program of requirements:

#### **Power nap enclosure**

The following requirement comes from the results showing that privacy should not come from the product itself, but from the context in which the product is placed.

- The concept should not be fully closed-off and should have at least 1 open side.

#### **Privacy**

The next requirement stems from the users indicating that privacy is important, especially when someone (accidentally) enters the power nap space.

- The concept should provide sufficient privacy to the user. The line of sight should be blocked from at least one and a half of four sides of the mattress (The half should block sight to the head and upper torso).

#### **Comfort**

The next requirement stems from the users indicating that comfort is important.

- The concept should be comfortable. Users should rate its comfort at least 5 out of 7.

#### **Temperature regulation**

The requirements regarding temperature regulation stem from the users experience of being cold during night shifts.

- The concept should be able to provide power to an electric heating blanket.
- The user should be able to use an additional blanket when using the concept.

## Features

The following requirements all stem from the section about perceived value of certain features. After consideration, these requirements were added.

- The concept should be able to equip casters for contexts that require them.
- The concept should be able to effectively (in at least 95% of users) wake the user at the end of the power nap program, but not in an aggressive, harsh way.
- The concept should have a pillow
- The concept should optionally have a blanket.
- The concept should have storage space available for clean bedlinen in case a pillow and/or blankets are used.

### 3.4.6 Discussion

Despite the small sample size, the results were useful as a guideline for the design process. They should however not be considered as 'truths' as a larger sample size is necessary to filter out anomalies. Furthermore, the online nature of the interviews further increased the difficulty of interviewing and may have impacted the way participants answered. Together with more participants, future user research on this topic could explore and find more similarities and differences between participants from healthcare and industry. Furthermore, it would be interesting to find potential differences between participants that already have power nap facilities available and those that do not.

## **3.5 Context analysis**

To be able to design a product that does not only suit the user and meet stakeholders requirements, but also fits in its context, it is important to understand the context. The context of power napping facilities is two-fold. It manifests on both a macro and micro scale. First, the industry and type of work performed by the users play a large role in context related factors. These have mostly been discussed in the user research, but a few additional significant differences that influenced the design between the two industries were found. Second, the position or placement of the facility also matters in the context related factors. This sub-chapter describes the (future) context of the concept and describes how this context translated to requirements.

### **3.5.1 Power napping in different industries**

Although night shift work occurs in a multitude of industries, the current market of power nap facilities focusses on just two industries; healthcare and industry. Although a lot of similarities between these two industries exist in terms of power napping and the requirements set for power nap facilities, there are some differences. This section describes the two main differences not yet discussed, public vs private nature of the context and the unpredictability of workload and how those affect the design. The other major difference between the industries is the required level of hygiene, as discussed in chapter 3.3.

The first difference is in the public vs private nature of the contexts. Healthcare is a public facing industry whereas industry is generally a private industry. The public facing nature of healthcare work means that healthcare workers are more subject to public opinions. Furthermore, hospitals are partly public buildings that anyone can enter, whereas most industry buildings are private buildings that require of access to enter. Although areas like power napping rooms in hospitals are generally not accessible to the general public, the line between public and private or restricted access is thinner. These two reasons may lead to power napping users in healthcare to feel an increased need for privacy. This additional need for privacy led to the required sightline blocking from one and a half side as opposed to one.

The second difference between industry and healthcare is the unpredictability of the workload. Although workload is never fully predictable, this problem appears to be larger in healthcare. The unpredictability can, and often does, lead to shift workers not having time to take a power nap during a busy night. Although this cannot be solved through the design, it is still a context factor that needs to be recognized, as users may only sporadically use the product.

### **3.5.2 Power napping rooms**

Facilities to take a power nap have been placed in a wide variety of contexts over the years. From hallways and staff rooms to lactation rooms and dedicated power nap rooms. Some solutions, like the BOOZTR pods are designed to be placed in hallways and (semi-) public spaces, while other solutions,

like the NEWAS chairs and the Ahrend Loungescape powernap are meant to be placed in dedicated resting rooms. The importance of the conditions for a good power nap, as described in chapter 3.1.3.3, indicate that a dedicated space, in which these conditions can be controlled is beneficial. Participants from the user research confirmed that power napping in a (dedicated) private space is preferred over hallways and staff rooms. For these reasons and from their experience, NEWAS already recommends dedicated power nap rooms. Therefore, the concept is designed to be placed in a (semi-) dedicated power nap room or space.

Most existing power nap spaces are more or less the same. A power nap space is usually a small room that is furnished with the power nap solution, a small table, some minor decorations and curtains if the room has a window. The room can be closed and sometimes even locked from the inside to provide privacy. In almost all power nap rooms, the light can be controlled through a regular wall mounted light switch or dimmer. Turning off the light before entering the solution and having to find the light switch when in the dark when the power nap is finished can be troublesome. Some power nap rooms have the ability to regulate temperature. The images in figure 3.13 show real-life examples of power nap rooms and other rooms used for power napping. These images are taken by participants of the user research.

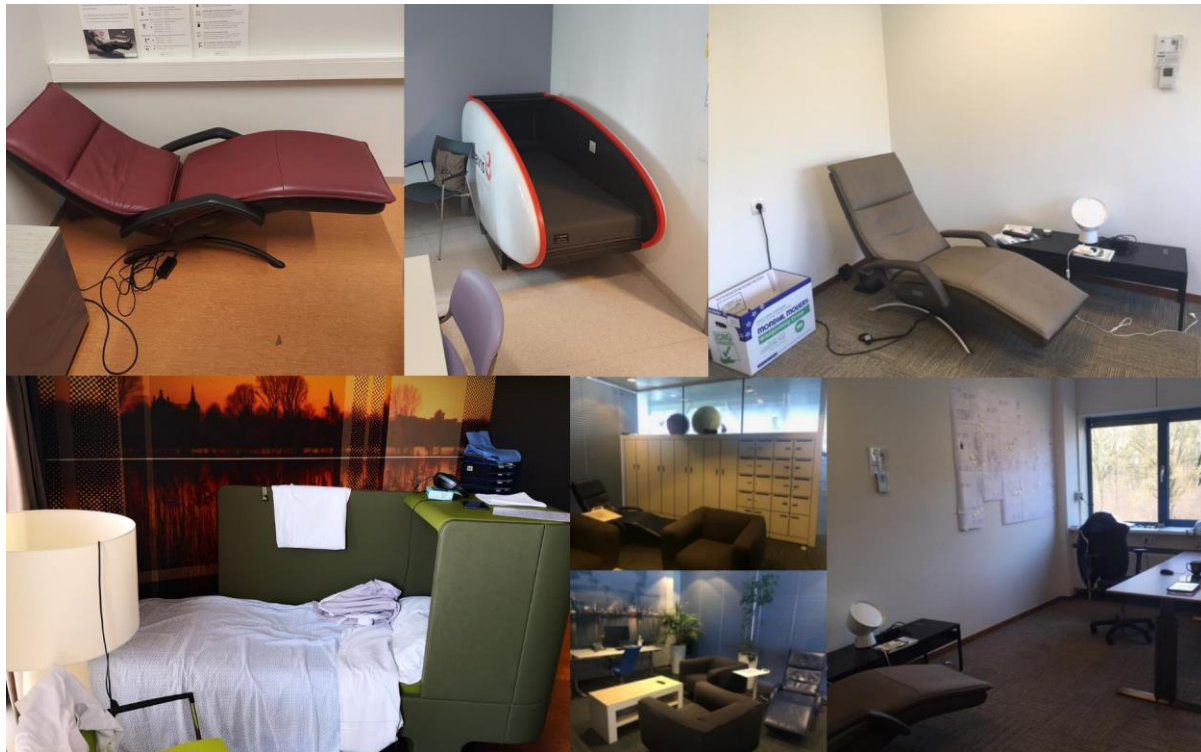


Figure 3.13 – Existing power nap rooms

### 3.5.3 Conclusions from the context analysis

Although power napping is an effective solution to combat the negative consequences of all types of night shift work, only two industries, healthcare and industry, are currently interested in using this

strategy. As a result, the concept is focussed on providing the optimal power nap solution for those specific contexts. Even though there are many differences between the two industries, very few of them affected the final design.

Because the concept should preferably be placed in either dedicated power nap rooms, it is designed to fit in this context. By having a dedicated power napping space issues like privacy, noise and darkness are less prevalent. This allows the design to not be a fully closed-off structure and reduces the need for providing complete darkness or total sound reduction. Because power napping spaces are generally quite small, especially in healthcare, the concept was designed to easily fit in most small rooms.

### **3.5.4 Requirements derived from the context analysis**

The context analysis led to the following requirements in the program of requirements:

#### **Privacy**

The following requirement comes from the additional need for privacy in the healthcare.

- The concept should provide sufficient privacy to the user. The line of sight should be blocked from at least one and a half of four sides of the mattress. (The half should block sight to the head and upper torso)

#### **Footprint**

The following requirement stems from the limited size of power napping rooms.

- The concept should have a maximum footprint of 225 \* 125 cm.

#### **Wayfinding**

The following requirement stems from the wall mounted light switches making wayfinding difficult when entering and exiting the solution.

- The concept should include wayfinding lights that can be dimmed or turned off by the user.

#### **Aesthetics**

The next requirement originates from the need to fit in the context aesthetically.

- The concept should fit in its context in terms of aesthetics. (Colours, materials and textures).

## 3.6 Program of requirements

Based on the research conducted in the first phase, input from the client and general best practices, a program of requirements was developed. This set of requirements provided both a starting point for ideation and a method for comparing and validating ideas. Some requirements were added later, as new requirements were found during the ideation and conceptualisation phase.

### General functionality and geometry

- Req 1. The concept should be able to house an FPS-mattress of 2000\*800\*180mm and its control box of 150\*250\*92mm (see chapter 1.3).
- Req 2. The concept should not be fully closed-off and should have at least 1 open side (see chapter 4.1).
- Req 3. The concept should integrate the bed and shielding structure to enable implementation of functionality.
- Req 4. The concept should not have multicurve bodies, as this requires more complicated manufacturing processes with higher costs (see chapter 4.5).
- Req 5. The concept should provide a (partial) barrier between the user and:
  - a. Light coming from above (e.g. ceiling mounted lights) (see chapter 4.1).
  - b. Light coming from 2 sides (e.g. windows in a corner room) (see chapter 4.1).
  - c. Sightlines from others entering a power nap space (for privacy purposes) (See chapter 3.5.4).
- Req 6. The concept should have a maximum footprint of 225 \* 125 cm (see chapter 3.5.4).
- Req 7. The concept should not facilitate power naps longer than 30 minutes (see chapter 3.1.5).
- Req 8. The concept should allow for passive airflow to ensure the air quality inside the concept is similar to the room air quality (see chapter 3.1.5).

### User ergonomics

- Req 9. The concept should be easy to enter and exit. The user should not have to crawl into the concept, but instead should be able to sit down on the side of the mattress, turn and lie down (see chapter 3.2.9). Both the ingress and egress should take a healthy user with no prior experience no longer than 15 seconds.
- Req 10. The user should be able to enter and exit the concept from the long side of the mattress (see chapter 3.2.9).

- Req 11. The maximum length of the sidewall should be 70 cm from the head-end of the mattress. (see chapter 5.2.1).
- Req 12. The concept should be able to support the weight of P99,5 male, which is 120 kg (DINED, dutch males 20-60, n.d.). As an additional safety-factor, the concept should be able to support this weight 1.5 times (180 kg).
- Req 13. The concept should allow P95 length males, 1954mm, to lie down flat in the concept (DINED, dutch males 20-60, n.d.).
- Req 14. The inner height of the concept (from mattress to the internal ceiling) should be at least 80 cm (see chapter 5.2.1).
- Req 15. The concept should provide a comfortable environment for power naps. Participants of the validation research should rate the perceived comfort at least 5 out of 7 (see chapter 3.2.9 and 3.4.5).
- Req 16. The concept should have haptic or manual controls (referring to physical buttons etc.) to avoid blue light from tablet-style controls and make finding and using the controls in the dark possible. (see chapter 3.2.9)
- Req 17. The concept should make controlling the FPS mattress simple and easy to understand. A one-time explanation should suffice.

## **Features**

- Req 18. The concept should provide sufficient privacy to the user. The line of sight should be blocked from at least one and a half of four sides of the mattress (The half should block sight to the head and upper torso) (see chapter 3.4.5 and 4.2).
- Req 19. The concept should minimize the noise from outside a power nap- or resting room through absorption or redirection of sound (see chapter 3.1.5).
- Req 20. The concept should optionally aid in controlling- or enable users to control the microclimate temperature (see chapter 3.1.5).
- Req 21. The concept should be able to effectively (in at least 95% of users) wake the user at the end of the power nap program, but not in an aggressive, harsh way (see chapter 3.4.5 and 4.2).
- Req 22. The concept should include wayfinding lights that can be dimmed by the user (see chapter 3.4.5, 3.5.4 and 4.2).
- Req 23. The light used in the concept for wayfinding and waking, should have a colour below 2700K and an intensity below 800 lumen (see chapter 3.1.5).
- Req 24. The concept should have a pillow and optionally a blanket (see chapter 3.4.5 and 4.2).
- Req 25. The concept should have storage space for clean bed linen (see chapter 3.4.5 and 4.2).



- Req 26. The concept should have a dedicated space to display information about the different available FPS programs (see chapter 4.2).
- Req 27. The concept should optionally have an additional method of relaxation other than the FPS technology (see chapter 3.1.5).
- Req 28. The concept should be able to convey its purpose (napping) and effectiveness to HR or team leaders during the purchasing process through implementing sufficient use-cues and visual cues (see chapter 3.2.9 and 3.3.6).

### **Hygiene and cleaning**

- Req 29. The concept should be easily cleaned with cleaning detergent and a wet cloth (see chapter 3.3.6).
- Req 30. The concept should not have hard to reach parts that require frequent cleaning (see chapter 3.3.6).
- Req 31. The concept should not have corners, ridges or other geometry that collect dust and dirt (see chapter 3.3.6).
- Req 32. The concept should provide easy access to the floor for vacuuming and mopping the floor, potentially through the use of casters (see chapter 3.3.6).
- Req 33. The mattress should be easily removed from the concept for deep cleaning and disinfection. The concept should not have a mechanical connection between the mattress and the housing and the wires to the control box should be easily accessible for disconnecting (see chapter 3.3.6).
- Req 34. The concept should use materials that are easily cleaned and don't absorb dirt or liquids (see chapter 3.3.6).
- Req 35. The concept should avoid having porous or permeable surfaces on the outside of the product. (see chapter 3.3.6).
- Req 36. The concept should avoid the use of regular, permeable textiles for the mattress upholstery (see chapter 3.3.6).

### **Product durability and lifespan**

- Req 37. The concept should minimize the use of moving parts, as these tend to be more susceptible to wear (see chapter 3.3.6).
- Req 38. The concept should have wear-resistant upholstery on parts that the user is frequently in contact with (e.g. the mattress) (see chapter 3.3.6).

Req 39. The 'high traffic' parts of the concept (e.g. mattress, FPS interface and other parts users physically interact with) should last at least 5 years without major maintenance, repairs or replacement parts (see chapter 3.3.6).

Req 40. The 'low traffic' parts of the concept (e.g. structural parts and parts users don't interact with) should last at least 8 years without major maintenance, repairs or replacement parts (see chapter 3.3.6).

Req 41. The maintenance of the concept should be easy, and require no specialized skills or tools (see chapter 3.3.6).

Req 42. Parts that are prone to wear should be easily accessible and disassemble to make repairing or replacing parts require little time (see chapter 3.3.6).

### **Aesthetics and design.**

Req 43. The concept should fit in its context in terms of aesthetics (colours, materials and textures) (see chapter 3.5.4).

Req 44. The concept should look comfortable to use (see chapter 3.2.9).

Req 45. The concept should look inviting (see chapter 3.2.9).

Req 46. The concept should look calming or relaxing (see chapter 3.2.9).

Req 47. The concept should look soft (see chapter 3.2.9).

Req 48. The concept should share elements with the existing NEWAS products.

Req 49. The concept have a be low gloss or matt surface finish (see chapter 4.3.2).

### ***Production costs, methods and materials***

Req 50. The concept should have a maximum manufacturing cost of €1500,- excluding V.A.T. and mattress with FPS technology (see chapter 3.2.9).

Req 51. The concept should not use production methods that require high initial investments of over €5000,- for a single part.

Req 52. The concept should not use any materials that are toxic or harmful to the user.

Req 53. The concept should be manufacturable with either thermoformed or vacuum casted plastics, CNC-milled or steam bent wood, or bent or rubber pressed steel (see chapter 4.5)

### **Transport and delivery**

Req 54. The disassembled or partially assembled concept should fit through a regular Dutch door. This is 85 cm according to the 'Beoordelingsrichtlijn 2211' (SKH, 2010).

Req 55. The disassembled or partially assembled concept should be easily assembled in its room and should not require complex skills or tools.

Req 56. The disassembled or partially assembled concept should easily fit on a EPAL 2 pallet and when delivered should allow a pallet jack to carry the entire product.

Req 57. The sub-assemblies of the concept should be able to be carried by two people. Weighing a maximum of 50kg.

### **Safety**

Req 58. The concept be free of toxic or harmful materials.

Req 59. The concept should have any sharp points or sides.

### **End of life**

Req 60. The disassembly of the concept should be easy. It should require no more than 3 tools.

Req 61. The concept should preferably be re-used. However when disposed, materials should be non-toxic when thermally recycled (burned), as this is the most common method of disposing waste in the Netherlands.

# Chapter 4. Ideation

The ideation phase was the second phase in the design process that led to the Asper. The program of requirements (PoR), that was made during the ideation phase, is the backbone of each design and provided a starting point for ideation. This chapter provides an overview of each step taken during the ideation phase, including their respective results. The ideation phase led to the three ideas that were selected for conceptualisation.

## 4.1 Product archetypes

Defining the general shape and structure of the final product, was the first step during the ideation phase. The main goal of the archetypes is to narrow down the design direction and to create a solid base for generating ideas. With an underlay, 40 quick side view sketches were made to explore different directions (see figure 4.1; a full resolution image of these sketches can be found in appendix E). The sketches were then evaluated with the following set of 4 archetype criteria:

- The archetype cannot be a closed-off pod type. (At least 1 side open)
- The archetype cannot be a stand-alone partition type. (For implementation of features and functionality)
- The archetype must provide a (partial) barrier between the user and:
  - Light coming from above (e.g. ceiling mounted lights).
  - Light coming from 2 sides (e.g. 2 windows in a corner room).
  - Sightlines from others (for privacy purposes).
- The archetype must have relatively simple shapes for production purposes.

Based on the selected sketches, three archetypes were found to fit within the criteria.

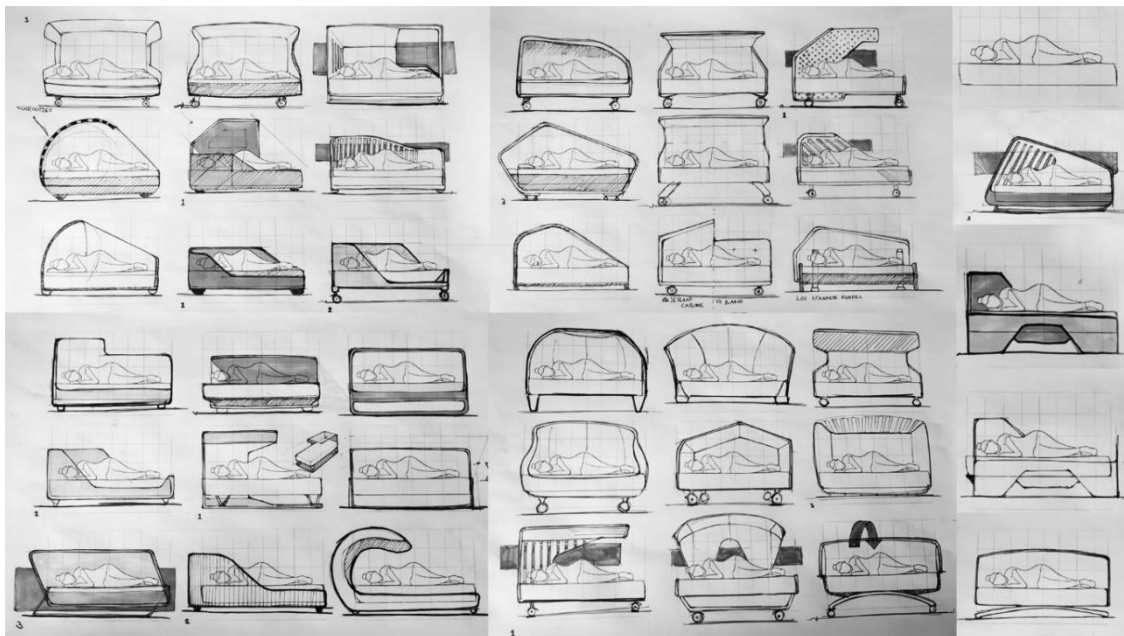


Figure 4.1 – 40 side view sketches (underlay on top right)

#### 4.1.1 Archetype 1 – Overhanging cliff

The first archetype is the overhanging cliff (see figure 4.2), which is characterized by its overhanging ceiling that is supported on one side. The structure of the overhanging cliff fully covers the head side of the bed and partially covers at least one side of the bed. It is also relatively high when compared with archetype 2.

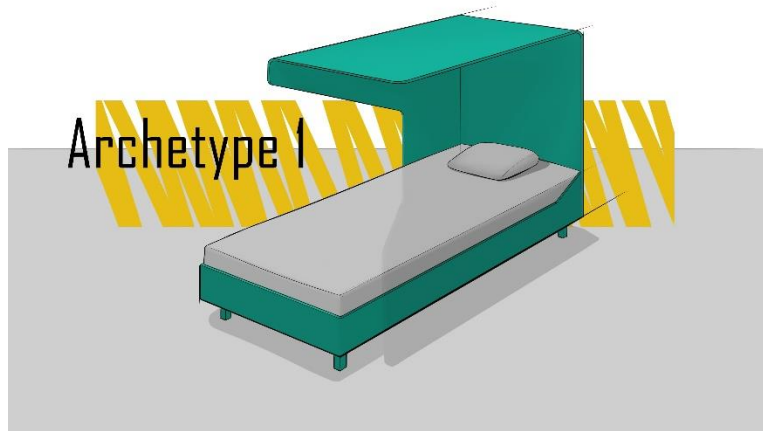


Figure 4.2 – Overhanging cliff

#### 4.1.2 Archetype 2 – Head pod

The second archetype is the head pod (see figure 4.3), which is characterized by its enclosure around the head and upper torso. The structure of the head capsule is lower than the other two archetypes and partially covers the sides of the user. These sides can be asymmetrical in length.

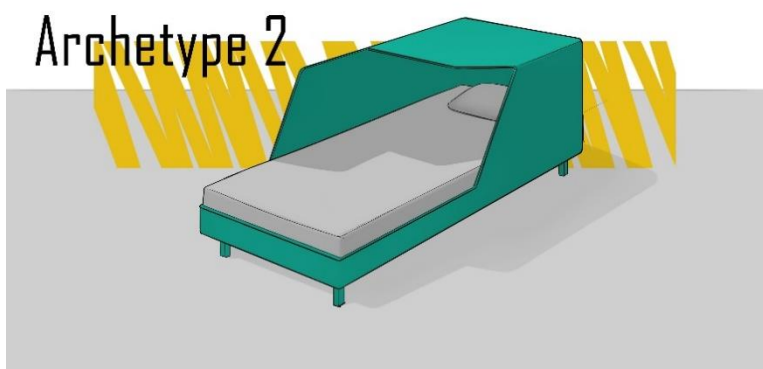


Figure 4.3 – Head pod

### 4.1.3 Archetype 3 – Theatre

The third archetype is the theatre (see figure 4.4), which is characterized by its full cover of one side and both head- and foot end. The structure of the head capsule is the highest of the three archetypes. The ceiling covers, the entire length of the bed.

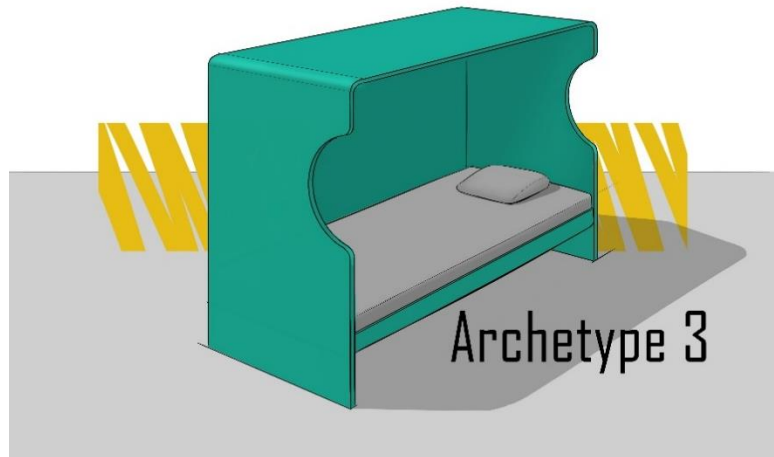


Figure 4.4 - Theatre

### 4.1.4 Archetype selection

Together with the client, two archetypes were chosen as the basis for further ideation. Archetype 1 and 2 were selected and archetype 3 was excluded. The main reason for excluding archetype 3 was its large and closed-off appearance and structure. According to the client, such an appearance and structure might lead to placement of the product in large, open or even public spaces like hallways, which is undesirable. Furthermore, due to its larger appearance, it could look out of place in a small power nap space. Another reason for excluding the third archetype was that tall users or users with dirty work shoes (in industry) could not let their feet hang out when lying down. Lastly, archetype 1 and 2 provided more form- and thus design freedom.

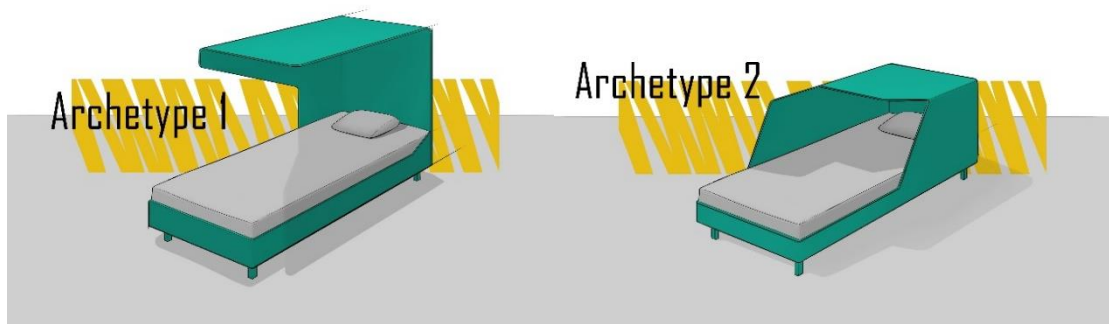


Figure 4.5 – Selected archetypes

## 4.2 Product feature ideation and selection

During the analysis phase, a wide range of features to specific problems and issues related to power napping was developed. Most feature ideas were validated during the user research (see chapter 3.4). Other features that were developed after the user research were considered based on their merits. This section describes the feature ideation process, all features that have been considered in the design process of the Asper and the reasoning behind the design choices that led to them either being implemented, optional or excluded from the final product.

### 4.2.1 Feature ideation

Features were mainly ideated on with mind maps. First, a general mind map with categories was made (see figure 4.6). Then, the categories that made sense for feature ideation were further elaborated on (see figure 4.7). All mind maps can be found in appendix F. Some other feature ideas popped-up throughout the design process. Most ideas were validated during the user research (see chapter 3.4). Others we're either included or rejected based on other research from the analysis phase and their merits.

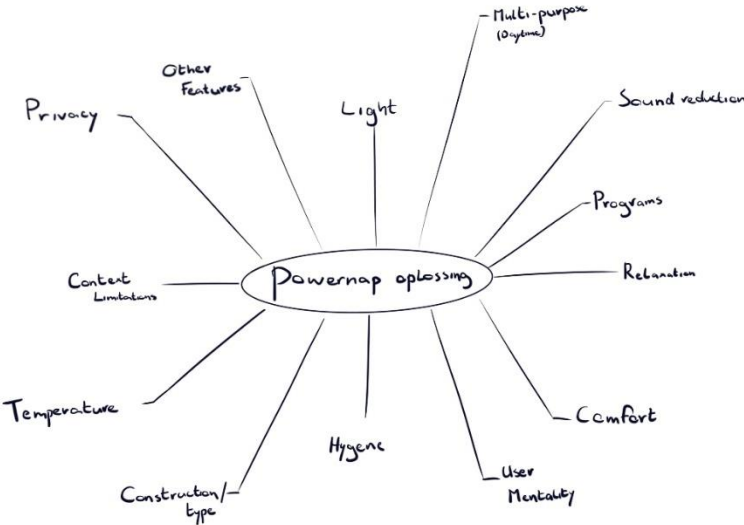


Figure 4.6 – Mindmap categories

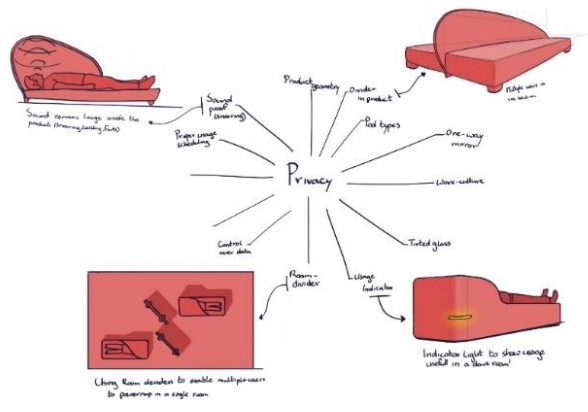
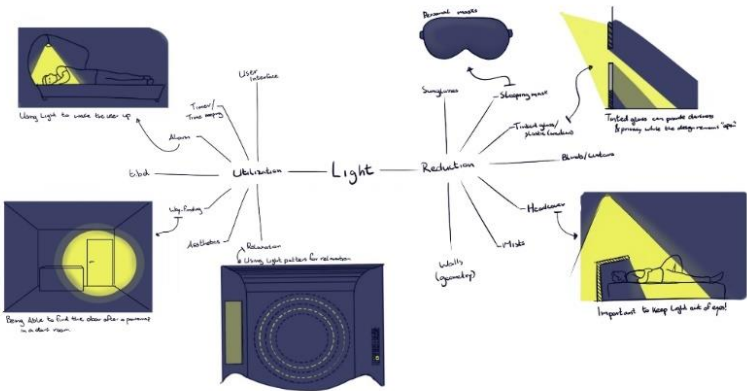
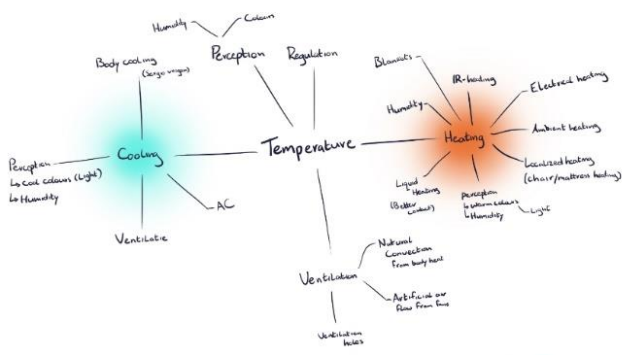
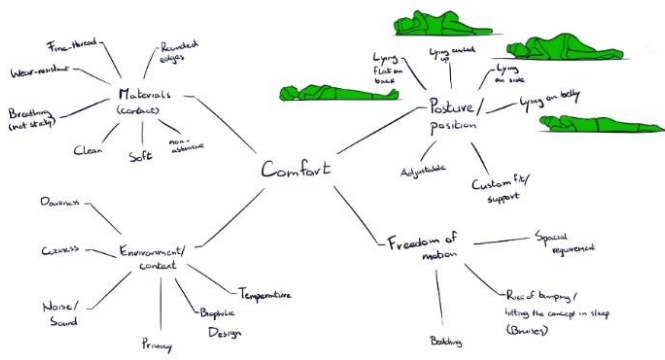


Figure 4.7 – Mindmaps: Comfort, temperature, light and privacy



## 4.2.2 Implemented features

The following features have been selected for implementation in every Asper as they are an integral part of the design.

### **Sightline and light blocking structures**

An important feature of the Asper are the structural parts that block both light and line of sight. The structure ensures that the user can nap comfortably, even in space with high light levels. The structure also provides privacy to the user.

### **Waking assistance**

Waking assistance helps the user to wake up at the end of the duration of their power nap. According to Janssen (2018), waking up and getting out of the power nap facility is vital to a successful power nap, as doing so prevents deep wave sleep. Furthermore, giving the user the confidence that they will be woken makes it possible to fully relax. Assisting the user with waking and ending their power nap is achieved through a combination of sensory stimulations.

- *Light*  
During the last 45 seconds of the power nap program, lights inside the Asper start to slowly light up. The light gradually becomes more intense, until a light intensity of up to 800 lumen is reached. This light intensity should be sufficient to wake the user from light sleep. Lamps with a temperature of 2700 Kelvin should be used. The lights then stay on for another 120 seconds. Similar usage of light for waking can be seen in Philips wake-up lights.
- *FPS technology*  
During the last 20 seconds of the power nap program, the FPS technology is used to assist in waking the user. This is done by rapidly increasing the intensity of the vibrations in the last 20 seconds of the program.

### **Wayfinding lights**

The Asper's intended context is to be placed in dedicated power nap- or resting rooms. For the purpose of taking a power nap, these rooms are often either dark or very dimly lit. To be able to find the Asper when entering the room and find the exit of the room at the end of the power nap, higher light levels are required. However, controls for the lights are always wall-mounted. Forcing the user to find their way in a dark- or dimly lit room. The Asper has integrated lights that ease wayfinding. The lights are on by default, and turn off or dim when a power nap program is started. Another benefit of including wayfinding lights is that resting rooms no longer require dimmable lights, which is a common modification needed when setting up a resting room. Now, power nap room lights can be off by default during night shifts.

### **Pillows and bed linen storage**

The user research clearly showed the desire for a pillow. Therefore, a pillow will be implemented in the final product. A storage space for clean bed linen will also be implemented in the design as this makes changing the sheets easier and more accessible.

### **Hygiene features**

Because hygiene is an important factor for both the end users and in the decision process of facilities managers, especially in healthcare, the Asper comes with multiple features that improve hygiene and ease cleaning.

- The fabrics used in the Asper are durable, non-permeable, and can be cleaned with alcohol based detergents and a wet cloth.
- The mattress is easily accessible and can be removed from the Asper for deep cleaning.
- The inside of the Asper is made from materials that are coated to not be porous and cannot absorb moisture.
- Both the in- and outside can be cleaned with alcohol based detergents and a wet cloth.

### **Sound reduction**

As discussed in chapter 3.1.3.3, sound plays an important role in the quality of sleep and power naps. Reducing sound is therefore an important feature to add to the Asper. A multitude of tactics exist for tackling this problem with varying degrees of effectiveness. Because the Asper has to be relatively simple, complex solutions like noise cancelling and reflection strategies requiring complex geometry are ruled out. Instead, the Asper uses materials that absorb sound and prevent reverberation. The materials used are: polyethylene (PE) foam and fabrics.

### **Program information storage option**

Because the Asper's purpose and complex features are difficult to explain through just design, a space to provide information on when- and how to take power naps and the included FPS programs is included in the design.

## **4.2.3 Optional features and add-ons**

The features mentioned in the next sections will not be implemented in each Asper. Instead, customers can select and configure the Asper to their needs. This keeps the base price of the Asper low, while making the Asper adjustable in order to meet specific contextual requirements. The Asper is made in such a way that these features can easily be implemented or added when the customer wants a certain feature.

### **Casters**

In healthcare, this feature is almost considered a must. All healthcare participants in the user research indicated to value casters, as did the interior and furniture manager. The main purpose of casters in healthcare is to ease cleaning. In industry, the need for this feature was less apparent. Besides easier cleaning, casters also allow users to easily and quickly adjust to position of the Asper. Another benefit of easing transportation is the potential of sharing the Asper between departments for trialling the product, potentially increasing demand. Casters also allow for easy installation and internal relocations.

### **Electric and passive heating blankets**

Temperature regulation is a topic that has received a lot of attention. Especially providing enough warmth to the user is relatively easy and can be done in many different ways. Because quickly adjusting and regulating the room climate is difficult, air temperature regulation is excluded from the design. Instead, the design optionally targets the microclimate around the user. To do this, two optional features can be purchased and are supported by the Asper. The first option is an electric underblanket that fits the mattress. The Asper internally has a point that can provide power to this underblanket. Another option is to purchase one of the passive heating blankets in NEWAS' stock. Both blankets can be sold as an add-on to the product to keep the user warm.

### **Coat hook and temporary storage**

A coat hook can be useful in certain contexts, where users are wearing jackets or other context specific items like safety helmets, stanoscope, etc. that are usually taken off before lying down. A place to temporarily store items such as glasses, phones, wallets or other context specific items such as a pager, ear protection, etc. can be included. No place for shoes is included in the Asper. These will stand on the floor or are sometimes kept on during the power nap.

### **Usage indicator**

Because the intended context of the Asper is a dedicated small room, where a user is alone and the product not visible from the outside, this feature cannot be on or in the product itself. Therefore, NEWAS could offer a simple in use / not in use indicator for placement on the door.

### **Relaxation guidance**

Relaxation guidance through breathing exercises is another optional feature. When installed, the user can select the program and will be given a breathing exercise through the lights inside the Asper. Because the complete development of this feature is out of the scope of the project, a simple version is implemented. This feature should be further developed at a later stage.

#### **4.2.4 Excluded features**

The excluded features have been considered and were found to either not add enough value to offset their costs, not add any practical value at all, or be impractical in the design. None of these features will be available in the Asper.

##### **Aromatherapy or aroma dispersion**

The Asper will not use aromatherapy, smell or essential oils. The main reason to not use these is that such features require very regular refilling, thus adding maintenance or requiring users to spend time on things other than power napping during their nap time. Furthermore, because such a feature requires consumables, cost over time would add up to a significant amount over years of use.

##### **Audio system**

Although having an integrated audio system may add some value, the drawbacks of this feature outweigh the benefits. The main benefits of an integrated audio system include being able to play music or relaxing sounds while power napping and using sound in the alarm at the end of power nap. However, drawbacks such as reduced sleep quality and increased sleep onset, additional product costs and complexity and having to connect a phone far outweigh the benefits. Therefore a (user-controllable) audio system is excluded.

##### **(Wireless) Charging**

Despite some competitors offering this feature, user research showed that the perceived added value of this feature is minimal. The main reason given was that charging for 20 minutes during a break would not make a big difference. Another drawback of this feature is that users would have their phone with or on them when taking a power nap, this is usually recommended against when trying to fall asleep. The added complexity does not outweigh the minimal added value.

##### **Feedback on power naps**

Feedback on power naps is another feature that is not implemented in the product. There are multiple reasons for this exclusion. First, the added required technology, sensors and software would require a significant amount of money to be developed, making the product significantly more expensive. Secondly, users from the user research generally found this feature to not provide a real benefit. The limited perceived benefit for a significant price hike causes this feature to be excluded.

##### **Mirrors**

The idea behind this feature was that users may wish to look at- and adjust their appearance after a power nap. However, the feature will not be included as most power nap spaces either already have a mirror or are close to a sink with a mirror. The feature also does not offer enough value to warrant changing or adapting the design to facilitate this feature.

##### **Cooling**

Cooling the context has been excluded from the Asper as it is more or less impossible to cool down the air temperature without a heat-outlet. Contact cooling the user is another excluded feature as it generally requires liquids, greatly increasing the complexity and costs of the product.

## 4.3 Product look and feel – mood boards

To aid in the design and ideation process, multiple mood boards were made. These mood board provided both inspiration and examples of, in my opinion, good aesthetic design. The following three mood boards were most influential during the ideation and conceptualisation phase.

### 4.3.1 – Multi-material transitions

During the ideation phase, the need for multiple materials in the design became apparent. The frame, made from either wood, metal or plastic, would have to meet up with the upholstery of the head capsule. The images in this mood board (see figure 4.8) explore methods of transitioning between the materials in the design as well as potential material and colour combinations.

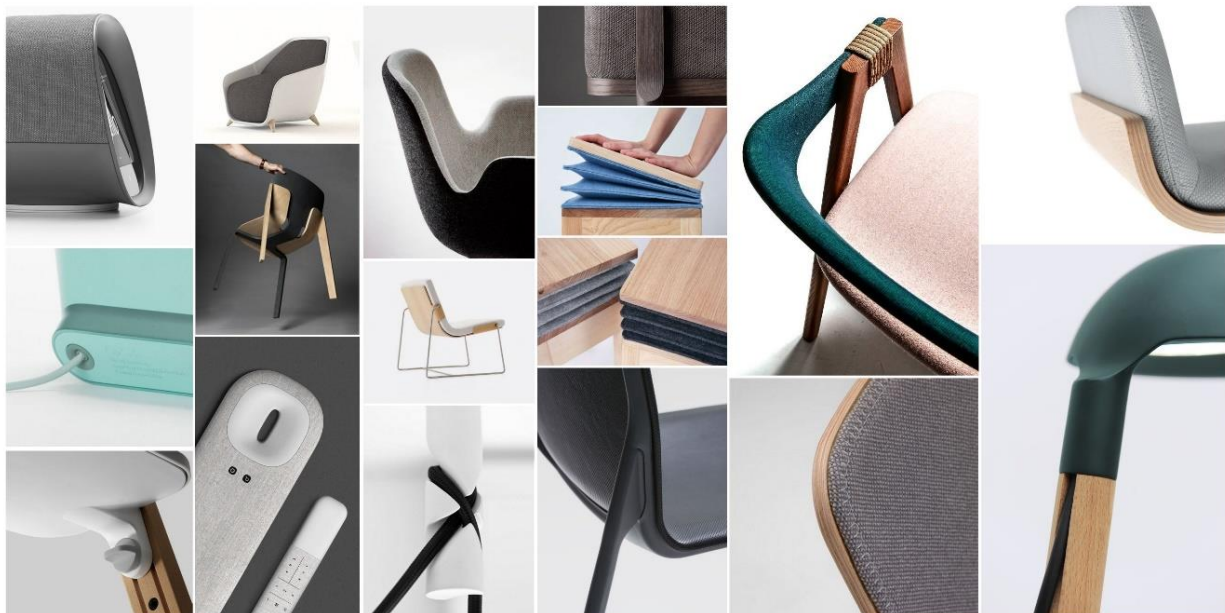


Figure 4.8 – Mood board material transitions

### 4.3.2 – Form language

To meet the aesthetic requirements (requirements 44 - 47) set in chapter 3.2.9 (the concept should look: comfortable, inviting, calming or relaxing and soft and easy going), a mood board was made with designs and products that already, subjectively, meet these criteria (See figure 4.9). This mood board was used as inspiration. Products in this mood board have a few things in common that most likely cause them to look comfortable, inviting, calming or relaxing and soft and easy going. First, most products have large rounded corners that are either filleted or chamfered. Second, the products use low-gloss to matt surface finishes. Third, the products often use desaturated colours. These characteristics were used during the design process and in the final Asper.

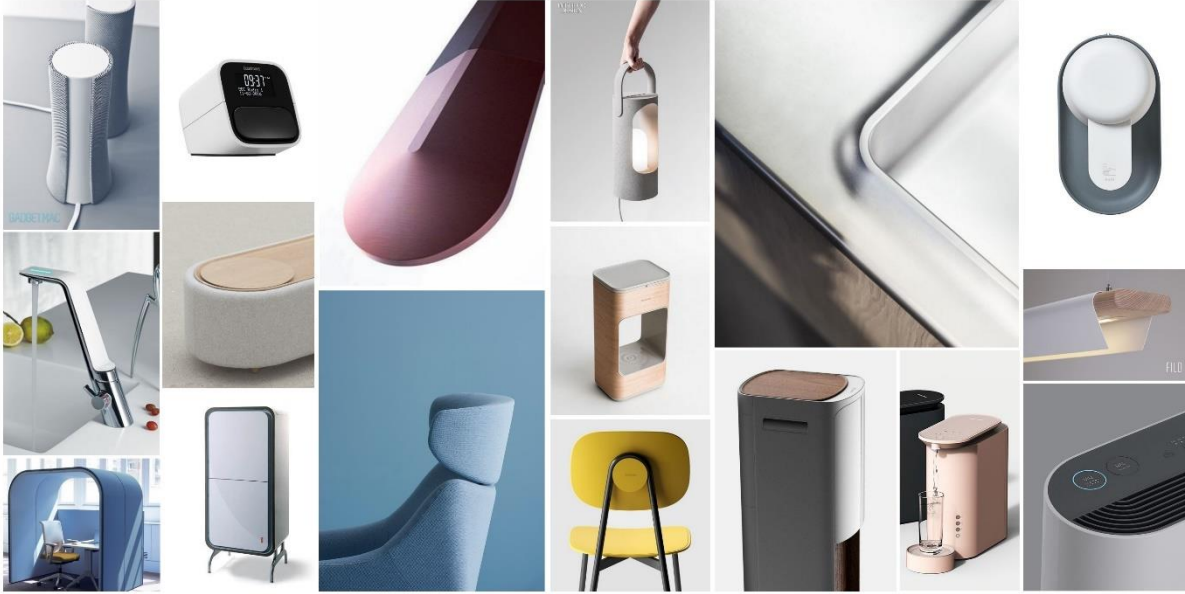


Figure 4.9 - Form language

### 4.3.3 - Fabric details

The third mood board (see figure 4.10) contains images that deal with fabric details. As the mattress and upholstery will play a large role in the concepts design, inspiration was gathered for the stitches and connections to other materials. This mood board was used as inspiration for the upholstery.

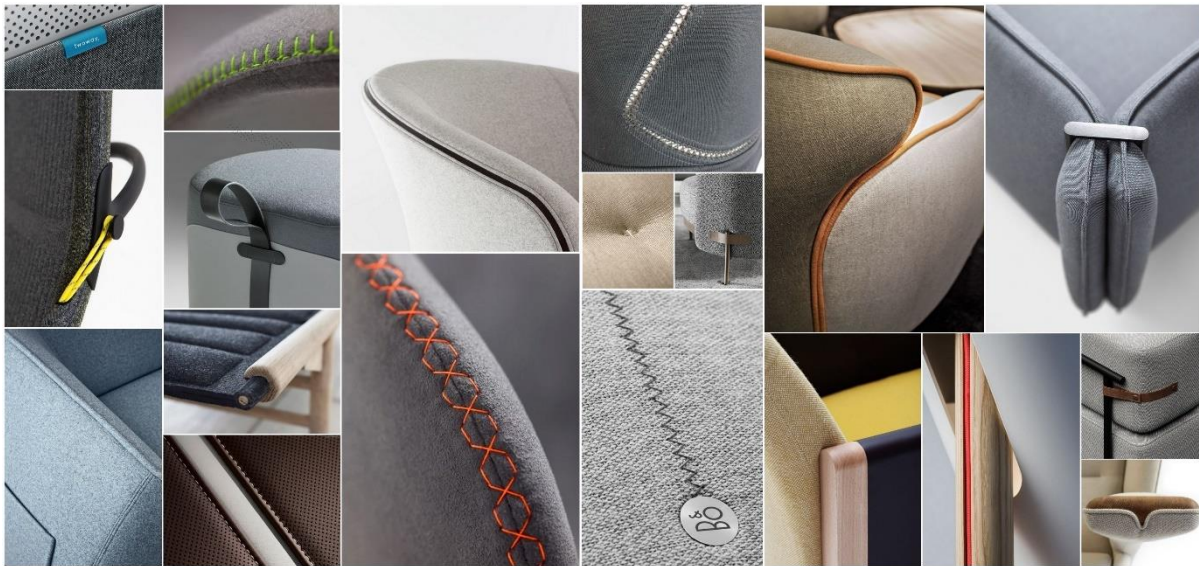


Figure 4.10 - Fabric details

### 4.3.4 - Mood boards conclusion

The mood boards provided inspiration during the design process. In the design of the ideas, round shapes with either fillets or chamfers were used. The material transitions were used to select a method of transition between the frame and the upholstery. Lastly, the fabric details mood board inspired the material choice in the final design.

## 4.4 Ideation sketches

With the program of requirements, selected archetypes, decisions on features and mood boards, ideation could start. This section shows the different initial sketches for both selected archetypes 1 and 2. During the sketching process, the need to explore manufacturing methods suitable for low volumes became apparent, as these would limit form freedom. The exploration of viable manufacturing methods can be found in chapter 4.5. Sketches from before the manufacturing exploration can be seen in section 4.4.1, sketches from after the exploration are in section 4.4.2. All full resolution sketches can be found in appendix G. The colours and materials in these sketches are not final, as the sketches were intended not intended to define exact material and colour, instead the goal was to explore and show the geometry of potential solutions.

### 4.4.1 - Sketches first batch

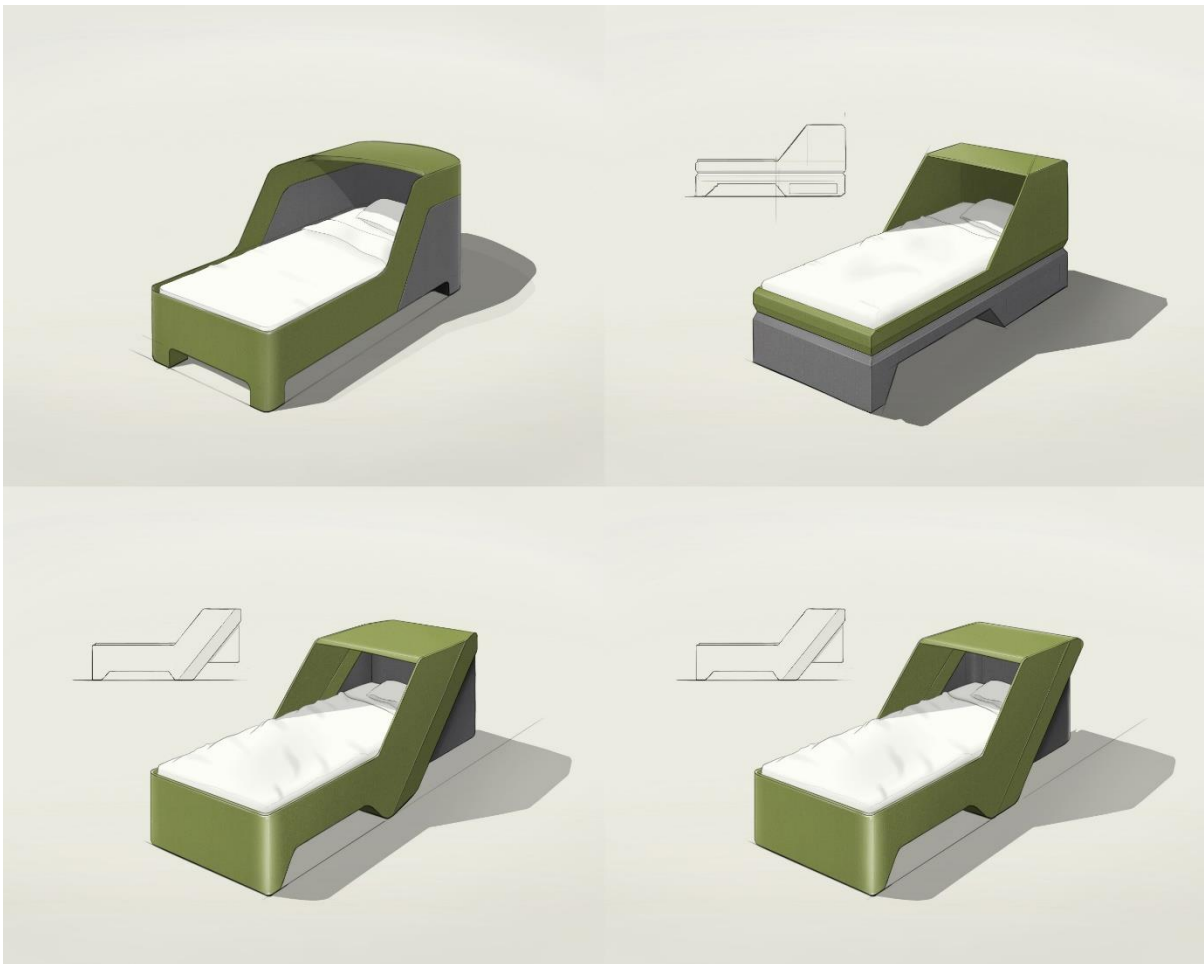


Figure 4.11 - Ideation sketches 1 - 4

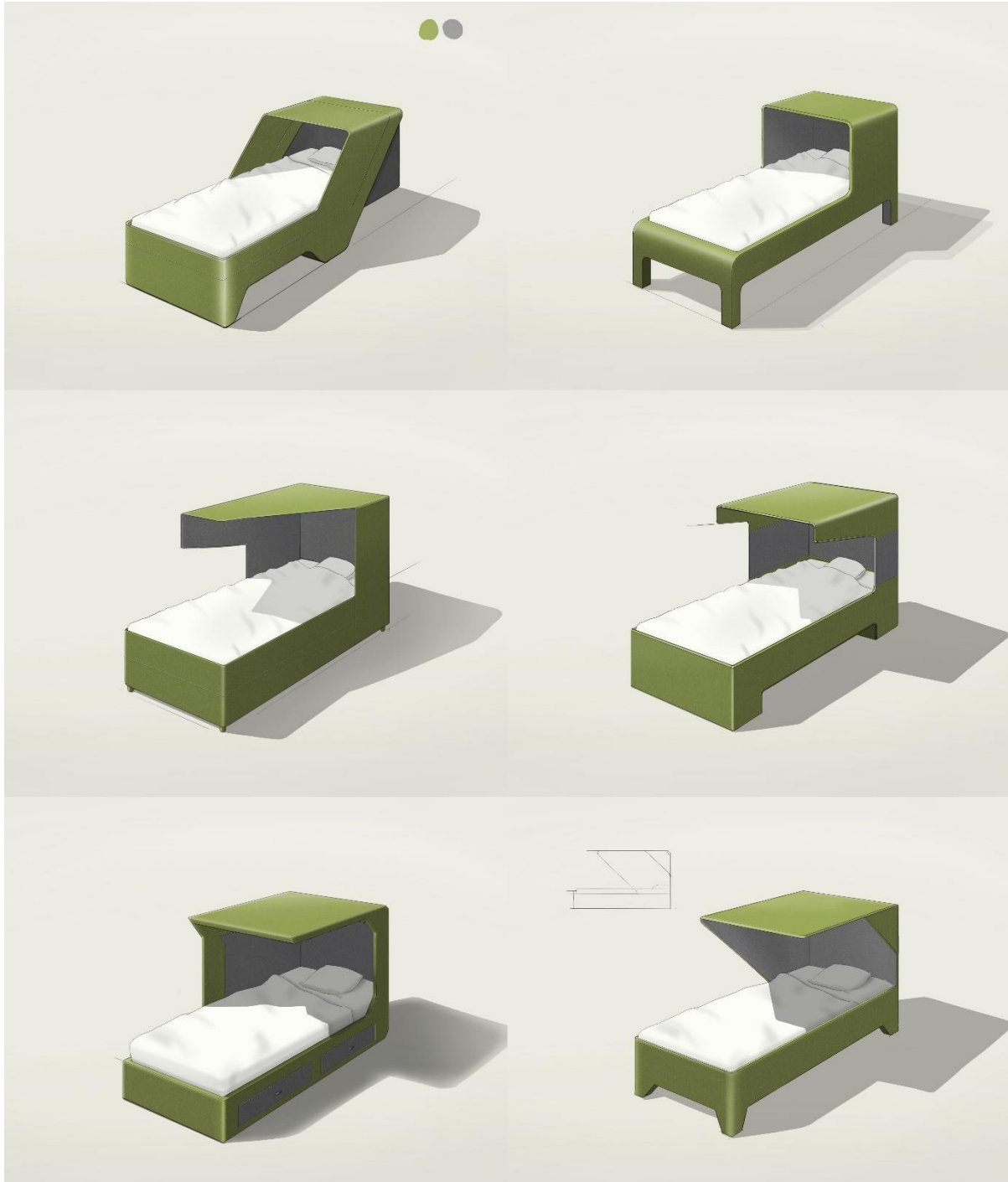


Figure 4.12 - Ideation sketches 5 - 10

Ideation sketches from the first phase explored different designs for both archetypes. These sketches were quite rough, and often lacked the soft, comforting and inviting aesthetic that was desired. This was most likely due to a lack of round or soft shapes (with the exception of sketch 1 and 5). In sketches from the second batch, these qualities were implemented more. The second batch was also informed by the preliminary material and manufacturing selection.



4.4.2 - Sketches second batch

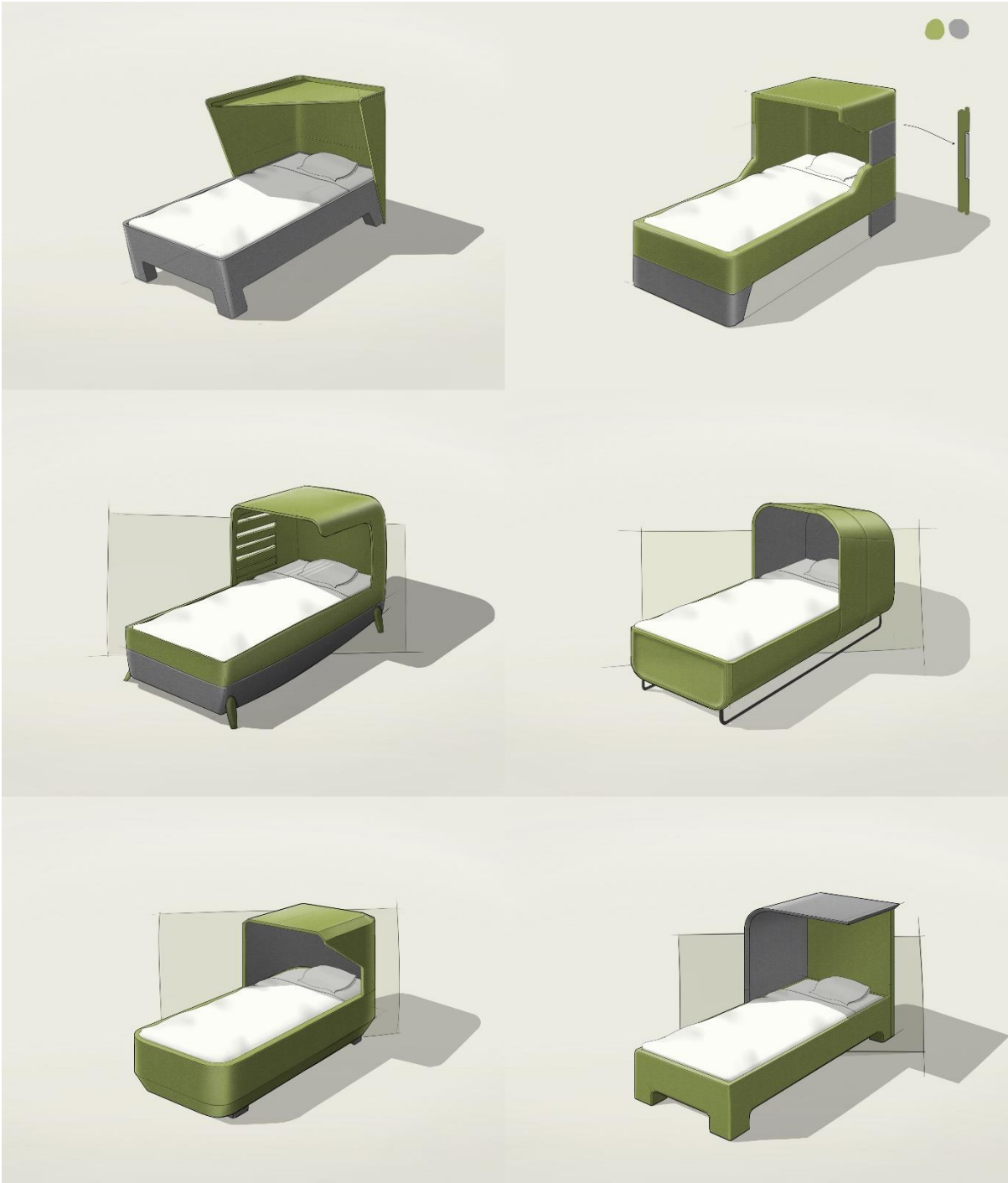


Figure 4.12 - Ideation sketches 15 - 15

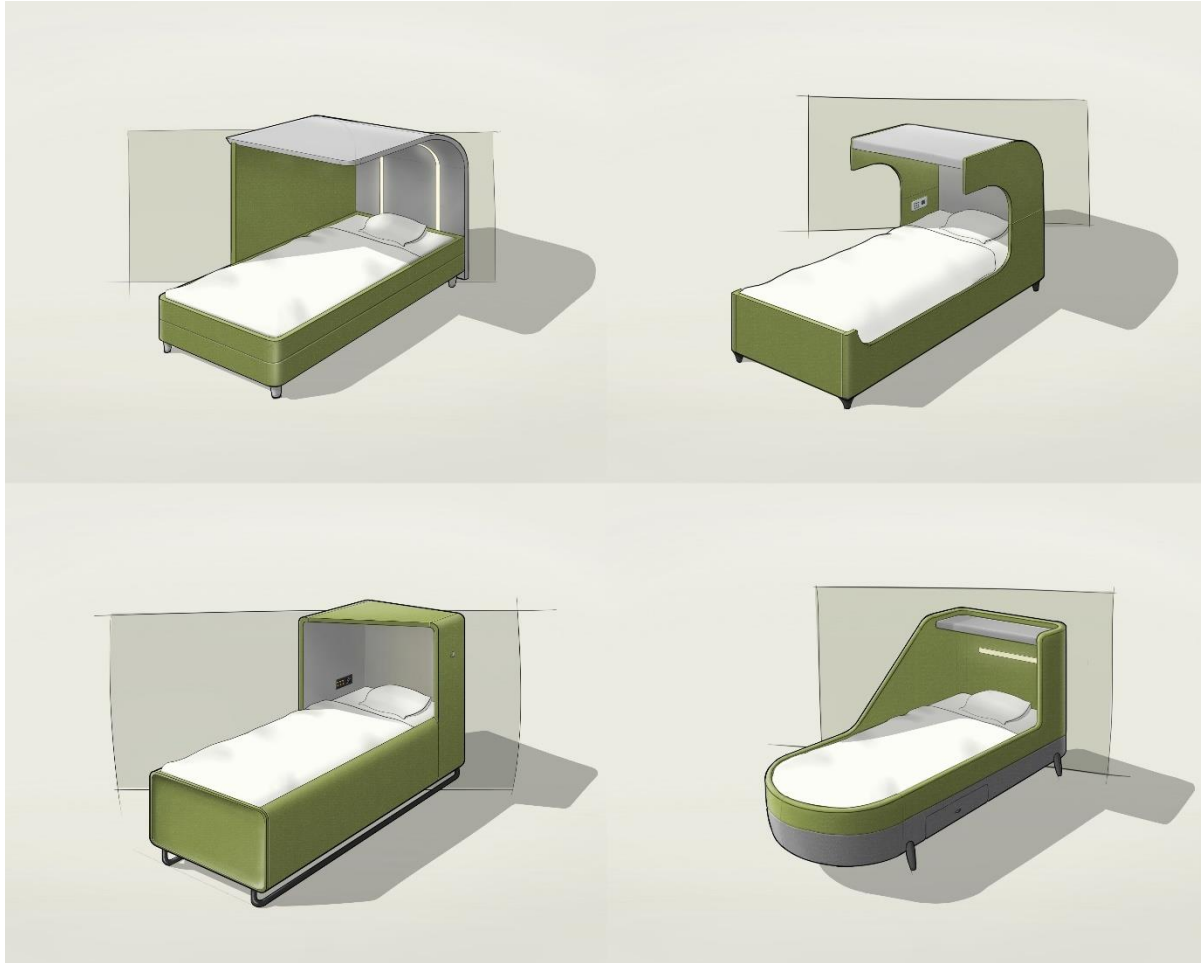


Figure 4.13 - Ideation sketches 17 - 20

The sketches from the second batch were more refined and showed more potential. They had more inviting and soft characteristics and also had more features already drawn in (e.g. lights, drawers, control panel, etc.). Because a preliminary selection of materials and manufacturing was made before the second batch (see chapter 4.5), the sketches also took construction and manufacturing in account. This made it easier to compare the sketches and reflect on them than the sketches from the first batch.

## 4.5 Preliminary manufacturing and material selection

During ideation, the need to define potential materials and manufacturing methods for the product became apparent, as material choices and manufacturing methods place limitations on the design freedom. This sub-chapter covers the materials and manufacturing methods that were considered applicable for the project during the ideation phase. The three main materials considered applicable for this project are: plastics, wood and steel. Aspects such as costs, product quantity and product size played a large role in the considerations. In the conceptualisation and product development phases, the exact material choices and manufacturing methods were selected. This preliminary selection's main purpose was to be able to create more informed design sketches. The book: *manufacturing and design; understanding the principles of how things are made*, was used almost exclusively for the information in this chapter (Tempelman, van Eyben, & Shercliff, 2014).

### 4.5.1 Manufacturing plastics

Despite the plethora of manufacturing methods for plastics, only two methods are considered applicable for the main body of the product. These are thermoforming and vacuum casting. Other manufacturing methods were excluded for a variety of reasons, such as the required batch size, product size and surface quality of the final product.

Manufacturing methods that were excluded because of the low product volumes include injection molding, blow molding and thermoplastic foam injection molding (FIM). Manufacturing methods that were excluded because of the large product size are, among others: CNC milling, compression forming and printed injection molding (PRIM). PRIM could still be an option for smaller parts and details. Methods that are excluded because of their poor surface quality include 3D printing and rotational molding. Other plastic forming methods like extrusion and injection blow molding simply don't fit the project because of their geometry restrictions.

#### 4.5.1.1 Thermoforming

Thermoforming, also known as vacuum forming, is a relatively simple manufacturing method. A thermoplastic sheet is heated and then shaped using a pressure difference to pull the sheet over a cold mold. Thermoforming allows for great form freedom and a large material selection, as most thermoplastics can be thermoformed. Regular sheet thickness lies between 0.2 and 10 mm, however thickness can go up to 25mm depending on material choice and geometry. Although slight negative draft angles are possible in some cases with low sheet thickness, they should generally be avoided. A material that deserves a mention in this section is Hi-Macs. This thermoplastic can be thermoformed and glued seamlessly to create complex shapes. Hi-Macs is one of the materials considered for the design.

#### **4.5.1.2 Vacuum casting**

Vacuum casting, sometimes referred to as urethane casting, is a manufacturing technique often used for rapid prototyping and small series of parts that would otherwise be made with injection molding. In vacuum casting, the parts are cast in a silicone mold under a vacuum. Because of the mold material, this method requires relatively low initial investments. Maximum part sizes depend on the available vacuum chamber, but larger manufacturing companies allow for parts up to 2\*1\*1 meters. Shape limitations are similar to injection molding, but less draft is required as the mold is somewhat flexible. Molds last up to 50 uses, making this method not suited for larger quantities. Plastics used in this method are always polyurethanes.

#### **4.5.2 Manufacturing wood**

Another material that has been considered for construction of the Asper is wood. Wood is a versatile material that can be shaped in a few different ways. Based on the initial sketches (See section 4.4) a few shaping, or manufacturing, methods were deemed possible. Shaping square or flat parts is straightforward and can be done with relatively simple machinery like saws, drills, routers planers and jointers. Curved parts can either be made using CNC milling or wood bending. An important aspect to keep in mind when working with wood is the joinery. To create the Asper from (mainly) wood, many joints are necessary. Another drawback of using wood is that the material requires a coating, which can be labour intensive and expensive to put on.

##### **4.5.2.1 CNC milling**

CNC milling of wood allows the wood to be shaped in practically every way, depending on the machine. Size limits also depend on the machine, but large wood manufacturing companies allow for parts of up to 1.5\*1.5\*2.5 meter. The main drawback of CNC milling is that if the grain is visible in the design, solid woods need to be used, which are expensive. Parts that are not visible from the outside, or painted/coated can be made from multiplex's or other composite woods.

##### **4.5.2.2 Steam wood bending**

The second option to achieve curved wood is wood bending. Wood bending is a technique where birch or beech plywood are heated up and hydrated with steam. This makes the wood flexible. Then, the wood is pressed into its final shape on a wooden or aluminium die. This manufacturing method can create both single and double curved surfaces. Because wood bending is always done with plies, the grain will always be visible when not coated. Wood bending or using bent wood appears to be more economical than CNC milling, especially as numbers increase but does require an upfront investment in a die if a specific non-standardized shape is required.

### **4.5.3 Steel**

The last material that has been considered for the manufacturing of the Asper is Steel. Steel can be used for both the internal structure and be used in the embodiment. Like wood, steel needs a paint- or powder coating. Shaping techniques that are considered applicable for the size and volume of production are bending, roll bending and rubber pressing. Besides shaping techniques, connections are required. These would mainly be done with welding.

#### **4.5.3.1 Bending and roll bending**

Single curved pieces, like sheet metal, tubing and beams can all be bent to a desired radius. A minimum radius does however exist, and depends on the thickness or diameter of the piece. Because no part specific tooling is needed for creating parts with bending or roll bending, initial investments are low.

#### **4.5.3.2 Rubber pressing**

For double curved pieces in sheet metal, a technique called rubber pressing could be used. Because this technique requires a die, the initial investment is larger than bending or roll bending. Rubber pressing could be a useful manufacturing method for specific parts of the outer shell of the Asper where double curved shapes are added for aesthetic reasons. The main limitations of this technique is the limited 'draw' depth, meaning that the maximum depth of the shell. This is between 5 and 200 mm, depending on the shape, sheet thickness and press used.

### **4.5.4 Conclusion**

During the ideation phase, multiple materials with related manufacturing methods were considered. For plastics, thermoforming and vacuum casting were considered viable options. For woods, CNC milling and steam bending were considered viable options, besides the regular operations done on wood like sawing, sanding, drilling etc. For steel, bending or roll bending and rubber pressing were considered the best options for the size and types of parts needed in this project, besides the regular operations like cutting, drilling and welding.

## 4.6 Preselection ideation sketches

From the 20 idea sketches, a preselection of 10 idea sketches was made. From this preselection, three ideas would be selected for concept development together with the client. This preselection was based on the estimated level of fulfilling the aesthetic requirements, estimated manufacturability and the possibility to implement all selected features. The selected sketches were touched up to ensure the sketch quality of all 10 sketches was equal (See figure 4.14 – 4.23). For full resolution of each sketch, see appendix H.

### 4.6.1 Updated sketch 1

The power nap bed in updated sketch 1 has curved front feet and a fully curved back, resulting in a soft and inviting look. The LED strip is mounted across the backwall and follows the profile of the angled sidewalls. The sidewalls are unequal in length, creating a preferred side to enter the concept. Updated sketch 1 is based on ideation sketch 1.

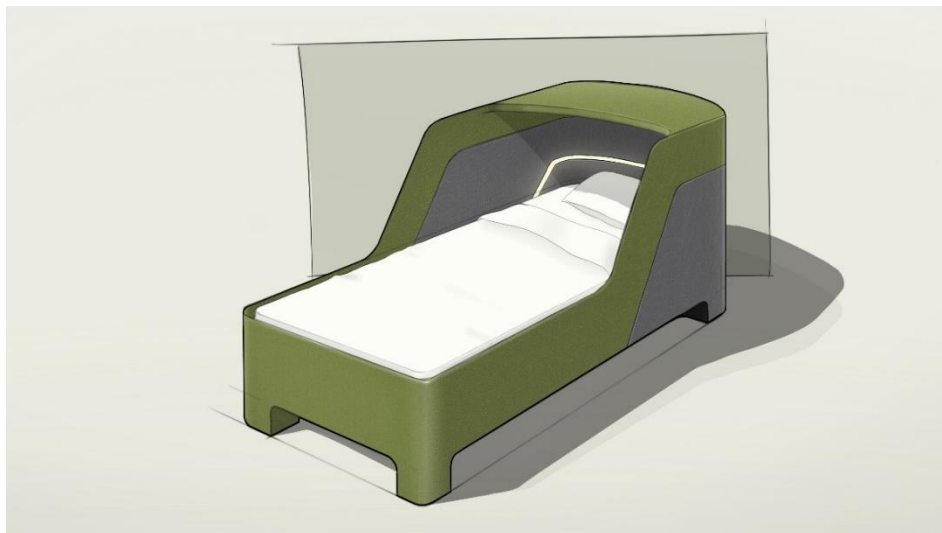


Figure 4.14 - Updated sketch 1

### 4.6.2 Updated sketch 2

The power nap bed in updated sketch 2 has an angled head cover with rounded corners. The back-side of this sketch is mounted in the 'ceiling' of the headcover. The angled design makes updated sketch 2 stand out when compared to the other sketches. The LED strip is mounted in the sidewall in this sketch. Because the concept is symmetrical, ingress and egress can happen on both sides of the bed. Updated sketch 2 is based on ideation sketch 5.

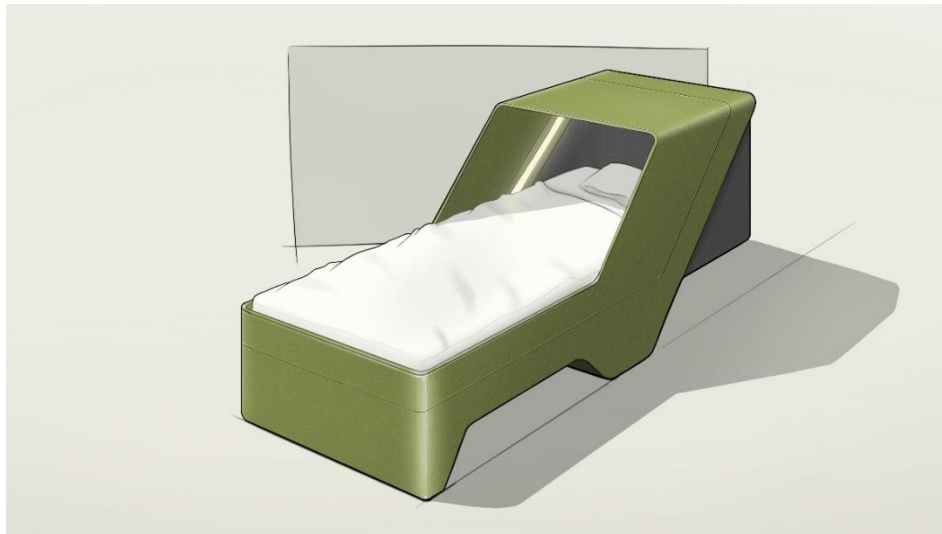


Figure 4.15 - Updated sketch 2

### 4.6.3 Updated sketch 3

The power nap bed in updated sketch 3 is a simplistic, yet elegant design. The sketch combines square shapes with rounded edges to create an inviting look. The legs of this concept are square, with slight fillets on the edges. The LED strip of this concept is mounted on the sidewall. Updated sketch 3 is based on ideation sketch 6.



Figure 4.16 - Updated sketch 3

#### 4.6.4 Updated sketch 4

The power nap bed in updated sketch 4 consists out of two separate parts that are screwed onto each other. The angled bedframe carries the FPS mattress, while the angled headcover contains the other functionality. The light is mounted on the short side of the sidewall. Like the earlier asymmetric sketches, the bed in sketch 4 would have a preferred side for ingress and egress. Updated sketch 4 is based on ideation sketch 11.



Figure 4.17 - Updated sketch 4

#### 4.6.5 Updated sketch 5

Updated sketch 5 shows another curved design for the power nap bed. Both the bedframe and the head capsule have a slight inward curve, creating a soft and comfortable aesthetic. The slits in the sidewall of the concept should provide airflow while retaining privacy. The LEDs in this concept are mounted in the top corner. Because of the outward facing feet, the concept also looks friendly. Updated sketch 5 is based on ideation sketch 13.



Figure 4.18 - Updated sketch 5



#### 4.6.6 Updated sketch 6

The power nap bed in updated sketch 6 slightly resembles an old-school cradle. Its large rounded headcover that tapers towards the back make the bed look both comfortable and inviting. The LED strips in this concept would be mounted across both of the sidewalls and ceiling of the head capsule. Furthermore, the feet of this bed create a link between this design and the design of the existing NEWAS chairs. Updated sketch 6 is based on ideation sketch 14.



Figure 4.19 - Updated sketch 6

#### 4.6.7 Updated sketch 7

Updated sketch 7 shows another design with a very large radius. The head capsule in this sketch curves around to make the backside and ceiling out of one piece, creating a unified and calming aesthetic. The LED strips are mounted in this same piece. Furthermore, the front of the concept has two small radii to make the bed appear even softer. Ingress and egress in this bed would always happen from the open side. Updated sketch 7 is based on ideation sketch 17



Figure 4.20 - Updated sketch 7

#### 4.6.8 Updated sketch 8

The power nap bed in updated sketch 8 would be made in such a way that the backside and ceiling of the head capsule would be clamped in between the two sidewalls, which are part of the bed frame. The cut-in on the sides of the mattress would make sitting on the concept more comfortable. The LED strip would be mounted inside the ceiling, and pointing towards the backside, creating a grazing light effect. Updated sketch 8 is based on ideation sketch 18.

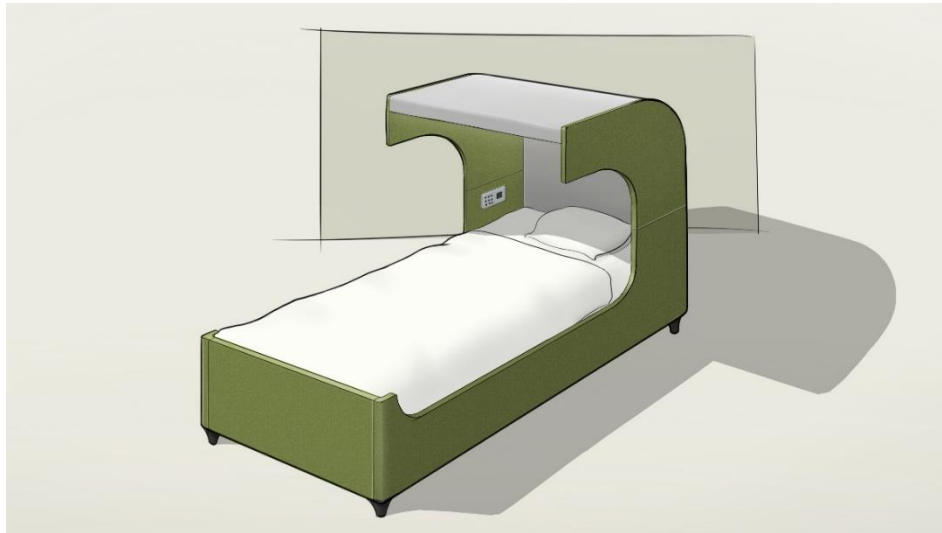


Figure 4.21 - Updated sketch 8

#### 4.6.9 Updated sketch 9

Updated sketch 9 contains a power nap bed that has a curved front, or feet- end. This round shape makes the bed look inviting and relaxing. This look is pushed more by the curved corners on the backside. The bed in sketch 9 also has a drawer for the storage of bedlinen. Its LED strip is mounted in the back. Updated sketch 9 is based on ideation sketch 19.



Figure 4.22 - Updated sketch 9

#### 4.6.10 Updated sketch 10

The power nap bed in updated sketch has a square head capsule with rounded corners and uneven sidewalls. This geometry, combined with the fillets on the side of the bedframe create a soft and inviting look. The control panel is mounted on the long sidewall, whereas the LED strip is mounted on the other side. The head capsule can be screwed on from the inside when assembled on site. Like in updated sketch 6, the steel feet create a link to the existing NEWAS chairs. Updated sketch 10 is based on ideation sketch 20



Figure 4.23 - Updated sketch 10

## 4.7 Idea selection

Together with the client, a final selection of three ideas was made from the 10 updated sketches. These selected ideas would be developed into concepts. During this process, two updated sketches (2 and 9) were combined into combined sketch 1 with some adjustments (see figure 4.26), which is the third selected idea. The other two selected ideas are updated sketch 2 and 10. (See figure 4.24 and 4.25). These sketches were chosen because it was estimated that they best met requirements 4, 51 and 52 about manufacturing and requirements 44 to 47 about aesthetic qualities.

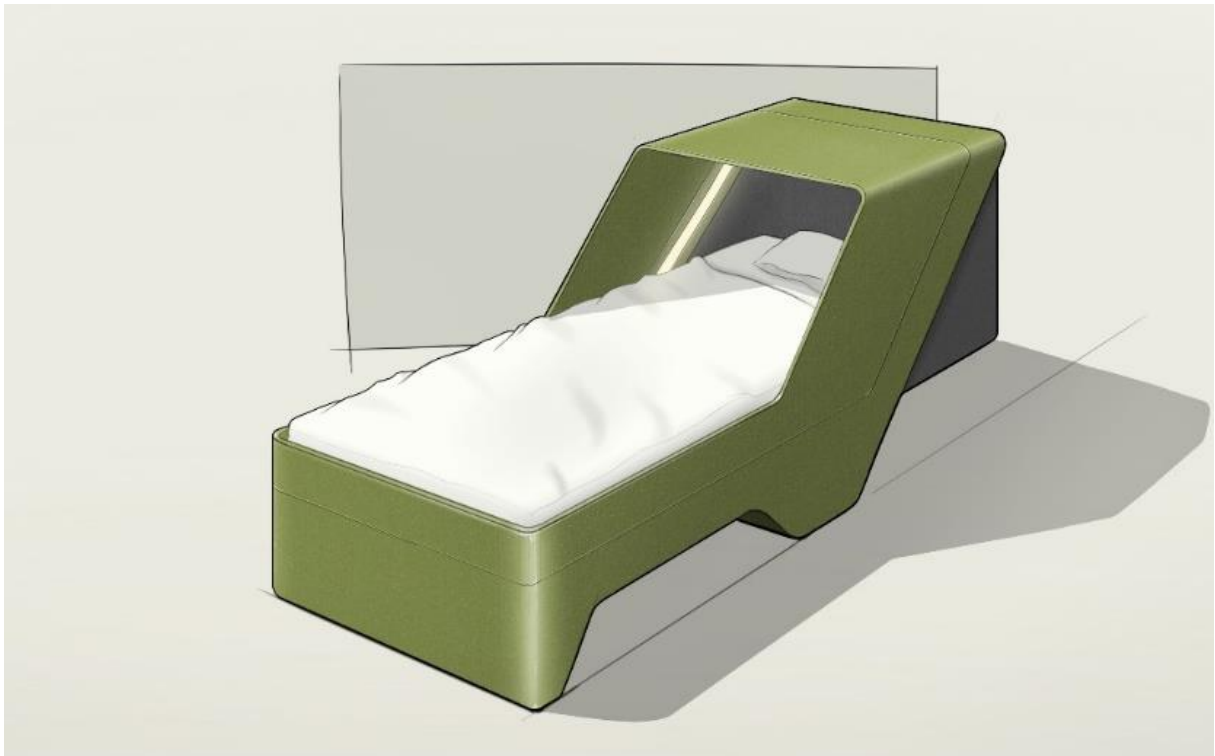


Figure 4.24 - Selected idea 1

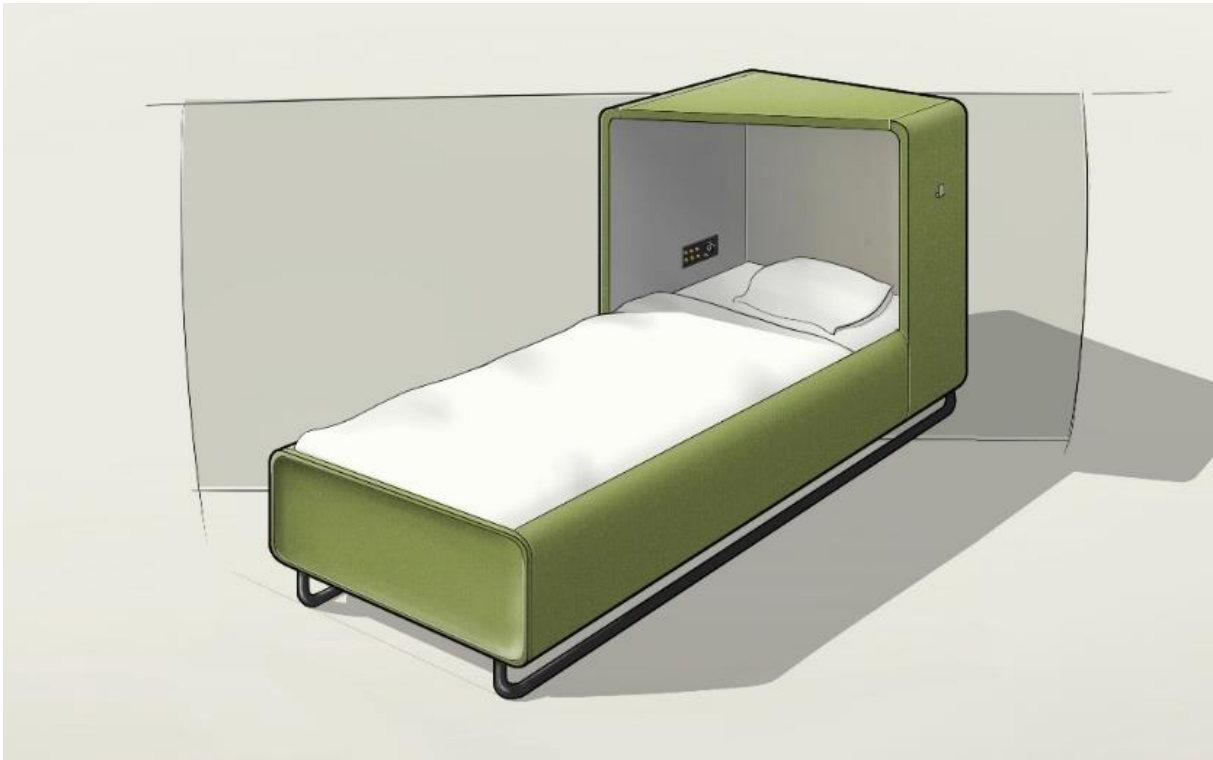


Figure 4.25 Selected idea 2

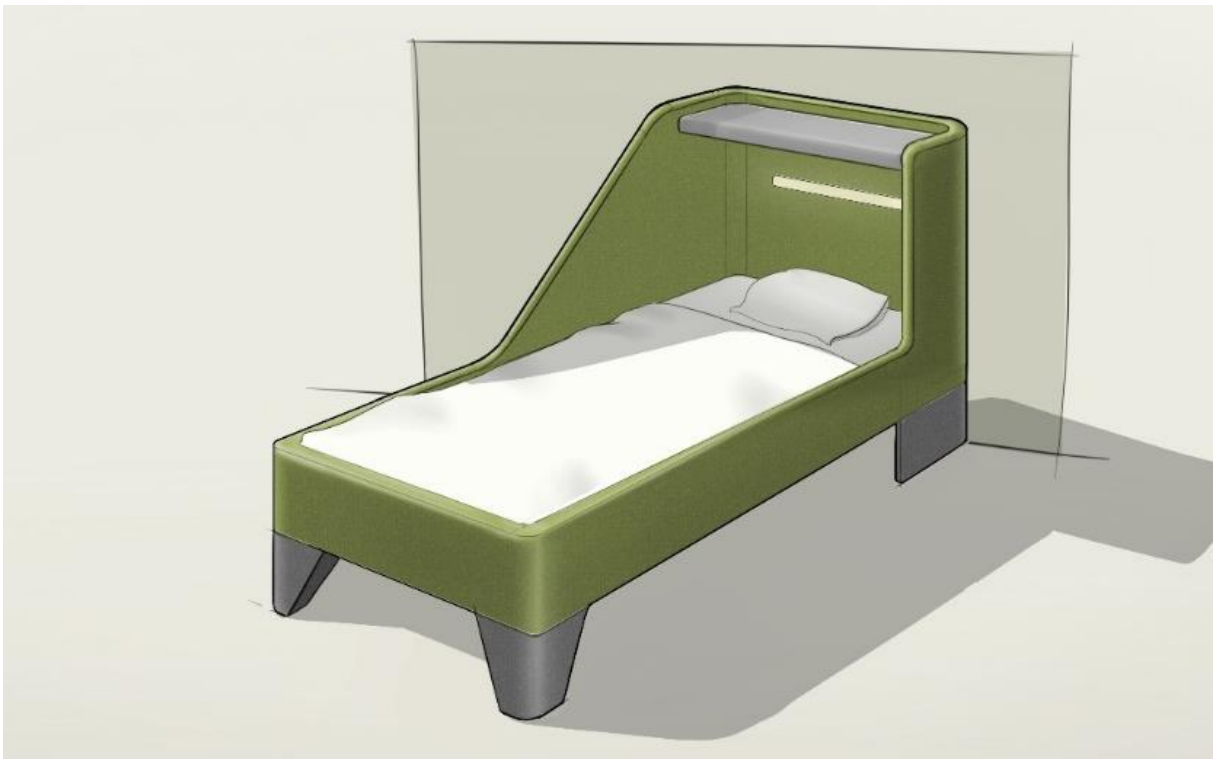


Figure 4.26 Selected idea 3

# Chapter 5. Concept development

This chapter describes the development process of the three selected ideas. During this phase, each idea was further developed into a concept that is more tangible than the updated sketches from the previous phase. To achieve this, the ideas went through a few steps. First, a general manufacturing and construction method was developed for each concept. Second, basic 3D models were made to render and provide a first 'real' look at the concepts. These two steps formed the first concept iteration. With the first iteration completed, the preliminary concepts were discussed with the client and feedback was gathered. The third step was to make new, parametric 3D models to be able adjust the main dimensions of each concept in combination with practical research about the required dimensions. In the fourth step, multiple adjustments to the dimensions and models were made. When the models were finished, a final set of renders was made for each concept. Together, the alterations to the 3D models and renders of the models formed the second iteration. Lastly, a thorough cost estimation was made for each concept. Then, one concept was selected to be further developed into a real product.

## 5.1 Concept iteration 1

The first concept iteration for each selected updated sketch contains a rough plan for manufacturing and assembly, as well as a preliminary 3D model that was used for creating a render. This render provides a first 'real-life' look at the product. Before creating the manufacturing plans however, materials and manufacturing methods would be selected. The main purpose of the first iteration was to gather feedback from the client and to identify areas that required more attention.

### 5.1.1 Manufacturing and construction methods

Although the potential manufacturing methods and materials had been explored in the ideation phase (See chapter 4.5), the manufacturing methods, materials and construction of the selected ideas was not yet developed. Doing this was the first step in the conceptualisation process, as it would largely influence the 3D models in the following steps.

All three material categories and corresponding manufacturing methods were considered for each concept. Plastics were mostly eliminated first from the potential materials, as manufacturing the concepts from plastics required the largest up-front investment and production run. Although the selected manufacturing methods from chapter 4.5 require relatively low investment compared to other plastics manufacturing methods, they are still significantly more expensive for this size of a product than wood or steel. Hi-Macs, a special thermoformable material, was also considered. However, material cost were found to be excessive, costing over €800,- in raw materials for the least material intensive concept (Concept 3). The only way in which plastics could still be interesting was in smaller sections or parts of the concept (e.g. a part of the housing or the control interface).

Both wood and steel were considered viable solutions, however NEWAS's existing partners and contacts are a lot more experienced with wood. Furthermore, the additional material thickness of wood, better fit the designs in the sketches. Lastly, using steel would drastically increase the products weight, thus making transport and assembly more cumbersome. Some parts in the designs are steel, however the main body will be made from wood. Wood is easily cut and shaped, and strong connections or joints can be easily achieved with either screws and (steel) brackets or wood glue and dowels. These two methods of joining pieces together have been used in all three concepts. A combination of CNC-machining and steam-bent wood is used for all concepts.

### 5.1.2 First iteration of concept 1

Concept 1 is the most complex concept of the three in terms of manufacturing and construction. The main difficulty is in the internal 'cabin' (sketched in grey). The outer dimensions of the internal 'cabin' have to match the inner dimensions of the external 'cabin' to achieve a good fit. This means that relatively high tolerances are required. To achieve a good fit of the internal 'cabin' into the external 'cabin', three options were considered. The first option was to use either Hi-Macs or pre-bent wood sections to match the inner radius of the external 'cabin'. The second option was to make the internal 'cabin' square, use spacers to position it in the external 'cabin and to backfill the gaps with either foam or wood faces. The third option was to make the rounded corners square and avoid the problem all together, this would however drastically change the design. After consideration, the first option with bent wood was chosen. The wooden sections of both the inner- and outer 'cabin' are connected with dowels and wood glue. The front of the concept is connected in a similar way, however, two steel brackets are added for additional strength. See figure 5.1 for an overview of the construction method of concept 1.

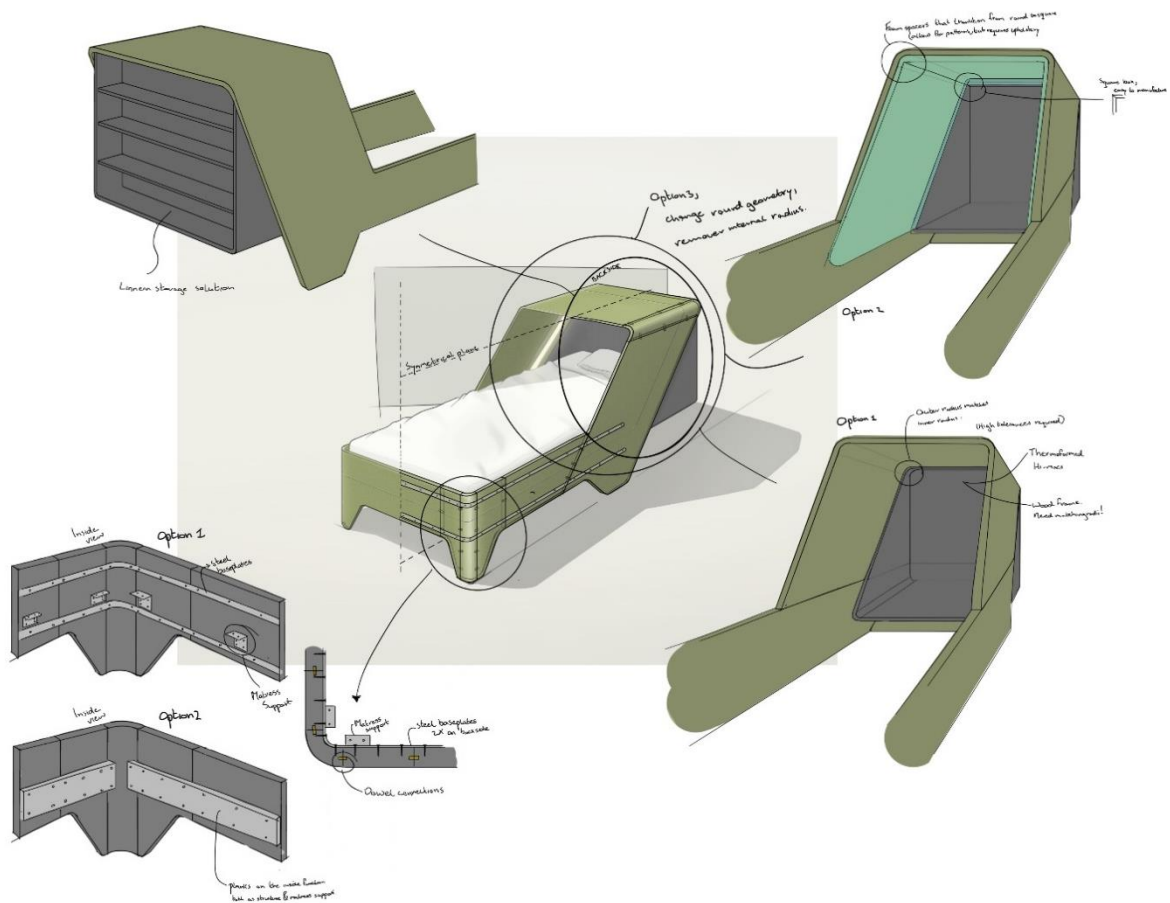


Figure 5.1 - Construction method of concept 1, iteration 1



With the plan of construction and manufacturing complete, a preliminary 3D model was made for concept 1. This 3D model was then used to create the render in figure 5.2, which was discussed with the client to gather feedback and identify areas of attention.

In this version of the concept, the backside or inner cabin, was still made from Hi-macs. This would create a nice visual contrast between the wood and high-grade plastic and would resolve the issue of the wood working unevenly between the inner- and outer cabin. When discussing this option however, it was decided that this part would be made from wood in the next iteration, as it would make the supply chain simpler. Furthermore, it would reduce costs and make potential repairs easier.

Another area of attention for iteration 1 of concept 1 are the proportions. The design does not look balanced because the height of the cabin is significantly higher than in the sketches. Furthermore, the width of the angled part is too large, covering the sides of the mattress too much.

In the next iteration, these issues were addressed.



Figure 5.2 - First render of concept 1, iteration 1

### 5.1.3 First iteration of concept 2

Concept 2 is significantly less complex than concept 1. Like all three concepts, it uses both steel brackets with screws and dowels with wood glue to join the important pieces together. To ensure sufficient stiffness in the headcover, the backside is a single plate that is screwed onto sides of the headcover boards. The entire headcover structure can then be screwed into the back and sides of the bedframe from the inside. Because this concept has square corners, steel webbed corner angles (struts) can be used to both connect the pieces and support the baseplate that supports the mattress. See figure 5.3 for an overview of the construction method of concept 2.

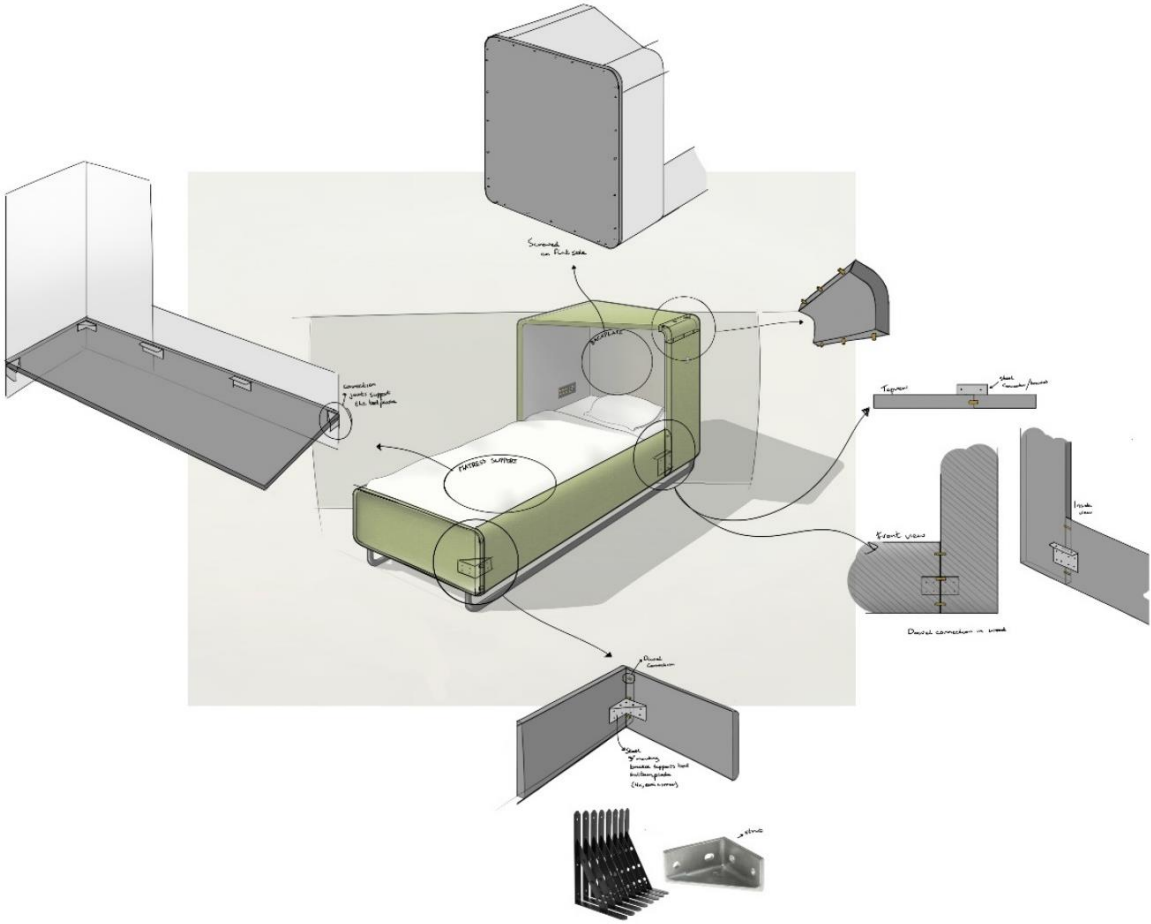


Figure 5.3 - Construction method of concept 2, iteration 1

Like with concept 1, a preliminary 3D model was made for concept 2 once the construction and manufacturing plan was complete. This 3D model was then used to create the render in figure 5.4, which was discussed with the client to gather feedback and identify areas of attention.

When discussing this iteration of concept 2 with the client, a few things stood out. First, some of the dimensions and proportions of the concept appear to be incorrect. For example, the drawer on the front of the concept appears to be very shallow. Another proportion that is off, is the width of the bed in relation to its length. Despite it being the same length and width as the other two concepts, it appears to be further off in this image. This is most likely the result of the wall thickness of the frame. Furthermore, the mattress in this concept is recessed into the frame. This would be uncomfortable during ingress and egress for the user. Lastly, the position of the control appears to be wrong, as it is too close to the backwall of the headspace.

In the second iteration, these issues were addressed.

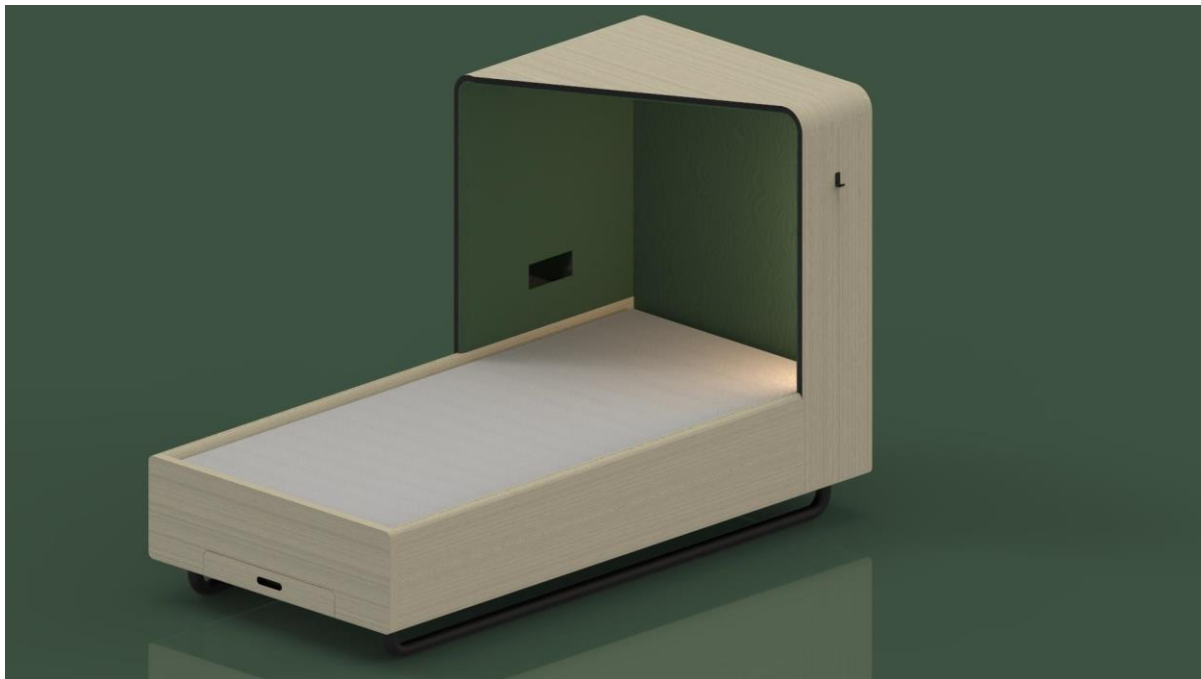


Figure 5.4 - First render of concept 2, iteration 1

### 5.1.4 First iteration of concept 3

Concept 3 is the least complex concept. By utilizing four L-profile pieces of bent wood as corner posts and connecting them with boards, the main structure is complete. The four corner posts are connected to the boards with both dowels and steel brackets. The brackets are large steel gussets that span across the rounded piece to connect the corner pieces to both boards. Like in concept 3, the gusset provides a support for the baseplate of the mattress. The top, or ceiling, of the concept is supported by a small beam that secured with small brad nails. See figure 5.5 for an overview of the construction method of concept 3.

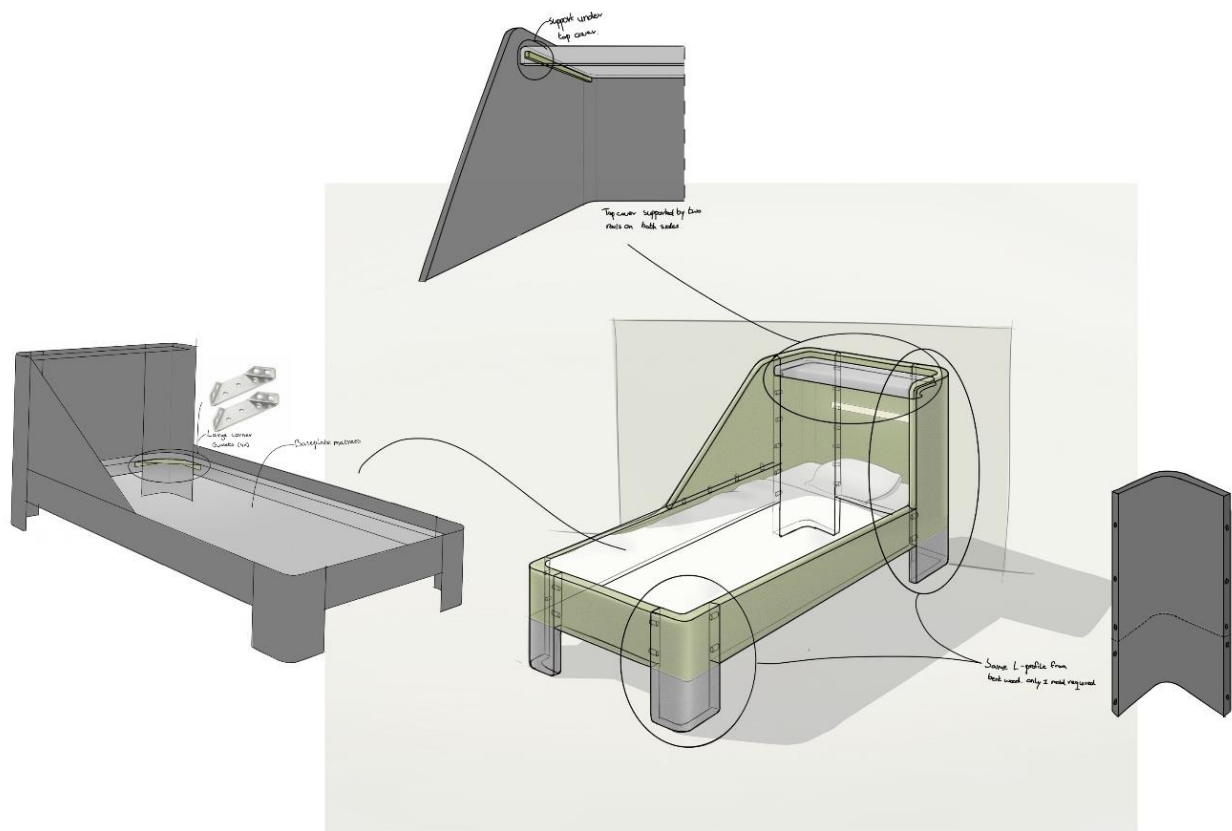


Figure 5.5 - Construction method of concept 3, iteration 1

As with the previous two concepts, a preliminary 3D model was made for concept 3 once the construction and manufacturing plan was done. This 3D model was then used to create the render in figure 5.6, which once again was discussed with the client to gather feedback and identify areas of attention.

This version of concept 3 has a few areas that need attention. First of all, like in concept 2, the mattress is recessed into the concept, meaning that ingress and egress are uncomfortable for the user. Second, the sidewall is rather short, providing very little privacy. Lastly, the sidewalls appear to be unnecessarily high, especially as the top is rather short.

In the next iteration, these issues were addressed.

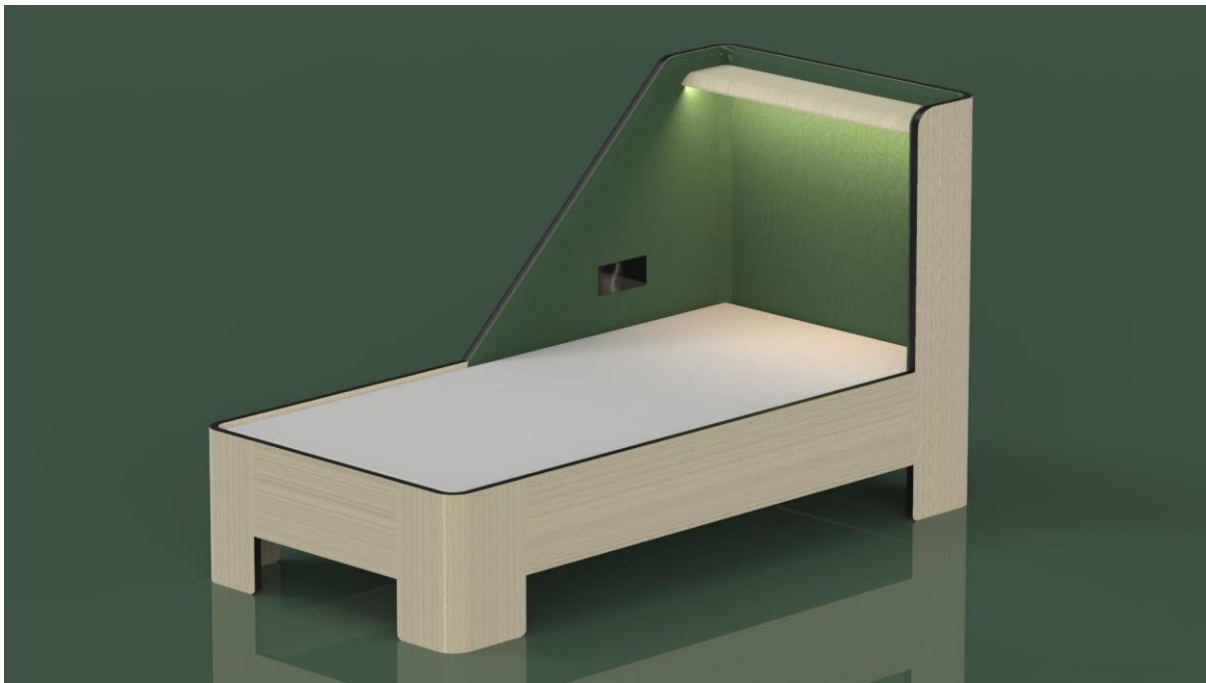


Figure 5.6 - First render of concept 3, iteration 1

### 5.1.5 Conclusions from concept iterations 1

The first iteration of each concept revealed that all concepts had multiple issues. An issue found in all concepts was that some dimensions and proportions of the concepts were incorrect. Especially the height of the tops, or ceilings, appeared to be too high in all concepts and the depth of the head capsules was inconsistent. Another issue found in two concepts is that the mattress is recessed into the frame, making ingress and egress uncomfortable. These, and the other mentioned issues are addressed in the next iteration.

## 5.2 Defining and implementing concept dimensions

Addressing the main point of attention for all concepts, determining and defining the exact dimensions, required two things. First, the lower and upper limits of certain dimensions had to be determined to provide boundaries for the models and thus designs. Second, the initial 3D models had to be rebuilt from the ground up into parametric models that allowed for fast yet flexible adjustments. With the parametric models, multiple variations were explored until a suitable combination of dimensions was found. The models with a suitable combination of dimensions formed the basis for the second concept iteration.

### 5.2.1 Researching and defining dimensions

Because the proportions seemed off in the initial 3D models, it was necessary to define four main dimensions. These dimensions would both aid in improving the proportions of the design and improve user ergonomics. The first main dimension needed was the minimal ceiling height (measured from the mattress surface). Although the value of the minimal ceiling height is correlated to the ceiling depth (measured from the backside of the concept), a general minimum value was required. The second main required dimensions were the minimal and maximum head capsule length (measured from the backside of the concept at the height of the mattress surface) on the entry side. See image 5.7 for a visual for both measurements. The third dimension that needed to be defined was the height of the mattress surface measured from the floor. The fourth set of dimensions were for the mattress, and determined its length, width and height.

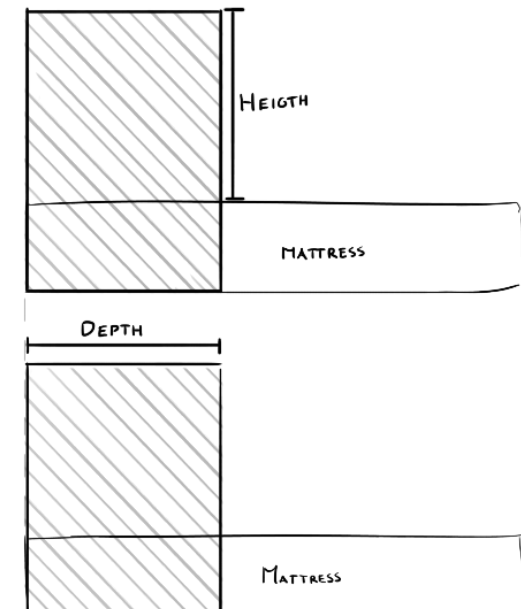


Figure 5.7 - Ceiling height and head capsule depth

### 5.2.1.1 Head capsule dimensions

To find the minimum head capsule ceiling height and maximum and minimum head capsule depth, cardboard test set-ups were made (See image 5.8 and 5.9 for height and depth respectively). To determine the minimal ceiling height, tests were conducted on myself. I am 1934 mm tall (P94,5 males 20-30; DINED). The minimal height I required was 75 cm. To allow even taller users to comfortably enter and exit the concepts, 5 cm was added. When comparing these values to the sitting height of P95 males in DINED, they do not match. The sitting height of P94,5 males 20-30 is 1021mm (DINED, n.d.). This difference is most likely caused by a person not having their upper body fully stretched when lying down or sitting back up, while the measurements are in a fully stretched position up against a wall. Furthermore, the 75 cm was necessary with a cardboard ceiling spanning over 120 cm of the bed, while none of the concepts has such a long ceiling. With a shorter ceiling, the minimal height is expected to be lower, as the user's motion is arced when lying down or sitting back up (See figure 5.10). Therefore, the minimal ceiling height is set at 80 cm.

To define the maximum depth, tests were conducted with the shortest person in my direct social circle because of the COVID-19 restrictions. The reason for testing with a shorter person was that height was expected to be the determining factor in this dimension. The shorter the user, the lower the maximum depth, as the turning point when sitting down on the mattress would be closer to the pillow. The participant was 1,67cm tall (P40 females 20-30; DINED) and found the maximum depth at which she could still easily enter to be 90 cm. To take shorter users into account, the maximum value was reduced by 20 cm. Therefore, the maximum depth was set at 70 cm.



Figure 5.8 and 5.9 - Cardboard test set-up

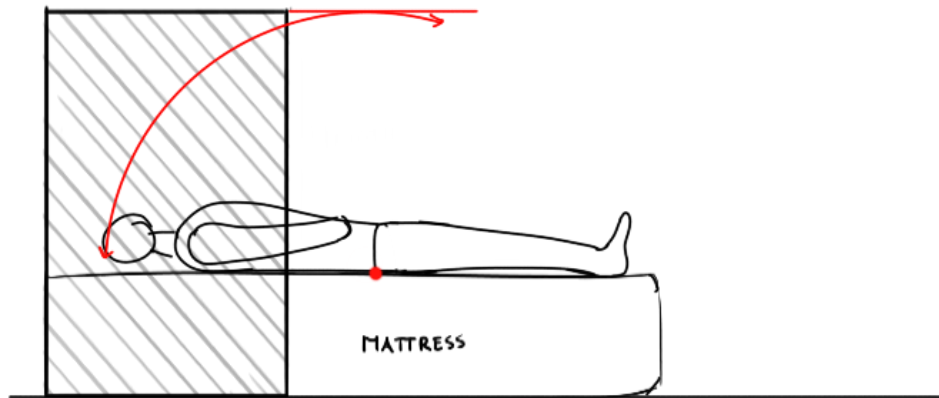


Figure 5.10 - Illustration arced motion

The minimal depth was determined together with the client. The head capsule had to be deep enough to cover the head and shoulders from the side. Because the exact dimensions to achieve this largely depend on the positioning of the user, and not necessarily on their size, a quick mock-up was made at the premises of NEWAS B.V.. The set-up was similar to the test set-up in figure 5.9, but used an actual FPS mattress instead. After trying multiple sizes, the minimal depth was set at 40 cm.

### 5.2.1.2 Mattress height and size dimensions

Determining the range of optimal range of mattress heights was less straight forward, as they largely depend on personal preferences and what a person is used to. First, standards were sought, but none were found. Then, three bed stores (Beter bed, Auping and Coppens) were contact and asked about the average height of beds sold to customers in the age range of 20 - 60 (the age range of most night shift workers). According to these stores, common heights are between 40 cm and 60 cm. Although these values were just estimations, they provided a useful guideline in the design.

Another set of dimensions defined the mattress. Its length should be 200cm, as this is a standard size, the mattress width should be between 70 cm and 90 cm and its thickness should be between 16 and 20 cm.

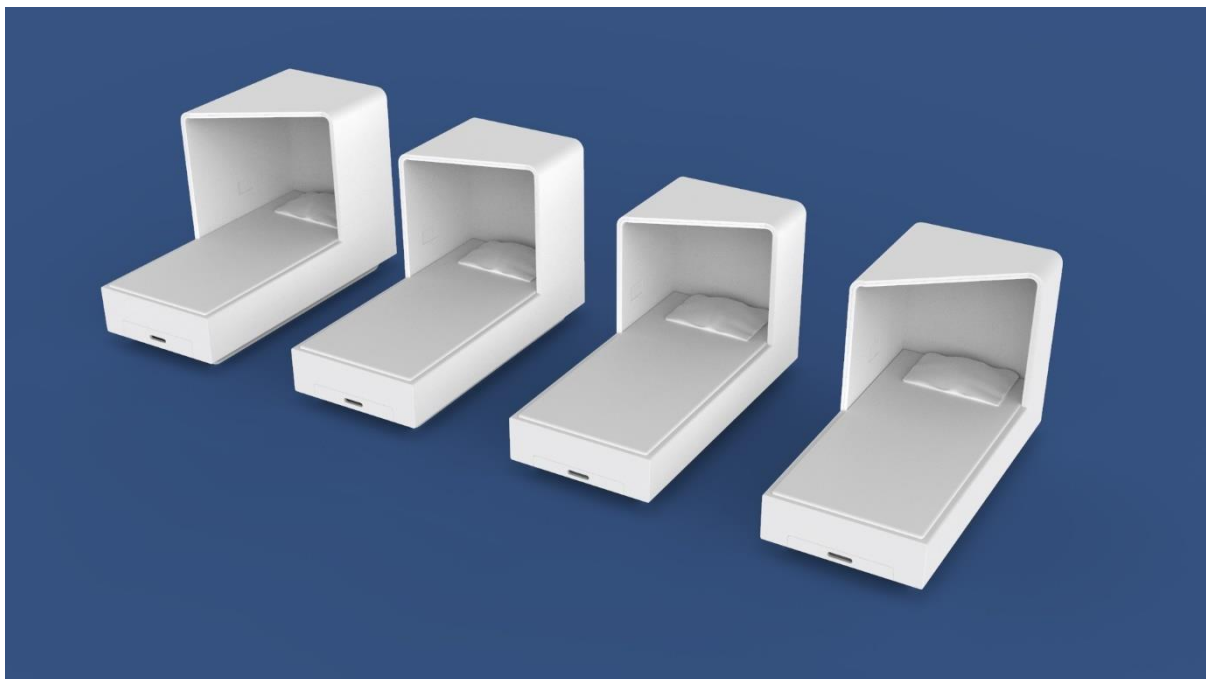


## 5.2.2 Implementing dimensions through parametric modelling

With the newly defined dimensions, a new set of 3D models was made, one for each concept. For the new models, all parts were drawn independently and put together in an assembly. Within the assembly, the dimensions of the parts were made to be parametric. By doing this, each dimension could be easily adjusted without breaking the model. This allowed for extensive, yet fast tweaking of multiple dimensions in the same model. An example of multiple variants for concept 2 can be seen in figure 5.11. The models were also made to be manufacturable, following the methods described in the first iteration.

Besides the implementation of the newly defined dimensions, the other issues that required attention, like the cabin of concept 1 being made out of wood, the drawer of concept 2 being too low, the short sidewall of concept 3 and the recessed mattress in concept 2 and 3 were fixed.

Each concept was adjusted multiple times, until a combination of dimensions was found that is both aesthetically balanced and within the lower and upper dimension limits. These final variations formed the basis for concept iteration 2.



5.11 - Dimension variations of concept 2

### 5.2.3 Conclusion defining and implementing dimensions

The defined dimensions are shown in the table 5.1. These dimension limits have been implemented in parametric 3D models, enabling fast alterations to the models to create models that both looked good and are within the upper and lower dimensions limits.

Dimension (name)	Size (mm)
Minimum ceiling height	800
Minimum head capsule depth	400
Maximum head capsule depth	700
Minimum mattress surface height	400
Maximum mattress surface height	600
Mattress length	2000
Minimum mattress width	600
Maximum mattress width	800
Minimum mattress thickness	160
Minimum mattress thickness	200

Table 5.1 - Defined range of measurements

### 5.3 Concept iteration 2

After adjusting the dimensions, fixing the issues of the first iteration and tweaking each concept, the second iteration of concepts was ready to be rendered and presented. The purpose of this iteration was to be able to compare the strengths and weaknesses of each concept and select a single concept for further development. The manufacturing and construction of the designs is based on the sketches in chapter 5.1. In the visualisations, preliminary materials and colours were chosen and used for each concept. These colours and material are however not definitive. In the next phase a material and colour study is conducted for the chosen concept.

### 5.3.1 Second iteration of concept 1

Concept 1, as shown in figure 5.12, is the most visually unique concept of the three concepts. Its angled geometry combined with curved corners and internal 'cabin' inside the frame provide an aesthetic that stands out amongst the other concepts and competitors. Because of the angled head capsule, the minimal height can be slightly lower, as the front of the ceiling is further back. Furthermore, the back-foot allows for an easy integration of the FPS technology in an accessible place. The complex geometry does however also have its drawbacks, as both manufacturing and assembly are more complex than for the other concepts. More curved wood and relatively tight tolerances are needed for the inner 'cabin', resulting in higher production costs. The integrated storage space in the back can be very useful, however its value largely depend on the concept's placement. If the backside to the wall, the storage cannot be used. Another drawback of this design is the inability to integrate casters without altering the design. For the full resolution images of concept 1, see appendix I.



Figure 5.12 - Renders of concept 1 iteration 2

### 5.3.2 Second iteration of concept 2

The geometry of concept 2 (see figure 5.13) is significantly less complex than that of concept 1. Despite being less complex, it still has its own unique aesthetic qualities. Besides the geometry creating the concept's aesthetic qualities, it also makes manufacturing and assembly of the concept significantly less complex, reducing costs. Furthermore, because of its relatively simple geometry, the concept can easily be mirrored. The integrated storage on the front is another benefit, as it can easily be adjusted to improve functionality. Because the steel feet are separate parts, later adjustments to the height of the concept can easily be made. Furthermore, casters can easily be integrated by replacing the feet. Some drawbacks of concept 2 include the increased complexity of the supply chain, since the steel parts have to be made at another supplier, the steel feet making mopping or vacuuming the floor underneath the concept more difficult and the slight alterations required to fit the FPS technology. For the full resolution images of concept 2, see appendix I.

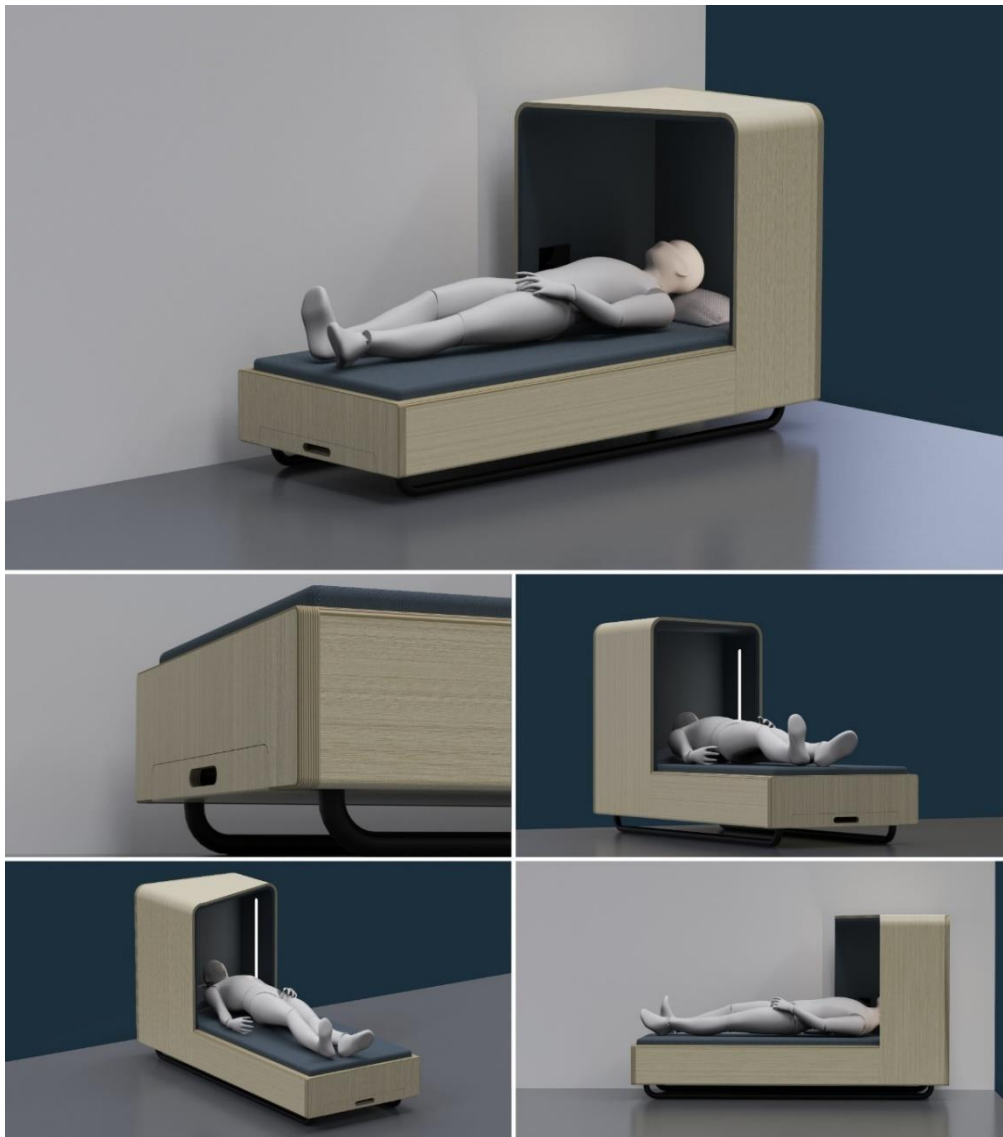


Figure 5.13 - Renders of concept 2 iteration 2

### 5.3.3 Second iteration of concept 3

Concept 3 has the simplest geometry of the three concepts. This makes the concept easy to manufacture and assemble, but comes at the cost of potentially being perceived as basic. A benefit of the concept's simplicity and geometry, is that it is easiest to access for cleaning and easy to mirror. Another benefit of this concept when compared to the other two is the ability to integrate the light into the ceiling of the headspace. The inability to integrate casters without altering the design is, like concept 1, a major drawback. Furthermore, this concept does not provide storage space for bedlinen. Integrating storage would likely significantly change the design. Like concept 2, slight alterations need to be made to be able fit the FPS technology. For the full resolution images of concept 3, see appendix I.

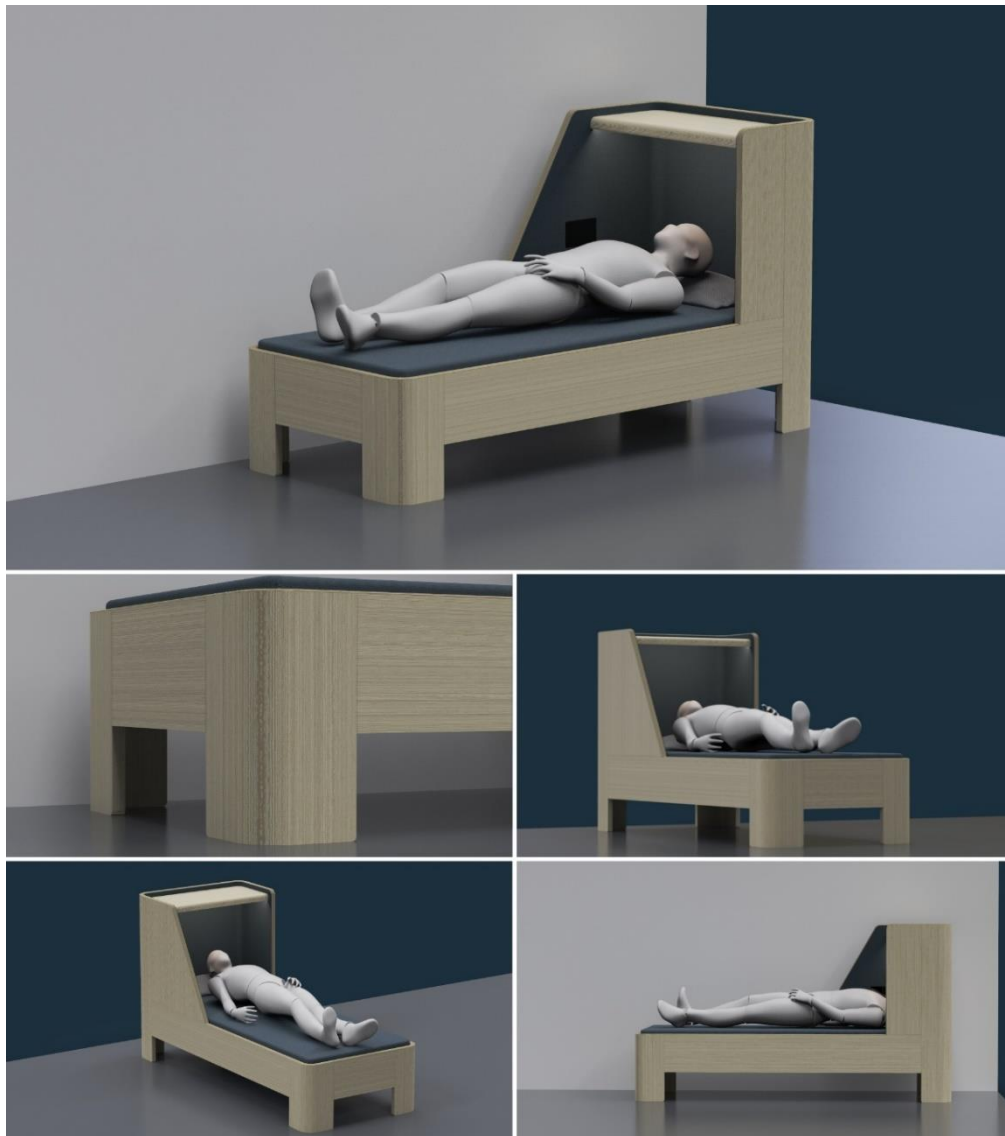


Figure 5.14 - Renders of concept 3 iteration 2

### 5.3.4 Conclusions iteration 2

The main purpose of iteration 2 was to move the designs forward and identify the strengths and weaknesses of each concept. These were used to aid in the selection of a single concept for further development (see chapter 5.5). In table 5.2 an overview of each concept's strengths and weaknesses is given. Concept 2 has most the most strengths and least weaknesses. Concept 3 has the least strengths, and an equal number of weaknesses as concept 1.

Overview main strengths and weaknesses					
Concept 1		Concept 2		Concept 3	
Strength	Weakness	Strength	Weakness	Strength	Weakness
Most unique look	Most complex	Desired aesthetic qualities	More complex supply chain	Simplest geometry	Basic looking
Lower ceiling height	Highest costs	Less complex to manufacture than concept 1	Feet make vacuuming under the concept harder	Lowest cost	No integrated storage
Easy integration of FPS box	Unable to integrate casters at this point	Easy to mirror	Slight alterations required to fit the FPS box	Easiest to access for cleaning	Unable to integrate casters without major alterations
Largest storage space	Storage space utility depends on placement	Drawer that can easily be adjusted (location & size)	-	-	Slight alterations required to fit the FPS box
-	-	Easy integration of casters	-	-	-

Table 5.2 - Overview main strengths and weaknesses

## 5.4 Cost analysis

Besides the strengths and weaknesses of the designs, another aspect that would play a large role in the selection of the final concept are the estimated manufacturing costs. Although the varying complexity of the concepts can be used to predict the order of manufacturing costs from low to high, it does not provide insight to the actual costs. To make a more accurate estimation of the manufacturing costs, each concept's expected costs were broken down in three categories. First, the material costs for each part were determined. Then the required operations for each part were determined and the time required to execute this operation was estimated. This time estimation was multiplied by an hourly labour rate. Lastly, an estimation was made for assembly time and costs for each concept. These three components together provided a relatively accurate cost estimation.

The first concept is, like expected, the most expensive to produce at an estimated cost of €1690,-. Concept 2 comes second with an estimated cost of €1360,-. The cheapest concept is concept 3, with an estimated cost of €1210,-. For a full breakdown of the cost, see appendix J.

With the renderings from the previous chapter, the client contacted a manufacturer he had previously worked with and asked for rough cost estimates. This manufacturer estimated that the concepts would cost roughly between €1200,- and 1800,-, validating the cost estimation. All cost estimations are excluding VAT.

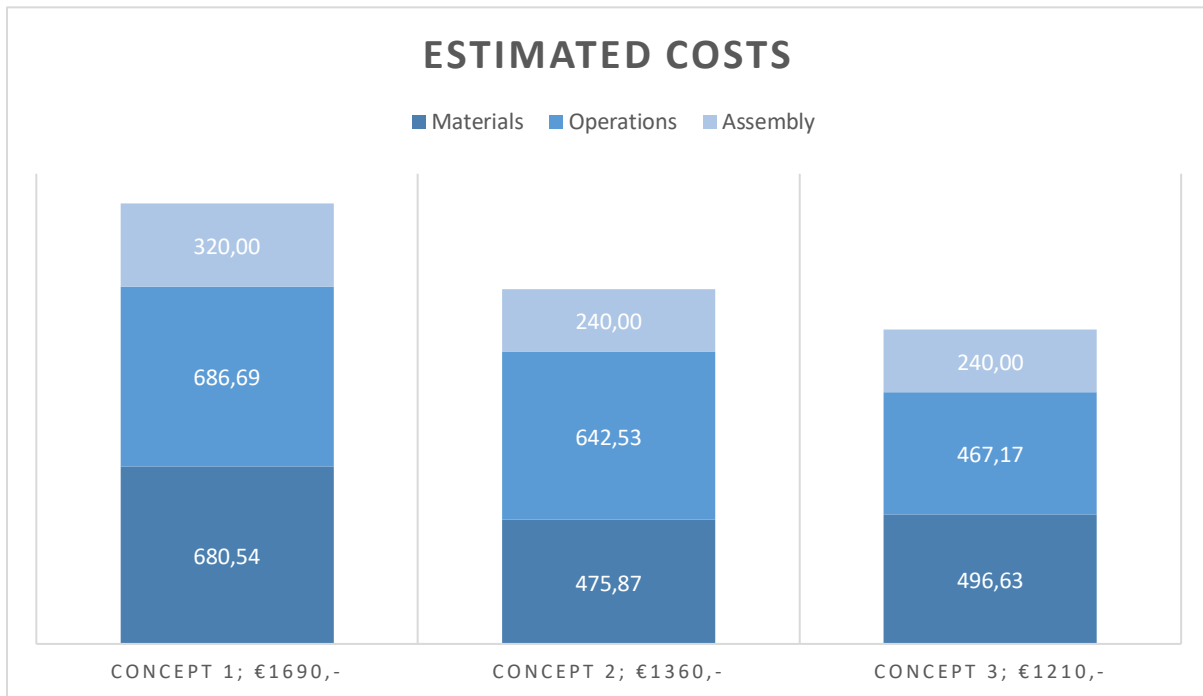


Figure 5.15 - Cost estimation graph

## 5.5 Concept selection

With the concepts developed and their cost estimated, a single concept was selected for further development. This was done in consultation with the client based on the requirements and on the concepts' strengths and weaknesses.

### 5.5.1 Concept selection process

The first requirement that was used to evaluate the three concepts was requirement 50: *The concept should have a maximum manufacturing cost of €1500,- excluding V.A.T. and mattress with FPS technology.* Concept 1 does not meet this criteria according to the cost estimation. The possibilities of reducing the manufacturing costs were explored and discussed, but it was deemed impossible to significantly reduce the cost without making major changes to the design. Therefore, concept 1 was eliminated from the selection.

With concept 2 and 3 remaining, using other requirements in combination with weighing up the strengths and weaknesses of both concepts was needed to select the final concept. After thoughtful consideration, concept 2 was selected as the final concept. The reasons for selecting concept 2 were:

1. According to the client and me, concept 2 better fulfilled requirements 44 to 47, about aesthetic qualities.
2. The steel feet of concept 2 provided a clear connection in terms of form language to the existing NEWAS chairs (requirement 48).
3. Concept 2 already has storage space integrated into the design which provide additional value (requirement 25).
4. Concept 3 has a ridge that easily collects dust. Hence not meeting requirement 31.
5. Concept 2 outperforms concept 3 in both the number of strengths and weaknesses.
6. The steel feet of concept 2 allow for easy adjustment of the height of the concept later down the line. Although this is not a requirement, the client felt like this also added value as customers had frequently asked for a higher version of the chair.



# Chapter 6. Product development

This chapter discusses all steps that were taken to reach the fourth and final iteration of concept 2, the Asper. First, a third concept iteration was made that improved on the second iteration by addressing certain issues identified during the concept selection process. Then, a colour study was conducted to select the colour combinations that would be used in the design and eventually produced Aspers. Meanwhile, a prototype of the Asper was built to verify the construction method of the third iteration. The second purpose of this prototype was to find improvements in the construction and manufacturing methods. These improvements were then implemented in the fourth and final iteration of the Asper.

## 6.1 Iteration 3 of concept 2

During the concept selection process, multiple aspects of the design that required further attention were identified and discussed. These aspects are addressed in the next iteration, iteration 3. The aspects are:

1. Exploring different feet to remedy the weakness of not being easily vacuumed under.
2. Alter the location of the drawer to ensure it can be opened when the Asper is positioned in a very small room where both the feet- and head end of the bed are close to walls.
3. Address (partially) missing or not yet integrated features:
  - Power supply for electric blankets
  - Coat hook and temporary storage for small items (e.g. glasses, pager, etc.)
  - Relaxation guide
  - Program information explanation position
  - Defining integration of casters
4. Further define the construction- and manufacturing methods.

After these four aspects were addressed, the third concept iteration was finished.

### 6.1.1 Exploring feet alterations

The first aspect that needed to be addressed in the third iteration were the feet of the concept. As discussed in chapter 5.3.2, the feet of concept two make vacuuming or mopping under the concept difficult. To solve this problem, two variations of the feet were made that could reduce the severity of this issue (See figure 6.1). In the first solution, the feet were made higher, increasing the space between the frame and the feet. In the second solution, the direction of the feet was changed, from following the long side of the bed to following the short side of the bed. Because the second option made the concept look out of balance, the first option was chosen.

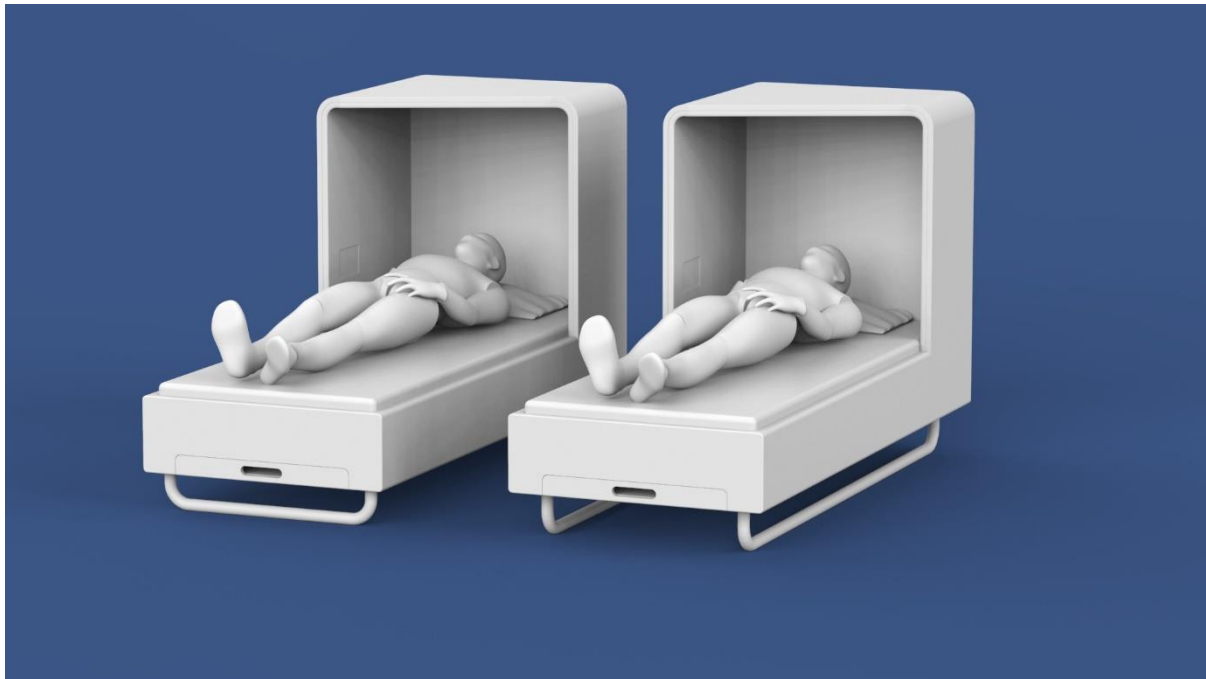


Figure 6.1 Feet variations

### 6.1.2 Exploring drawer alterations

The second aspect that was addressed in the third iteration of the Nappi, was the drawer placement. Although the drawer is useful, its placement is not ideal as it could be hard to use when the Asper is positioned in a very small room. Therefore, the drawer was moved to the side of the bed. Multiple configurations of one and two drawers on the side of the frame were tested. The configuration shown in figure 6.2 was considered the best, as it maximized the drawer space while still looking balanced. Furthermore, slight alterations were made to the construction of the concept to further increase the drawer height.



Figure 6.2 - Drawers configuration with maximum height.

### 6.1.3 Missing features

Although all critical features had been addressed in concept 2, the optional features were still partially missing or poorly defined. These features are: a power supply for electric blankets, a coat hook with storage for small items, relaxation guide, program information display and integration of casters. In iteration 3, these features are further implemented and defined.

### 6.1.3.1 Power supply for electric blankets

Having electric (under) blankets is an optional feature in the Asper. To be able to power these blankets, a power outlet on the concept is required. Furthermore, a cut-out for the cable and plug to go through is necessary. These features were added to the Asper in iteration 3, see figure 6.2.

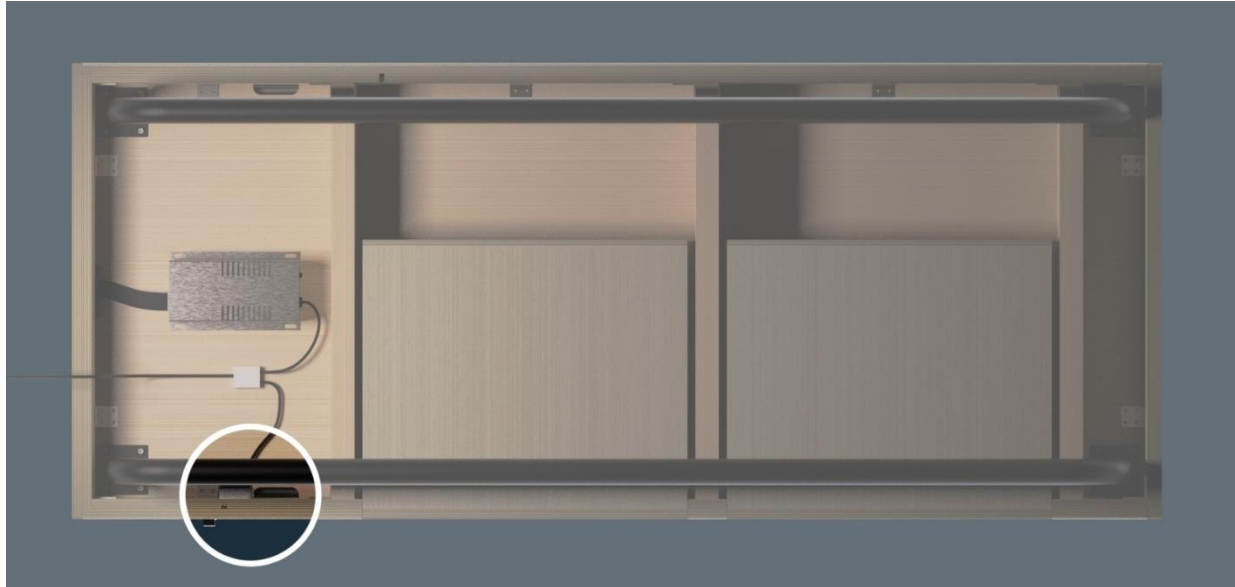


Figure 6.2 cut-out and power outlet position (underside of the concept).

### 6.1.3.2 Coat hook and temporary storage for small items

Two other optional features are a coat hook and a storage space for small items such as glasses, phones, pagers and tools. In the third iteration, a coat hook that fit the design was selected (see figure 6.3) and its position was determined (see figure 6.4). The selected coat hooks are the Intersteel 0023.695010 (black) and Intersteel 0035.695010 (Stainless steel). Furthermore, a divider was added to the drawer furthest from the feet end of the bed (see figure 6.5). This section can be used to store small personal items while power napping.



Figure 6.3 - Selected coat hook



Figure 6.4 - Coat hook position



Figure 6.5 - Drawer division

### 6.1.3.3 Relaxation guide

Relaxation guidance is an optional feature that was not fully defined yet. Because the development of this feature is out of the project scope and in itself could be an entire graduation project, a simple version is developed. Future development can elaborate on this feature.

The current version of the relaxation guidance works through the use of the integrated lights. When a user activates a power nap program with the optional relaxation guidance, the guide program starts. During the first two minutes of the power nap, the LEDs will gradually dim to being off over a period of four seconds, followed by a four second period during which the LEDs become brighter. This dimming and undimming cycle repeats 15 times and visualises a simple breathing exercise. As the 2 minutes progress, the maximum brightness slowly reduce from 650 lumen to 100 lumen. After the 15<sup>th</sup> cycle, the LEDs remain off.

### 6.1.3.4 Program information explanation position

Because power napping facilities are often placed and explained once, not all users may be familiar with the FPS power napping programs, especially when a new employee joins a company with an FPS power nap facility. Therefore, NEWAS currently provides a hand-out to their clients. These are often put on the wall next to the power nap chairs (see chapter 3.5 and figure 3.13). A wish from the client was a place or position to put these explanation hand-outs in. For aesthetic reasons they should not be on the outside of the concept. Therefore, these handouts can be stored in the same drawer division as personal items (see figure 6.5).

### 6.1.3.5 Defining integration of casters

Casters are the last optional feature that had not yet been fully integrated in the design. First, casters were selected. The recommended casters for the Asper are the Tente Stylea 5925XGI075L51-10 DOM20 combined with the P41-65x65/10 plate connection (see figure 6.6 and 6.7). With the right casters selected, the 3D model was adjusted to be able to support the casters. The result of these alterations can be seen in figure 6.8.



Figure 6.6 Tente Stylea wheel



Figure 6.7 - Wheel connection plate



Figure 6.8 concept 2 with casters.

## 6.1.4 Concept construction and manufacturing

In the third iteration, construction and manufacturing were further defined and improved upon. The first thing that required further definition were the materials. In earlier iterations, materials were no further specified than wood. To be able to design- and account for the differences between the vast variety of woods and wood types, materials were selected. The Asper would mostly be made from 18mm thick plywood. The exact wood type was not selected, but narrowed down to three possible types with similar properties: beech, birch or poplar. With this selection, adjustments were made to the base frame and head capsule.

### 6.1.4.1 Base frame

The base frame (see figure 6.9) consists of eight main pieces: two long sides, two short sides, one base plate and three supporting beams. The short side on the feet-end of the bed and the two long sides of the base frame are made from two layers of 18mm plywood sheet, resulting in a thickness of 36 mm. The outer layers of both sides do not cover the entire length of the frame. A cut out is left in the outer layer, the head capsule is mounted in this cut-out. To assemble the base frame, the beams are screwed to the bottom side of the base plate. The foot-end and sides of the bed are connected with a dowel connection and are then attached to the baseplate with the large corner brackets and to the beams with the small brackets. The single sheet for the back-side of the base frame is then screwed onto the sides of the frame. These screws are later covered by the head capsule in the complete assembly. Then, the feet are mounted onto the baseplate of the concept. For a full resolution of figure 6.9 see appendix K.

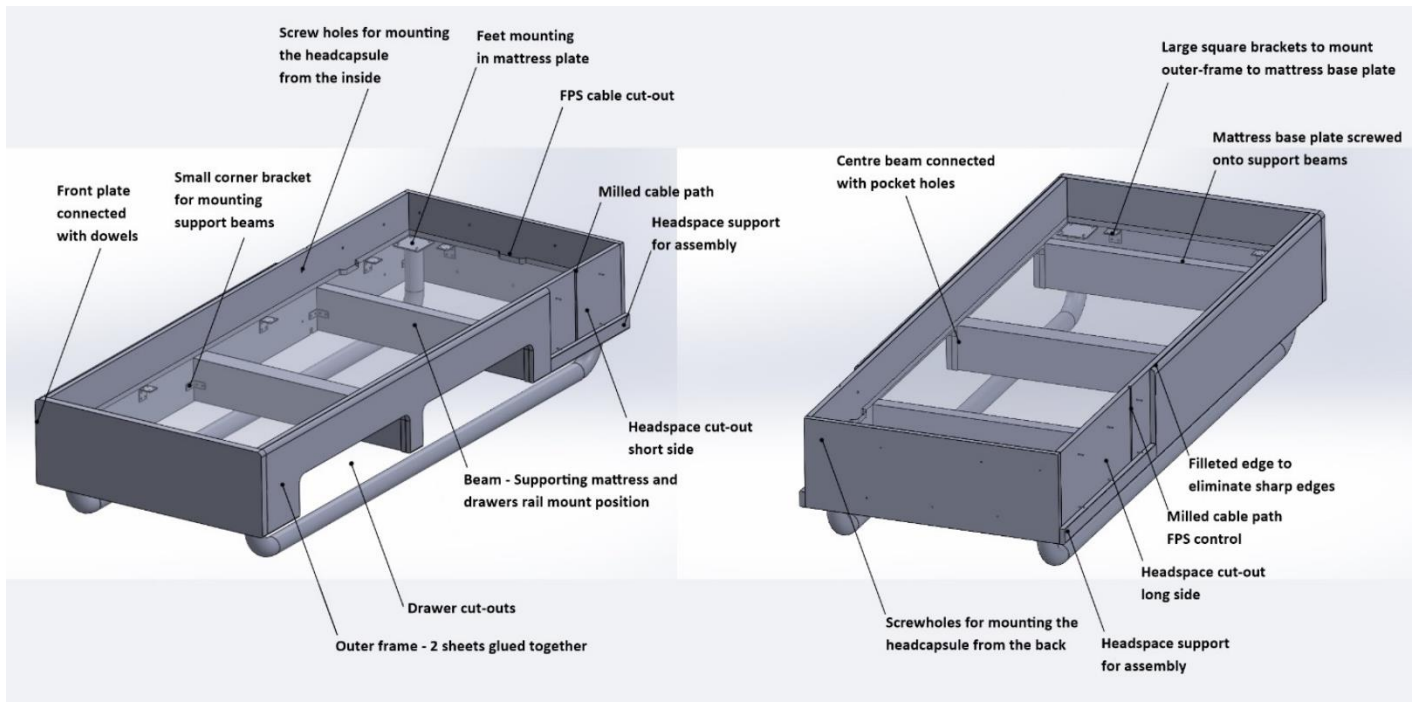


Figure 6.9 - Base frame construction

### 6.1.4.2 Head capsule

The structure of the head capsule consists out of 6 main pieces (see figure 6.10). The 5 pieces (short side wall, short curved piece, ceiling, long curved piece and long side wall) that form the sidewalls and ceiling are all connected to each other with lamello connections. Lamellos are chosen over dowels in the curved pieces, as this connection is thinner, reducing the risk breaking through the surface in the curve. This piece is then screwed onto the backplate. On the backplate, a shoulder is installed, the shoulder is made from strips of 18mm plywood. These shoulders stiffens the entire head capsule. Furthermore, the shoulder is used to attach the upholstery of the backplate to with a staple gun. The bottom shoulder is used to rest on the base frame during installation. The square gap between the shoulders is filled with 20mm polyethylene (PE) foam. The upholstery on the sidewalls and ceiling is attached in a similar way. The front of the upholstery is folded over and stapled to the wood, The back of the upholstery is attached to a small shoulder. The LED strip and FPS control panel are attached to the wood through cut-outs in the upholstery.

The bent wood can be bought from the German suppliers Holz in Form Niedermeier GmbH and Lang Formholz Technik GmbH or the Austrian supplier xyloton GmbH.

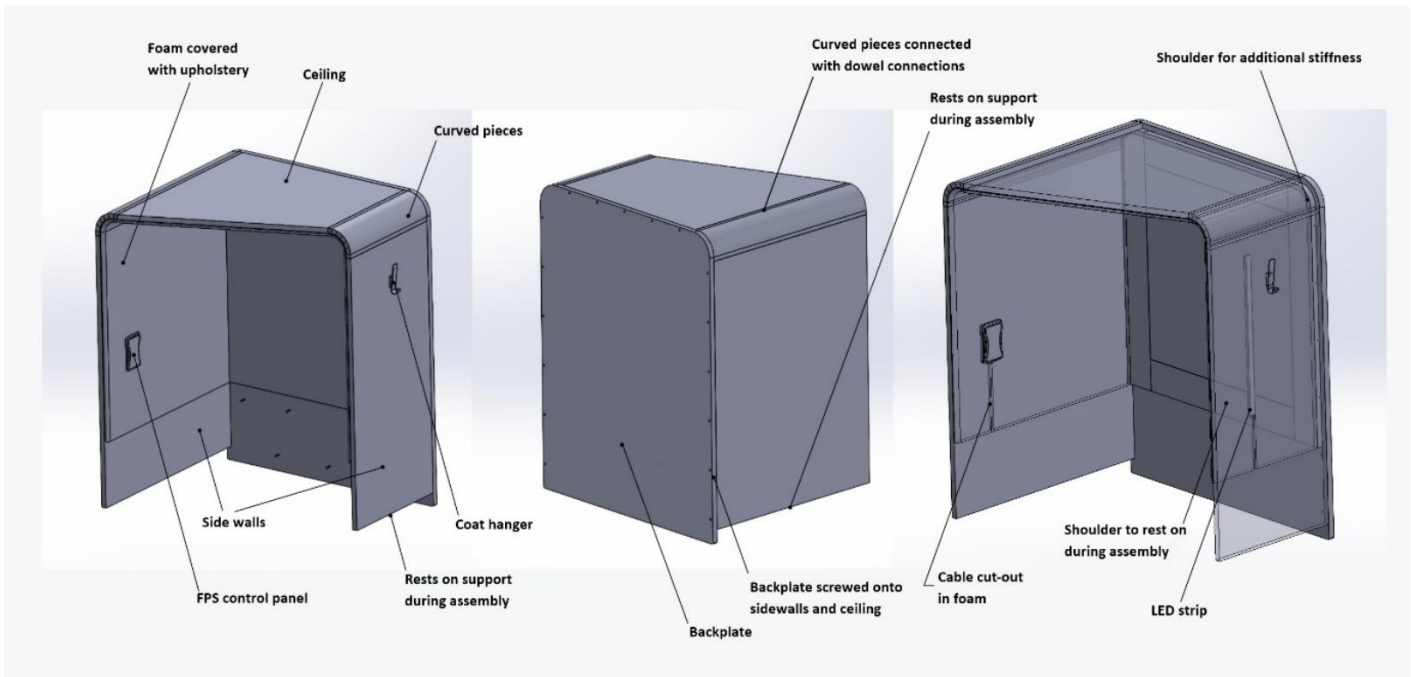


Figure 6.10 - Head capsule construction



### 6.1.4.3 Complete assembly

For the complete assembly (see figure 6.11), the head capsule is attached to the base frame by resting it on the support ridges and then screwing the capsule in place from the inside of the base frame. The complete assembly also includes the drawers, which have not yet been mentioned separately, as they are fairly straightforward. The rails are attached to the beams of the base frame and then the drawers are put into the rails.

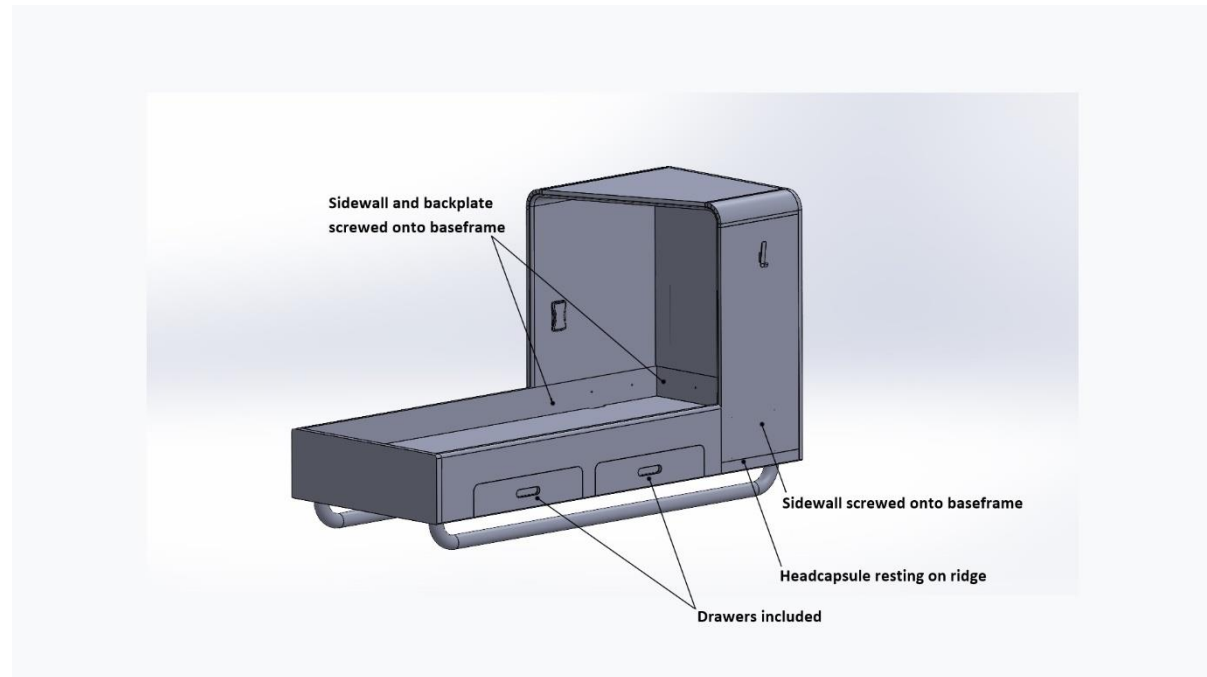


Figure 6.11 - Complete assembly

### 6.1.4 Conclusion iteration 3

With the updated construction- and manufacturing methods, the updated feet and drawers and newly integrated optional features, iteration 3 was finished. The 3D model of this iteration was used in the next two steps, the colour study and prototyping.

## 6.2 Colour study

Until after the third iteration, final colours were not yet determined because this is best done when the geometry of the product is more or less defined. When the third iteration was complete, the chances of making significant changes to the final geometry were considered low. Therefore, a colour study was initiated. Colours and textures had to be selected for the four main visible parts:

1. The wooden structure
2. The steel feet
3. The fabric of the upholstery
4. The fabric of the mattress

With multiple options for each part, variations were made to explore the best look.

### 6.2.1 Colour and texture variants for the wooden structure

Up until the third iteration, the wooden structure had been visualised with a visible woodgrain. During the colour study, both visible woodgrain and opaque painted versions were visualised to compare the results. The visible woodgrain would still need to be painted with a clear coat or stain. The main benefit of using opaque paints is that the surface quality of the plywood can be lower, resulting in lower material costs (assuming that the clear and opaque coats cost roughly the same).

The following stain colours were visualised during the colour study: white, dark brown, pink, saturated brown and dark grey. These are shown the top row in figure 6.12 from left to right. The low-gloss opaque coated colours are: black, light blue, light green, navy blue, desaturated yellow, olive green, petrol, salmon, white and terra. These colours can be seen in the two bottom rows of figure 6.12. These colours were selected based on the mood boards in chapter 4.3.



Figure 6.12 - All wooden structure colour and texture variants.

### 6.2.2 Colour and texture variants for the steel feet

To match the available colour and texture variants of the NEWAS power nap chair feet, the steel feet that were tried during the colour study are powder coated black and brushed stainless steel (see figure 6.13). The optional coat hook colour matches the colour of the feet.



Figure 6.13 - Feet colour variations

### 6.2.3 Colour and texture variants for the upholstery

Initially, faux leather or real leather appeared to be the only suitable fabrics for the upholstery, as the fabric has to be non-porous and water resistant for use in healthcare (requirement 36). Because these two fabrics did not match the required aesthetic, an alternative was sought and found. The upholstery of the head capsule and mattress will be made with Pintail's Wetcare. This fabric is water (and urine) resistant and is commonly used in healthcare furniture. The fabric used for the head capsule is called Prato Alpacano (see figure 6.14). This fabric has a soft and smooth texture and is available in a large range of colours. The colours used during the colour study are: elephant, herbs, sea blue, pebble, black, terra and maiz (see figure 6.15 from top to bottom).



Figure 6.14 - Prato Alpacano texture

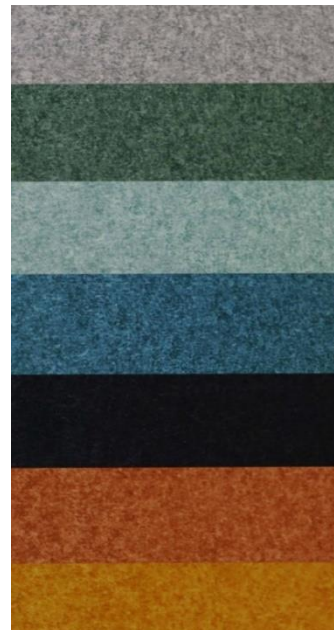


Figure 6.15 used colours

#### 6.2.4 Colour and texture variants for the mattress

For the mattress upholstery, another fabric, called Riva, from Pintail Wetcare was used (see figure 6.16). The main reason for selecting this fabric is that it is more resistant to wear than most other Pintail Wetcare fabrics. For the mattress, the colours grey, charcoal, cement, navy, steel blue, maiz, peacock and light grey were used (see figure 6.17 from top to bottom).



Figure 6.16 - Riva texture



Figure 6.17 used colours

### 6.2.5 Colour variations

With the previously selected colours, textures and fabrics, 52 different variations were made. These variations can be seen in figure 6.18. For the full resolution image of this image, see Appendix L. From the 50+ variations, 24 were selected in a preselection round. These variations were discussed with the client to choose the final 4 combinations (see figure 6.19 to 6.24). See appendix L for full resolution images of figure 6.18 to 6.24.

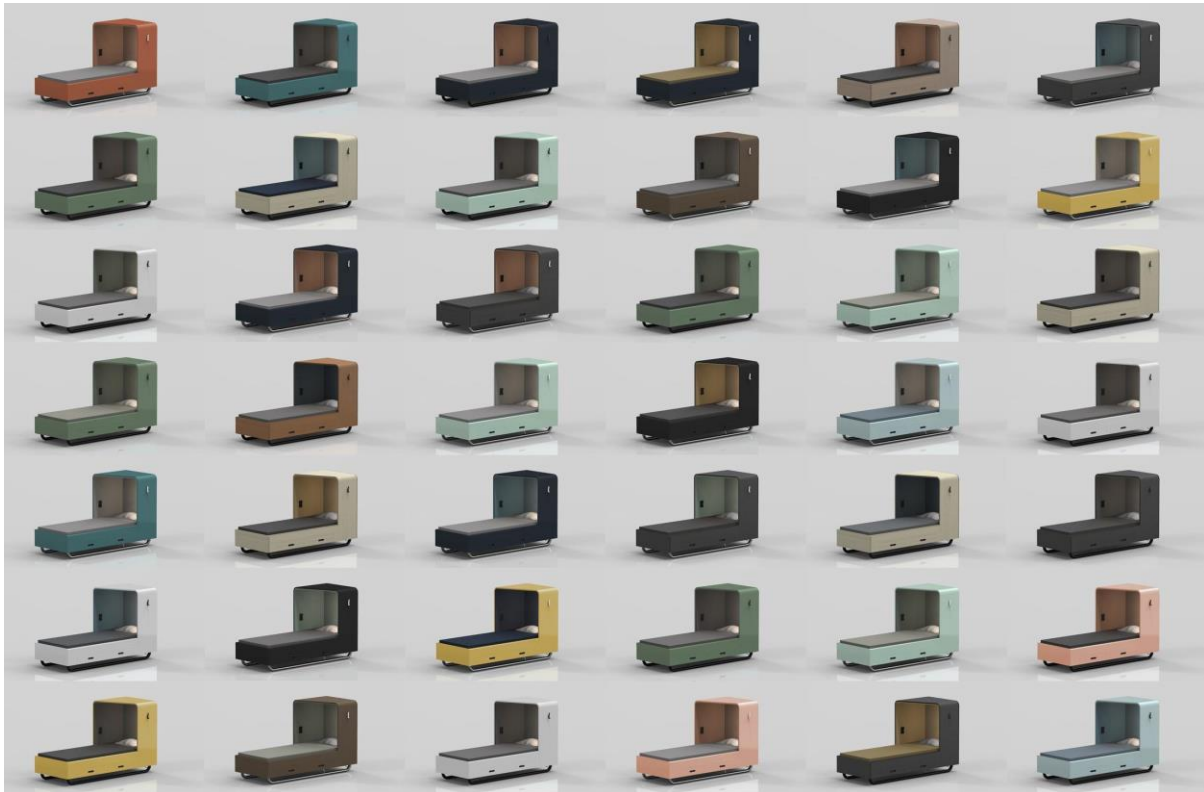


Figure 6.18 - 48 of the 52 colour variations.



Figure 6.19 - Preselection 1-4



Figure 6.20 - Preselection 5-8



Figure 6.21 - Preselection 9- 12



Figure 6.22 - Preselection 13-16



Figure 6.23 - Preselection 17-20



Figure 6.24 - Preselection 21-24

### 6.2.6 Colour selection

Together with the client, four final colour variations were chosen. The goal of the selection process was to end up with both *light* coloured and *dark* coloured variations. Furthermore, it would be cost effective to try and minimize the variations in fabric, as fewer rolls would be required during production. Lastly, the variants had to be aesthetically pleasing and fit into the context in which these concepts would be placed (req. 43). With these criteria, four colour variations were selected.

#### Colour variant 1; nights rest:

The first colour variant is an anthracite low-gloss paint, with brushed stainless steel feet, light gray mattress fabric and maiz upholstery. The ACC-code (Acoat Colour Codification) for the paint is: DN.00.25.



Figure 6.25 - Colour variant 1

**Colour variant 2; Natural nap:**

The second colour variant is a slightly desaturated, dark green (*olive-army green*) low-gloss paint, with black powdercoated feet, black mattress fabric and herbs upholstery. The ACC-code for the paint is: J0.20.50 (4041).



Figure 6.26 - Colour variant 2

**Colour variant 3; Sweet dreams:**

The third colour variant is a slightly desaturated mint green low-gloss paint, with brushed stainless steel feet, black mattress fabric and sea blue upholstery. The ACC-code for the paint is: M8.06.85 (4041).



Figure 6.27 - Colour variant 3



#### **Colour variant 4; Cloud sleeper:**

The third colour variant is a off-white low-gloss paint, with powdercoated black feet, light grey mattress fabric and elephant upholstery. The ACC-code for the paint is: JN.00.83.



Figure 6.28 - Colour variant 4

#### **6.2.7 Conclusion colour study**

To select the final colours and surface textures of the Asper, a colour study was conducted. 52 Colour variations were created, of which four were chosen. These four all have an low-gloss opaque coating, in the colours: DN.00.25 (anthracite), J0.20.50 (slightly desaturated darkgreen), M8.06.85 (slightly desaturated mintgreen), and JN.00.83 (off-white). The fabric used for the mattresses is Pintail Wetcare Riva in colours light grey and black. The head capsule upholstery is made from Pintail Wetcare Prato alpacano in the colours: maiz, herbs, sea blue and elephant. The feet of the Asper are either powdercoated black or brushed stainless steel, matching the feet in NEWAS's chairs. The four colour combinations will be used in visualisations of further developments, validation of the concept and in the 0th production run.

### 6.3 Prototyping

Based on the 3D model from iteration 3, a prototype was built (see figure 6.29 to 6.31). The main purpose of this prototype was to validate the construction, manufacturability and assembly methods as well as the concept's ability to carry the required load (req. 12). The prototype was also used to test ingress and egress (req. 9). Furthermore, the prototype was used to identify potential improvements that could be made to the design.



Figure 6.29 - Prototype without mattress and upholstery



Figure 6.30 - Prototype feet

### 6.3.1 Prototype validation

The prototype was built to find answers to the following questions:

1. Do the parts, as dimensioned in the 3D model, fit together?
2. Can the concept be assembled in a logical order?
3. Are any adjustments required to make the concept manufacturable?

Furthermore, the ability of the concept to meet the following requirements were checked with the prototype:

Req 9. The concept should be easy to enter and exit. The user should not have to crawl into the concept, but instead should be able to sit down on the side of the mattress, turn and lie down (see chapter 3.2.9). Both the ingress and egress should take a healthy user with no prior experience no longer than 15 seconds.

Req 12. The concept should be able to support the weight of P99,5 male, which is 120 kg (DINED dutch males 20-60, n.d.). As an additional safety-factor, the concept should be able to support this weight 1.5 times (180 kg).

Req 29. The concept should be easily cleaned with cleaning detergent and a wet cloth (see chapter 3.3.6).

From the prototyping process, it was found that the parts do fit together as dimensioned in the 3D model. Furthermore, the concept can easily be assembled in a logical order. Lastly, no adjustments are required to make the third iteration of the concept manufacturable. However, one issue was found that does require adjustments. This issue is discussed in chapter 6.3.2.



Figure 6.31 - Prototype without mattress and upholstery

The prototype, also meets requirements 9, 12 and 29. Two people were asked to lay down and get out of the prototype. Ingress was done in 7 and 6 seconds and egress took 10 and 11 seconds respectively. Furthermore, two people (my dad and I) both holding 20 kg of water in buckets, weighing approximately 200kg in total, stood inside the prototype to test its strength. To test the prototype for a concentrated load, I stood inside the frame on one foot on what was expected to be the weakest point (above the drawer) (see figure 6.30). Lastly, a fake cleaning of the concept with a dry cloth was done to see whether or not all parts could easily be reached. This was the case.

Information and images from the entire prototyping process can be found in appendix M. The colour in the images is not the prototype's final colour.



Figure 6.32 - Me standing on one foot on the weakest point of the frame

### 6.3.2 Improvements derived from the prototype

Although the prototype showed promising results, a few areas of improvement were found that had to be addressed. The main problem of the prototype and therefore third iteration, was that the entire construction was very heavy. Although good for the overall strength of the concept, the thick sheets and large beams (see figure 6.31) made the third iteration unnecessarily strong and added a lot of weight. This unnecessary material also increased the material cost. Another smaller issue was that the supports holding the head capsule during assembly, created split lines that looked out of place.

Lastly a more accidental improvement derived from the prototype, was the increased radius of the curved pieces. As a result of the method used to create these pieces, the radius had become significantly larger than in the original design and 3D models. This looked good, so a small increase to the radius was added in the fourth iteration.



Figure 6.31 - Thick sheets and large beams in prototype

## 6.4 Iteration 4 of concept 2; the Asper

The final iteration of the Asper was an overhaul of the construction based on the insights gathered from building the prototype. The main goal was to reduce the weight of the concept and required materials. Most of the changes were made to the base-frame as it required the most materials, making it a logical place to start removing material. Some minor changes were made to the head-capsule and method of assembling the two pieces together. For full resolution images of the figures in this section, see appendix N. Another decision made in the 4<sup>th</sup> iteration was the material used in the Asper. Poplar was chosen as it was light, strong and the cheapest of the remaining options.

### 6.4.1 Overhaul base frame

The required materials to build the base frame has been drastically reduced in iteration 4. This was achieved by separating the base frame into two parts. The inner base frame (on the left side of figure 6.32) and the outer base frame (on the right side of figure 6.32). Instead of gluing two 18mm sheets to each other to create the sides and front, like in iteration 3, the inner frame is now made from 12mm plywood, and the outer frame from 18mm plywood. Furthermore, the inner frame is approximately 140mm lower, because it is mounted under the mattress baseplate. Another change to the frame is the removal of the wooden beams. These have been replaced by 12mm thick sheets of plywood. Another sheet has been added towards the back, as this allowed small wooden plates to be added in the corners of the frame. By mounting the feet on these plates, the steel feet can be about 140 mm lower, further reducing weight. The outer frame is screwed onto the inner frame from the inside, hiding any screws. Because the exposed outer frame's thickness has been reduced from 36mm to 18mm, the radius on the fillet has been adjusted.

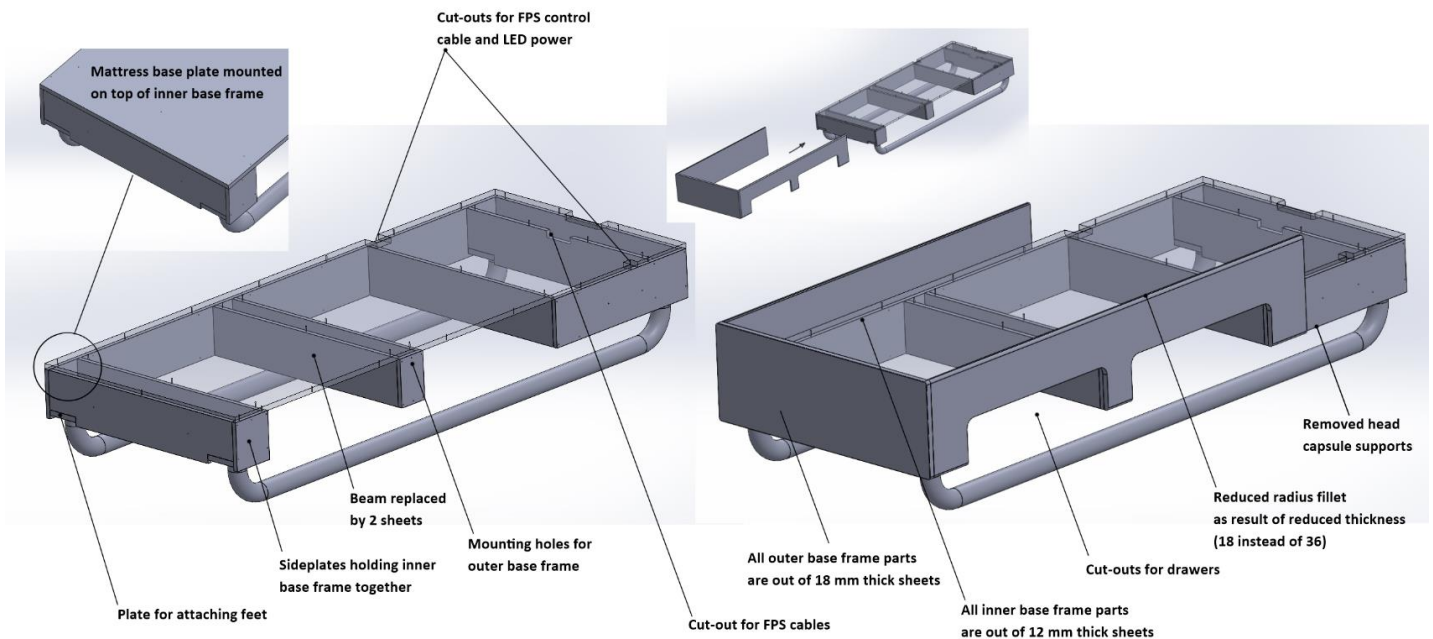
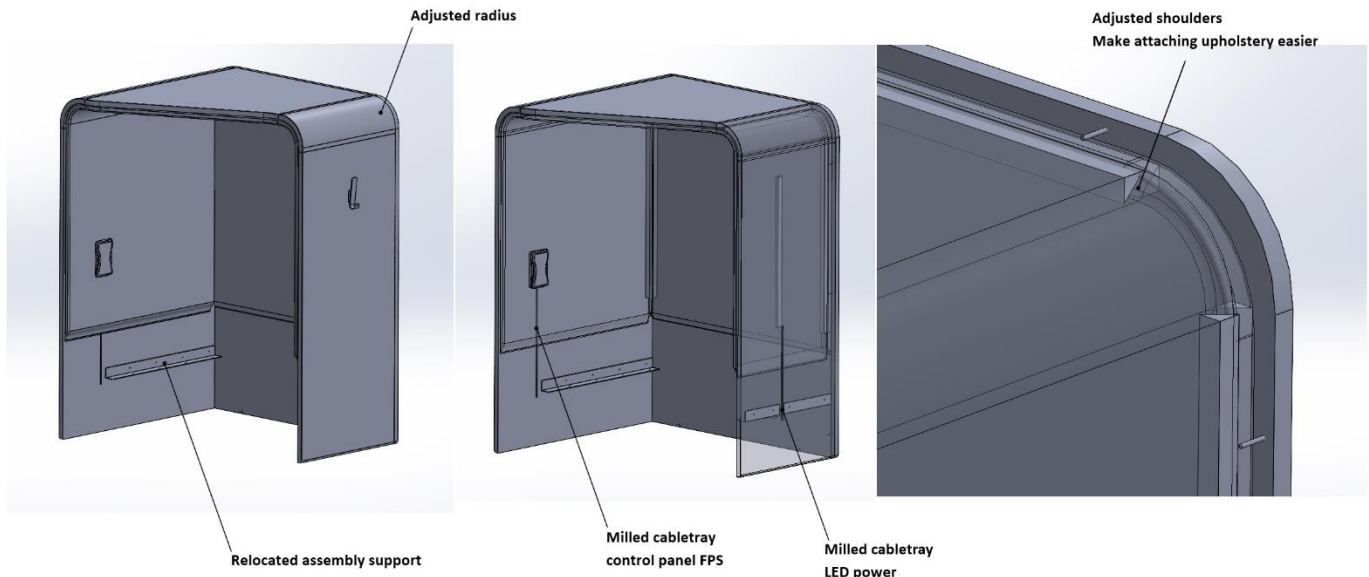


Figure 6.32 - Baseframe iteration 4

## 6.4.2 Adjustments to head capsule

In iteration 4, a few alterations were made to the head capsule. The main alteration was the relocation of the assembly support from the base frame to the head capsule. Steel angled brackets are used for both supporting the concept during assembly and mounting the head capsule to the base frame. Two additional screws at the bottom of the sheets are still required on each side to prevent undesired bending. The milled cable trays have also been moved from the base frame to the head capsule, as a 5 mm deep milled slot in the 12 mm base frame would create a weak spot. Another adjustment is the slight increase in curve radius. The last adjustment is a change in the shoulders. They are significantly smaller and angled, making the upholstery attachment easier. A second set of shoulders has been added to the sidewalls and ceiling to allow for easy attachment of the upholstery.

Figure 6.33 - Headcapsule iteration 4



## 6.4.3 Conclusion iteration 4

The wood saved by iteration 4, is approximately  $0.034 \text{ m}^3$  during manufacturing. The third iteration required approximately  $0.072 \text{ m}^3$  for the base frame, whereas the fourth iteration requires approximately  $0,039 \text{ m}^3$  for the base frame. This translates to a material reduction of  $0.031 \text{ m}^3$  in the concept. The difference between manufacturing and product volume exists because of material losses during manufacturing. Furthermore, approximately  $4 * 150 \text{ mm}$  less steel tube is required in iteration 4. These two reductions of material usage result in a weight saving of roughly  $18.5 \text{ kg}$  (depending on the exact density of the plywood). Another positive effect of iteration 4 is the eliminated need for steel brackets, further reducing the weight. By reducing the required amount of material, both the weight and the cost of the concept are reduced. Furthermore, the reduction of both materials and waste is an environmental net-positive.

## Chapter 7. Asper design in depth

With iteration 4 finished, the design of the Asper is complete. Although more improvements are undoubtedly possible, the current version is developed far and well enough for a 0<sup>th</sup> production run. This chapter provides a lot of in depth and detailed information about the design and its implementation. For a more condensed overview of the Asper, see chapter 2.



Figure 7.1 - Asper design; sweet dreams



## 7.1 Program of requirement checklist

The requirements from the program of requirements (PoR) as defined in chapter 3.6 should all be met in the design of the Asper. Table 7.1 in this subchapter shows whether or not the Asper meets the requirements. Most requirements can simply be checked-off, these are marked with a check mark: ✓. As some requirements are difficult to validate in the given timeframe, an estimation is made. These estimations are marked with ~ and elaborated on below the table.

<b>Requirement</b>	1	2	3	4	5	6	7	8	9	10
<b>State</b>	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
<b>Requirement</b>	11	12	13	14	15	16	17	18	19	20
<b>State</b>	✓	✓	✓	✓	✓	✓	~	✓	✓	✓
<b>Requirement</b>	21	22	23	24	25	26	27	28	29	30
<b>State</b>	~	✓	✓	✓	✓	✓	✓	✓	✓	✓
<b>Requirement</b>	31	32	33	34	35	36	37	38	39	40
<b>State</b>	✓	✓	✓	✓	✓	✓	✓	✓	~	~
<b>Requirement</b>	41	42	43	44	45	46	47	48	49	50
<b>State</b>	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
<b>Requirement</b>	51	52	53	54	55	56	57	58	59	60
<b>State</b>	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
<b>Requirement</b>	61									
<b>State</b>	~									

Table 7.1 - Overview of requirements

The requirements that are harder to fully validate are:

Req 17. *The concept should make controlling the FPS mattress simple and easy to understand. A one-time explanation should suffice.*

Because the FPS control panel is still in development (and not part of the scope of this project), testing the full interaction with the FPS system and mattress is difficult. Based on the preliminary versions of the control panel and its prominent positioning in the concept, it is estimated that it is easy to understand that the Asper can be controlled through its control panel. The exact process of controlling the FPS system is not part of the scope.

Req 21. *The concept should be able to effectively (in at least 95% of users) wake the user at the end of the power nap program, but not in an aggressive, harsh way (see chapter 3.4.5 and 4.2).*

With the COVID-19 restrictions and the significant time required to test the effectiveness of the alarm for waking a user, no extensive testing was done to confirm this functionality. However, based on some tests conducted on myself, the alarm appears to be effective.

Req 39. *The 'high traffic' parts of the Asper (e.g. mattress, FPS interface and other parts users physically interact with) should last at least 5 years without major maintenance, repairs or replacement parts (see chapter 3.3.6).*

Req 40. *The 'low traffic' parts of the Asper (e.g. structural parts and parts users don't interact with) should last at least 8 years without major maintenance, repairs or replacement parts (see chapter 3.3.6).*

Requirement 39 and 40 are hard to validate without extensive durability testing. The materials selected for the concept however are high quality and strong. Because of this, the concept is expected to be long lasting.

Req 61. *The concept should preferably be re-used. However when disposed, materials should be non-toxic when thermally recycled (burned), as this is the most common method of disposing waste in the Netherlands.*

The toxicity when thermally recycling the Asper largely depends on the glues and paints used during the manufacturing process of the plywood and during the manufacturing process of the Asper. Because of the high temperatures reached in incineration facilities, toxicity is expected to be low to non-existent.

## 7.1 Features in depth

This subchapter describes both the regular- and optional features integrated into the design of the Asper in detail. Both the purpose of each feature and its final implementation are discussed.

### 7.1.1 FPS technology

FPS, or frequency physio support, technology is the first feature implemented in the Asper. Four special impulse speakers are integrated into the mattress that allow the system to create a vibration that 'flows' across the length of the mattress. Multiple power napping programs with different frequencies, intensity and flow are integrated in the Asper.

The control panel of the FPS system is mounted on the long sidewall. This position is easily accessible when entering the bed, before lying down and when lying down. The centre of the control panel is mounted at 233,3 mm above the mattress surface and 525 mm away from the internal upholstery. (see figure 7.2). The control box of the FPS system is mounted on the underside of the plate that supports the mattress. The wires connecting to the mattress and control panel are routed through dedicated cut-outs (see figure 7.3).

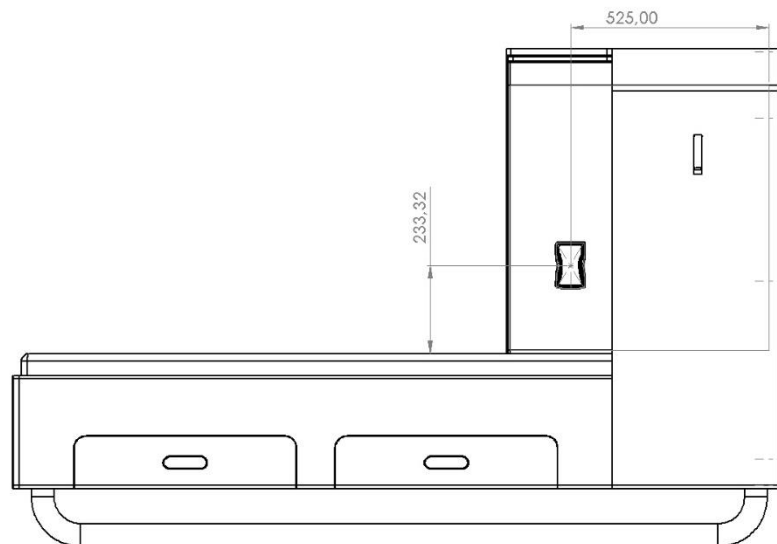


Figure 7.2 - Location of FPS control panel

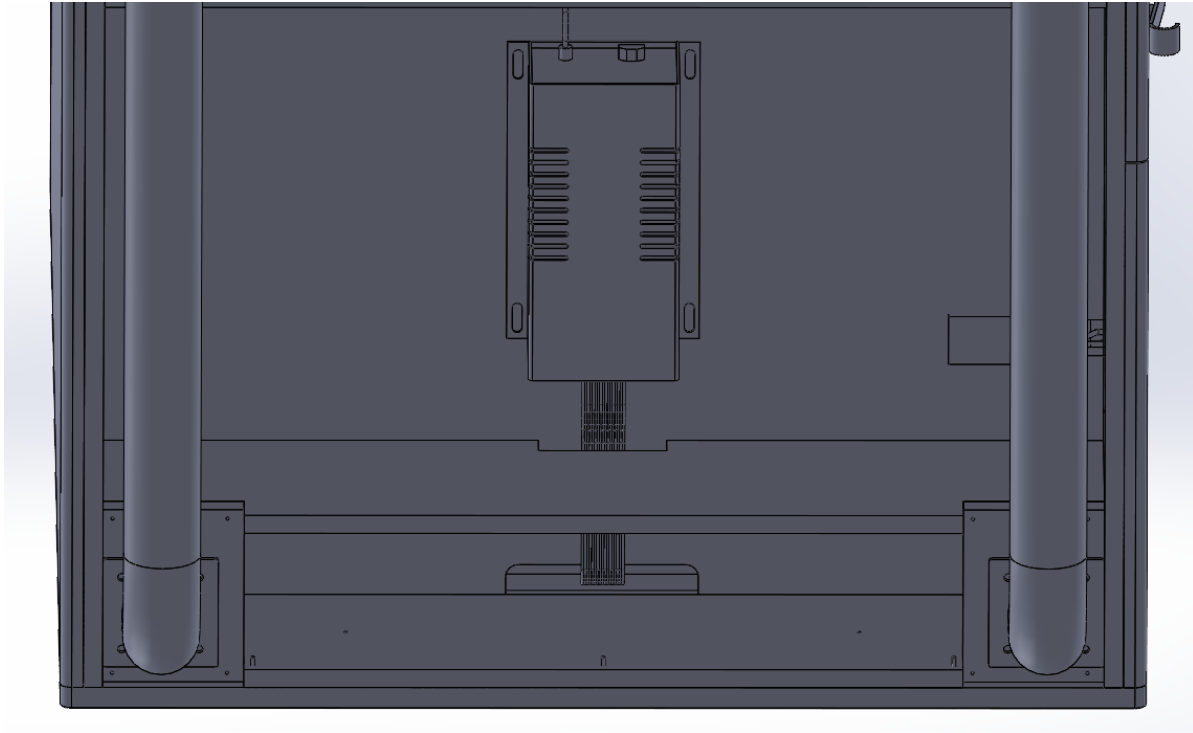


Figure 7.3 - Dedicated cut-outs for FPS cables.

### 7.1.2 LED lighting

The Asper has integrated LED lighting. The lighting in the Asper has multiple functions. The first function is part of a feature that aids the user to wake up after a power nap, this feature is discussed in more detail in the next section (7.1.3). The second function of the LED lighting is to provide a way-finding light. The last function is in its relaxation guidance, an optional feature.

The lighting requires the following parts to function:

1. 480 mm of an 500+ LEDs/meter COB LED-strip, like the LuxaLight long life (LS24WWCOBPLX2700K). This LED strip was selected because of its high durability, colour rendering index, and required intensity. The main benefit of using a COB (chip on board) LED-strip over an SMD (surface mounted device) LED-strip is the continuous line of light (see figure 7.4).
2. A small LED power source. The source needs to be 24V and at least 0,7A. A recommended power source is the FTPC20V24-C from POS.
3. A low, wide aluminium profile. The recommended profile is the PZBL2310-IBST01.
4. An LED-driver and dimmer that integrates with the FPS technology. This part has to still be developed by COMAX, the electronics supplier of NEWAS.

Although recommended parts are given for the LED lighting, the final selection should be made by COMAX, as these might influence the integration with the FPS system. All recommended parts are

available through ledstripkoning.nl With the selected LED-strip an approximate maximum light intensity of 650 lumen is reached. The LED strip is mounted in the centre of the head capsule's short wall.



Figure 7.4 - Comparison COB and SMD LED strips.

### 7.1.2.1 Wayfinding light

When the Asper is powered on, the wayfinding lights will be dimly lit. This means that when the Asper is positioned in a dark room during a night shift, users can still easily find the Asper without having to turn on lights or use their phone as a light source. The lights automatically dim when a program is started and turn back on when a program is finished. This allows the user to easily find the door in a dark power napping room after taking a power nap.

### 7.1.2.2 Relaxation guidance

The optional relaxation guidance in the Asper is a simple breathing exercise communicated through the LED strip. During the first two minutes of the power nap, the LEDs will gradually dim to being off over a period of four seconds, followed by a four second period during which the LEDs become brighter. This dimming and undimming cycle repeats 15 times and visualises a simple breathing exercise. As the 2 minutes progress, the maximum brightness slowly reduce from 650 lumen to 100 lumen. After the 15<sup>th</sup> cycle, the LEDs remain off.

### 7.1.3 Waking assistance

The waking assistance is another feature that utilizes the LED strip. By slowly lighting up during the last 45 seconds of a power nap, the user is awoken to ensure they do not sleep longer than the maximum recommended power nap time. This prevents entering slow-wave-sleep. To ensure the user wakes up, the intensity of the FPS program is significantly increased during the last 20 seconds of the program.

### 7.1.4 Privacy structure

Part of the Asper, is the head capsule. This head capsule provides the user with sufficient privacy when power napping. The head capsule is asymmetrical, making ingress and egress from the short side of the capsule easier and providing additional privacy from the other side. The internal dimensions of the head capsule are 770mm wide, 800mm tall and between 440 and 720mm deep (see figure 7.5). With these dimensions, the structure obstructs the lines of sight to the users head and upper torso.

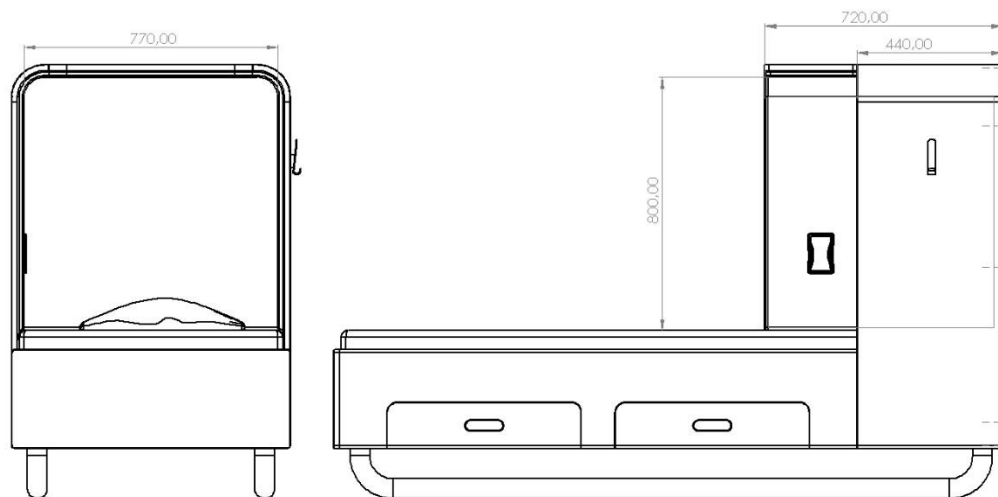


Figure 7.5 - Dimensions privacy structure (head capsule)

### 7.1.5 Electric blankets

Enabling users to use electric (underblankets) is an optional feature in the Asper. The main reason for using this feature is that a portion of night shift workers tends to be cold during their night shift as a result of the circadian rhythm causing their core temperature to drop. Practically, this means that an additional power outlet on the concept is required. When ordered, the additional power outlet will be mounted on the inside of the inner base frame. A larger cut-out is made in the mattress base plate that allows a plug to go through.

### 7.1.6 Integrated storage space

The Asper comes with integrated storage, in the form of two drawers. These drawers can be used to store clean bedlinen and blankets. The back drawer has a small partition that can be used to store pamphlets with information about the Asper and its FPS programs and to store small personal items. (e.g. glasses, phone, pager, tools, etc.) The internal dimensions of the drawers are: 541 mm wide, 556 mm deep and 130 mm deep (see figure 7.6). The recommended drawer slides are the Würth ball-bearing guide 550mm rails with product number 0684303550 (See figure 7.7).

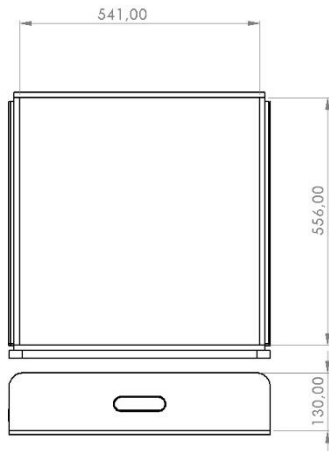


Figure 7.6 - Dimensions drawer



Figure 7.7 - Würth slides

### 7.1.7 Sound absorption

To prevent the wooden structure from acting as a soundbox (*'klankkast'*) and in attempt to reduce external noise, the interior of the head capsule is lined with 20mm closed cell polyethylene (PE) foam padding (see figure 7.8). This foam is non-absorbent and waterproof. The padding is upholstered with Pintail wetcare Alpacana. This combination of foam padding and textile upholstery greatly reduces the reverberation inside the head capsule. The effect on reducing external noise is hard to determine without high grade sound equipment, but is most likely limited. Another benefit of the foam padding and upholstery is that it makes the internal side of the head capsule soft and comfortable, adding the desired product qualities. The foam can be purchased from eki.



Figure 7.8 - Polyethylene (PE) foam

### 7.1.8 Casters

The Asper optionally comes with casters (see figure 7.9a). The main purpose of the casters is to make cleaning in and around the Asper easier. This feature is expected to be valued highly in healthcare, as most furniture in hospitals has casters. Another benefit of using casters is that the concept can easily be moved from one resting room to another if the need arises.

The casters are mounted on the feet mounting plates in the inner base frame (see figure 7.9b). The recommended casters implemented in the design are the Tente Stylea 5925XGI075L51-10 DOM20 combined with the P41-65x65/10 plate connection (see chapter 6.1.3.5).

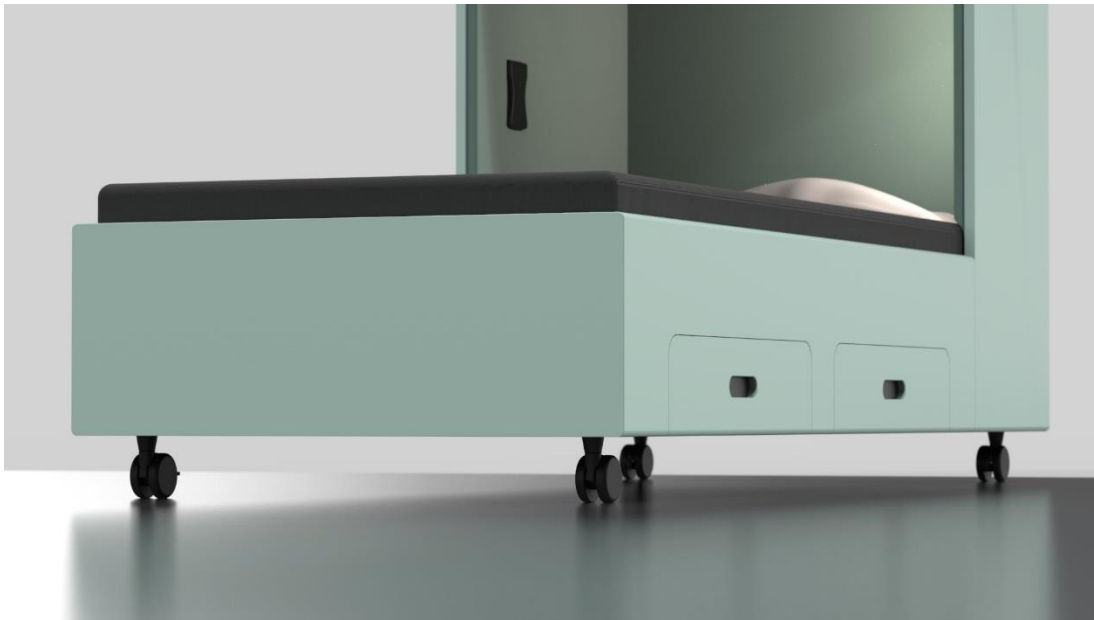


Figure 7.9a - Casters on the Asper

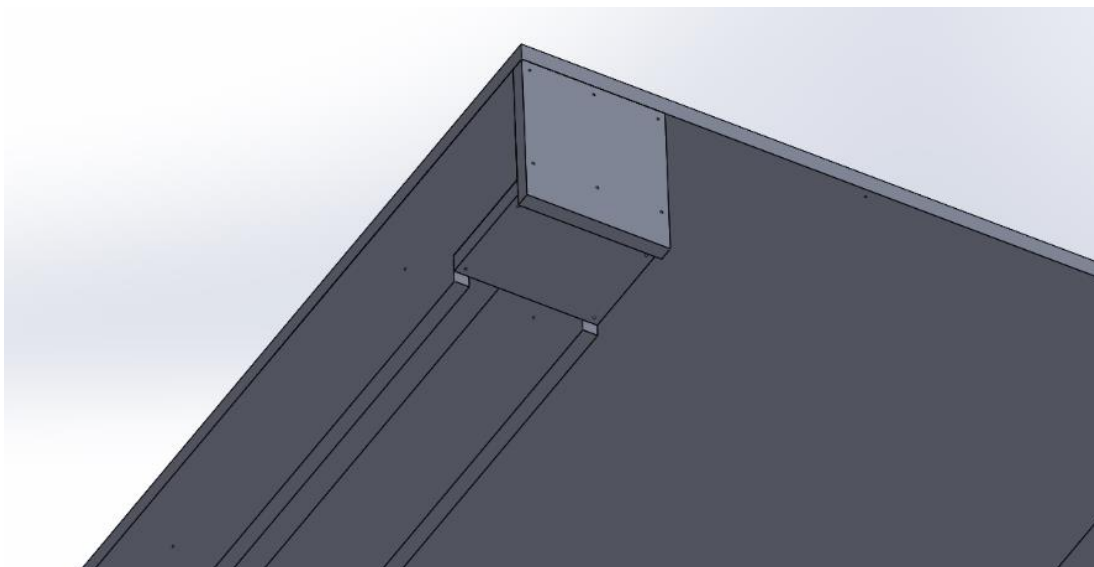


Figure 7.9b - Mounting position casters



## 7.2 Aesthetics in depth

This subchapter describes the aesthetic qualities, geometry and colour variants of the Asper. Furthermore, it discusses the aesthetic validation research.

### 7.2.1 Aesthetic qualities and geometry

The goal of the Asper design is to look: comfortable, inviting, calming or relaxing and soft and easy going (requirements 44 to 47). To achieve this goal, the following design decisions were made.

The Asper uses many curved surfaces. It has large, curved corners on the most prominent part of the design. Furthermore, the long edges on the outer frame are rounded off, as are the drawer fronts. The round shape also comes back in the design of the feet. Lastly, the hard edges are chamfered. The goal of the large radii and the broken edges is to make the concept appear soft and comfortable. The soft fabric of the upholstery and mattress add to these qualities. Another aspect aimed at making the Asper appear soft and comfortable is the use of low-gloss or matt paint. The surface finishes of these types of paint create a much softer look because highlights and shadows are softer on less glossy surfaces.

By not using a fully enclosed capsule, but instead using an open, asymmetrical head capsule, the Asper looks inviting. When walking around the Asper, the entire product can be inspected without having to crawl into the concept. Lastly, the dimly lit LED strips add to the calming aesthetic of the Asper, especially with the relaxation guidance turned on.



Figure 7.10 - Asper; cloud sleeper

## 7.2.2 Colour variations

The Asper will be available in four colour variations (see figure 7.11a to 7.11d). These colour variations are:

1. **Natural nap** - olive green low-gloss coating (J0.20.50 (4041)), black powder coated feet, Pintail Wetcare Riva black mattress, Pintail Wetcare Proto Alpacana herbs head capsule upholstery.
2. **Sweet dreams** - mint green low-gloss coating (M8.06.85 (4041)), brushed stainless steel feet, , Pintail Wetcare Riva black mattress, Pintail Wetcare Proto Alpacana sea blue head capsule upholstery.
3. **Cloud sleeper** - off-white low-gloss coating (JN.00.83), black powder coated feet, Pintail Wetcare Riva light grey mattress, Pintail Wetcare Proto Alpacana elephant head capsule upholstery.
4. **Nights rest** - anthracite low-gloss coating (DN.00.25), brushed stainless steel feet, Pintail Wetcare Riva light grey mattress, Pintail Wetcare Proto Alpacana maiz head capsule upholstery.

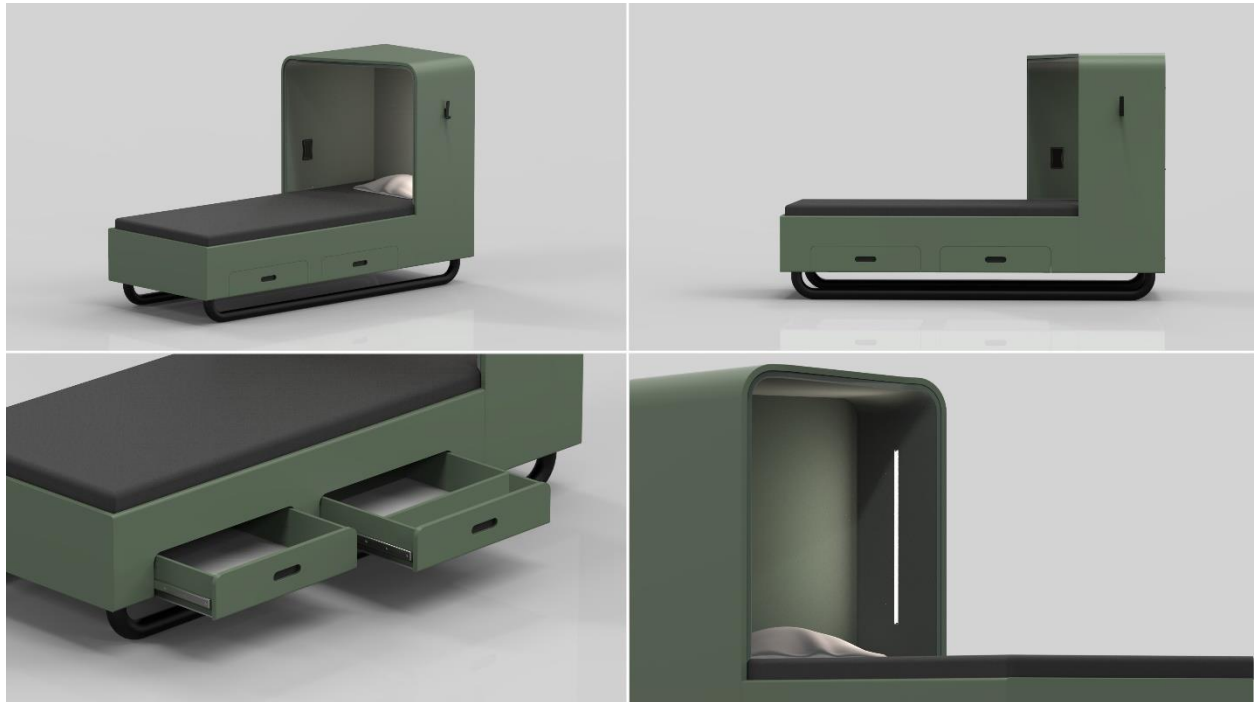


Figure 7.11a - Natural nap

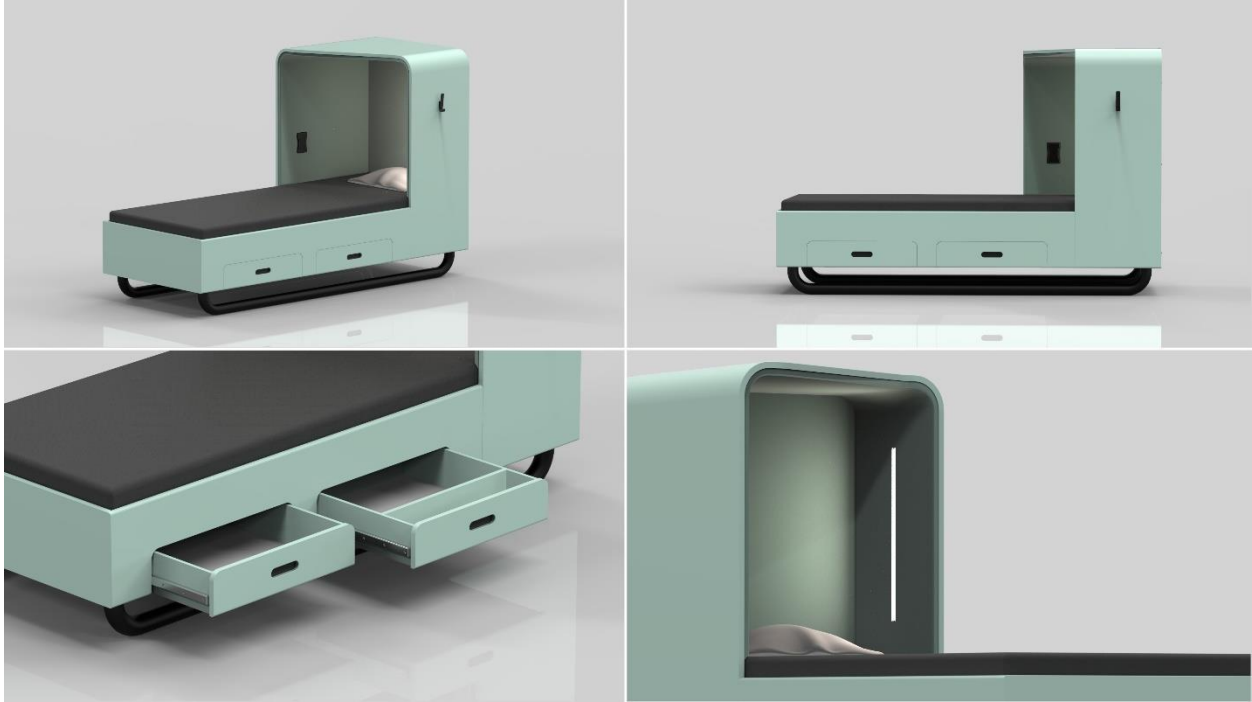


Figure 7.11b - Sweet dreams



Figure 7.11c - Cloud sleeper



Figure 7.11d - Nights rest

## **7.2.3 Aesthetic validation research**

To validate the desired aesthetic qualities of the Asper, a validation research was conducted. Through an online questionnaire, 40 people were asked to rate the Asper on the qualities as mentioned in requirements 44 to 47. For the entire research set-up and results, see appendix O.

### **7.2.3.1 Research set-up**

Through a google form, participants were first asked some basic questions about themselves like age, gender, and whether or not they worked night shifts. The participants were then asked to rate the Asper on looking: calming, comfortable, soft, inviting, high quality and private on a scale from 1 to 7. The users were also asked whether they would prefer to sleep on the Asper or the existing NEWAS chair.

### **7.2.3.2 Participants**

40 participants completed the questionnaire. 28 (70%) Participants were female, the other 12 (30%) were male. The participants were aged between 14 and 77. 8 (20%) Participants worked night shifts, the other 32 (80%) did not.

### **7.2.3.3 Results**

On average, all qualities scored above 5,0 (see figure 7.12). This means that requirements 44 to 47 are considered met. The qualities average scores are: 5,625 (calming), 5,025 (comfortable), 5,75 (soft), 5,4 (inviting), 6,275 (high quality) and 5,25 (private). Interestingly enough, comfort and privacy, two important factors scored just barely above 5.0. In future research it would be interesting to know why these two values scored lower than the others and more importantly, how to improve the perceived comfort and privacy.

When asked whether participants would prefer to nap on the bed or the chair, 33 (82,5%) preferred the Asper. From the 8 participants that worked night shifts, 7 (87,5%) preferred the Asper. The main reason given for preferring the Asper was that participants prefer to sleep on either their side or belly, which is not possible in a chair.

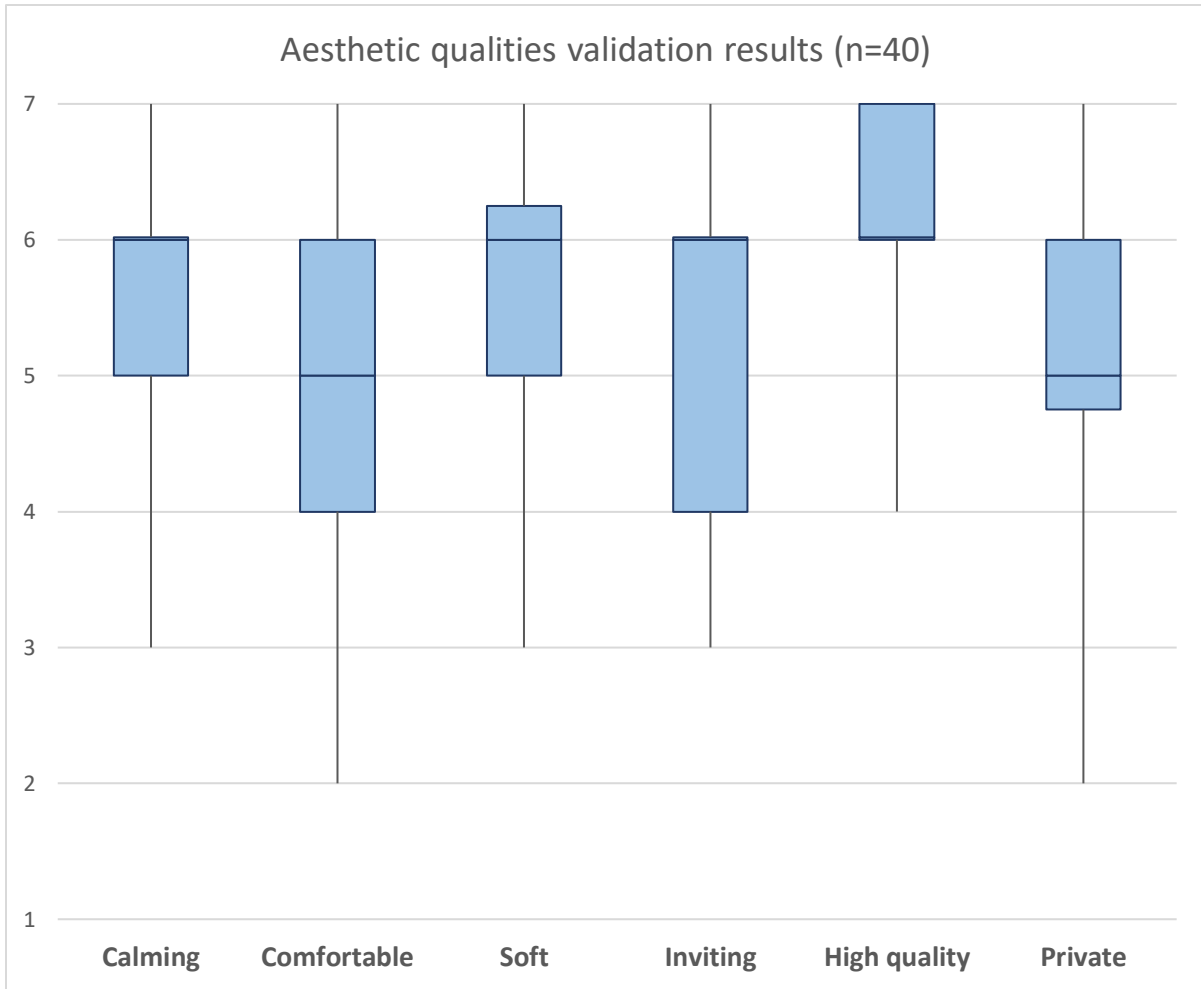


Figure 7.12 - Graph showing results of the aesthetic validation

## 7.3 Dimensions in depth

This subchapter discusses the main dimensions of the Asper and how those affect the user ergonomics of the product.

### 7.3.1 Inner dimensions

The mattress dimensions are 2000mm by 800mm by 180mm. These dimensions are based on a standard size mattress and allow P95 males to lie down comfortably (req.13). The mattress' top surface is 505mm above the floor, almost exactly in between the suggested minimum and maximum height (see chapter 5.2.1.2). The height from the mattress surface to the head capsule cabin is exactly 800mm. The head capsule is 720mm deep on the long side, and 440mm deep on the short side to be in accordance with requirement 11. The width of the head capsule is 770 mm, providing the user plenty of room to turn. See figure 7.13 for a visualisation of the dimensions.

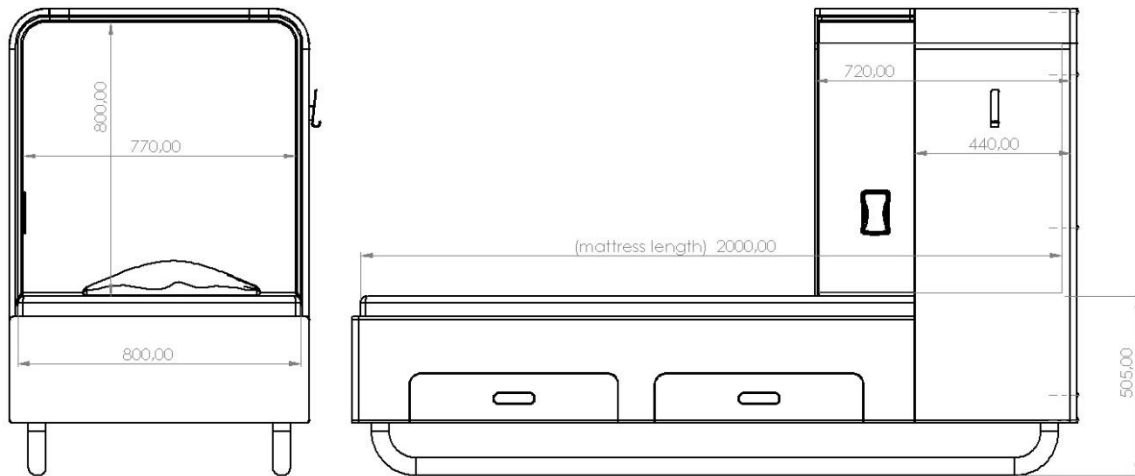
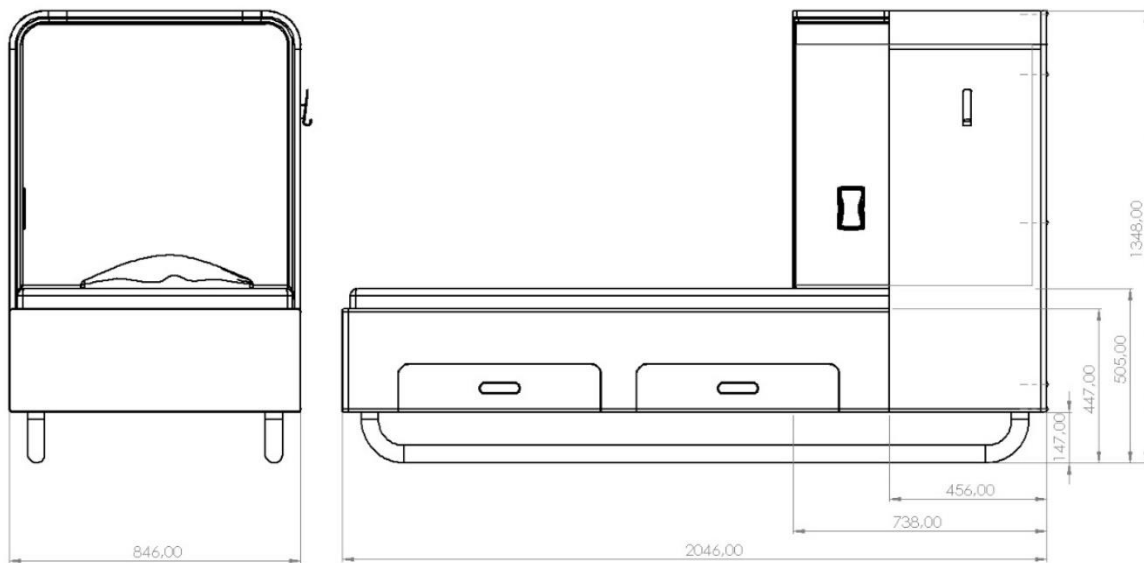


Figure 7.13 - Inner dimensions of the Asper

### 7.3.2 Outer dimensions

The footprint of the Asper is 846 mm by 2046mm. These measurements stem from the size of the mattress (2000mm\*800mm\*180mm). The additional 46 mm on both measurements comes from the material thickness times two plus 10mm play. From the floor to the ceiling of the head capsule, the concept is 1348mm high. The bottom of the Asper is raised 147mm above the floor, to allow a vacuum cleaner or mop to fit between the feet and the bottom of the sides. See figure 7.14 for a visualisation of the dimensions. The entire Asper weights approximately 90 kg.

Figure 7.14 - Outer dimensions of the Asper





## 7.4 Manufacturing in depth

This subchapter describes all consideration that went into the fourth iteration of the Asper. Both the material choices and required manufacturing methods are described. At the end of this sub-chapter some examples of technical drawings for the Asper are provided. The entire set of technical drawings is provided to the client after the graduation project.

### 7.4.1 Material choices

The main material from which the Asper is made, is poplar plywood. The internal base frame is made from 12mm, low surface grade, poplar plywood. The external base frame is made from 18mm BB/B poplar plywood. This grade can be painted over, as it does not have surface imperfections. Poplar was chosen as it is a strong, yet light material that is cheaper than birch- or beech plywood. The density of poplar plywood is approximately  $450 \text{ kg/m}^3$  (De Houtgroothandel, n.d.).

For the steel feet, a 50 \* 2.6 mm steel S235JRG2 tube should be used. This steel grade was recommended by Busschers staalwerken B.V.. In consultation with the final supplier however, another construction steel type could be selected. S235JRG2 steel has a density of approximately  $7850 \text{ kg/m}^3$  (theworldmaterial.com, n.d.).

Other materials used for manufacturing the Asper's parts are paint , powder coatings, PE foam and Pintail wetcare fabrics for the upholstery, as discussed in chapter 6.2.3, 6.2.4 and 7.1.6.

### 7.4.2 Manufacturing methods

To create the Asper, multiple manufacturing methods are required. This subchapter provides an overview of the required manufacturing methods and operations to manufacture all parts of the Asper.

#### 7.4.2.1 Wooden parts

##### CNC-Sawing

The first step for every wooden part is CNC-sawing. This step cuts the parts to the final outer dimensions with great accuracy.

##### CNC-Milling

The second step for almost every wooden part is CNC-milling. During this step, cut-outs, rounded corners, rounded edges, cable slots, dowel holes, lamello holes and screw holes are made. By doing all these operations on CNC machines, tight tolerances and squareness are almost guaranteed, greatly improving the quality of the final product.

##### Filling, sanding and painting

In the last step, damaged surfaces and crosscut sides are filled and sanded. The parts are then painted

with multiple thin layers of paint. To prevent warping, all sides of the wood are coated. The internal base frame, excluding the mattress base plate, does not have to be painted.

### 7.4.2.2 Steel parts

#### CNC mandrel bending

The first step to create the steel feet is to bend the feet to their final shape. To achieve the relatively small radius without crimping or tearing of the tube, mandrel bending should be applied.

#### Plasma or laser cutting

After the tube is bent to shape, the ends (used to clamp the tube) are cut off. Furthermore, the attachment plate is cut from a larger sheet.

#### Welding

After both the tube and attachment plate are finished, the two parts are welded together. This can be done manually or with a welding robot.

#### Powder coating or brushing

Lastly, the feet are powder coated or brushed, depending on the desired surface finish (and material).

### 7.4.3 Technical drawings examples

For all parts of the Asper, technical drawings are supplied to the client after the project. This section shows some examples of technical drawings. See appendix P for the full resolution drawings.

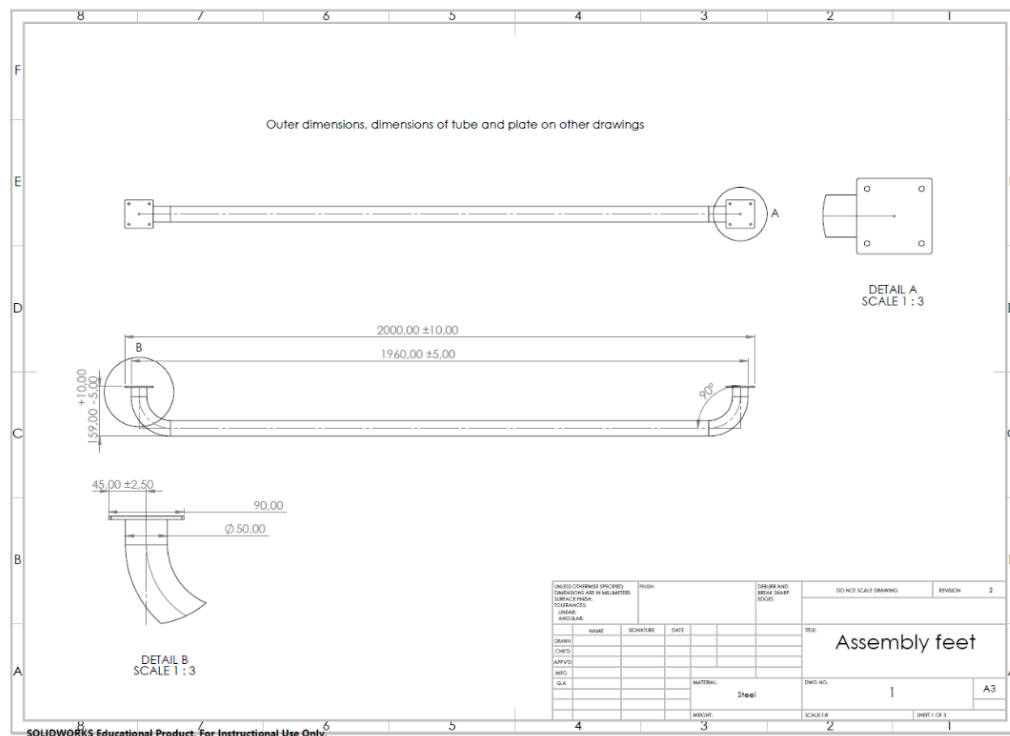


Figure 7.15 - Technical drawing assembly feet

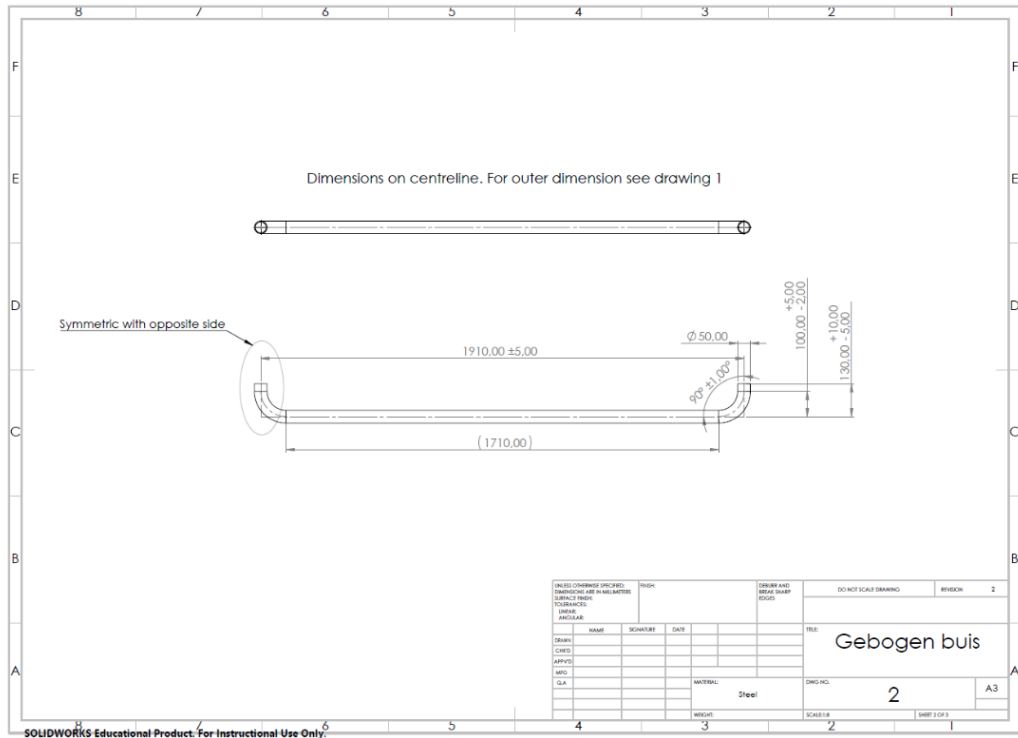


Figure 7.16 - Technical drawing bent tube

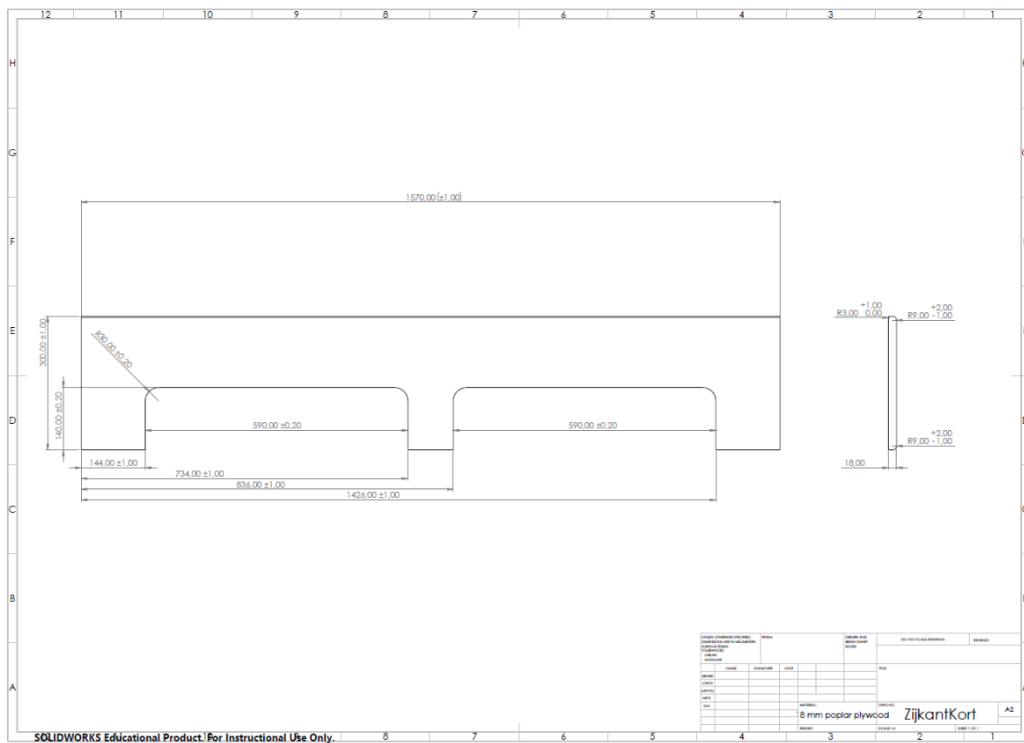


Figure 7.17 - Technical drawing outer frame side panel

## 7.5 Assembly in depth

This chapter contains the bill of materials and an assembly guide that outlines the order in which the Asper should be assembled.

### 7.5.1 Bill of materials

The bill of materials (BoM) has been split up into the five main sub-assemblies: base frame, head capsule, drawer 1, drawer 2 and the feet. Parts for optional features are at the bottom of the BoM . The bill of materials includes the part number, part name, outer part dimensions, part material, (estimated) part weight, part quantity and supplier of the part. Consumables that are applied to the parts (e.g. filler, paint, sandpaper and welding rod) are not included in the bill of materials.

Bill of materials (BoM)						
Part #	Part name	Outer part dimensions (mm)	Part material	(estimated) part weight (kg)	Part quantity	Part supplier
	<b>Base frame</b>					
1	FPS Box	117&248*92	Misc.	3,2	1	Comax
2	FPS mattress	2000*800*180	Misc.	8	1	NEWAS
3	Mattress baseplate	2010*810*18	18 mm poplar BB/B plywood	13,2	1	Schilte
4	W_supportwall_OCO	786*160*12	12 mm poplar CP/C plywood	0,68	3	Schilte
5	W_supportwall_2CO	786*160*12	12 mm poplar CP/C plywood	0,64	3	Schilte
6	W_supportwall_3CO	786*160*12	12 mm poplar CP/C plywood	0,63	1	Schilte
7	L_supportwall	2010*160*12	12 mm poplar CP/C plywood	1,74	1	Schilte
8	S_supportwall1	144*160*12	12 mm poplar CP/C plywood	0,12	1	Schilte
9	S_supportwall2	102*160*12	12 mm poplar CP/C plywood	0,09	1	Schilte
10	S_supportwall3	584*160*12	12 mm poplar CP/C plywood	0,5	1	Schilte
11	Feet_Mountingplate	110*144*12	12 mm poplar CP/C plywood	0,08	4	Schilte
12	FeetEnd	846*300*18	18 mm poplar BB/B plywood	2,1	1	Schilte
13	OuterFrame_Left	1570*300*18	18 mm poplar BB/B plywood	2,46	1	Schilte
14	OuterFrame_Right	1290*300*18	18 mm poplar BB/B plywood	3,31	1	Schilte
15	Dowel	6*40	Composite woodfibers	0,002	6	Schilte
	Woodscrew baseframe	4*25 & 4*16	Steel	0,005	81 + 4	Schilte

	Head capsule					
16	Capsule_Side_Long	720*1083*18	18 mm poplar BB/B plywood	6,32	1	Schilte
17	Capsule_Side_Short	440*1083*18	18 mm poplar BB/B plywood	3,86	1	Schilte
18	Bent_wood_Long	720*98(ir)*18	Fiberboard with poplar veneer	0,99	1	Holz in Form / Lang Formholz
19	Bent_wood_short	440*98(ir)*18	Fiberboard with poplar veneer	0,605	1	Holz in Form / Lang Formholz
20	Ceiling	720*620*18	18 mm poplar BB/B plywood	2,91	1	Schilte
21	BackPlate	1196*846*18	18 mm poplar BB/B plywood	8,2	1	Schilte
22	Angled_Bracket_Short1	35*35*220	Steel	0,24	1	Schilte
23	Angled_Bracket_Short2	35*35*160	Steel	0,16	1	Schilte
24	Angled_Bracket_Long	35*35*520	Steel	0,5	1	Schilte
25	FPS control panel	120*75*35	Misc.	0,3	1	Comax
26	FPS control wire	4*90	Misc.	0,05	1	Comax
27	LED strip	480*12*4	Misc.	0,08	1	Comax / LEDkoning
28	LED powersupply	159*46*18	Misc.	0,1	1	Comax / LEDkoning
29	LED controlbox	unknown	Misc.	0,2	1	Comax
30	LED wires	2,5*90	Misc.	0,05	1	Comax / LEDkoning
31	Alum_Extrusion	30*9,5*500	Aluminum	0,15	1	Comax / LEDkoning
32	PE_Foam_Sides	2400*720*20	PE (polyethelyne)	0,86	1	Eki
33	PE_Foam_Back	800*810*20	PE (polyethelyne)	0,38	1	Eki
34	Upholstery_Sides	2500*750	Polyester	0,72	1	Pintail
35	Upholstery_Back	850*850	Polyester	0,28	1	Pintail
36	Lamello type 20	56*24*4	Composite woodfibers	0,001	12	Schilte
37	HPL_Trespaschroef	4*30	Steel	0,005	12	Schilte
38	Shoulder sides	18*18*650	18 mm poplar BB/B plywood	0,058	4	Schilte
39	Shoulder ceiling	18*18*640	18 mm poplar BB/B plywood	0,056	2	Schilte
40	Staples	14*10	Steel	0,001	60	Schilte

	Woodscrew head capsule	4*25 & 4*16	Steel	0,005	12 & 18	Schilte
	<b>Drawer 1</b>					
41	Drawer_Baseplate	580*565*4	4 mm poplar BB/B plywood	0,55	1	Schilte
42	Drawer_Sides	556*125*12	12 mm poplar BB/B plywood	0,38	2	Schilte
43	Drawer_F&B	565*125*12	12 mm poplar BB/B plywood	0,38	2	Schilte
44	Drawer Frontplate	588*139*18	18 mm poplar BB/B plywood	0,58	1	Schilte
45	WurthSlides	550*35*12,7	Steel	0,8	2	Schilte
	Woodscrew drawer 1	4*25	Steel	0,005	12	Schilte
	<b>Drawer 2</b>					
41	Drawer_Baseplate	580*565*4	4 mm poplar BB/B plywood	0,55	1	Schilte
42	Drawer_Sides	556*125*12	12 mm poplar BB/B plywood	0,38	2	Schilte
46	Drawer_Divider	541*125*12	12 mm poplar BB/B plywood	0,36	1	Schilte
43	Drawer_F&B	565*125*12	12 mm poplar BB/B plywood	0,38	2	Schilte
44	Drawer Frontplate	588*139*18	18 mm poplar BB/B plywood	0,58	1	Schilte
45	WurthSlides	550*35*12,7	Steel	0,8	2	Schilte
	Woodscrew drawer 1	4*25	Steel	0,005	12	Schilte
	<b>Screws</b>					
47	Woodscrew total	4*25	Steel	0,005	117	Schilte
47	Woodscrew total	4*16	Steel	0,004	22	Schilte
	<b>Feet</b>					
47	Bent_Tube	1910*130 (50*2,6)	S235JRG2 steel	6,32	2	Busschers staalwerken b.v.
49	Connection_Plate	90*90*4	S235JRG2 steel	0,15	4	Busschers staalwerken b.v.
50	M6*30 Bolt	6*30	Steel	0,008	16	Schilte
51	M6 Nuts	8*8*4	Steel	0,003	16	Schilte
	<b>Casters</b>					
52	Tente Stylea 5925XGI075L51-10 DOM20	75*90*112	Misc.	0,29	4	Tente
53	P41-65x65/10	65*65*140	Steel	0,43	4	Tente

50	M6*30 Bolt	6*30	Steel	0,008	16	Schilte
51	M6 Nuts	8*8*4	Steel	0,003	16	Schilte
	<b>Coat hook</b>					
54	Intersteel 0023.695010	165*30*50	Steel	0,26	1	Intersteel
	<b>Electric blanket</b>					
55	Poweroutlet	70*70*40	Plastic	0,20	1	Schilte

Table 7.2 - Bill of Materials

## 7.5.2 Assembly guide

This guide provides a detailed description of all steps required to create the four wooden sub-assemblies as mentioned in the BoM. The steel feet only require 1 step, welding the mounting plates to the tube. In the last steps, the sub-assemblies are assembled to form the complete Asper.

### 7.5.2.1 - Base frame

#### 1. Assembling inner frame support front

To assemble the inner frame support front, part 8 and 2 times part 5 are required. Parts 5 are screwed onto part 8 in the (4) predrilled holes with 4\*25 screws.

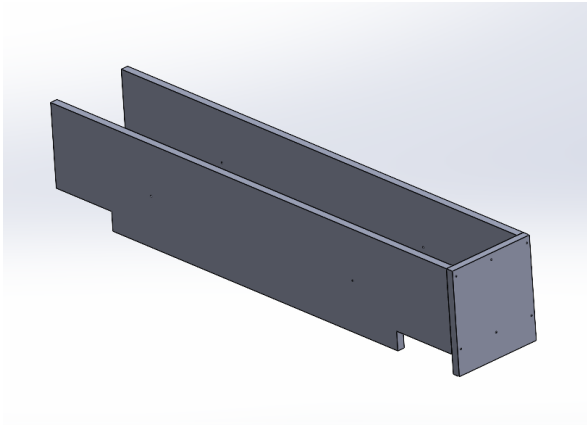


Figure 7.18 - Inner frame support front

#### 2. Assembling inner frame support middle

Assembling the inner frame support middle requires part 9 and 2 times part 4. Parts 4 are screwed onto part 9 in the (4) predrilled holes with 4\*25 screws.

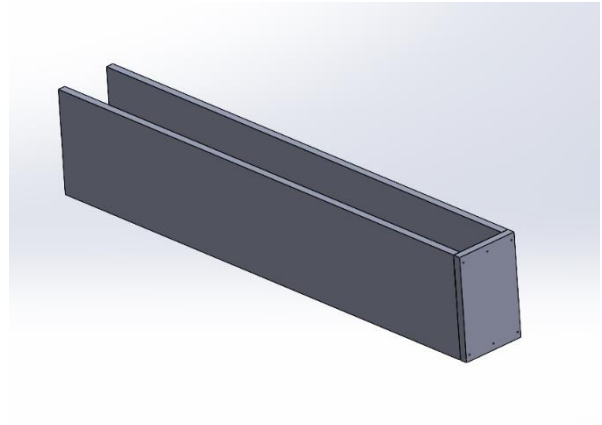


Figure 7.19 - Inner frame support middle

#### 3. Assembling inner support back

To assemble the inner frame support back, part 10, 2 times 5 and part 6 are required. Parts 5 and 6 are screwed onto part 10 in the (6) predrilled holes with 4\*25 screws.

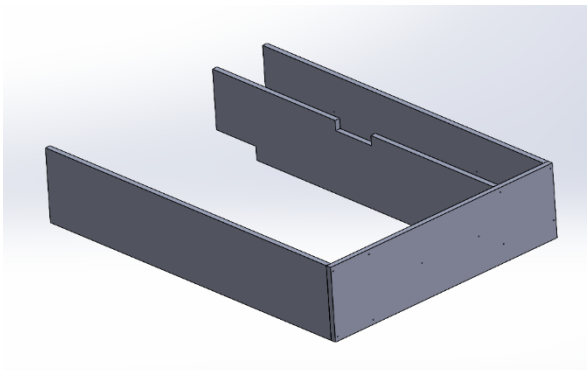


Figure 7.20 - Inner frame support back

#### 4. Connecting the Long support wall.

The squares from the previous steps are now connected to the long support wall (part 7). This is done with (14) 4\*25 screws.

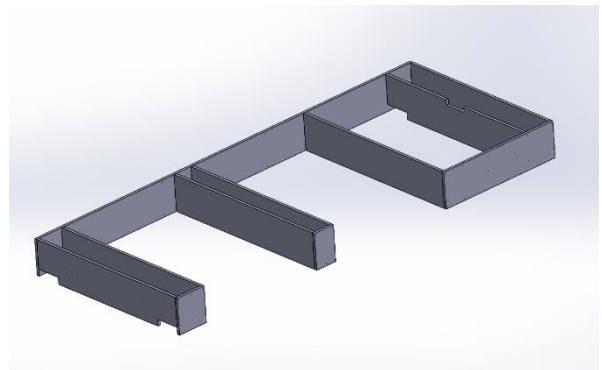


Figure 7.21 - Long support wall attachment



### 5. Attaching the mattress support base plate

The mattress support plate (part 3) is then screwed onto the previously connected parts. This is done with (23) 4\*25 screws.

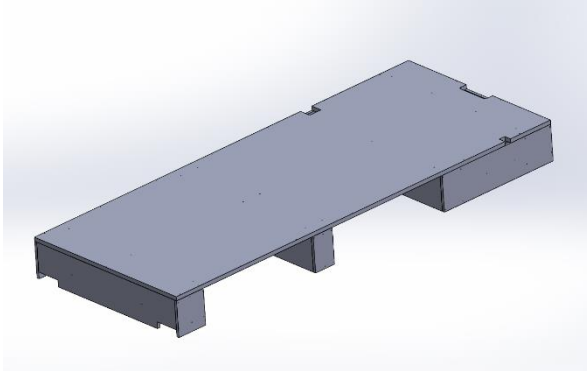


Figure 7.22 - mattress base plate attachment

### 6. Attaching the outer frame together

The outer frame requires part 12, 13 and 14. Part 13 and 14 (the sides) are attached to part 12 with glue and 3 dowels (part 15) each.

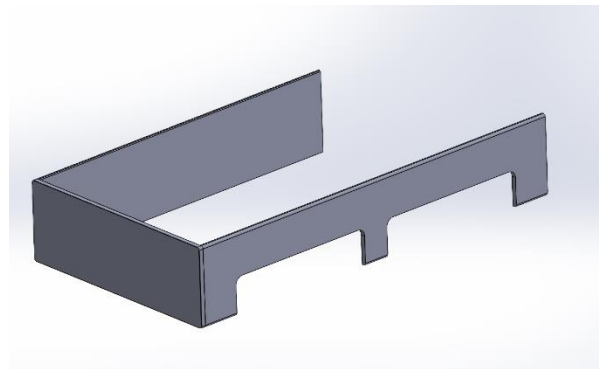


Figure 7.23 - Outer base frame

### 7. Connecting the inner frame and outer frame

The outer frame is slit over the inner frame and attached with (14) 4\*25 screws from the inside. The predrilled holes in part 7,8,9 and 10 are used.

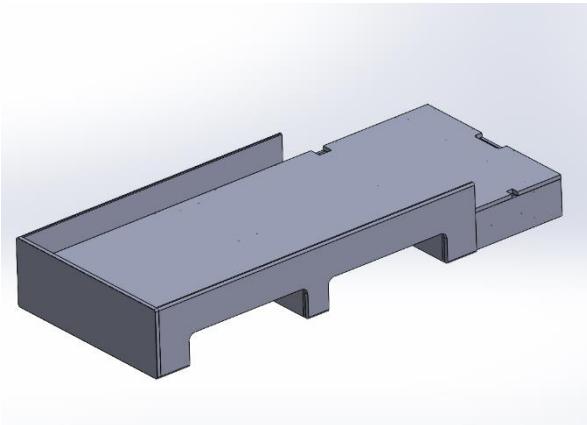


Figure 7.24 - Outer and inner base frame attachment

### 8. Attaching the feet mounting plates

The feet mounting plates (part 11) are attached by utilizing the 4 predrilled screw holes. Each plate is screwed into the inner frame support (parts 4,5 and 6).

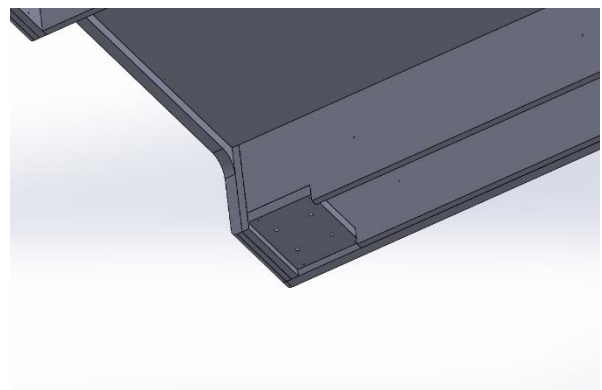


Figure 7.25 - feet mounting plates attachment

### 9. Screwing on the FPS box

When the baseframe is finished, the FPS box is screwed into the bottom with (4) 4\*16 screws. Holes for these screws are not predrilled.

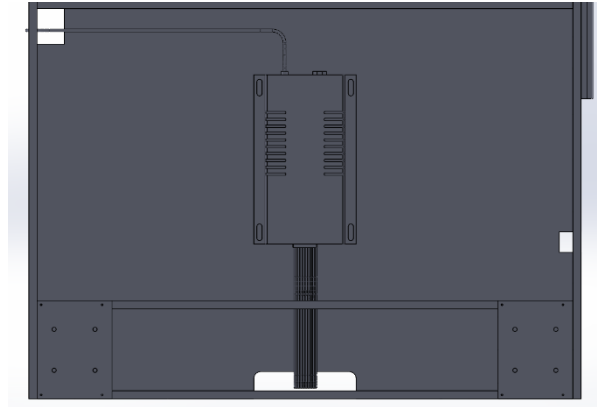


Figure 7.26 - FPS box attachment

### 7.5.2.2 - Head capsule

#### 1. Connecting the long sidewall and the long curve together

The long sidewall (part 16) and the long curved piece (part 18) are connected with the use of 3 lamellos and wood glue (part 36).

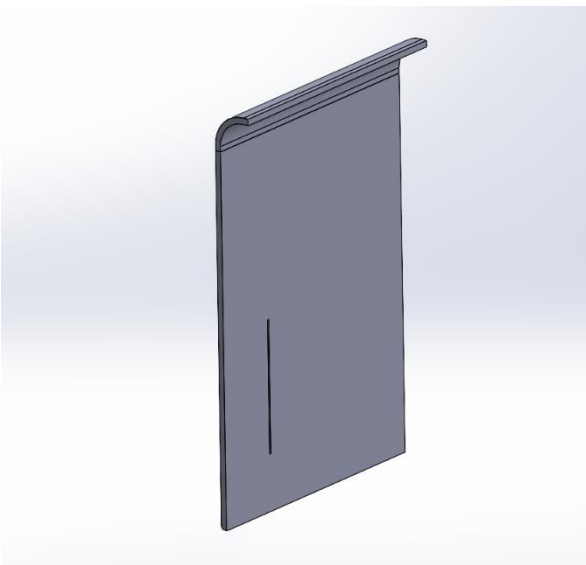


Figure 7.27 - Long sidewall & curve attachment

#### 2. Connecting the short sidewall and the short curve together

The short sidewall (part 17) and the short curved piece (part 19) are connected with the use of 3 lamellos and wood glue (part 36).

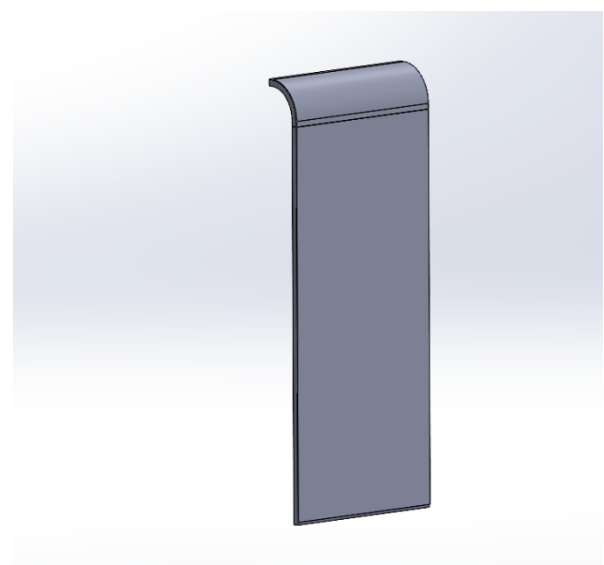


Figure 7.28 - Short sidewall & curve attachment

### 3. Connecting both sidewalls to the ceiling

After both sidewalls are attached to the curved pieces, they are attached to the ceiling (part 20). For each sidewall, 3 more lamellos (part 36) are used in combination with wood glue.

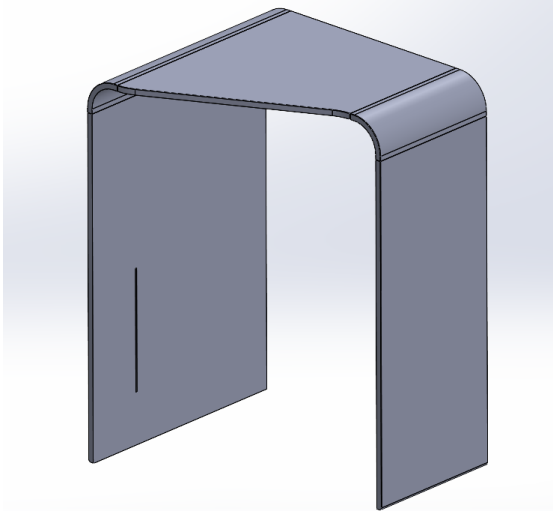


Figure 7.29 - Sidewalls & ceiling attachment

### 4. Attaching the internal shoulders

The internal shoulders (part 38 and 39) are glued and brad nailed in place. The shoulders are used to attach the upholstery to in step 5.

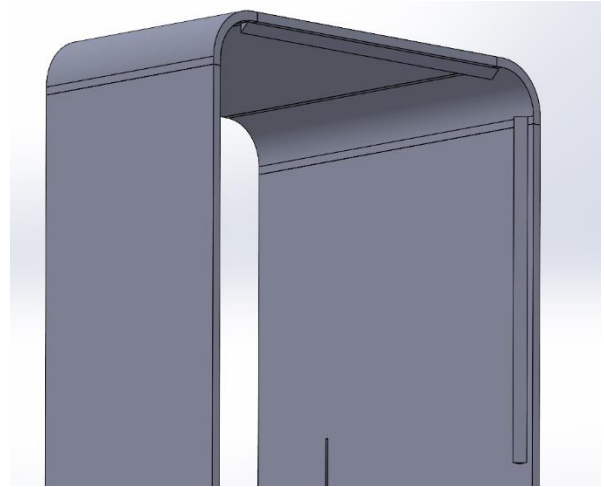


Figure 7.30 - Internal shoulders attachment

### 5. Inserting foam and attaching upholstery

The foam (part 32) is temporarily held in place with double sided tape, then the fabric (part 34) is stretched around the foam and attached with staples (part 40) in the sidewall, ceiling and internal shoulders.

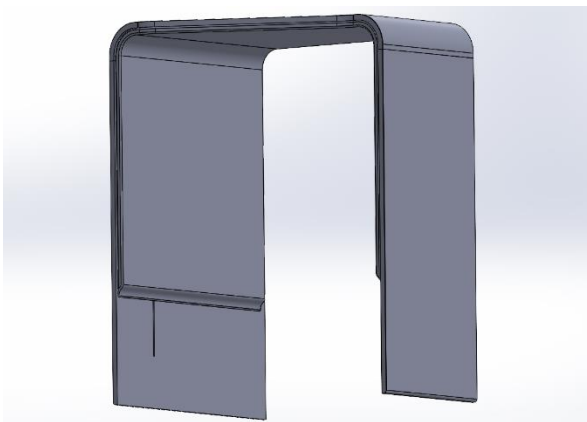


Figure 7.31 - Inserting foam

### 6. Attaching the FPS control panel

The fabric and foam are cut away to insert the FPS control panel (part 25). Its wire is routed through the cable cut-out (part 26).

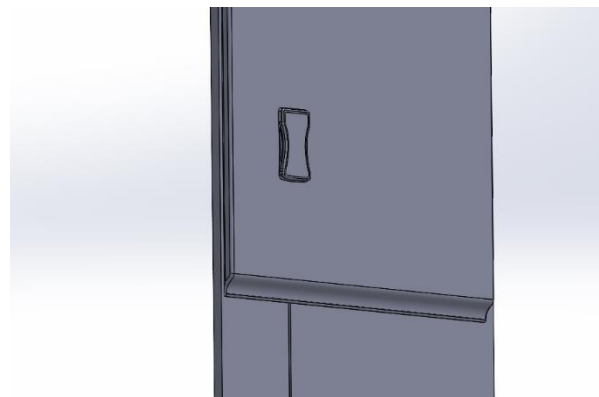


Figure 7.32 - Mounting FPS control panel

### 7. Inserting the LED strip

The after putting the LED strip (part 27) in its aluminium extrusion (part 31), a cut-out is made on its final location. The brackets are screwed into the wood and the extrusion is attached. The LED wire is fed through the cable cut-out.

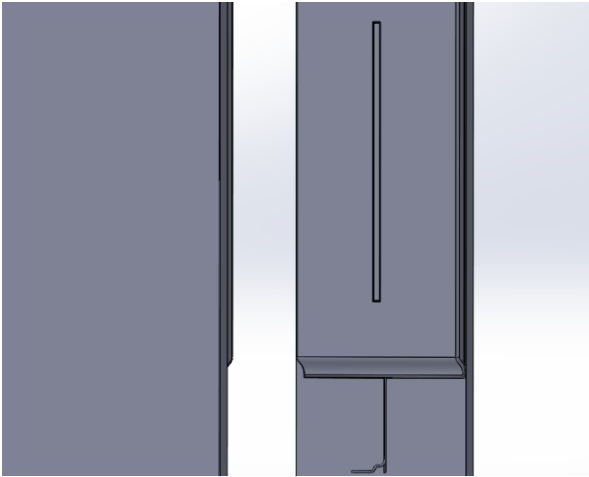


Figure 7.33 - Mounting LED strip

### 8. Attaching the backplate shoulders to the backplate

The backplate shoulders (part 38 and part 39) are attached to the backplate with brad nails and wood glue.

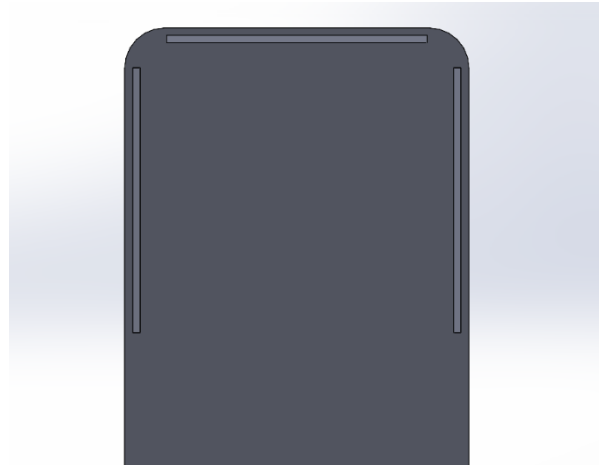


Figure 7.34 - backplate shoulders attachment

### 9. Inserting foam and attaching upholstery

The foam (part 33) is temporary held in place with double sided tape, then the fabric (part 33) is stretched around the foam and attached with staples (part 40) to the backplate and backplate shoulders.

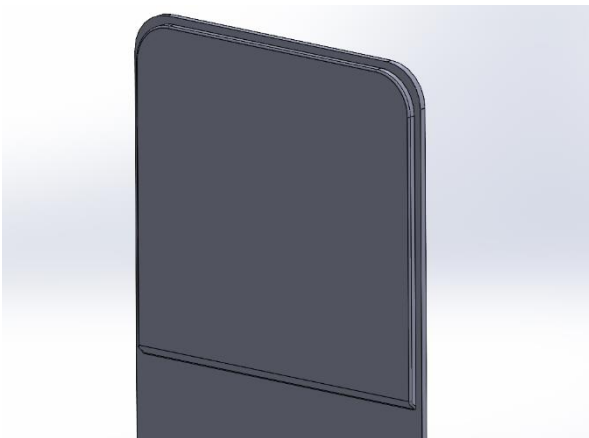


Figure 7.35 - Inserting foam and upholstery backplate

### 10. Attaching backplate to ceiling and sidewalls

The ceiling and sidewalls are attached to the backplate with (12) HPL 4\*30 decorative screws (par 37).

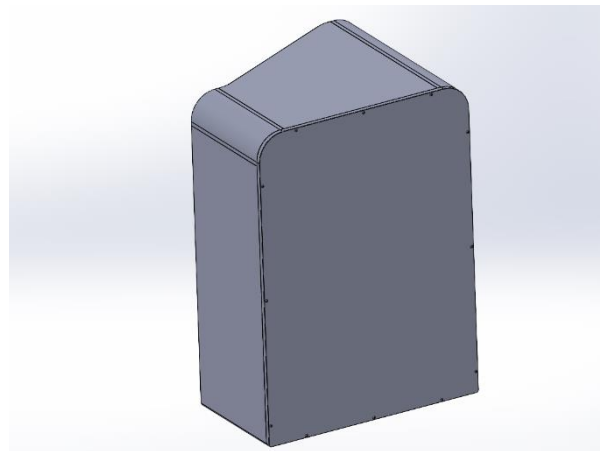


Figure 7.36 - Attaching backplate to sidewalls

### 11. Attaching the assembly support brackets

The assembly support brackets (22,23&24) are screwed into the head capsule sidewalls with (18) 4\*16 screws.



Figure 7.37 - Inserting assembly support brackets

### 7.5.2.3 - Drawer 1 and 2

#### 1. Drawer sidewalls and front + back

First, the sidewalls and front and back of the drawers (twice part 42 and 43) are attached. This is done with (8) 4\*25 screws that screwed in the predrilled holes.

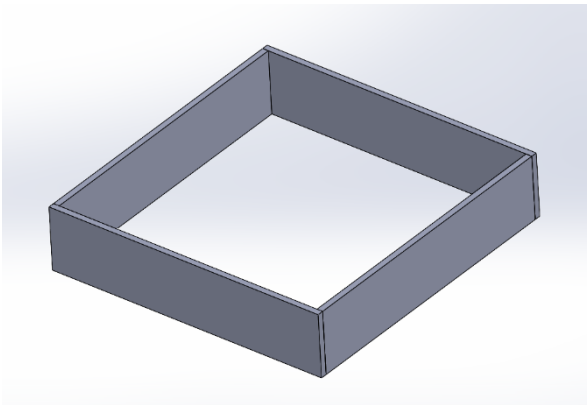


Figure 7.38 - Creating the drawer frame

#### 2. Bottom plate attachment

The bottom plate (part 41) is attached to the sides of the drawer with the use of brad nails.

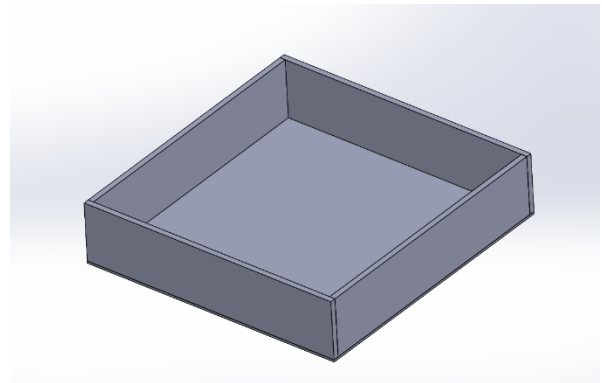


Figure 7.39 - Baseplate attachment

### 3. Attach the drawer rails

The drawer rails (part 45) are attached with the use of the screws that come with the rails to the sides of the drawer.

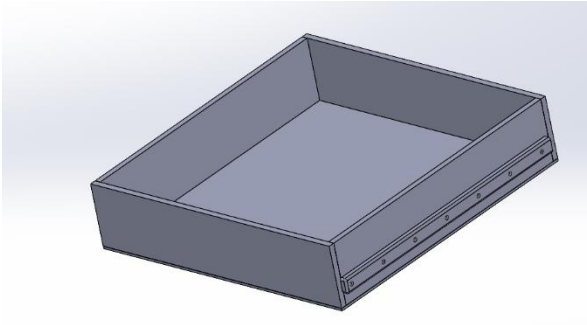


Figure 7.40 - Drawer rail attachment

### 4. (optional) Insert the drawer division

The drawer division (part 46) is inserted in drawer 2. In drawer 2, this step is skipped. The division wall is screwed in place from the outside of the sidewalls with (4) 4\*30 screws.

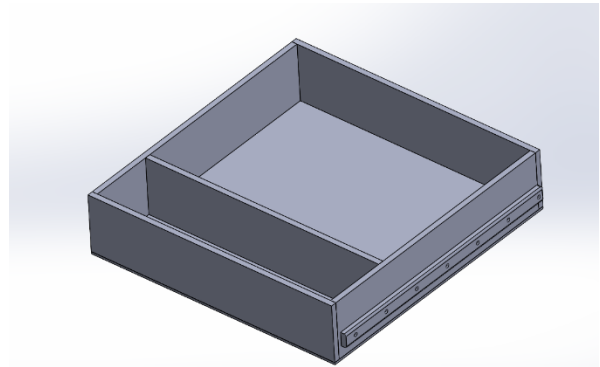


Figure 7.41 - Inserting drawer division

### 5. Insert drawers in base frame

To ensure proper alignment of the drawer front plate, the drawers are inserted into the base frame. The rails are screwed onto the inner frame supports with the rail screws.

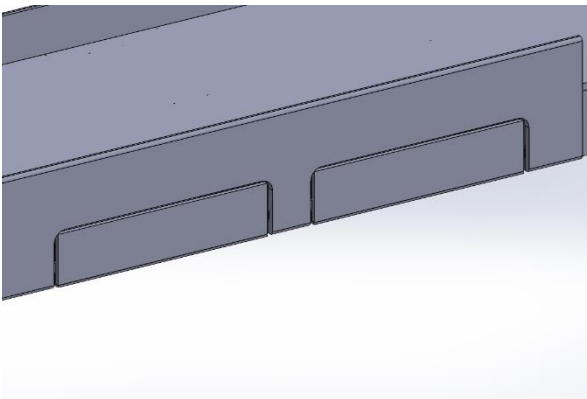


Figure 7.41 - Drawers in baseframe

### 6. Attach the front plate

The front plates are attached to the drawers in place. This allows them to be positioned just right, allowing for dimensions being slightly off in the base frame. The front plate temporarily attached with double sided tape until the right position has been reached, it is then permanently screwed in place from the back with (4) 4\*25 screws. After this step, the drawers are already attached to the base frame.

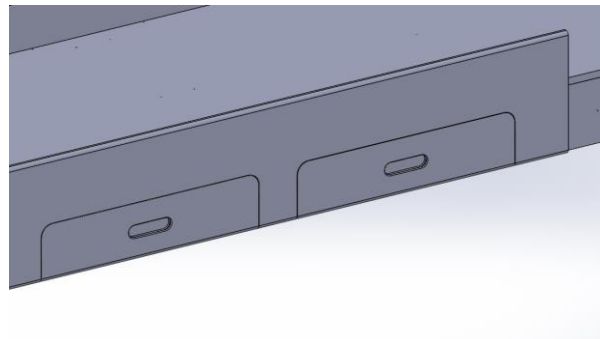


Figure 7.42 - Mounting drawer front plates

### 7.5.2.4 - Complete assembly

#### 1. Attaching the feet to the base frame

The first step in the complete assembly is to attach the feet to the complete assembly. The steel feet mounting plates (part 49) attach to the feet mounting plates in the base frame (part 11) with M6\*30 bolts and nuts (part 50 & 51).

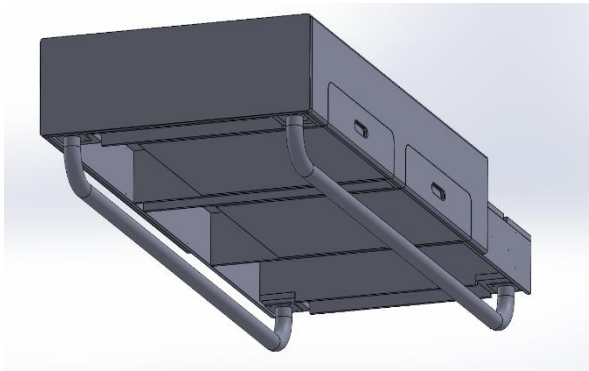


Figure 7.43 - Attaching steel feet

#### 2. Sliding the head capsule onto the base frame

On site, the two parts, head capsule and base frame are attached. The head capsule rests on the two brackets. These brackets are also used to attach the head capsule to the base frame with (18) 4\*16 screws. When attached, (4) more 4\*25 screws are screwed in from the inside of the base frame to prevent warping. These holes are predrilled.

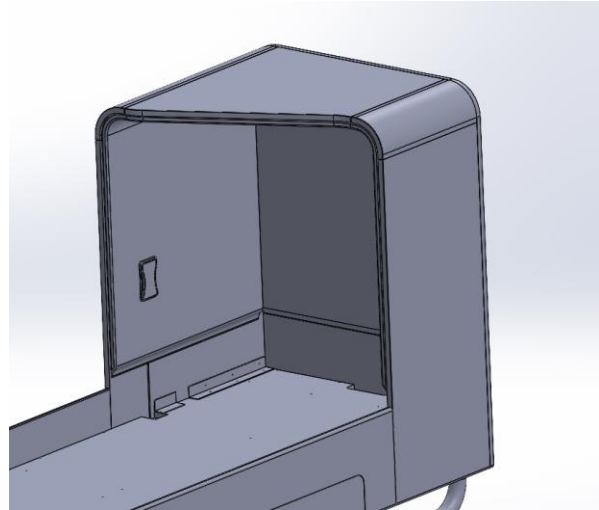


Figure 7.44 - Fixing base frame and head capsule

#### 3. Inserting the FPS mattress

When the structure is assembled, the FPS mattress is inserted.

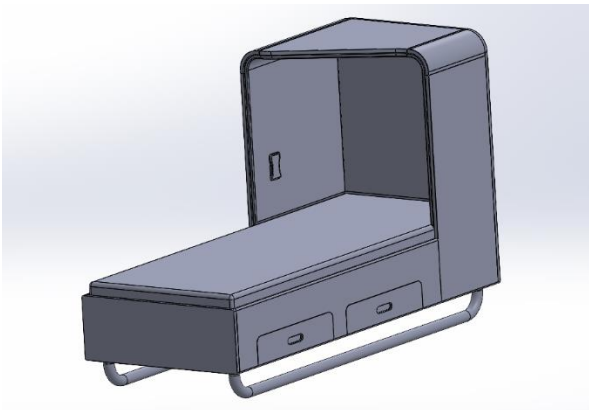


Figure 7.45 - Inserting FPS mattress

#### 4. Connecting all wires

Last, the FPS wires and LED wires are all attached to their respective energy sources.

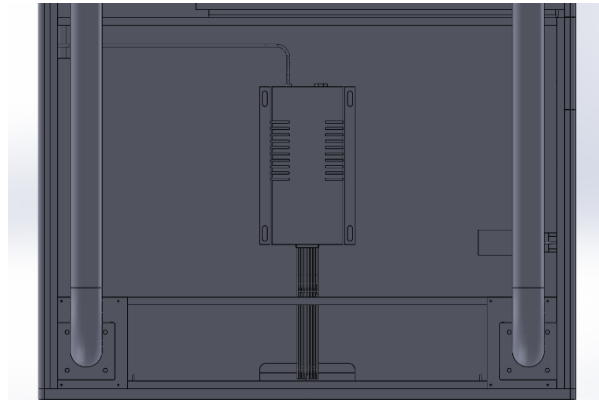


Figure 7.46 - Connecting wires

## 7.6 Conclusion

The Asper is a power nap bed that meets all requirements set in during the design process. Its design is soft, inviting and looks comfortable. The Asper will be available in 4 colour variants. The features included in the Asper are aimed at helping the user to take an effective power nap. Its dimensions are carefully selected to ensure the Asper fits in its context and is ergonomically sound. The Asper requires advanced manufacturing equipment, but is not excessively expensive to manufacture. The assembly process is simple and straightforward and has been described in detail. Overall, the design of the Asper is ready for its 0<sup>th</sup> production run and first users.



Figure 7.46 - Asper design



# Chapter 8. Conclusion

With the Asper ready for its 0<sup>th</sup> production run, this graduation project comes to an end. The design brief that was the beginning of this project was:

*Design a power napping bed, in which healthcare and industry night shift workers can take an optimal power nap. The design must cost less than €1500,- excl. VAT. to manufacture and should not require upfront investments of over €5000,- excl. VAT. The design should be comfortable, ergonomic and add value to the power nap besides the included FPS technology.*

Over the past 6 months, the Asper has been developed from what started as a few quick scribbles on paper to a fully developed product. First, extensive research was conducted about power napping, the context, users, stakeholders and competitors to create a complete program of requirements. Then ideation on product geometry, features, manufacturability and aesthetics was done. This led to three ideas being selected for concept development. Each concept went through 2 iterations during which the concepts were continually refined. After the second iteration and an extensive cost analysis, one concept was selected and iterated on twice more. These iterations defined the concepts final aesthetics and manufacturing methods. The fourth iteration is the Asper, a power napping bed in which healthcare and industry night shift workers can take an optimal power nap. The design costs less than €1500,- excl. VAT. to manufacture and does not require upfront investments of over €5000,- excl. VAT. The design is be comfortable, ergonomic and adds value to the power nap besides the included FPS technology.

## 8.1 Recommendations

From the design process and thesis, many recommendations can be derived for both students, researchers and NEWAS. To structure them, they have been divided in four categories.

### 8.1.1 Research recommendations

The first recommendations regard future research. These are recommendations for other students, scholars or researchers. They mainly pertain to the existing knowledge gaps both in the field of power napping and the design of the Asper.

- A universally accepted definition of a power nap should be developed to be able to better compare research on power naps.
- A standardized method of evaluating the effectiveness or quality of a power nap should be defined to improve further research efforts on the positive effects and effectiveness of power naps.

- More research should be done on the effect of (contextual and environmental) factors on the effectiveness of a power nap. By filling this knowledge gap, power napping can be optimized, enabling night shift workers to further reduce the negative effects of night shift work.

### **8.1.2 Further Asper development recommendations**

Despite the multiple iterations of the Asper, its development is not yet finished. Multiple aspects can still be further improved upon, as is usually the case with design projects. These recommendations describe areas of the Asper that could be developed further.

- The relaxation guidance feature should be further developed to aid user more with relaxing and falling asleep. This specific development might be an interesting topic for either a graduating Dfl student or a topic for a Dfl course.
- Although efforts have been made to significantly reduce the required material used in the Asper, more material can undoubtedly be removed. Either a redesigned inner frame or thinner plywood sheets can be tried. 2 additional 3D models will be provided to the client with 9mm and 8mm plywood sheets for the inner frame (instead of 12). No guarantee can be given about the strength of these models, however it might be worth testing.
- Another recommendation is to discuss the upholstery with a professional furnisher. Although the current solution will work and create a nice finish, a professional furnisher might have another, better solution that was not yet considered.

### **8.1.3 Manufacturing recommendations**

The following recommendations are about the manufacturing of the 0<sup>th</sup> series of the Asper.

- Before ordering the parts to be painted, double check that the selected colours match. The current colour combinations have been made with small fabric samples and a colour fan. If the colours do not match, either select a slightly different paint colour or contact me to help in selecting another colour.
- Attempt to minimize the number of suppliers. Ask if COMAX can also supply the LED's at (near) cost, since they will also be creating the LED controls. Make sure that the company bending the steel feet can also weld and powder coat or brush them.

### 8.1.4 Cost reduction recommendations

The next recommendations are provided in case costs need to be further reduced. They specify what parts can and cannot be changed to further reduce costs.

- The first element that should be considered when attempting to further reduce costs are the feet of the Asper. Although they add to the aesthetic qualities of the Asper, they also add a significant amount of material, manufacturing costs and weight. By replacing the feet with an available set of feet, significant cost reductions can be achieved.
- The second element that should be considered in cost reduction are the ball-bearing drawer slides from Würth. These can easily be replaced with a cheaper set of wheel rails. Replacing them does however come at the cost of quality and might make the drawers more wobbly.
- The third element that should be considered when trying to reduce costs is the fabric in the head capsule. A high quality, water and urine resistant fabric was selected as these qualities are required in healthcare, in industry however, such requirements do not exist. In these cases, another cheaper fabric might be worth considering.
- Things that should not be changed about the design of the Asper to further reduce costs are the main features (FPS, LED lighting, storage space and privacy structure) and outer geometry.

## 8.2 Acknowledgement

This graduation project marks the end of my study at the faculty of Industrial Design Engineering at the TU Delft. Although the project was individual, it could not have been accomplished without the support and advice from the amazing people around me.

First, I would like to thank Vera for the incredible amount of support through-out not only this graduation project, but my entire study at the TU Delft. I look forward to our future and whatever may come after this graduation.

Second, I would like to thank my supervisory team, Peter Vink and Maxim Smulders, for the great guidance, feedback and support given to me during the project. Peter, thank you for always being so positive, uplifting and understanding. Maxim, thank you for always being available to give great advice, even before I started my project.

Third, I would like to thank my client Peter Hartmanns for the opportunity and honest feedback. I really enjoyed working on this project and without you it would not have been possible. I especially appreciated openness to my ideas and willingness to discuss the design at any point. I look forward to hearing about the 0<sup>th</sup> production run and first sales.

Lastly, I would like to thank my parents, sister and friends for their support throughout my entire education. I could not have done it without you.

### 8.3 Reflection

Although the final result of this graduation project is, in my opinion, good, many (small) mistakes were made during this graduation project. I would like to mention the most important ones, to both learn from these myself, but also give potential pre-graduation students that are reading this report a heads-up.

The first thing I would like to mention, is to leave much more room for unforeseen activities, delays and other things that get in the way of staying on track of your original planning. Because of unforeseen delays and additional activities added to the project, my planning was hard to keep up with. The last few weeks have been exhausting, as I still had a lot of work to do. Although this hard work is worth it in the end, it probably could have been avoided.

Another thing I should mention is to integrate feedback instantly. A lot of valuable feedback I received from my supervisory team was integrated at later stages or even at the end of the project. This meant that some suggestions were no longer valid, as the project had already moved on.

Lastly, don't be afraid to involve experts into your project early on. Although this may seem obvious, I did not do this on time. By wanting to figure out things on my own, I spent a lot of time doing things that experts could have done or told me much quicker. This may be good for personal development and learning, but does come at the cost of project efficiency.

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# Appendix A - Original design brief

Personal Project Brief - IDE Master Graduation



Development of a powernap concept

project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 18 - 01 - 2021

18 - 06 - 2021

end date

## INTRODUCTION \*\*

Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

Vita Sentation, a label of NEWAS B.V., offers a range of power napping chairs. These chair provide a high level of comfort and relaxation thanks to their ergonomic design and Integrated Frequency Physio Support (FPS) technology. This technology utilizes low-frequency sound waves to generate vibrations that stimulate blood flow and relax the muscles. The existing chairs are currently used in a wide range of contexts by many different users for different purposes.

The most common use-cases are:

- Night shift recovery; people that work during the night, like in healthcare industry, are at a higher risk of heart and vascular diseases, diabetes, stress related problems and insomnia. These risks can be reduced by introducing recovery moments during a night shift. (NVAB, 2020) The chairs from Vita Sentation enable night shift workers to have effective recovery moments and feel more alert and vital.
- Corporate recovery spaces; A growing trend in companies is to provide employees with a space to relax during their workday. According to NEWAS b.v., this reduces stress and fatigue and increases productivity and quality of work. The powernap chairs enable employees to quickly and effectively rest and recover.
- Lounge areas; Vita Sentation also sells its chairs to places that have lounge areas like airports, hotels and even consumers that want to use the FPS technology for relaxation purposes.

During this project, the main focus will be on night shift recovery, as this has been identified to be the largest growth opportunity by NEWAS b.v.. Within this use case, a wide range of users and contexts exist like healthcare and industry. During the project an assessment will be made whether or not a more specific context needs to be selected. The commonality in these contexts is that there is a growing need for brief rest and relaxation during night shifts to increase alertness and reduce the risk of mistakes caused by fatigue.

Recently, NEWAS' existing customers have expressed their need for powernap solutions that allow the user to lay down, like in a bed. At the same time, competitors have started offering solutions that meet this demand. Ahrend offers the loungescape powernap and GoSleep offers their range of pods (Sold as BOOZTR in the Netherlands). NEWAS wants to offer a lay-down solution with their FPS technology that can compete with these products within the given context (environments where nightshift work is inevitable like healthcare and industry) and budget, between 4999,- and 6999,- retail. The development of this solution, a proof of concept, will be the main goal of this graduation project.

space available for images / figures on next page

**Personal Project Brief** - IDE Master Graduation

introduction (continued): space for images



image / figure 1: NEWAS power nap chair used by a construction worker.



image / figure 2: NEWAS power nap chair

**PROBLEM DEFINITION \*\***

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

Problem definition: develop a concept that meets the market demands for a lay-down power nap solution while balancing user needs like privacy when power napping, comfort and claustrophobic feeling when being in small a closed off space. The context is part of the design, and should be considered to strengthen the effect of the concept. The solution should be within budget, keep space restrictions (t.b.d.) in mind and other context related limitations.

In scope:

- Research: 1. Literature on relaxation, stress, power napping, shift work etc. 2. User needs and wants in night shifts.
- Research into - and definition of market demands and user needs.
- Exploration of other factors that can aid relaxation/power napping like: Light, sound, smell, temperature, colour etc.
- Ideation on potential solutions with sketching, collaging and other creative methods.
- Idea selection to be further developed. 2-3 Ideas selected Ideas max.
- Concept development of selected Ideas through sketching, 3D modeling and rendering.
- Concept selection for final proof of concept development.
- Developing final deliverable to client: proof of concept. (material selection, colours and textures and final geometry).
- Building testable prototype (potentially works-like real with scale looks like model).
- Testing and verifying proof of concept. Around technology readiness level 5 (Depends on subsystems)

Out of scope:

- Production engineering, i.e. final dimensioning, draft angles, tolerances, mounting positions, etc.
- After production engineering, i.e. assembly analysis and packaging analysis.
- Further development of FPS technology or extensive research on the effectiveness and working principles of FPS.
- Development of the FPS mattress.
- Creating promotional material for the product.

**ASSIGNMENT \*\***

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... . In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

During this assignment I will research various topics related to power napping, develop a range of ideas, select a few of them and further develop those into early concepts. One concept will then be chosen and further developed into a proof of concept product that meets market demand and balances the need for privacy, the risk of claustrophobia in closed of spaces and other context factors while being within budget (5-6k retail).

At the end of this graduation project, I expect to deliver a proof of concept for a lay-down power napping solution. This proof of concept will be a physical product that would fit in the context of hospital restrooms and common areas in industry. I will deliver a works-like-real prototype to test the effectiveness of the design. I also expect to implement some other features that improve or aid in the relaxation process, however it has not yet been decided what exactly these features will be.

**PLANNING AND APPROACH \*\***

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 18 - 1 - 2021 18 - 6 - 2021 end date



Above is my general planning. This might change slightly during the course of the project. I split up the project in 5 phases that last between 2 and 4 weeks. Each phase is worked out on a different sheet. See the added excel file.

## Appendix B - List of sleep hygiene recommendations

Retrieved from: [sleepeducation.org](https://sleepeducation.org)

- Keep a consistent sleep schedule. Get up at the same time every day, even on weekends or during vacations.
- Set a bedtime that is early enough for you to get at least 7-8 hours of sleep.
- Don't go to bed unless you are sleepy.
- If you don't fall asleep after 20 minutes, get out of bed. Go do a quiet activity without a lot of light exposure. It is especially important to not get on electronics.
- Establish a relaxing bedtime routine.
- Use your bed only for sleep and sex.
- Make your bedroom quiet and relaxing. Keep the room at a comfortable, cool temperature.
- Limit exposure to bright light in the evenings.
- Turn off electronic devices at least 30 minutes before bedtime.
- Don't eat a large meal before bedtime. If you are hungry at night, eat a light, healthy snack.
- Exercise regularly and maintain a healthy diet.
- Avoid consuming caffeine in the afternoon or evening.
- Avoid consuming alcohol before bedtime.
- Reduce your fluid intake before bedtime.



# Appendix C - Overview of competitors

<https://www.booztr.nl/>

## BOOZTR – Flatbed Pods



<https://www.booztr.nl/>

## BOOZTR – Flatbed Pods



### Description

BOOZTR is considered to be one of the main competitors of NEWAS. They sell different power napping solutions. One of those solutions is the Flatbed pod. Users can take a power nap in these pods in a lying position. Recently, BOOZTR has started selling the Flatbed pods with mattresses that are equipped with FPS technology. BOOZTR calls them deep relaxation pods. The user can manually pull the cover to close the pod from top to bottom.

### Pricing

The BOOZTR flatbed pods are sold for €5950,- excl. btw. The deep relaxation version with FPS technology costs €XXXX,- excl. btw.

### Dimensions

The BOOZTR flatbed pods are 225 x 100 x 116 cm.

### Materials

The BOOZTR Pods are probably made from vacuum formed plastic. The interior is covered with felt for noise reduction purposes. The mattress is made from a foam with latex wrapping.

### Features

The BOOZTR flatbed pods have the following features:

- Fully enclosed napping space that offers 90% light reduction and 15% noise reduction
- USB charging hub for phones and other devices
- Storage space for personal items
- Manual cover that closes from the top
- FPS mattress in the deep relaxation pods
- Can be personalized with wraps & stickers

### Design and other comments

The Flatbed pods are quite simplistic in design. This might attract users, as simplicity might be desired when introduced to the topic of power napping.

Its round shapes remind me of an egg. This shape also results in a friendly appearance.

From the inside, this product is very basic and slightly underdeveloped, the USB hub isn't neatly integrated. Furthermore, the folded, rough, steel construction underneath the pod does not match the soft appearance of the shell.

A main drawback of this design is the need to pull the cover manually, as the shape of the pod does not really allow the user to easily reach to the front of the pod when they are inside it.

## BOOZTR – Recliner Pods



## BOOZTR – Recliner Pods

### Description

BOOZTR is considered to be one of the main competitors of NEWAS. They sell different power napping solutions. One of those solutions is the Recliner pod. Users can take a power nap in these pods in a sitting or 'astronaut' position. The shells of this pod is the same as the shell from the flatbed pods, the interior however is different. A recliner frame is used to allow for adjustment in the sitting posture and position.



### Pricing

The BOOZTR recliner pods are sold for €7450,- excl. btw.

### Dimensions

The BOOZTR Recliner pods are 225 x 100 x 116 cm.

### Materials

The BOOZTR Pods are probably made from vacuum formed plastic. The interior is covered with felt for noise reduction purposes. The seating of the chair is made from foam with pleather upholstery.

### Features

The BOOZTR flatbed pods have the following features:

- Fully enclosed napping space that offers 90% light reduction and 15% noise reduction
- USB charging hub for phones and other devices
- Storage space for personal items
- Manual cover that closes from the top
- Adjustable seat
- Can be personalized with wraps & stickers

### Design and other comments

The Recliner pods are quite simplistic in design. This might attract users, as simplicity might be desired when introduced to the topic of power napping.

Its round shapes remind me of an egg. This shape also results in a friendly appearance.

From the inside, this product is very basic and slightly underdeveloped, the USB hub isn't neatly integrated. Furthermore, the folded, rough, steel construction underneath the pod does not match the soft appearance of the shell.

A main drawback of this design is the need to pull the cover manually, as the shape of the pod does not really allow the user to easily reach to the front of the pod when they are inside it.

## BOOZTR – Igloo Pods



## BOOZTR – Igloo pods

### Description

BOOZTR is considered to be one of the main competitors of NEWAS. They sell different power napping solutions. One of those solutions is the Igloo pod. Users can take a power nap in these pods in both a sitting or 'astronaut' position and while laying down. This pod is significantly larger than the other two pods and can also be used as a working space (according to BOOZTR) thanks to its foldable table. Its windows can be covered with blinds.



### Pricing

The BOOZTR Igloo pods are sold for ~€10000,- excl. btw.

### Dimensions

The BOOZTR Igloo pods are 230 x 100 x 152 cm.

### Materials

The BOOZTR Pods are probably made from vacuum formed plastic. The interior is covered with felt for noise reduction purposes. The seating of the chair is made from foam with pleather upholstery.

### Features

The BOOZTR flatbed pods have the following features:

- Fully enclosed napping space that offers 90% light reduction and 15% noise reduction
- USB charging hub for phones and other devices
- Storage space for personal items
- Manual cover that closes from the top
- Adjustable seat/bed
- Foldable table to turn the pod into a 'workspace'
- Dimmable light inside the pod
- Manual blinds on the sides to adjust privacy and light levels.

### Design and other comments

The Igloo pods are, in my opinion, ugly. They look like tiny caravans without wheels.

Its round shapes remind me of an egg. This shape also results in a friendly appearance.

The internals are, like the other pods, underdeveloped. The USB hub and other control panels are not neatly integrated. The windows are shaped in a strange manner and are set too far back into the panel.

I will not use this design for reference.

## Ahrend - Loungescape powernap



## Ahrend - Loungescape powernap

### Description

Ahrend, more specifically, the Loungescape powernap from Ahrend is another serious competitor in NEWAS' field. The Loungescape powernap is part of Ahrend's Loungescape line, an office furniture product line. The Loungescape powernap uses a 'wall' around the head and one side of the body to provide privacy and slightly reduce light and noise.



### Pricing

The Loungescape powernap is sold for €7000,- excl. btw.

### Dimensions

The Loungescape powernap is 228 x 80 x 118 cm.

### Materials

The Loungescape powernap is most likely made from timber and foam that is wrapped in a fabric like felt.

### Features

The Loungescape powernap has the following features:

- A privacy 'wall' that can be placed both on the left and right side of the product
- Hook to hang personal items from
- Headset (active noise control)
- Wireless smartphone charger
- A mattress with 'wholebody vibrations' from Neurosonic.
- The mattress is controlled through a tablet or phone with an app and can offer 3 different types of programs; relaxation, powernap and recovery
- Easily cleaned thanks to its fabrics (choice of fabric)

### Design and other comments

The Ahrend Loungescape powernap is a minimal, yet well designed power napping solution. Its shapes are soft and consistent. The colour use on this product is also excellent, highlighting the main functions with colour while not overdoing it.

The main drawback I see with this design is its limited ability to provide privacy, darkness and silence.

Furthermore, from preliminary research it was found that the use of shared headsets is not desired or even allowed in healthcare because of hygiene concerns.

Another drawback is the use of an app interface to control the system. Even though this provides a lot of opportunities to gather data and appears high-tech, it will either result in costs for keeping the software up-to-date or a degrading interaction as time passes and new software updates mess with the app.

The material and colour use in this design are something that might be useful when looking for inspiration.

# MetroNaps - EnergyPod



# MetroNaps - EnergyPod

## Description

Another competitor is the EnergyPod from MetroNaps. This futuristic recliner chair does not offer a massage/vibration mattress like the previous two competitors. It does however offer a comfortable, ergonomic 'zero-gravity' position that reduces pressure on the cardiac system. The EnergyPod also offers privacy with its visor. Inside the pod, music composed for the EnergyPod is played through its speaker or via headphone. Lastly, it comes with the 'I20' technology, the firmware that set the timer, plays music and helps the user to wake up with gentle vibrations and lights at the end of the nap.

## Pricing

The EnergyPod is sold for approximately €12000,- excl. btw.

## Dimensions

The EnergyPod powernap is 213 x 122 x 147 cm.

## Materials

The EnergyPod a plastic shell around a steel construction. The upholstery is made from high quality synthetic leather, making it easy to clean.



## Features

The EnergyPod has the following features:

- A rotating privacy visor.
- Ergonomic 'zero-gravity' position
- Powernap programs with composed music and gentle wake-up sequence with vibrations and lights
- Built in Bose speaker and headphone jack
- Two internal storage compartments
- Easy interface that allows the user to set the exact time.

## Design and other comments

The EnergyPod is a very futuristic looking powernap solution that sparks one's imagination. Its uncommon shape makes people curious and helps to sell its story, unlike for example the NEWAS chair.

Visually, the design is also appealing. It looks well developed and can definitely stand on its own. One drawback of such a design might be its inability to blend with its environment. It can also stand out like a sore thumb if the context doesn't match the design of the chair.

A small disadvantage in this design is the bent steel of the base. Like the pods from BOOZTR, this base does not fit with the visual style of the chair.

Colour wise, the EnergyPod is very basic, and might be considered a bit 'cold and unfriendly'. The use of warmer or more colourful colours might help, although this could also reduce its futuristic, spaceshipy look.

The EnergyPod and its design tell a story on itself without needing much explanation. This is a strong point and should be achieved in the design of the concept.

## Metawake – Powernap Pod



## Metawake – Powernap Pod

### Description

The Powernap Pod from Metawake is a basic solution to the powernap problem. It was designed by 2 TU Delft students and is now sold as a quick and basic option to try out powernaps. The Powernap Pod does not have many of the features the other solutions offer. It does however offer privacy with an automatic roller blind.

### Pricing

The Powernap Pod is sold for €1750,- excl. btw. Making it the cheapest available option.

### Dimensions

The Powernap Pods are 204 x 85 x 121 cm.

### Materials

The Powernap Pod is made from birch plywood. The mattress is upholstered with synthetic leather.



### Features

The Powernap Pod has the following features:

- Enclosed powernap space with an automatic blind
- Can be used as a 'stand-up' table.
- Relatively cheap when compared with competitors.

### Design and other comments

The Powernap Pod is extremely boxy. It looks like something that can easily be made in someone's shed.

In my opinion, it has very little design value. I do however like the material choice, as the natural aesthetic might help with relaxing and sleep (Biophilic design).

## Look industries – N.A.P.



## Look industries – N.A.P.

### Description

The N.A.P. is a powernap solution with a fixed 'sitting' position. It includes the same Neurosonic vibration technology as the Ahrend Loungescape Powernap. The N.A.P. is controlled through a built-in tablet where the user can select different (powernap) programs. It comes with casters, making the position much easier to manipulate.

### Pricing

The N.A.P. is sold for approximately €16000,- excl. btw.

### Dimensions

The N.A.P. is 210 x 80 x 148 cm.

### Materials

The N.A.P. is made from compression moulded birch, steel and high-quality foam upholstered with fabrics.



### Features

The N.A.P. has the following features:

- Neurosonic vibration technology with relaxation, recovery and activation programs.
- A tablet for ease of control.
- Casters for easy transportation.
- High quality fabrics from Kvadrat

### Design and other comments

The N.A.P. is a clean, minimalistic looking piece of furniture. Its external soft and round shapes form a nice contradiction with the harder, sharper shapes inside the cabinet.

One draw-back that I expect is the use of the tablet, this will quickly make the product seem old with the advancement of technology.

Another disadvantage is the lack of cover from one side. If the N.A.P. is positioned like in the previous image, it offers almost no privacy. This can of course be solved by turning it around, which is easy because of the casters.

Generally, I quite like this design. Except for the red version (see website).

## Sleepwing LTD - Podtime premium



## Sleepwing LTD - Podtime premium

### Description

Podtime is a powernapping pod that has a sliding housing (see image). Its round, unique design are visually attractive. The frame that holds the mattress can be configured to both be flat and s-curved. There is no further technology inside the pod.

### Pricing

The Podtime premium is sold for approximately €6500,- excl. btw.

### Dimensions

The BOOZTR Igloo pods are 223 x 120 x 132 cm.

### Materials

I currently do not know anything about the materials used in the Podtime. The mattress is covered with fabric.

### Features

The Podtime premium has the following features:

- 'Easy entry' thanks to the sliding door
- Privacy as a result of being a closed off capsule
- Ambient noisereduction.
- Flat and s-curve mattress configuration.
- Naturally ventilated (holes)
- Adjustable seat/bed

### Design and other comments

The Podtime premium is well designed on all fronts. Both the mattress, housing and construction are neat and well integrated. The shape language is uniform and consistent. I especially like the colour use for the mattress, as it contrasts well with the white shell.

My main concern is entering and exiting the pod, as the opening does not appear to be that large.

Another concern I have is the apparent limited space inside the pod. From the images it seems quite small.





# Napshell



# Napshell

## Description

Napshell is another solution to power napping. Despite its high-tech futuristic look, it is relatively old when compared to the others. It offers a semi-closed space to power nap in on its undulated, 15 cm thick, mattress. Inside the Napshell LEDs light up the space, sadly these are not used for relaxation or waking up purposes.



## Pricing

The Napshell is sold for €15000,- excl. btw.

## Dimensions

The Napshell is 292 x 134 x 144 cm.

## Materials

The Napshell is made from fiberglass-reinforced plastic and finished with a high-gloss varnish.

## Features

The BOOZTR flatbed pods have the following features:

- Semi-enclosed space to reduce visual interest / distractions.
- 15 cm thick cold foam mattress that contours the body.
- Undulated s-curved mattress with calfskin leather upholstery
- LEDs to light the space up and for decoration.

## Design and other comments

The Napshell is a well designed piece of furniture. It does however have a unique look that only fits in a very limited number of interiors.

A drawback of this design is the inability to provide sufficient privacy thanks to its openness.

Another missed opportunity of this design is the limited use of the LED's capability.

Overall, this design is good for inspiration but not very practical.

# Appendix D - User research questions

## Onderzoek nachtwerkers

### *Toelichting – Waarom dit onderzoek?*

NEWAS b.v. produceert momenteel powernap stoelen voor mensen met onregelmatige ploegendienst. (Zoals bijvoorbeeld vroege ochtend-, late avond- en nachtdiensten) Vanuit bestaande klanten krijgt NEWAS regelmatig vragen over een liggende powernap oplossingen. Deze markt vraag wordt door concurrenten beantwoord, maar nog niet door NEWAS. Dit onderzoek is onderdeel van een project om ook een liggende powernap oplossing te kunnen bieden.

Het doel van dit onderzoek is het beter in kaart brengen van de obstakels en behoeften die nachtwerkers hebben tijdens hun dienst omtrent powernaps. Door een beter beeld te krijgen van de eindgebruikers en het gebruik kan de oplossing beter aansluiten bij de vraag.

De vragen zijn opgedeeld in 3 categorieën, introductie vragen + extensie (pg.3), vragen over 'rust-factoren' en vragen over features of productkenmerken.

## Afbeeldingen – huidige oplossing NEWAS



**Datum :**

**Deelnemer:**

### **Introductievragen**

Het doel van deze vragen is mensen te introduceren, een paar makkelijke vragen te laten beantwoorden en relevante informatie over de persoon, diens werk en huidig gebruik van rustmomenten/powernaps te verkrijgen.

- Uit onderzoek blijkt dat leeftijd en het hebben van kinderen van invloed kan zijn op verschillende factoren bij nachtwerk; Hoe oud bent u en heeft u kinderen?

\_\_\_\_\_

\_\_\_\_\_

- Kunt u iets meer vertellen over uw beroep? Wat doet u zoal tijdens uw werk?  
(Sector/afdeling)

\_\_\_\_\_

\_\_\_\_\_

- Hoe lang werkt u al in dit veld? Is er veel veranderd in die tijd?

\_\_\_\_\_

\_\_\_\_\_

- Klopt het dat u dit werk in ploegendienst doet? Doet u ook nachtdiensten?  
Ja / Nee \_\_\_\_\_

- Kunt u wat meer vertellen over uw rooster? Hoeveel ochtend/dag/avond/nacht diensten draait u achter elkaar en in welke volgorde?

\_\_\_\_\_

\_\_\_\_\_

- Hoe kijkt u aan tegen het nemen van een rustmoment of powernap op het werk?

\_\_\_\_\_

\_\_\_\_\_

- Wordt het nemen van een rustmoment aangemoedigd op uw werk? Zo ja, zijn er faciliteiten om dit te doen? Zo nee, waarom niet?

Ja / Nee \_\_\_\_\_

\_\_\_\_\_

- Neemt u tijdens het werken wel eens een rustmoment of powernap? Zo ja, kunt u daar meer over vertellen? Zo niet, waarom niet?

Ja / Nee \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

**Vragen voor nachtwerkers die wel powernappen met faciliteiten.**

- Wat zijn voor u de randvoorwaarden om een goede powernap te doen of te ontspannen voor een herstelmoment?

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- Kunt u de faciliteiten die worden geboden door uw werkgever beschrijven? Hoe zouden deze kunnen worden verbeterd?

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---

**Vragen voor mensen die wel powernappen zonder faciliteiten.**

- Zou u baat hebben bij een faciliteit voor een rustmoment/powernap?

Ja / Nee \_\_\_\_\_

---

---

- Wat zijn voor u de randvoorwaarden om een goede powernap te doen of te ontspannen voor een herstelmoment?

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**Vragen voor mensen die niet powernappen met faciliteiten.**

- Kunt u de faciliteiten die worden geboden door uw werkgever beschrijven?

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- Zou u gebruik maken van andere rustmoment/powernap faciliteiten? Zo ja, waar zouden deze faciliteiten aan moeten voldoen om goed te kunnen rusten/powernappen? Zo nee, waarom niet?

Ja / Nee

---

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**Vragen voor mensen die niet powernappen zonder faciliteiten.**

- Zou u gebruik maken van een rustmoment/powernap faciliteit? Zo niet, waarom niet?

Ja / Nee \_\_\_\_\_

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- Wat zijn voor u de randvoorwaarden om een goede powernap te doen of te ontspannen voor een herstelmoment?

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### Vragen over 'rust-factoren'.

Er zijn een aantal factoren waarvan wordt verwacht dat deze belangrijk zijn bij het nemen van een rustmoment of powernap. Het doel van deze vragen is toetsen of dat klopt voor deze factoren en welke aspecten van de factoren mensen in ploegendienst belangrijk vinden.

- Hoe belangrijk is privacy voor u tijdens een rustmoment of powernap?

Zeer onbelangrijk	1	2	3	4	5	6	7	Zeer belangrijk
	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	

- Wat vindt u belangrijk aan privacy? (Niet zichtbaar, alleen zijn, niet hoorbaar, hoeveel privacy?, etc.)

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- Hoe belangrijk is comfort voor u tijdens een rustmoment of powernap?

Zeer onbelangrijk	1	2	3	4	5	6	7	Zeer belangrijk
	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	

- Wat vindt u belangrijk aan comfort? Welke aspecten hebben hierop invloed? (houding, temperatuur, kussens, licht, etc.)

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- Hoe belangrijk is stilte (of geluid) voor u tijdens een rustmoment of powernap?

Zeer onbelangrijk	1	2	3	4	5	6	7	Zeer belangrijk
	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	

- Wat vindt u belangrijk aan stilte of geluid? Welke geluiden wilt u wel/niet horen?

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- Hoe belangrijk is 'donker zijn van de ruimte' voor u tijdens een rustmoment of powernap?

Zeer onbelangrijk	1	2	3	4	5	6	7	Zeer belangrijk
	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	

- Hoe donker/licht is de ideale ruimte voor een powernap of rustmoment?

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- Hoe belangrijk is de juiste temperatuur voor u tijdens een rustmoment of powernap?

Zeer onbelangrijk	1 ○	2 ○	3 ○	4 ○	5 ○	6 ○	7 ○	Zeer belangrijk
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- Hoe zou u de temperatuur willen regelen? Hoe warm? Ventilatie?

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- Zijn er nog andere factoren die niet benoemd zijn maar in uw mening wel belangrijk zijn? Hoe belangrijk zijn deze op dezelfde schaal van 1 tot 7?

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**Vragen over product-kenmerken of features.**

Deze vragen gaan over potentiële product-kenmerken die potentieel in het ontwerp kunnen worden geïmplementeerd. Zo krijgen we vroeg in het proces een idee van wat gebruikers vinden van bepaalde kenmerken.

- Vind u een opslagmogelijkheid voor bijv. persoonlijke spullen in het product belangrijk? Ja/nee, want: \_\_\_\_\_

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- Vind u een (draadloze) oplaadmogelijkheid voor uw telefoon of andere apparaten in het product belangrijk?

Ja/nee, want: \_\_\_\_\_

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- Vind u de mogelijkheid muziek te spelen d.m.v. speakers in het product belangrijk?

Ja/nee, want: \_\_\_\_\_

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- Vind u het belangrijk dat het product verrijdbaar of anders makkelijk verplaatsbaar is?

Ja/nee, want: \_\_\_\_\_

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- Vind u het belangrijk dat het product achteraf informatie/feedback geeft op uw rustmoment / powernap?

Ja/nee, want: \_\_\_\_\_

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- Vind u het belangrijk dat het product helpt met ontspannen d.m.v. bijv. ondersteunende ademhalingsoefeningen?

Ja/nee, want: \_\_\_\_\_

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- Vind u het belangrijk dat het product een klokje/ wekkertje heeft om diepe slaap te voorkomen?

Ja/nee, want: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

- Vind u het belangrijk dat het product een spiegeltje heeft om na het ontwaken jezelf te fatsoeneren?

Ja/nee, want: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

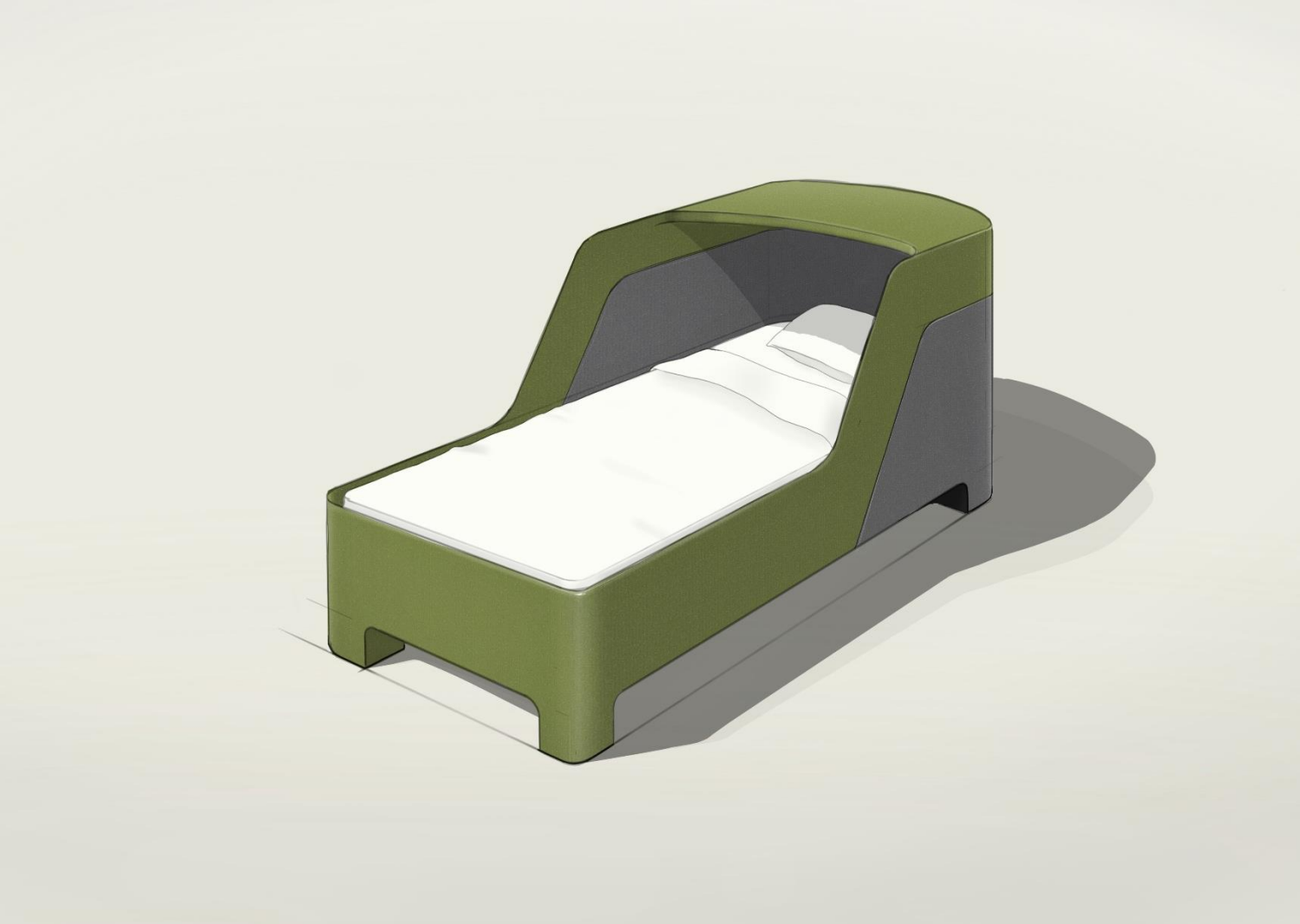
- Vind u het belangrijk dat het product een deken en/of kussen heeft?

Ja/nee, want: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

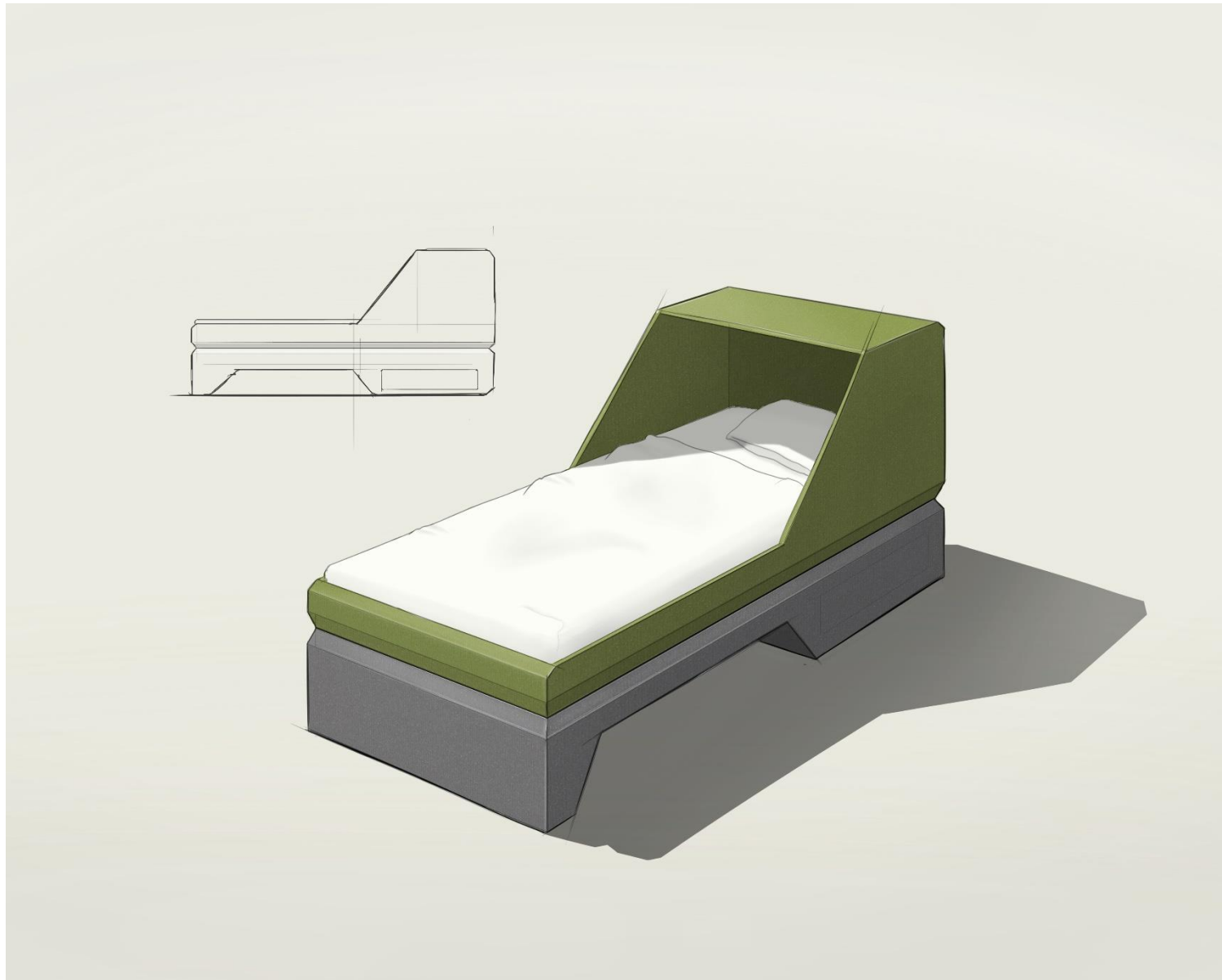
- Zijn er nog andere product-kenmerken die u graag terug ziet in het product?

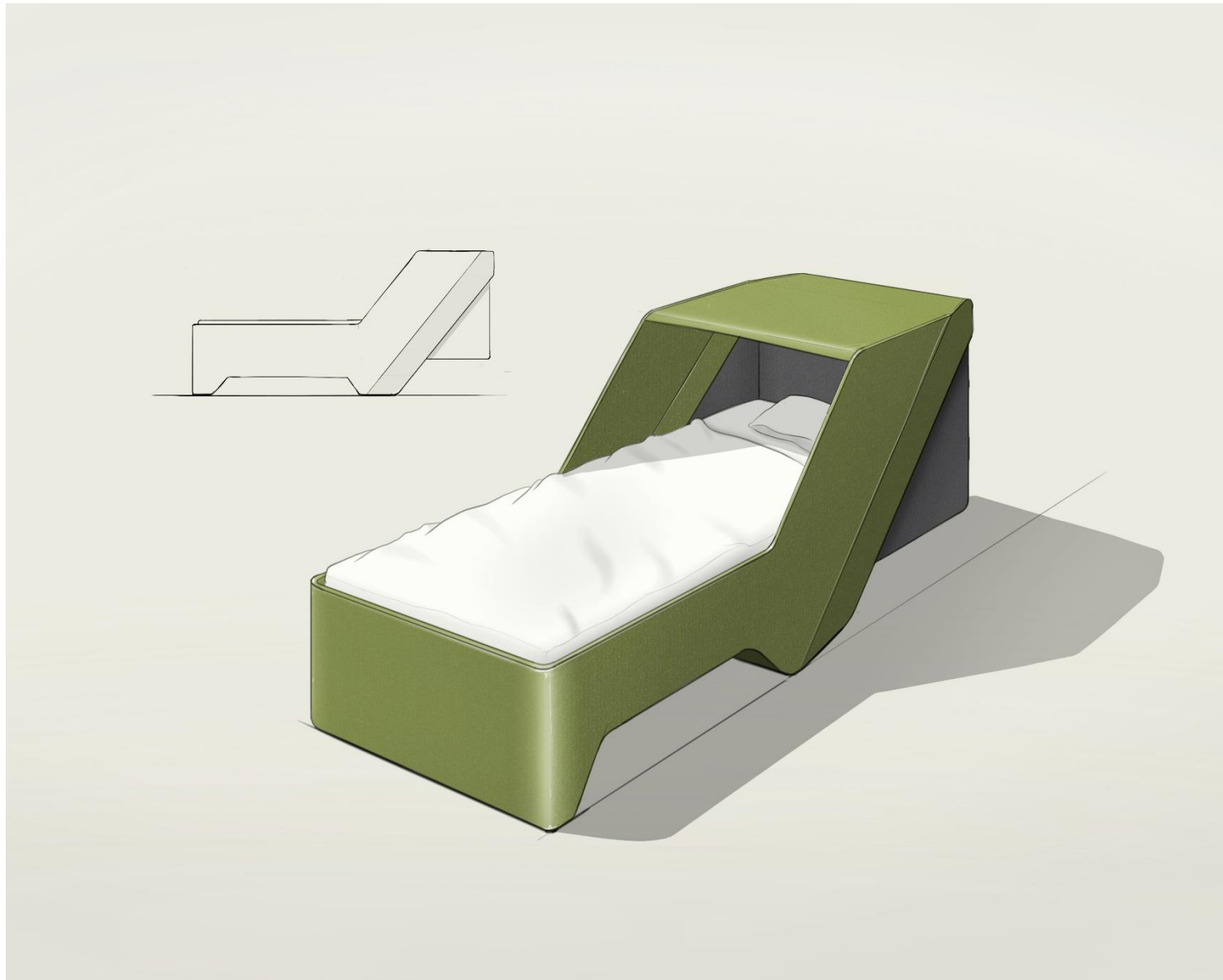
**Ja, namelijk:** \_\_\_\_\_

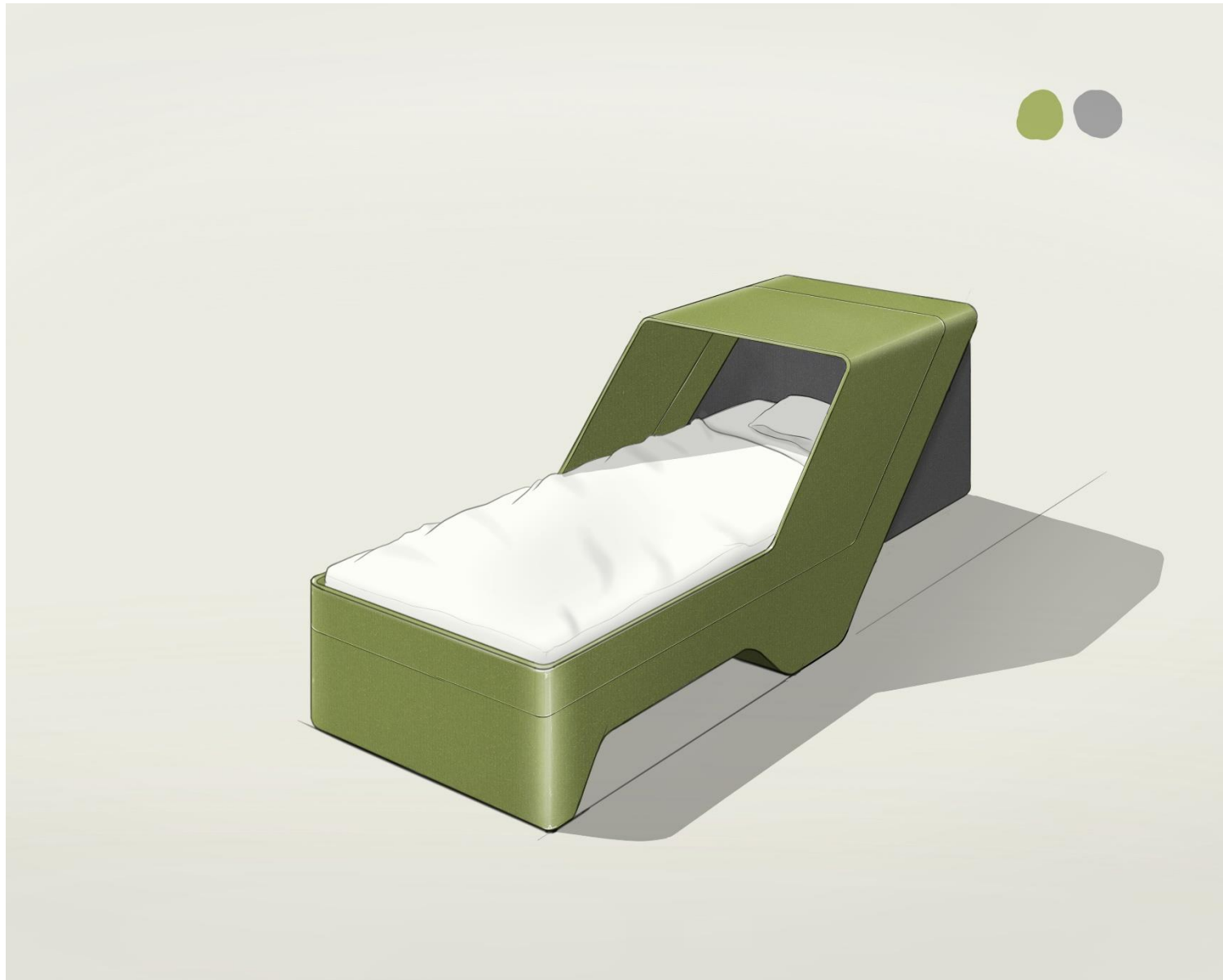
**Appendix E - Full resolution ideation sketches**

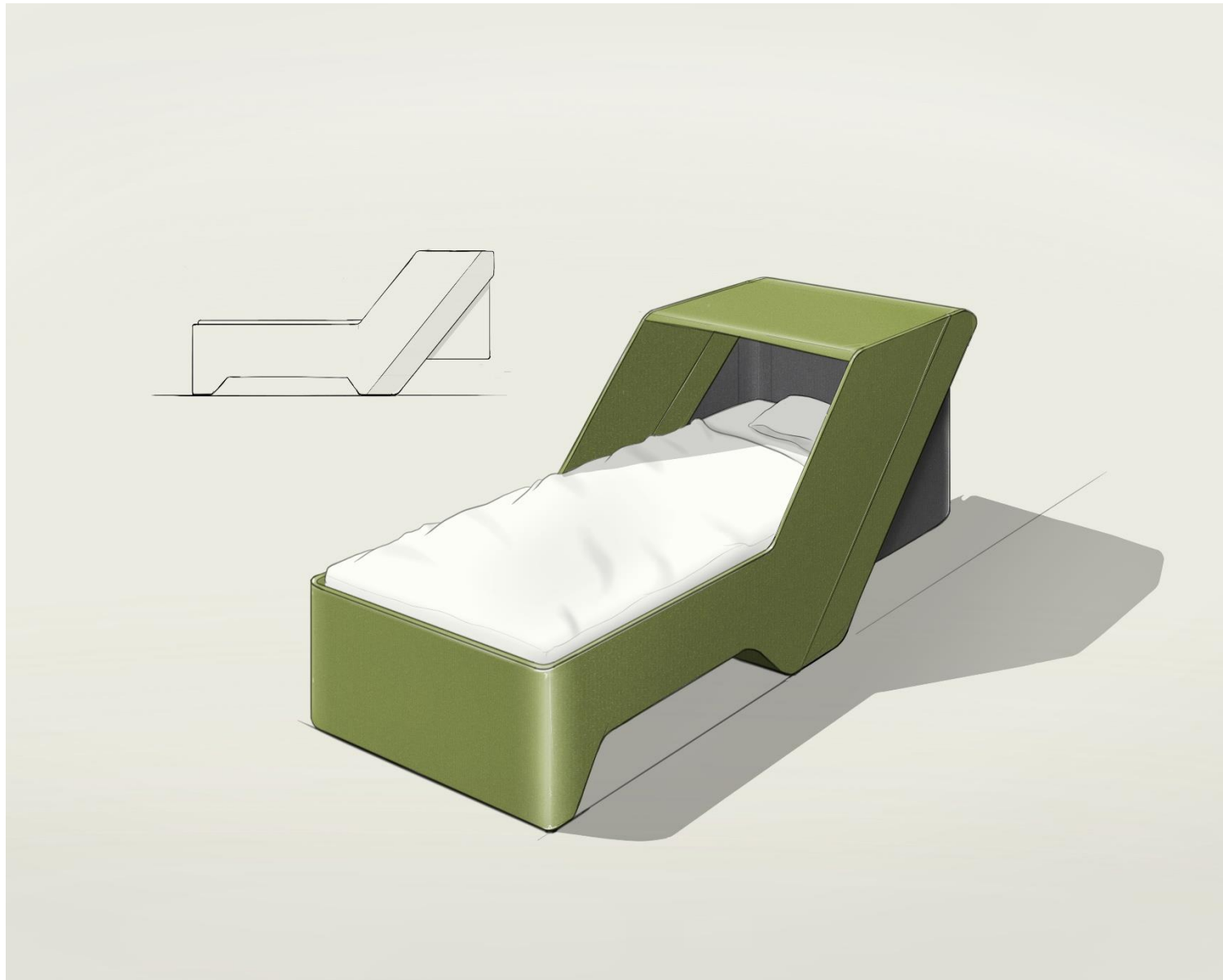




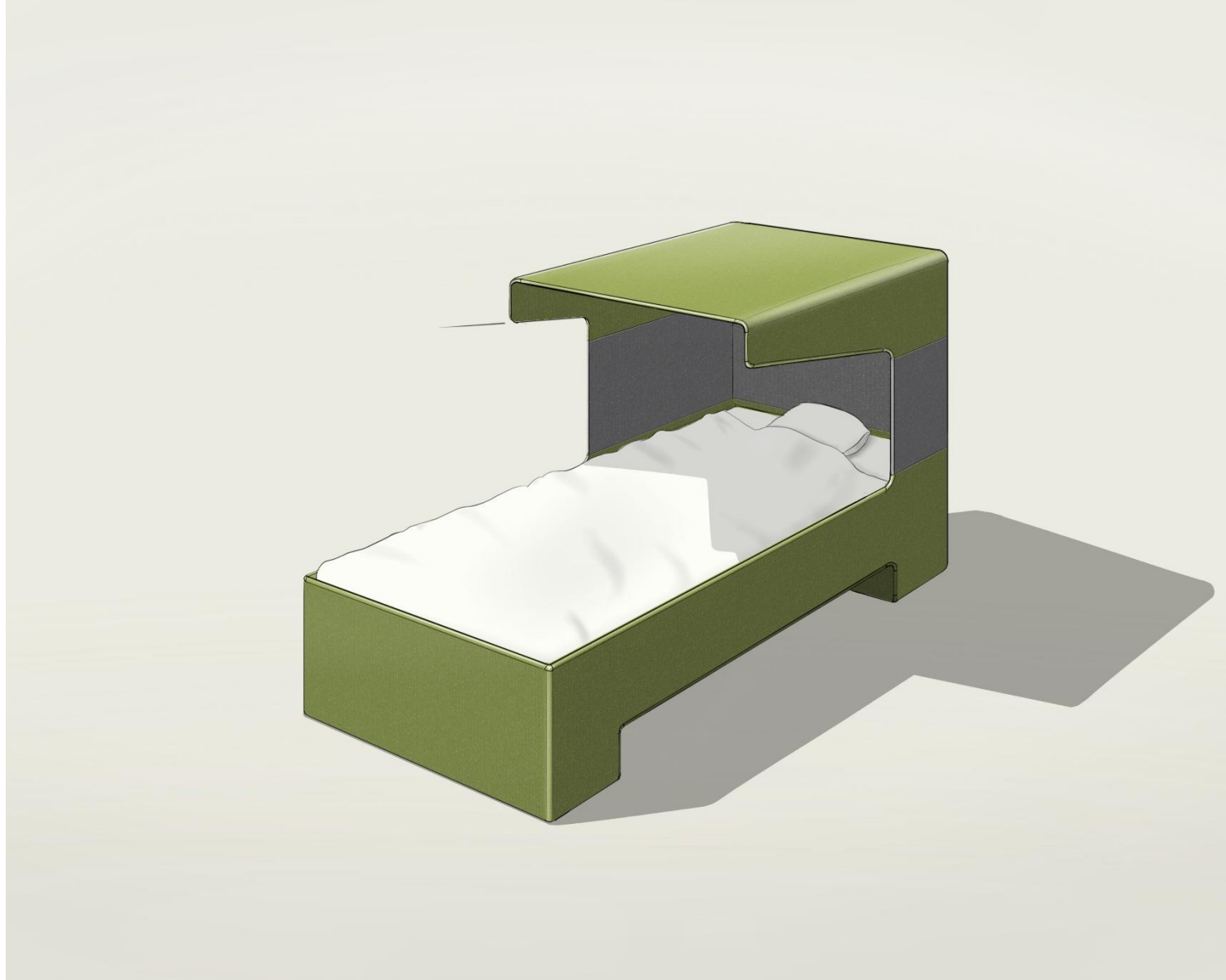


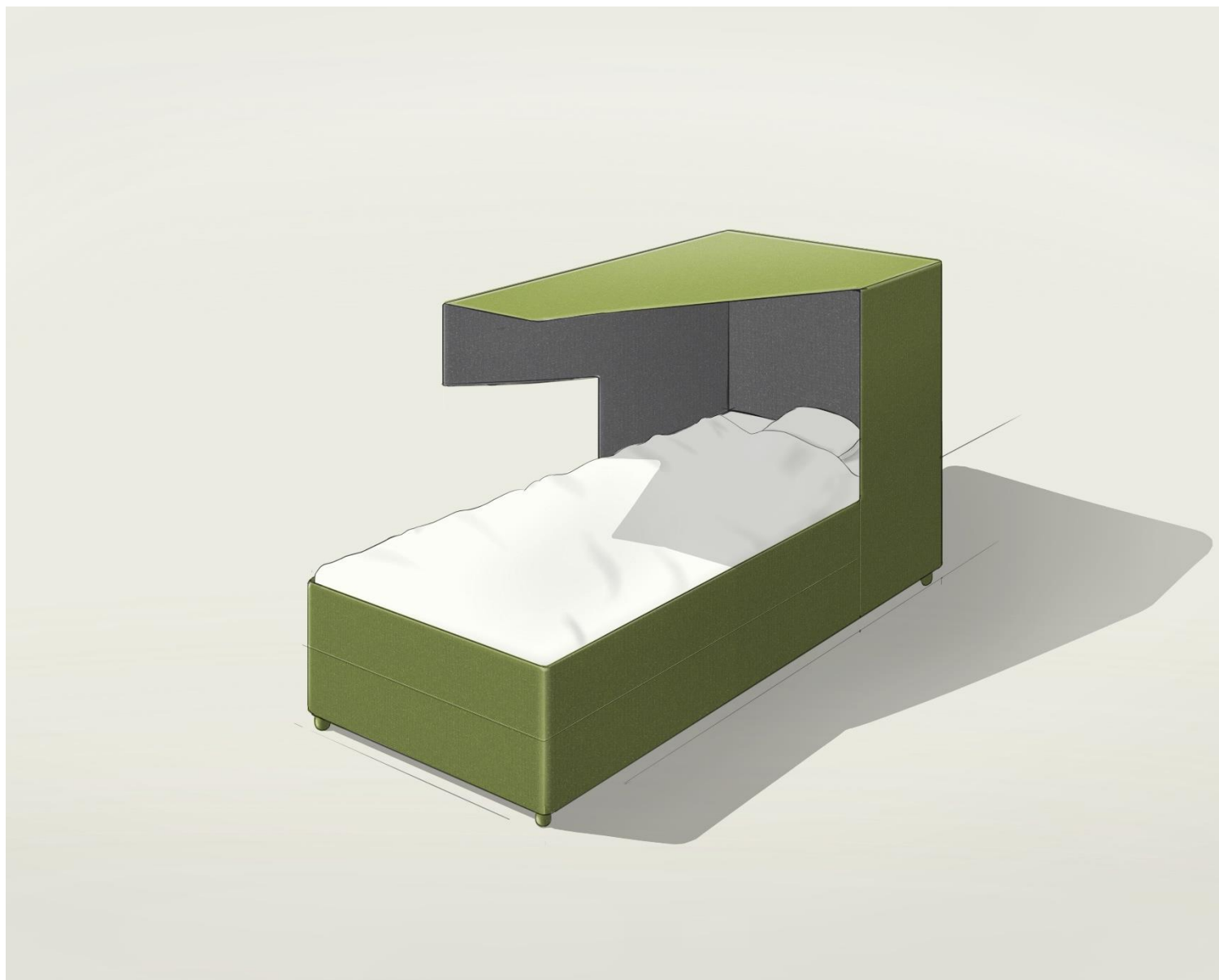


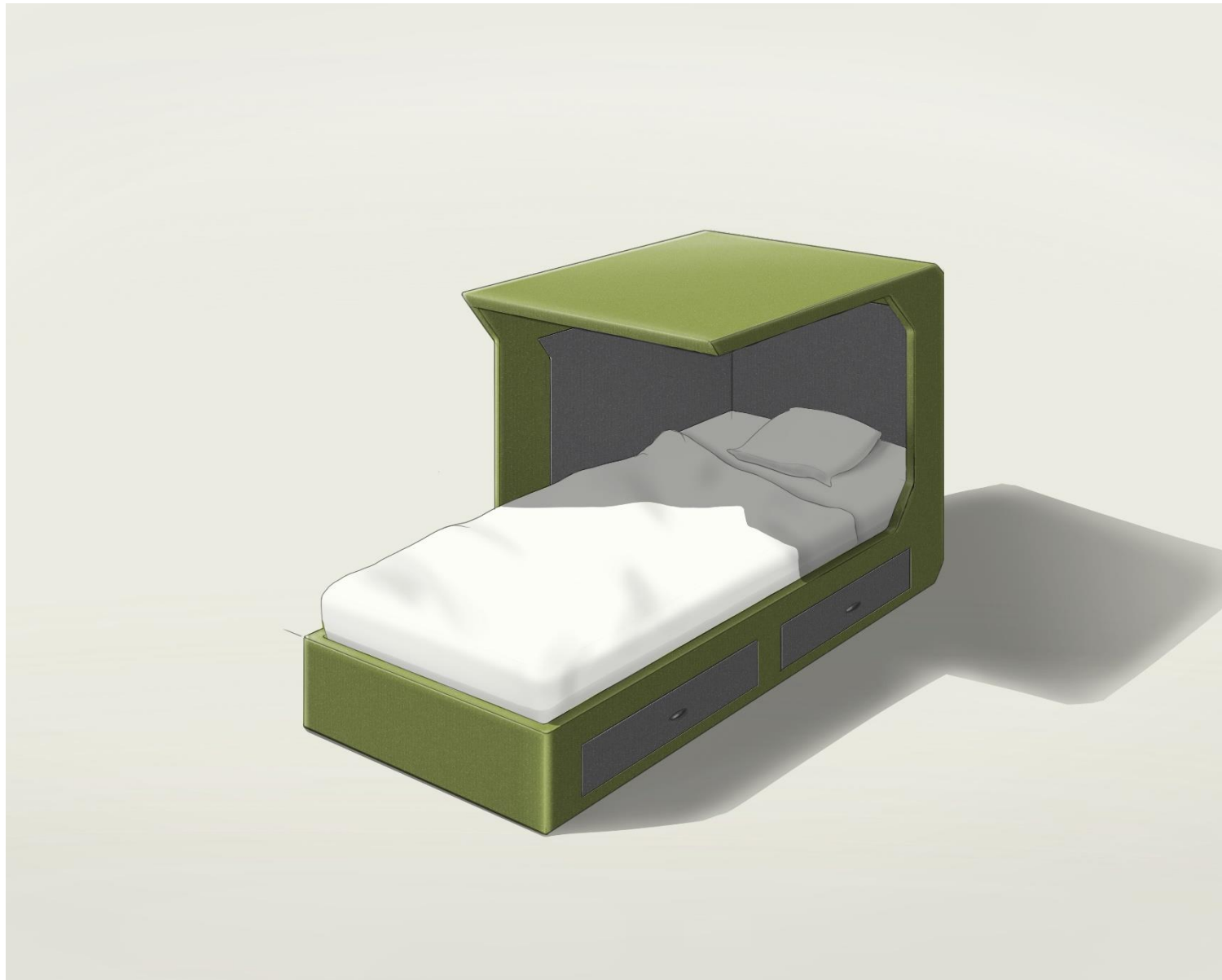




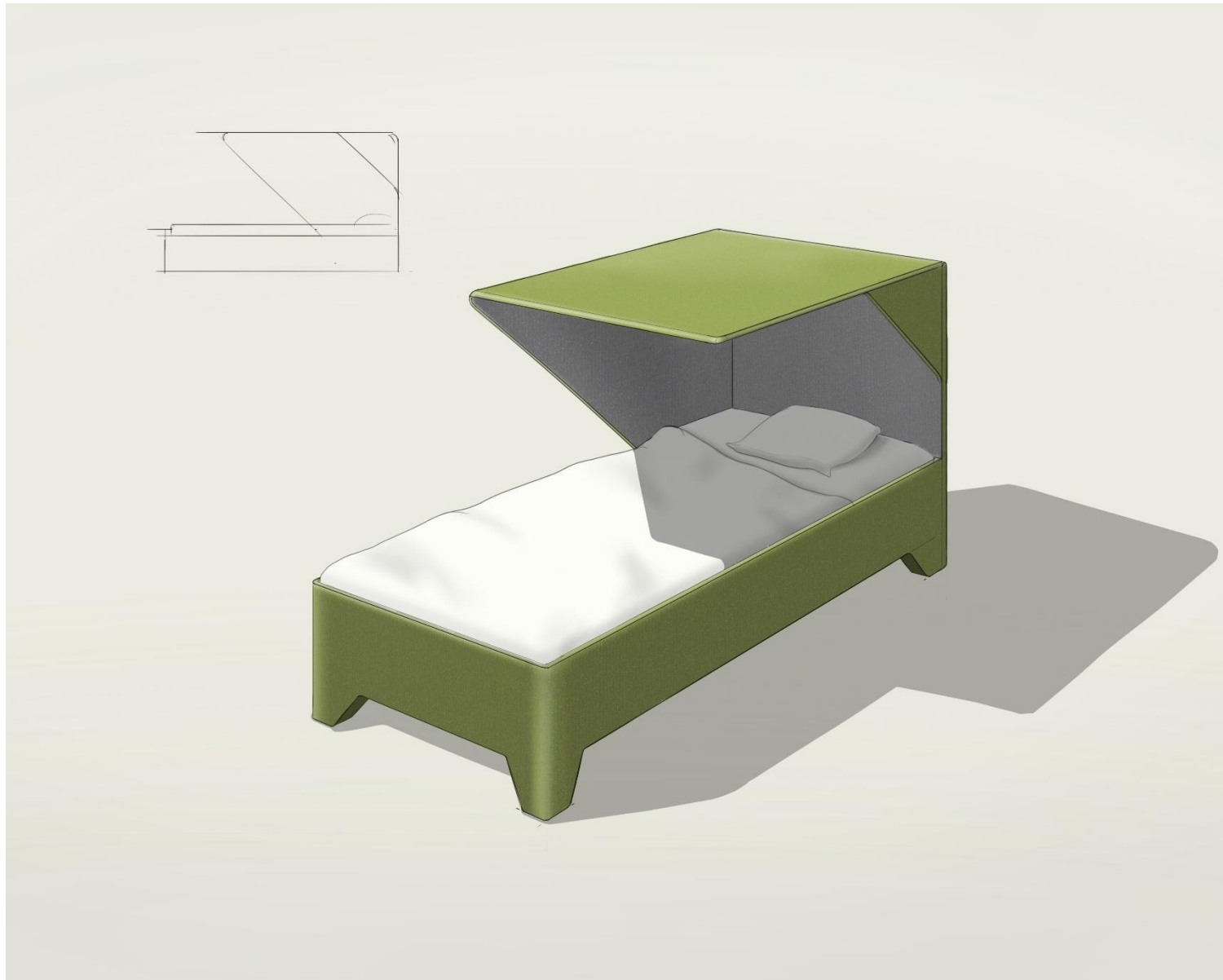


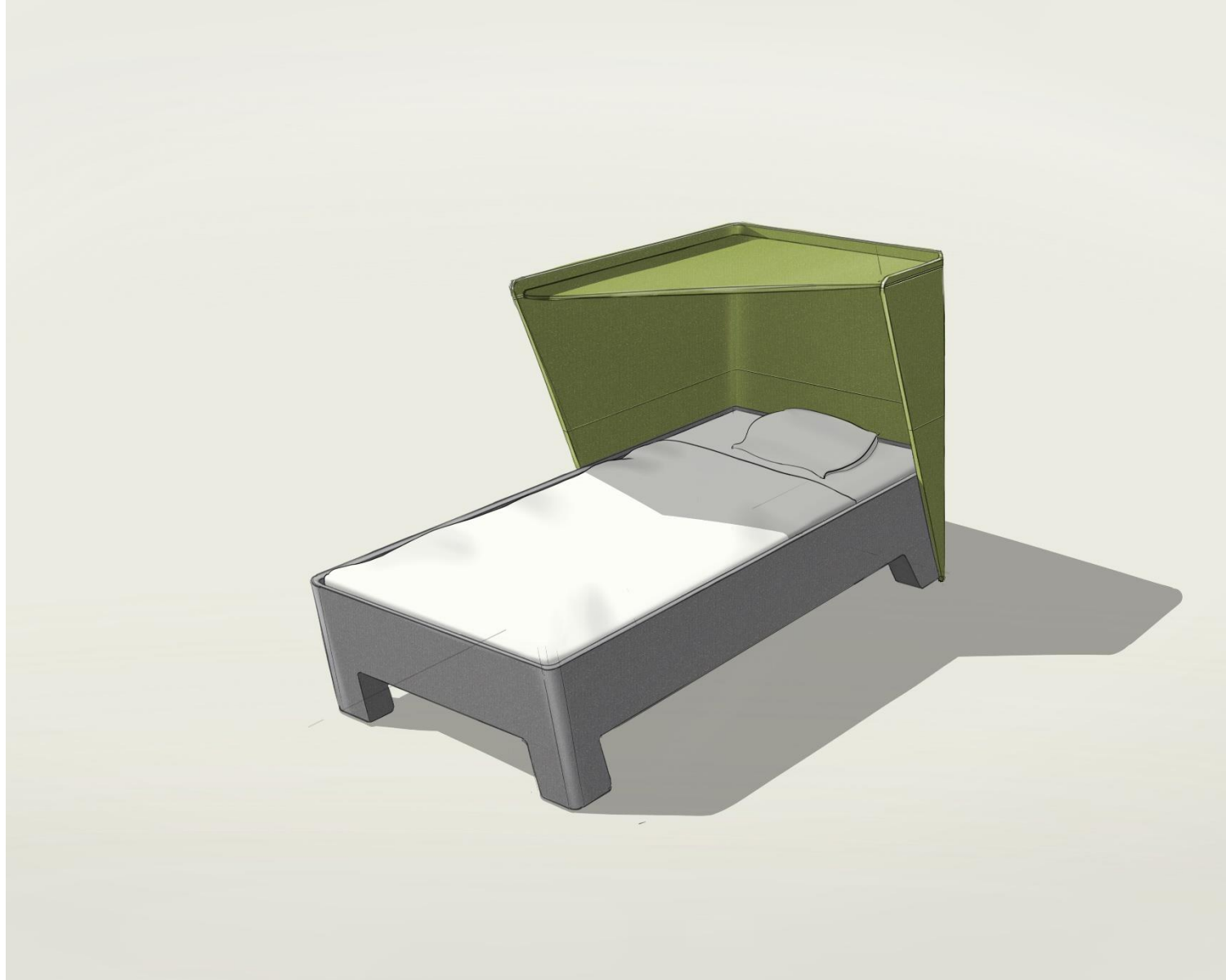


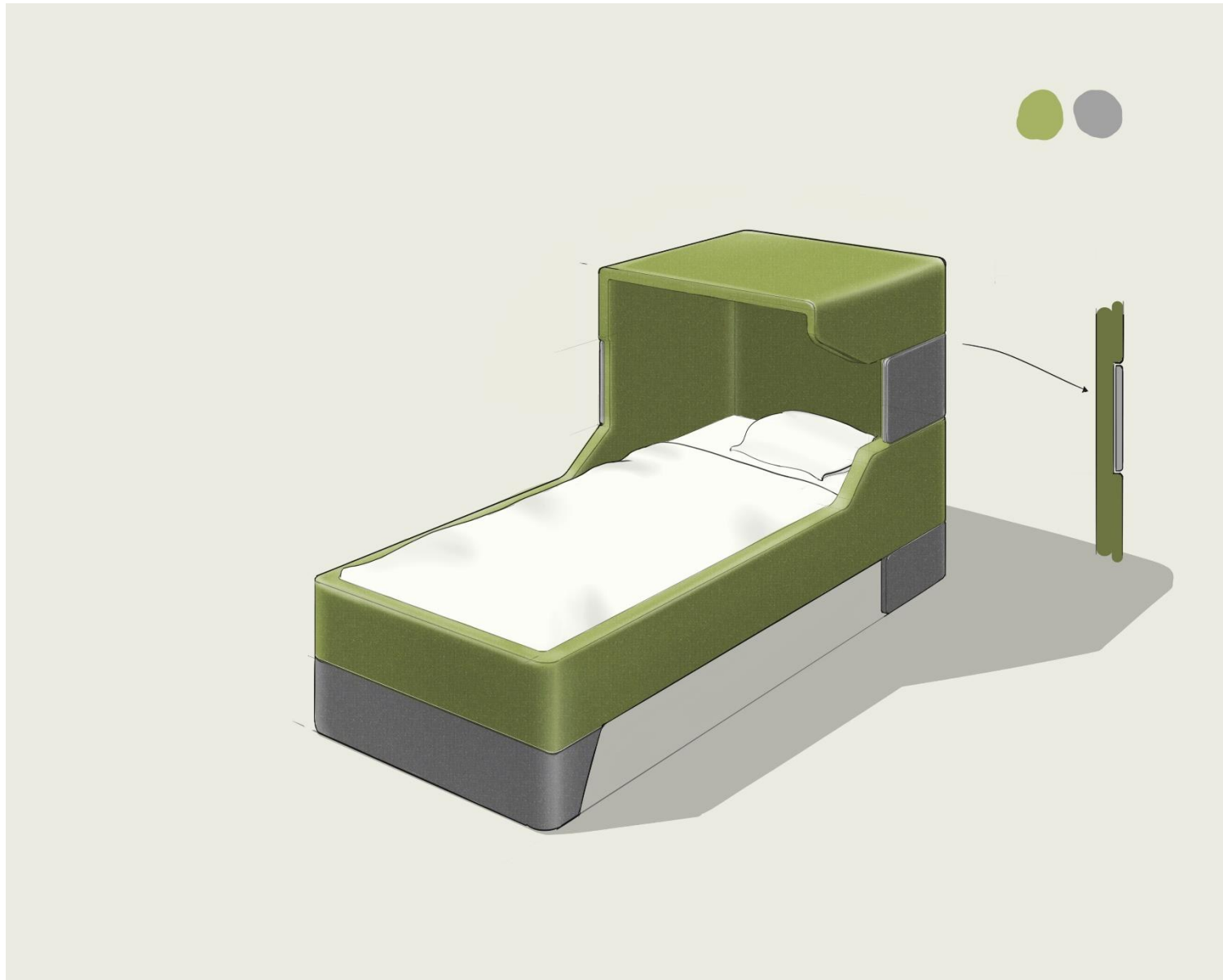


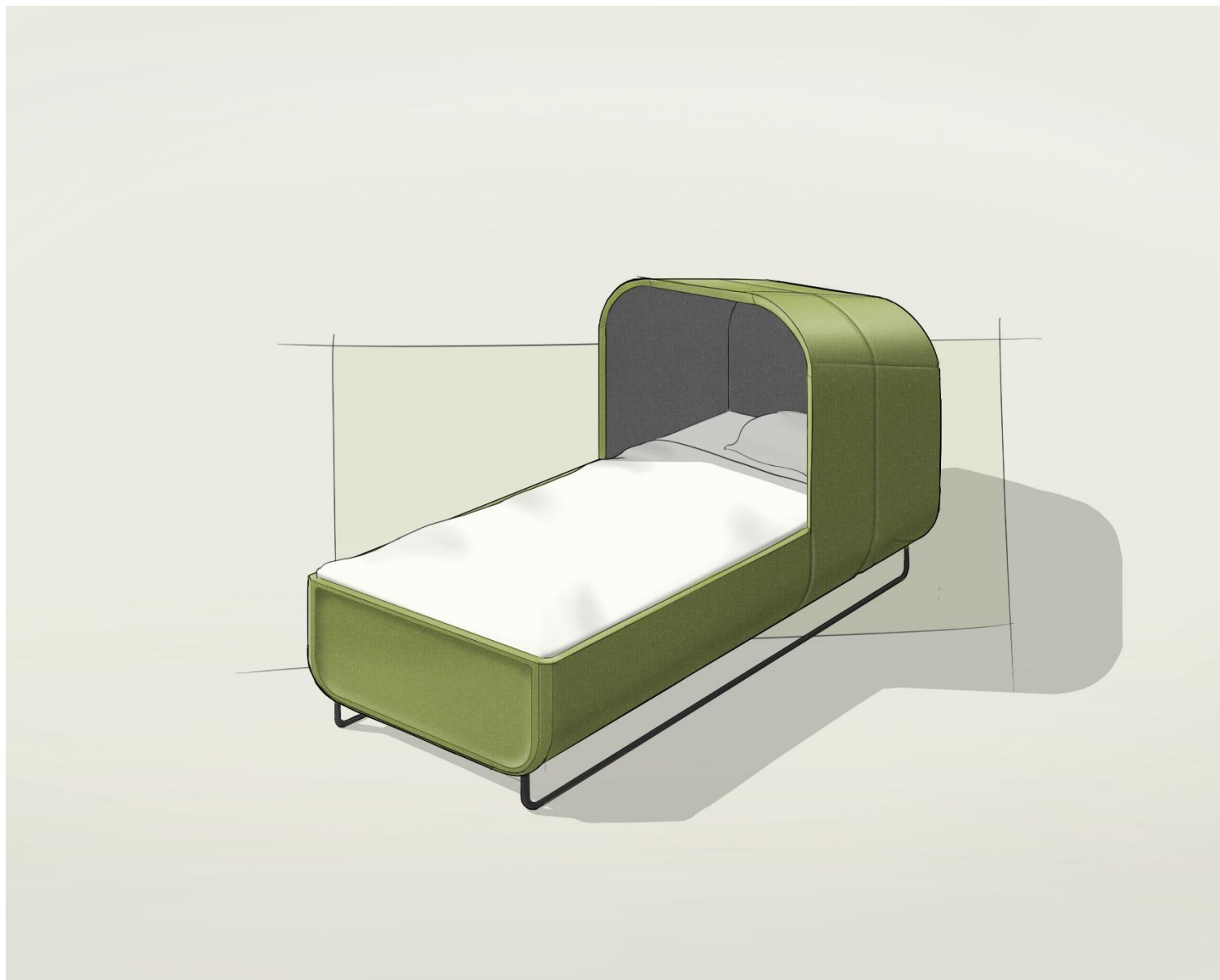


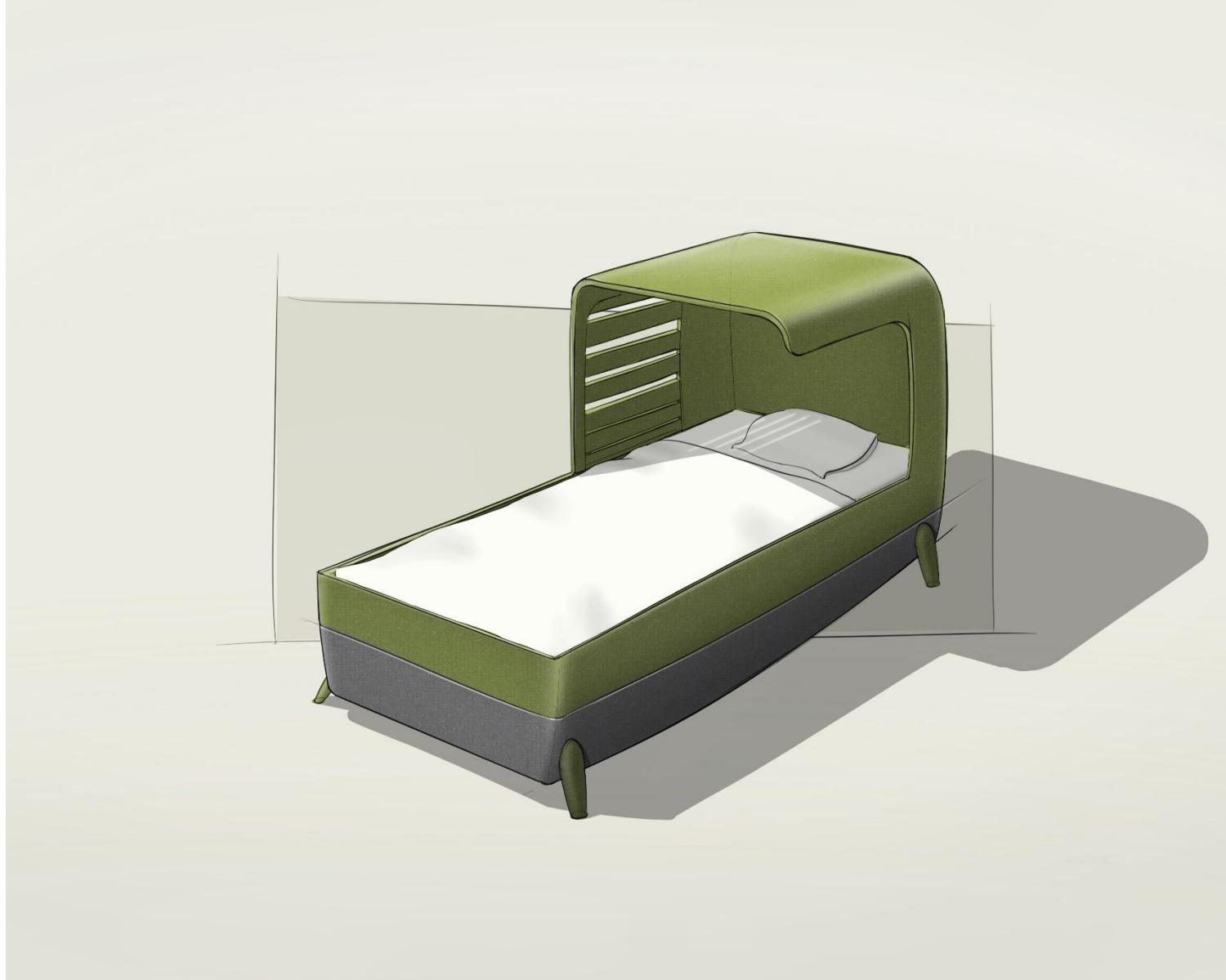


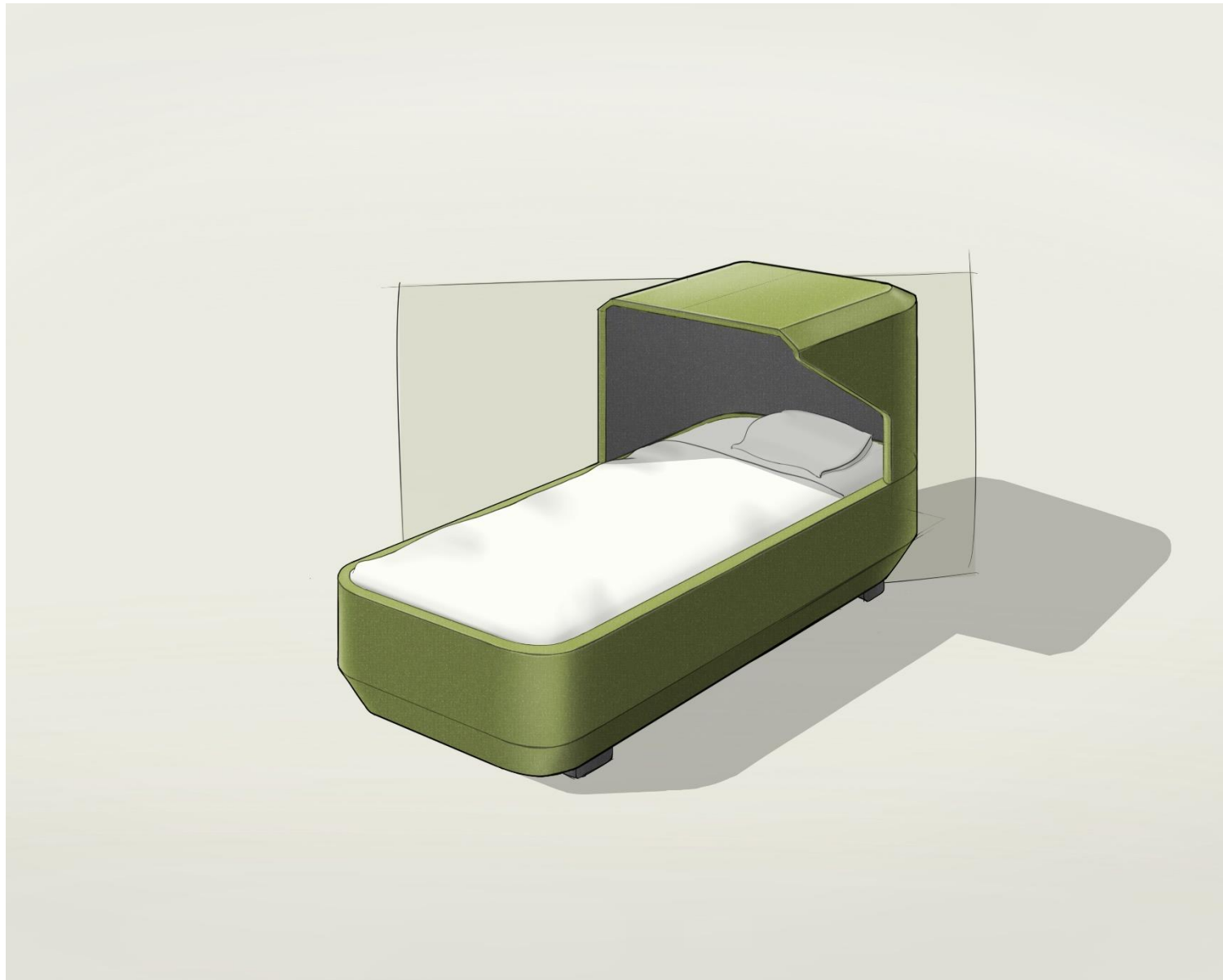


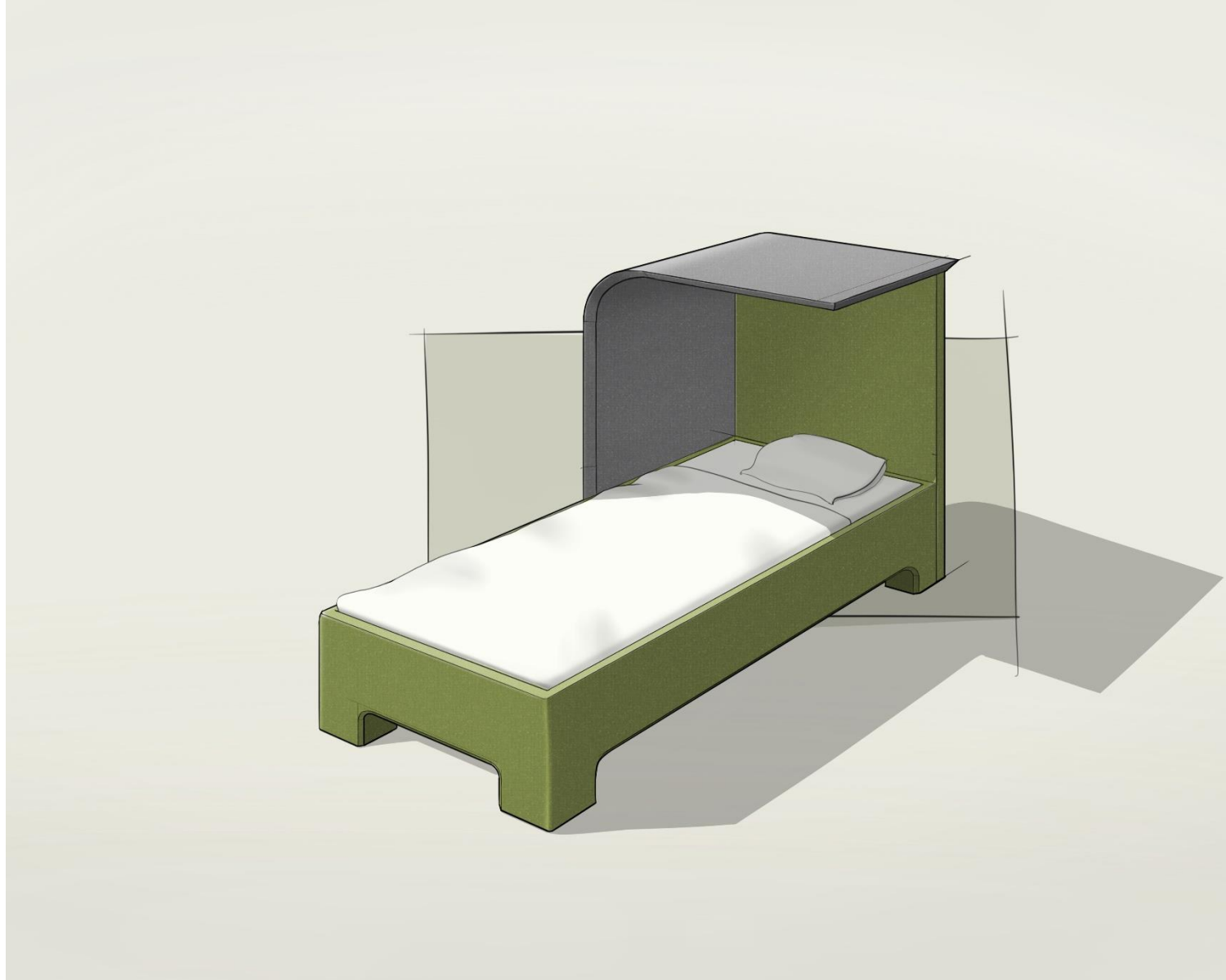


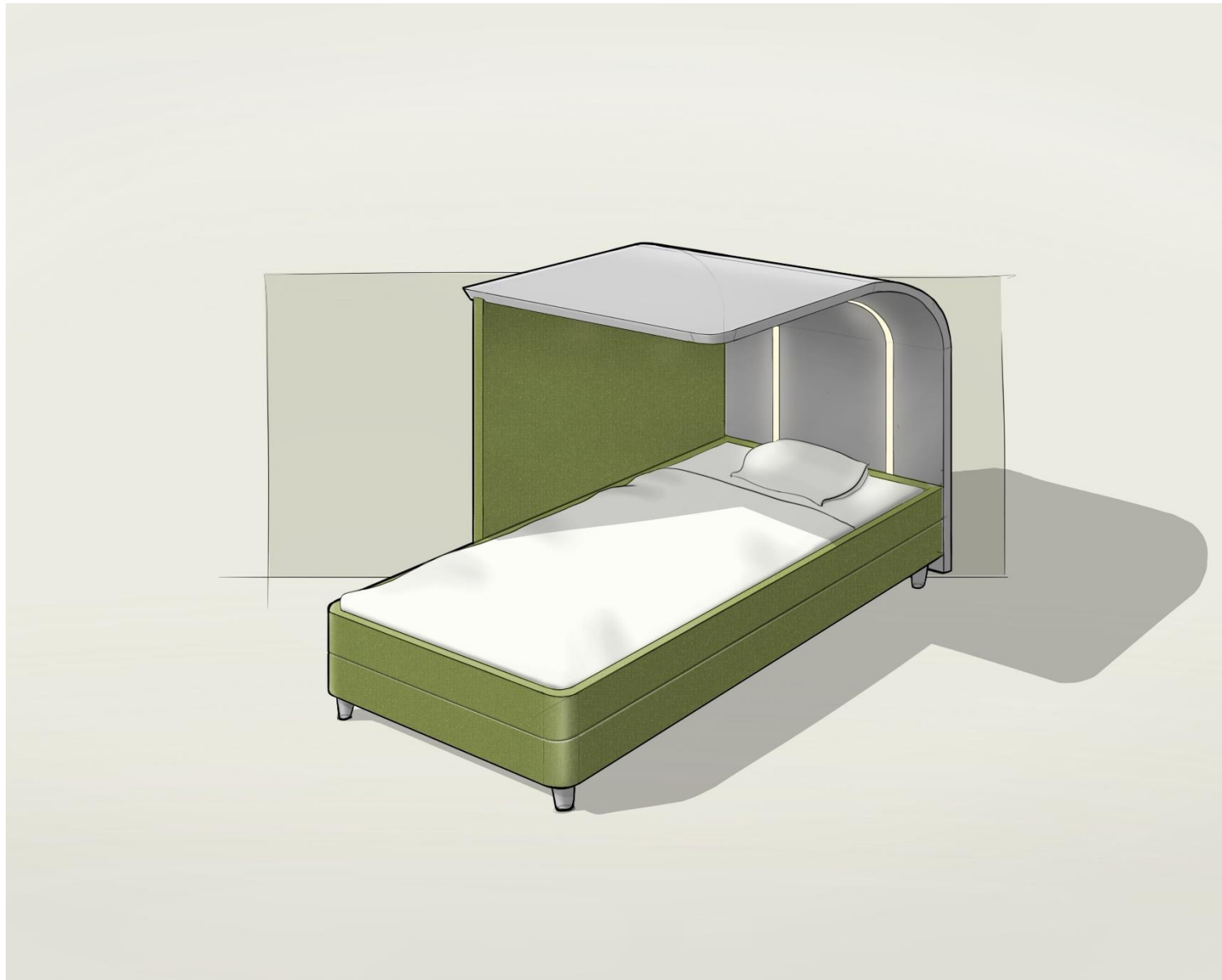




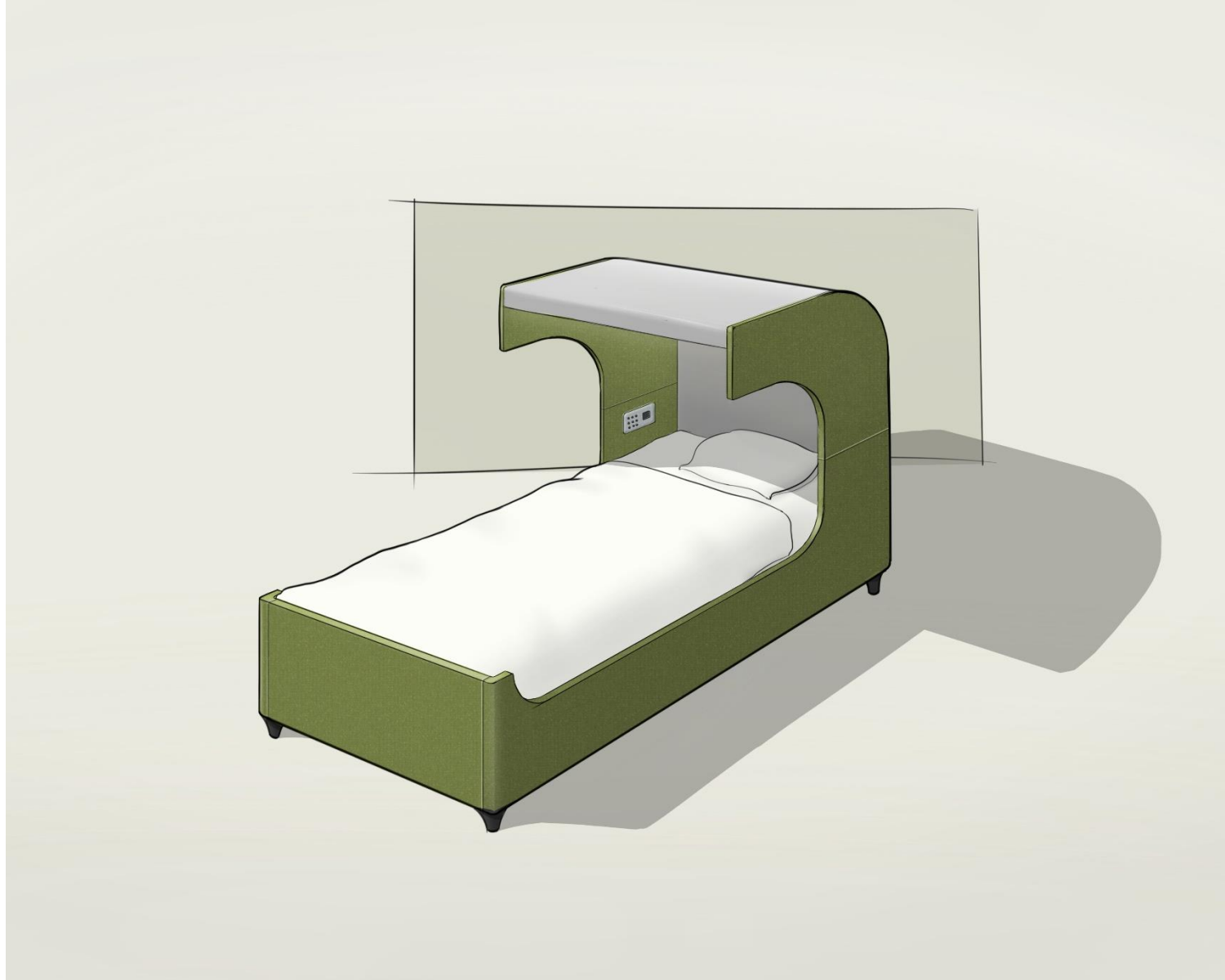


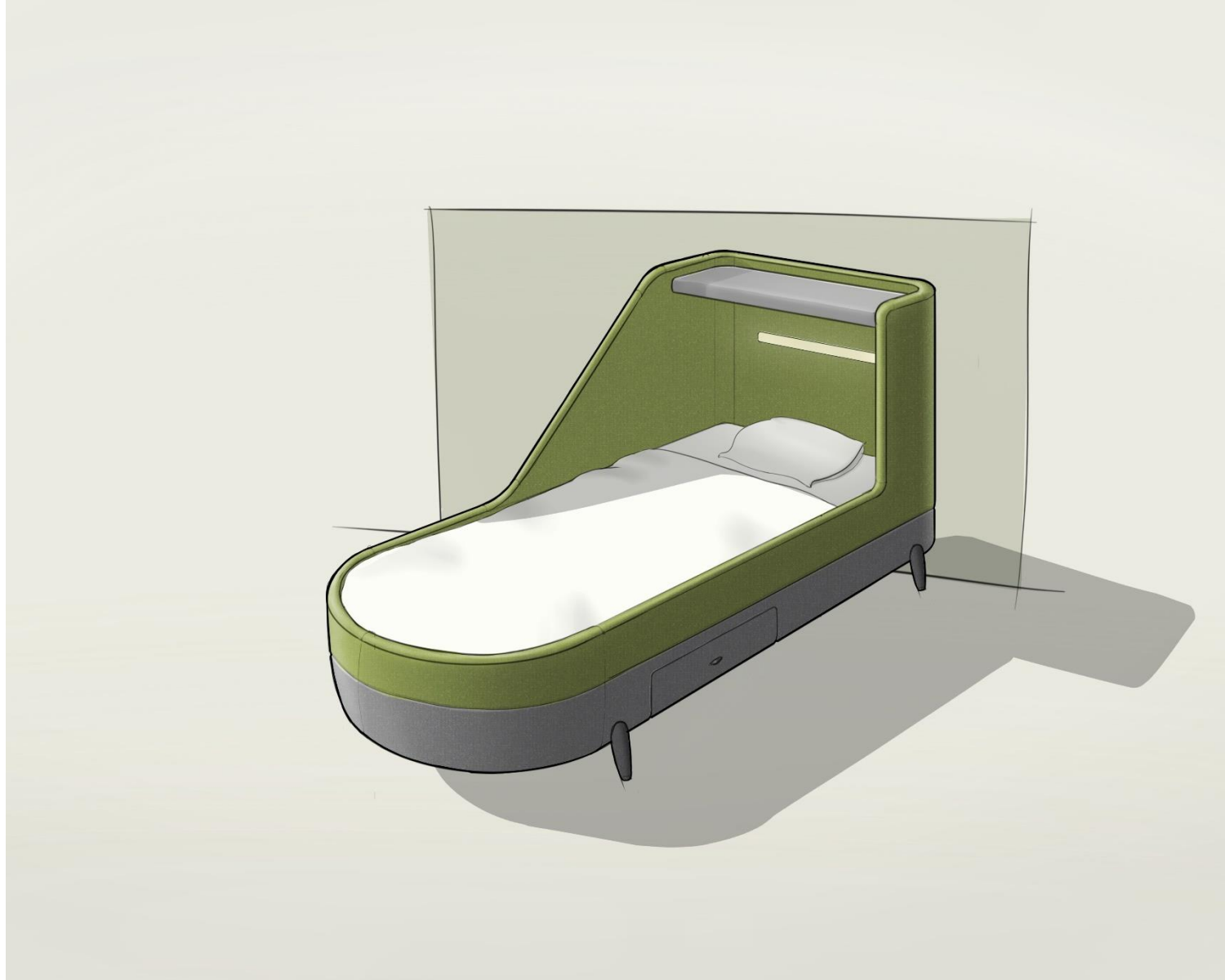


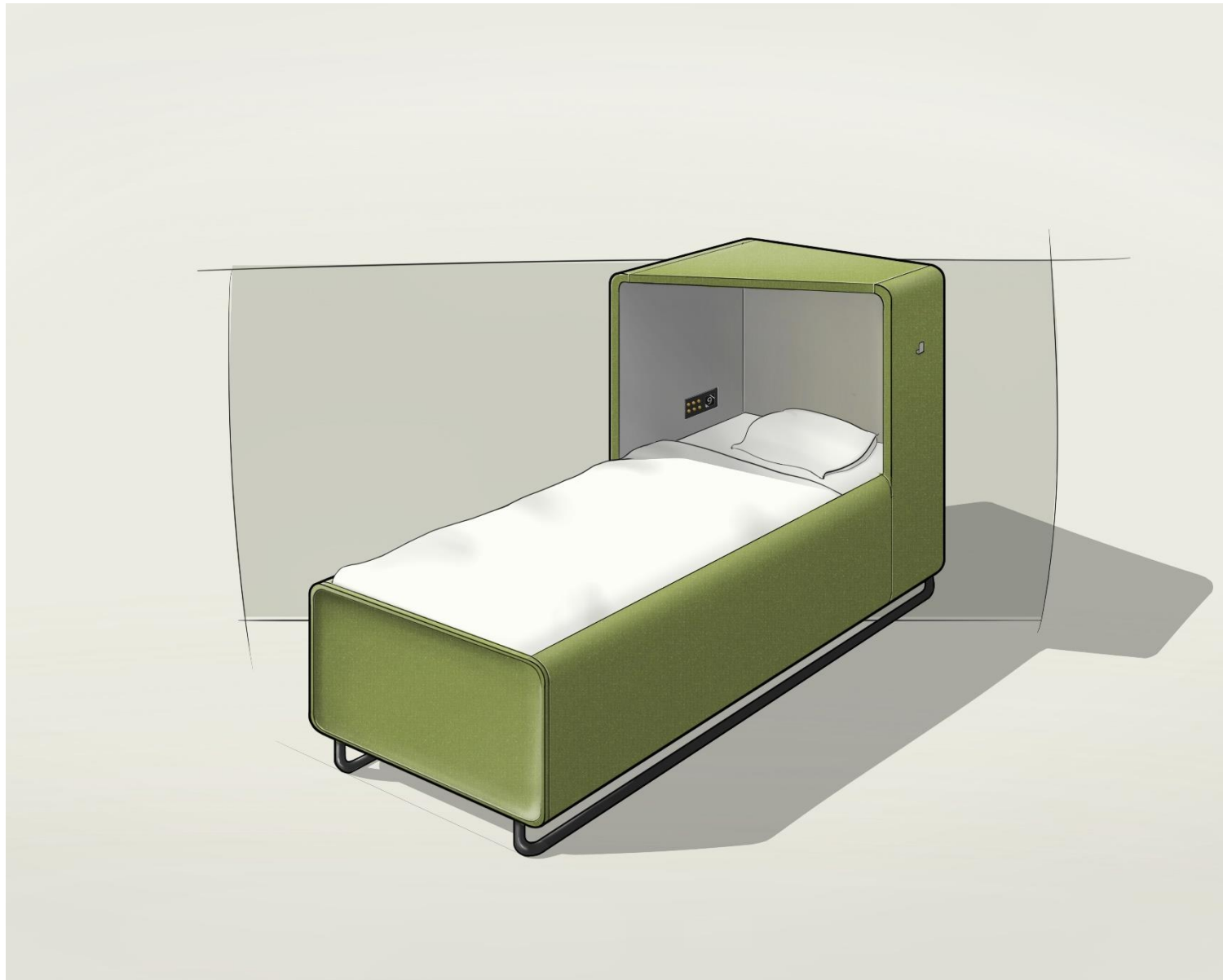


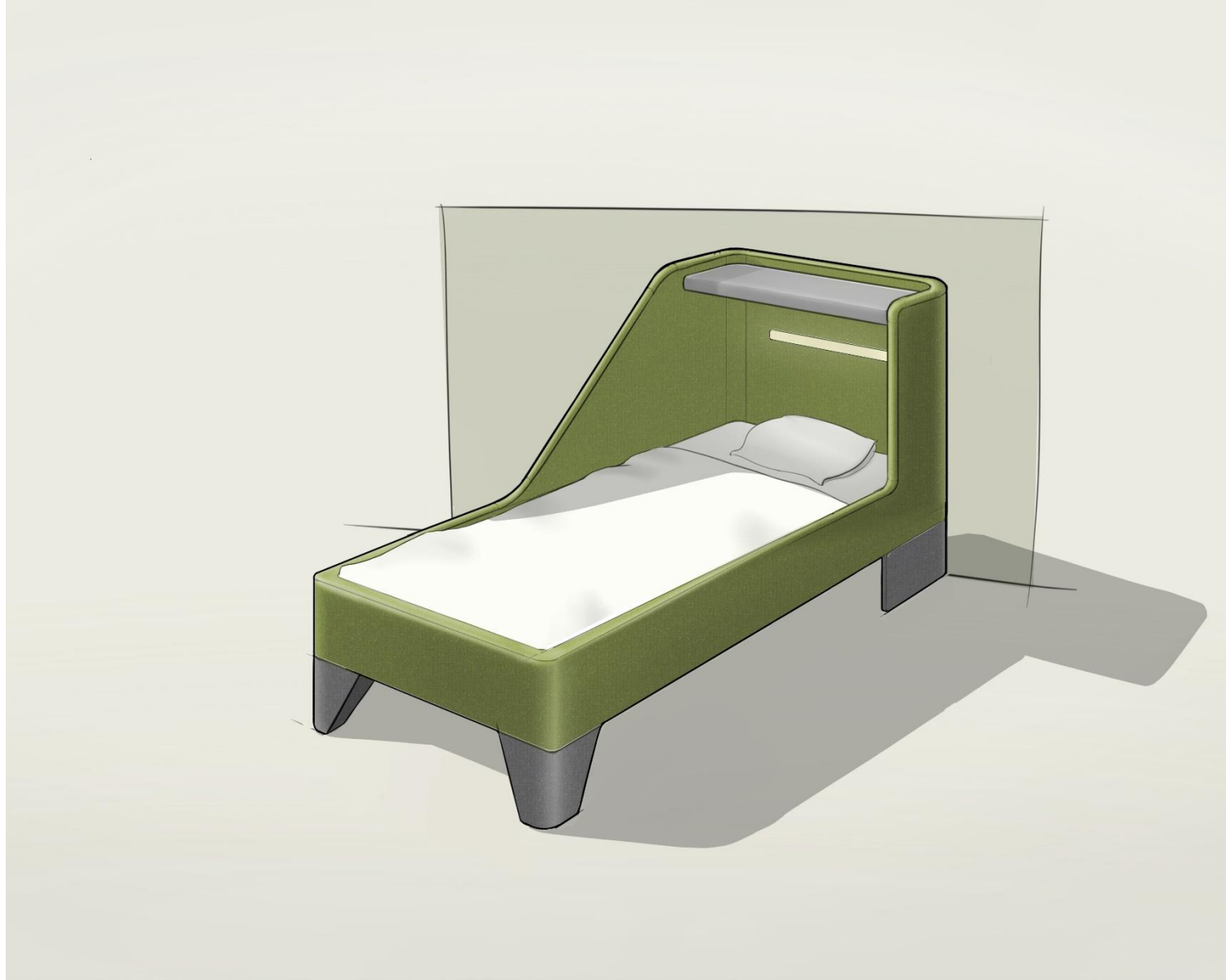




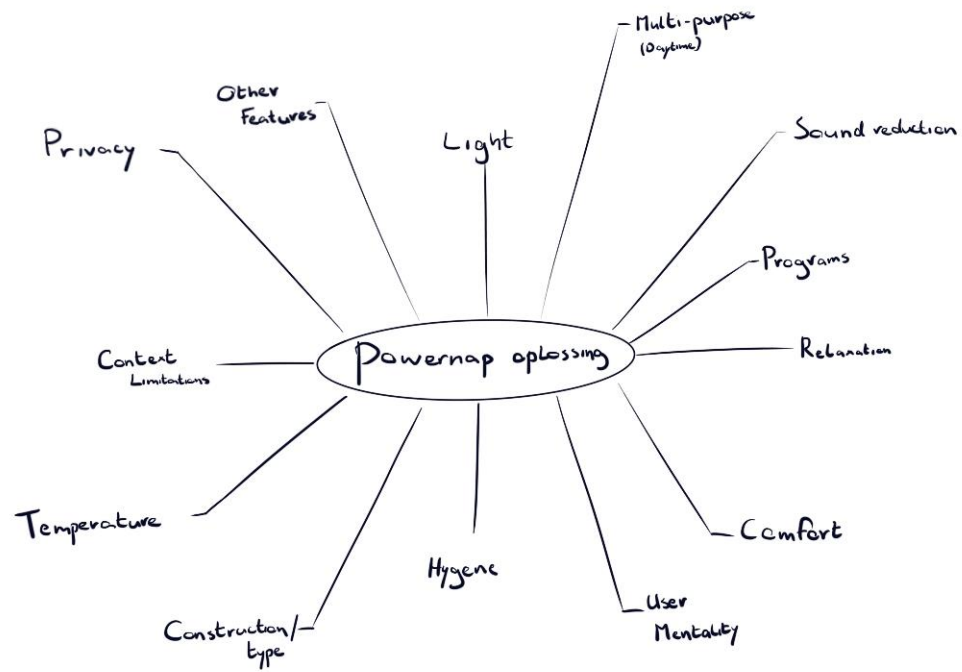


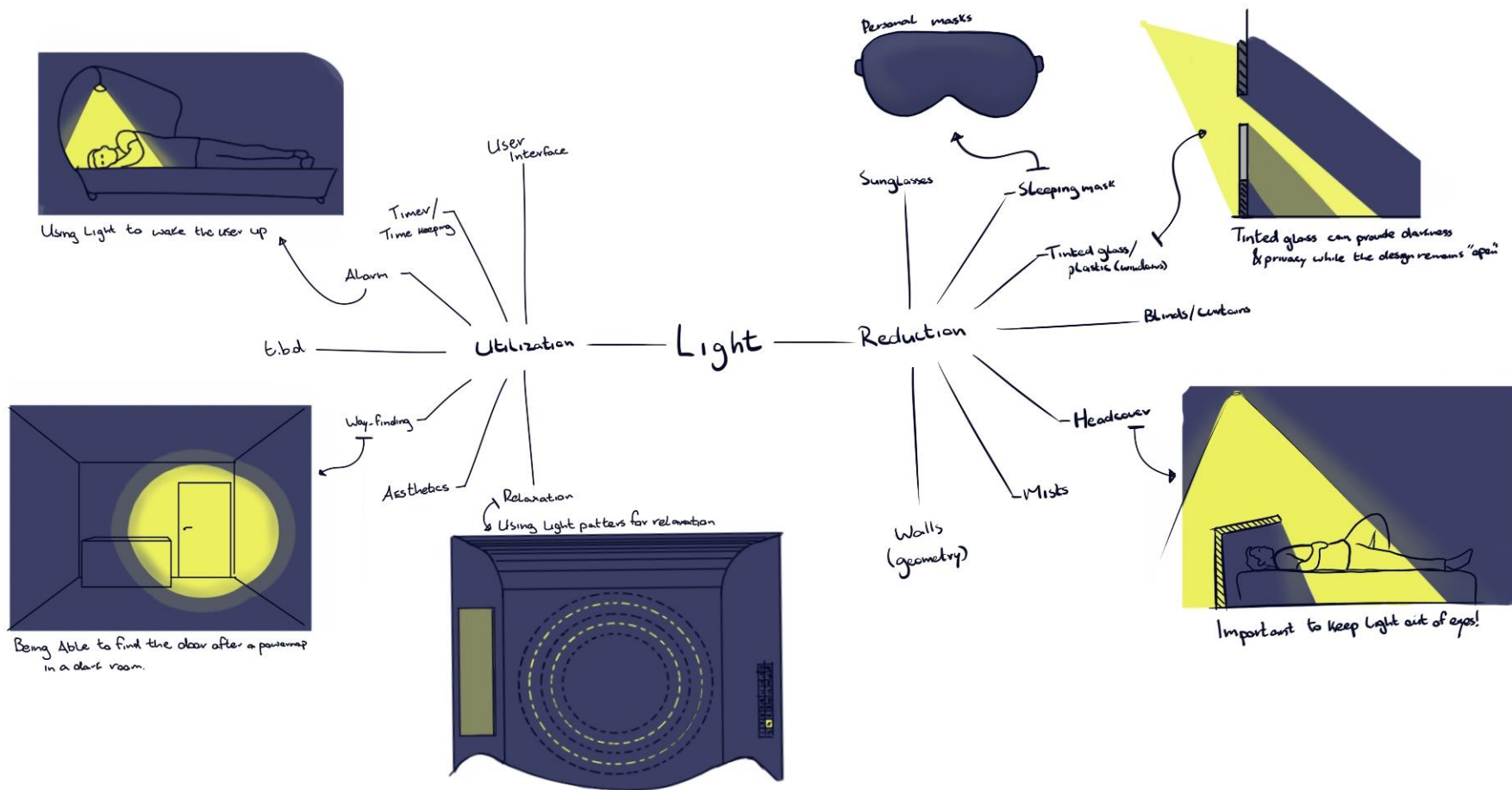


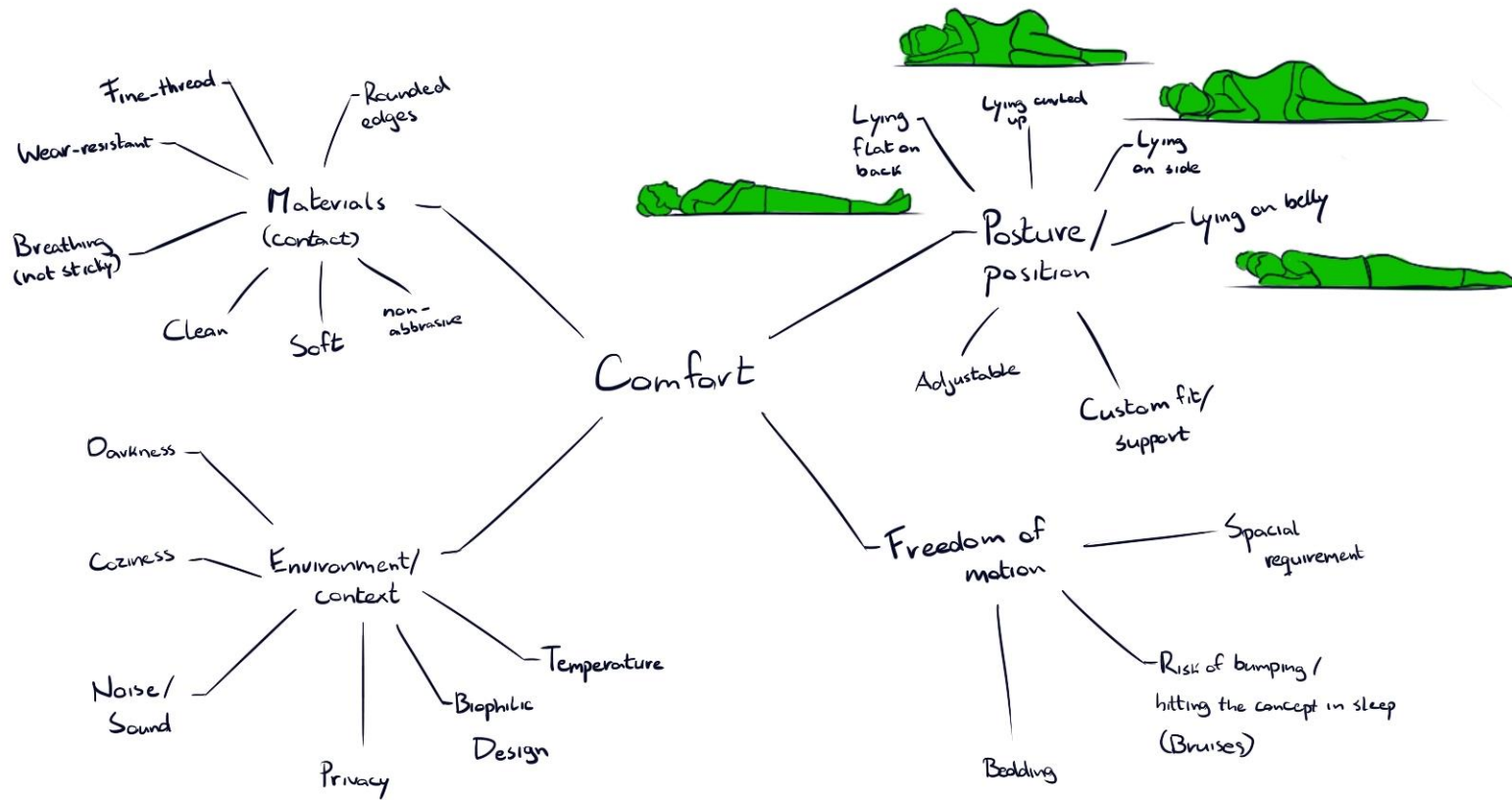


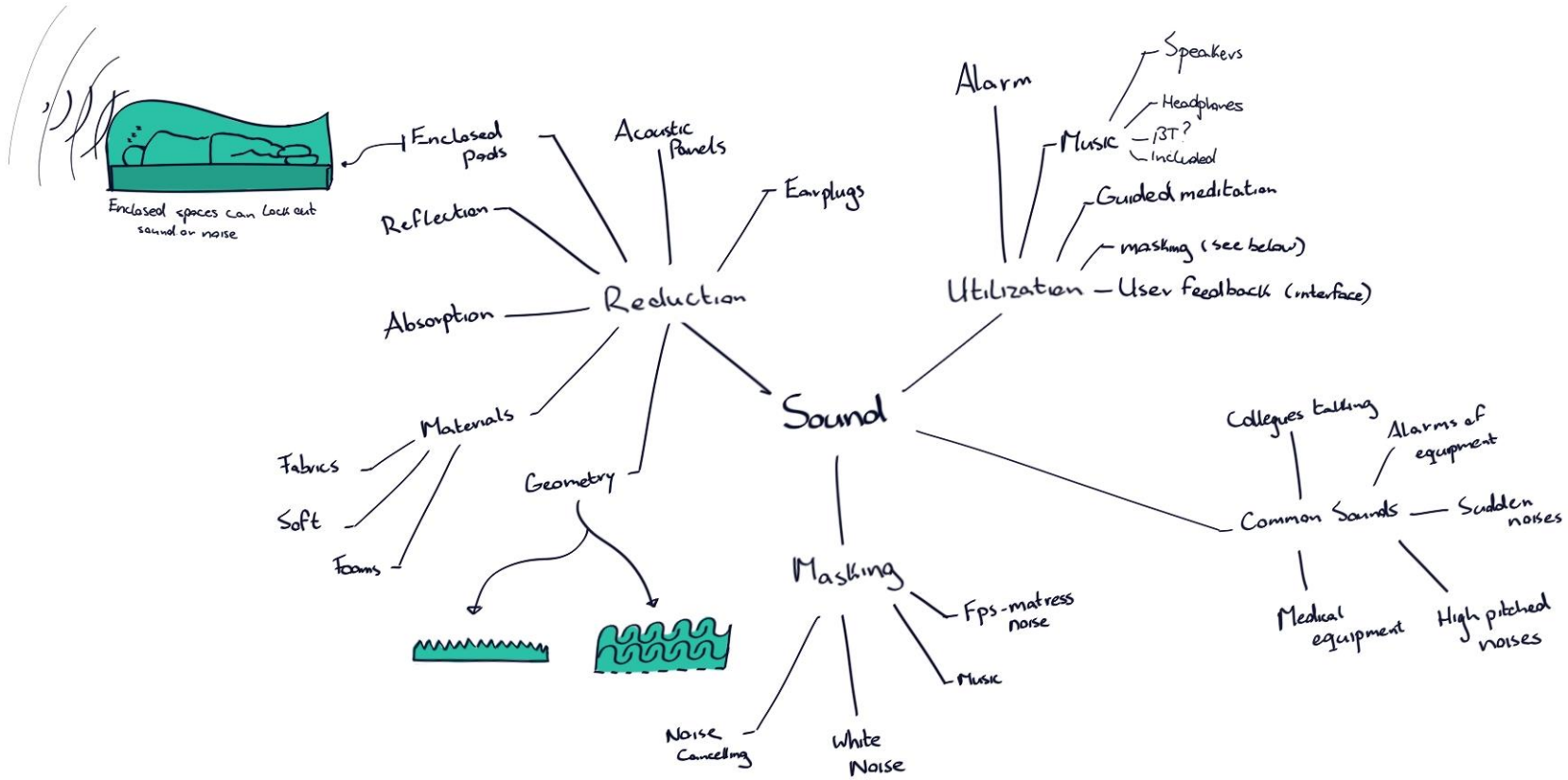


## Appendix F - Mind maps ideation

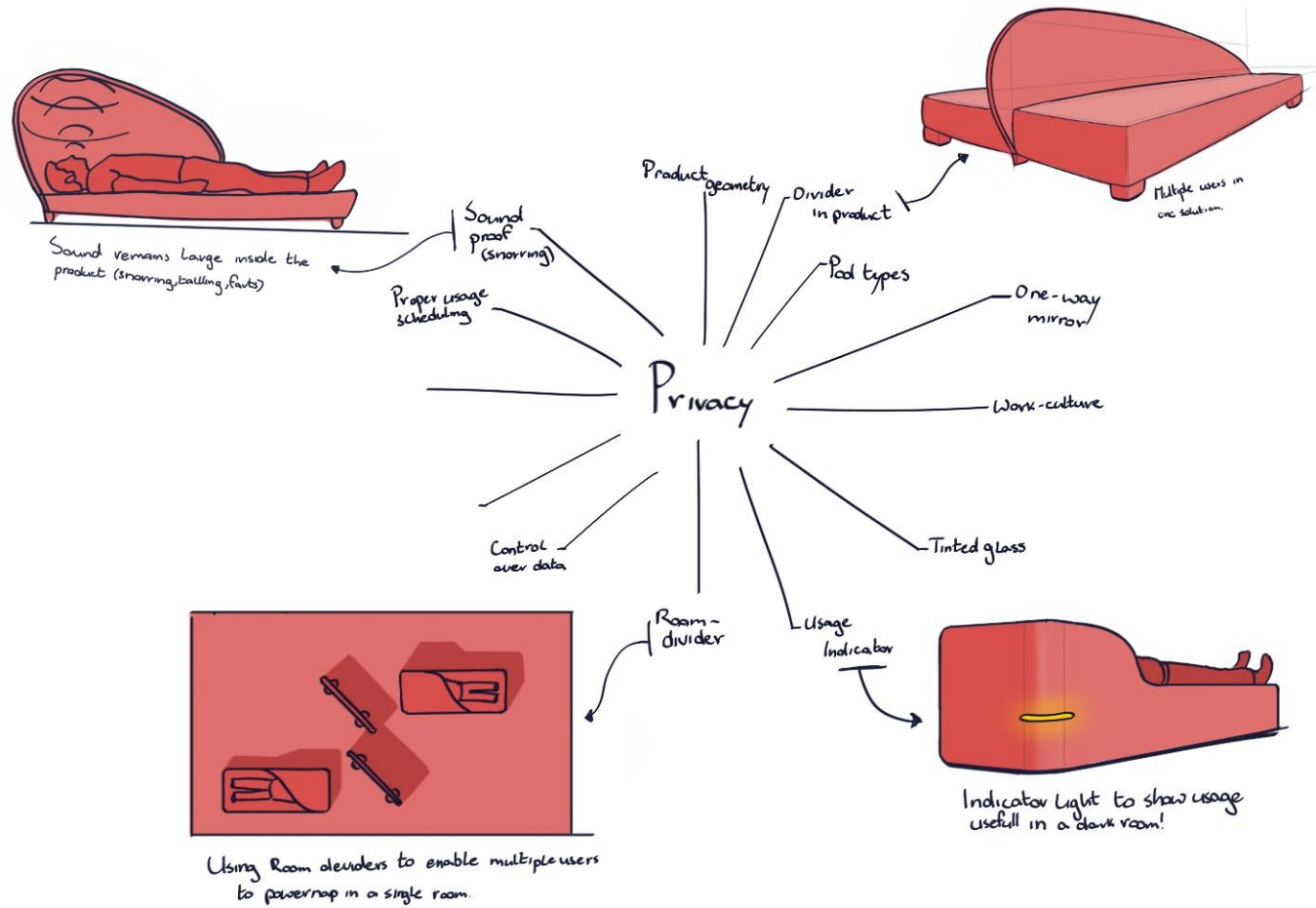


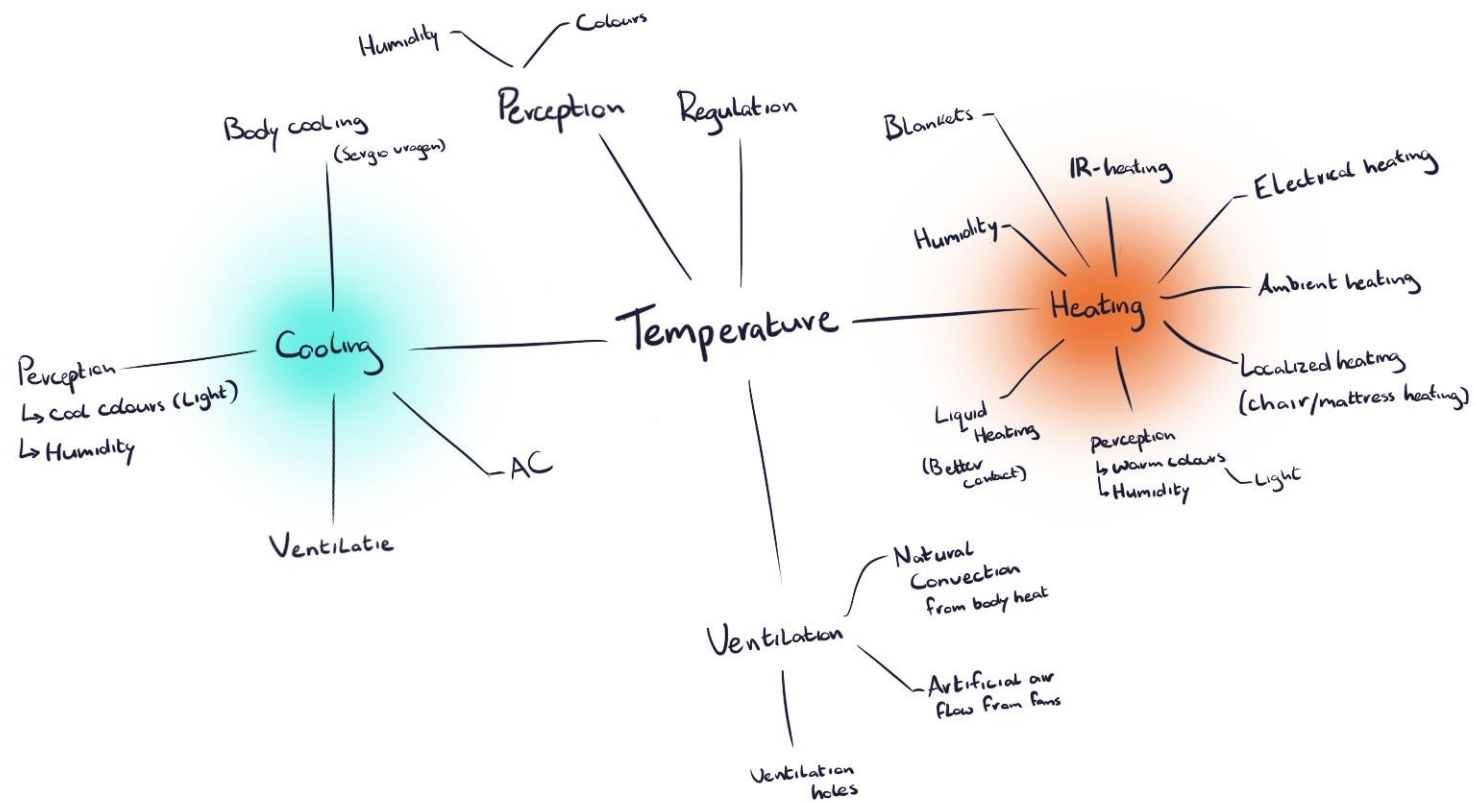




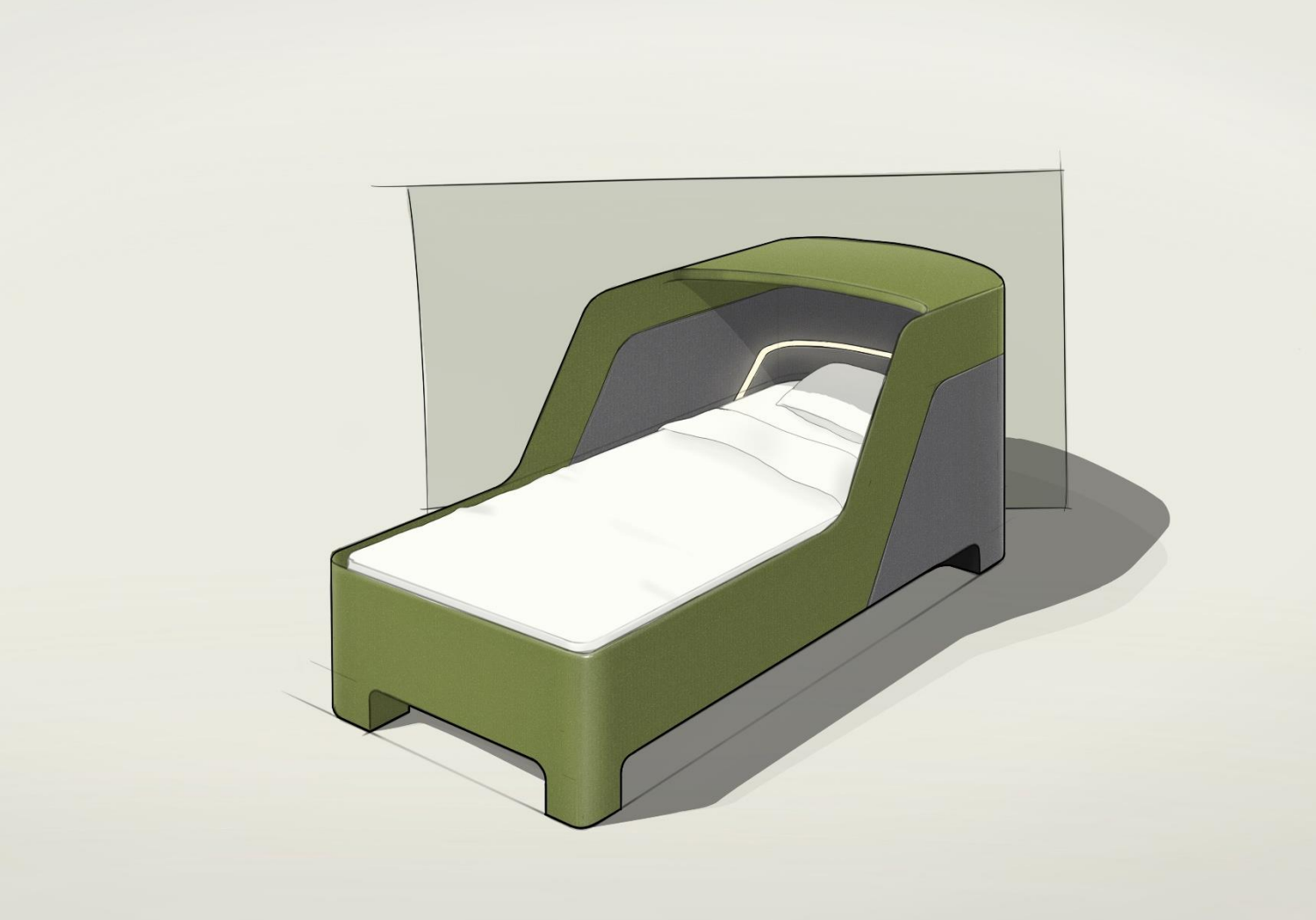


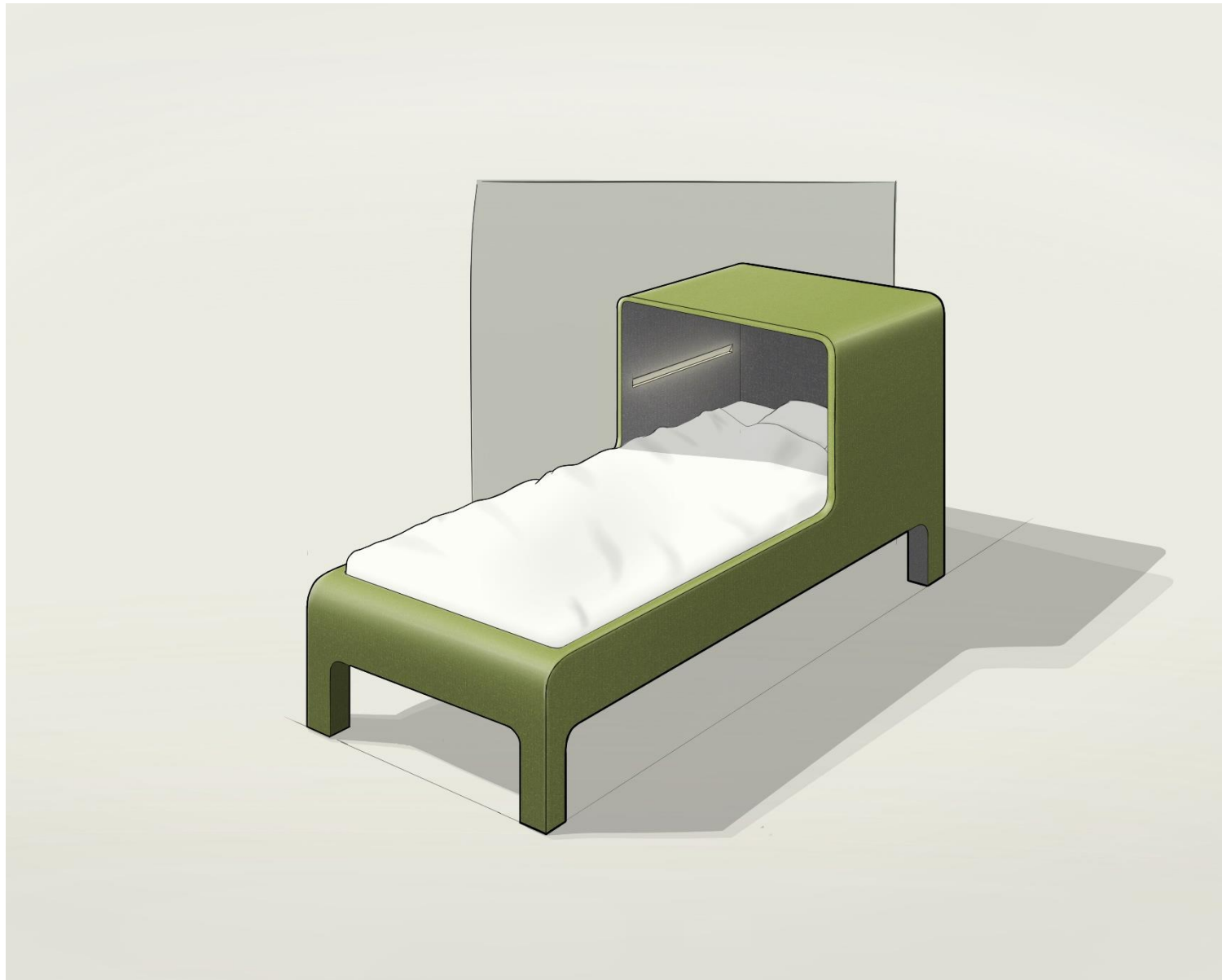


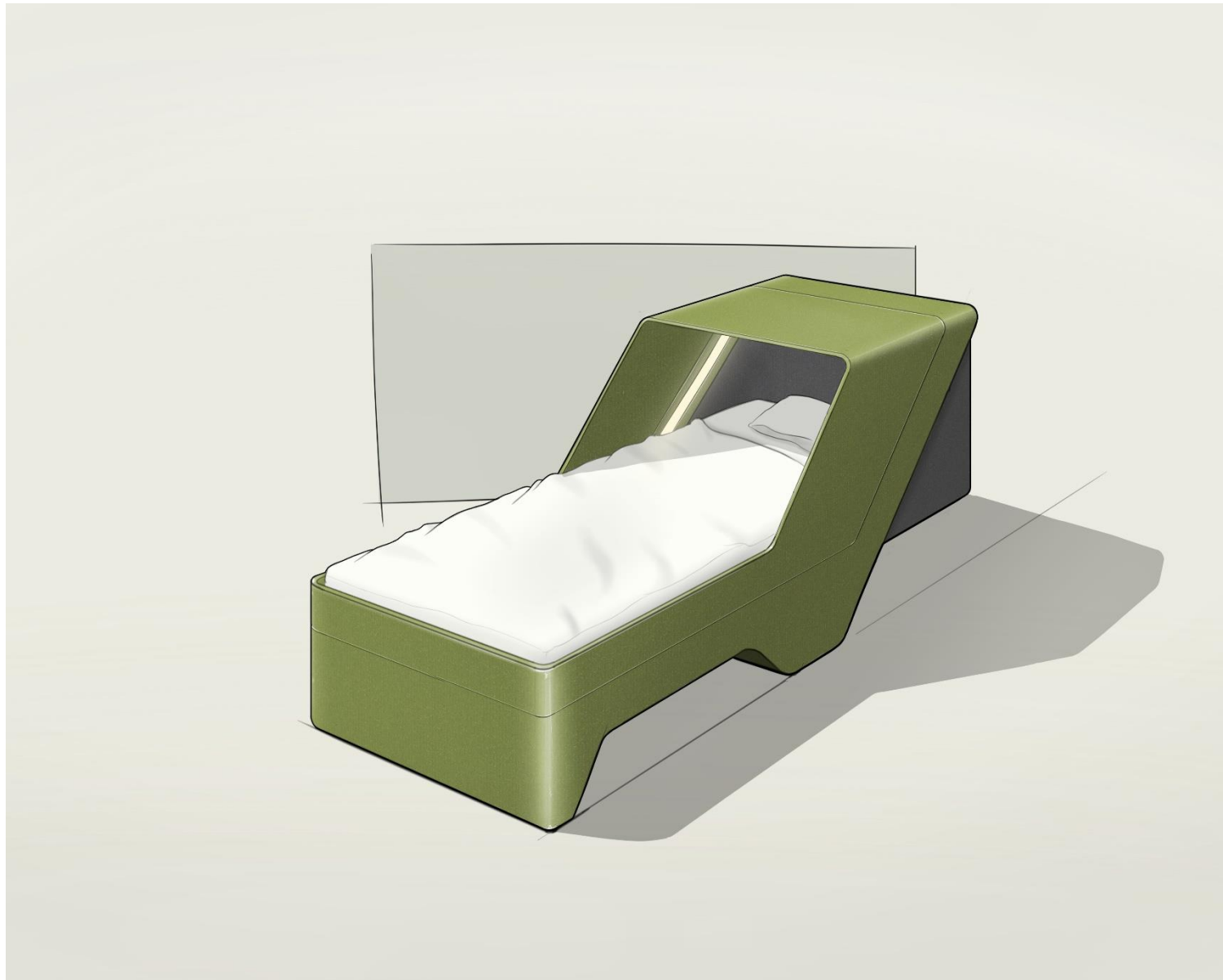


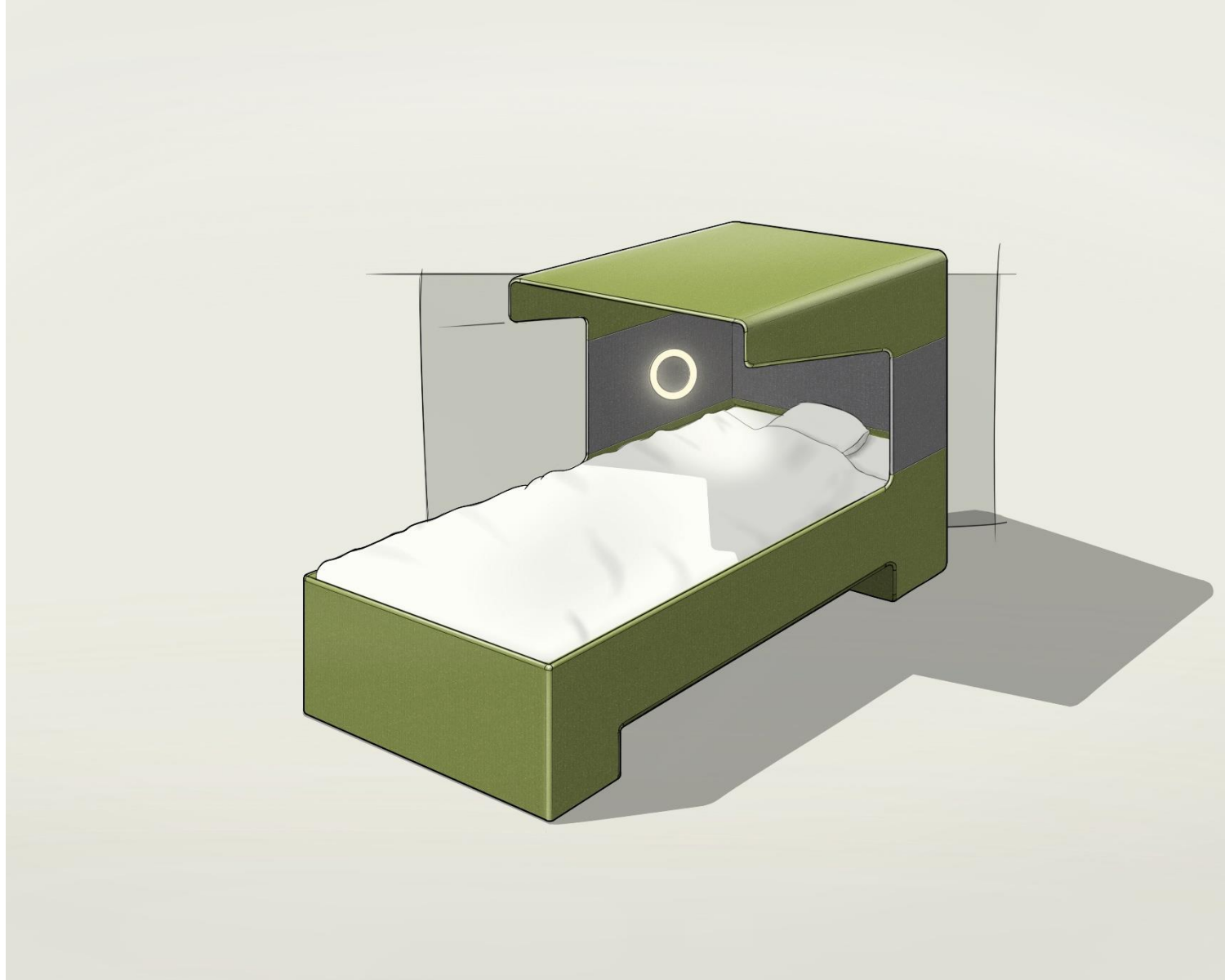


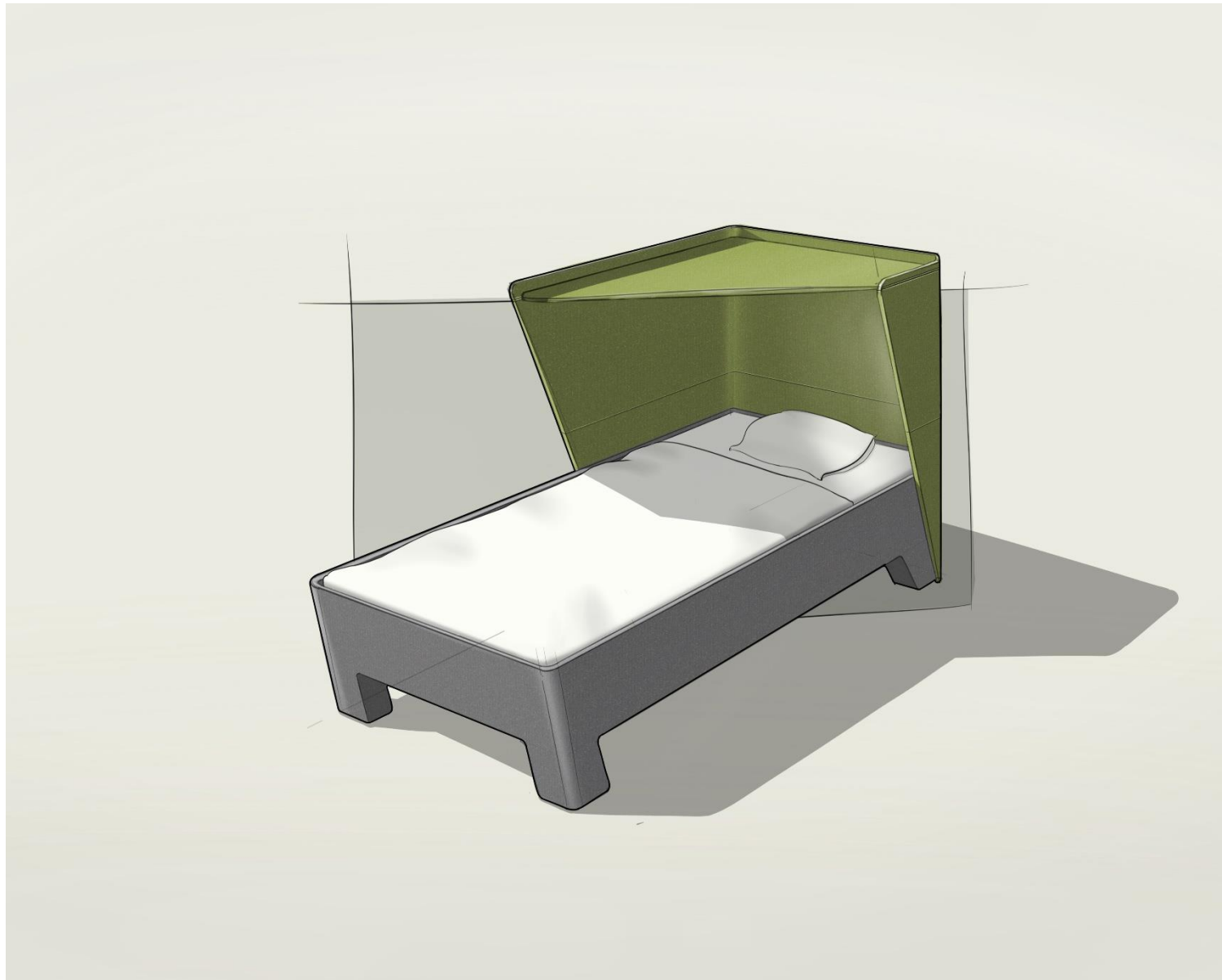
**Appendix G - Updated sketches**

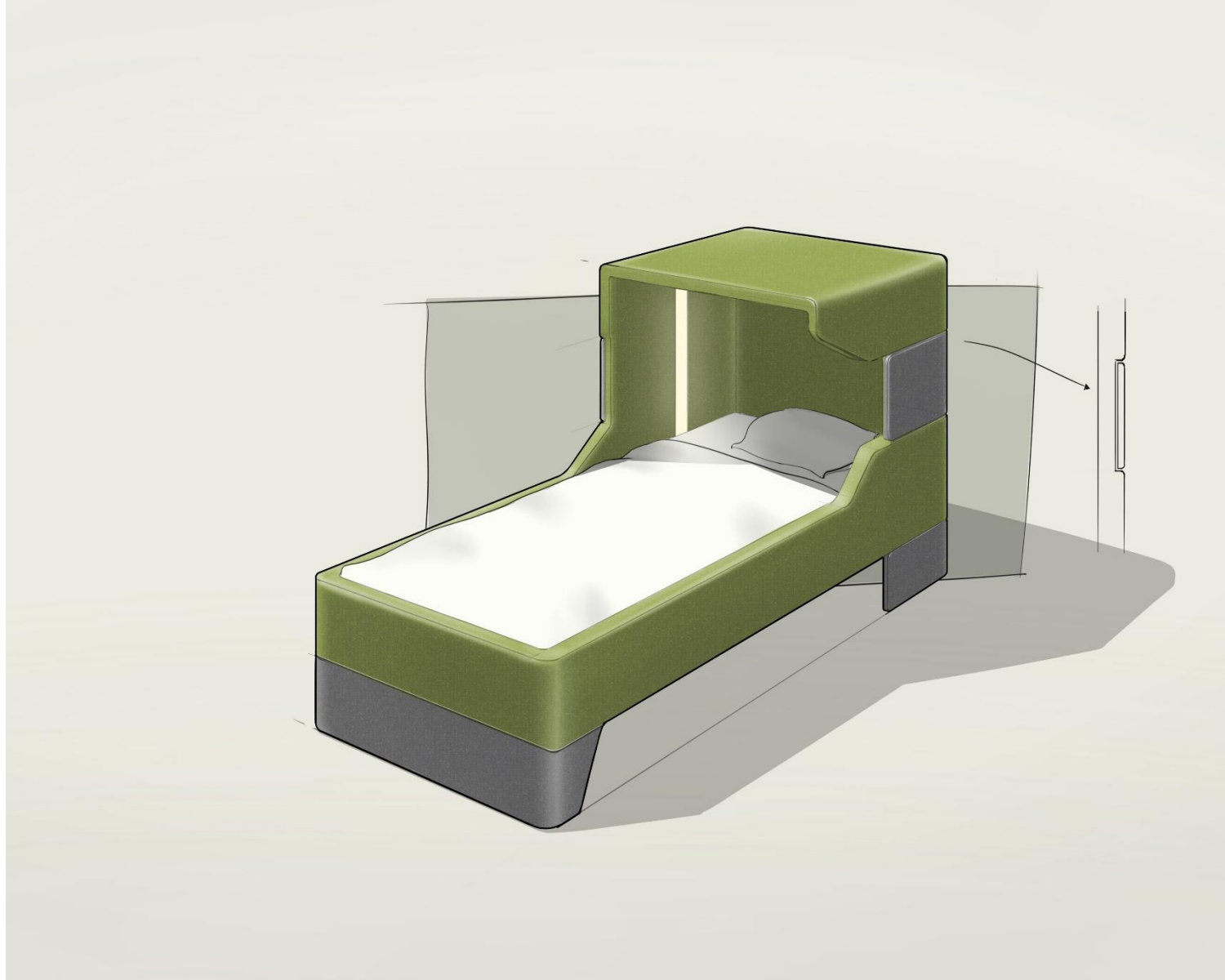






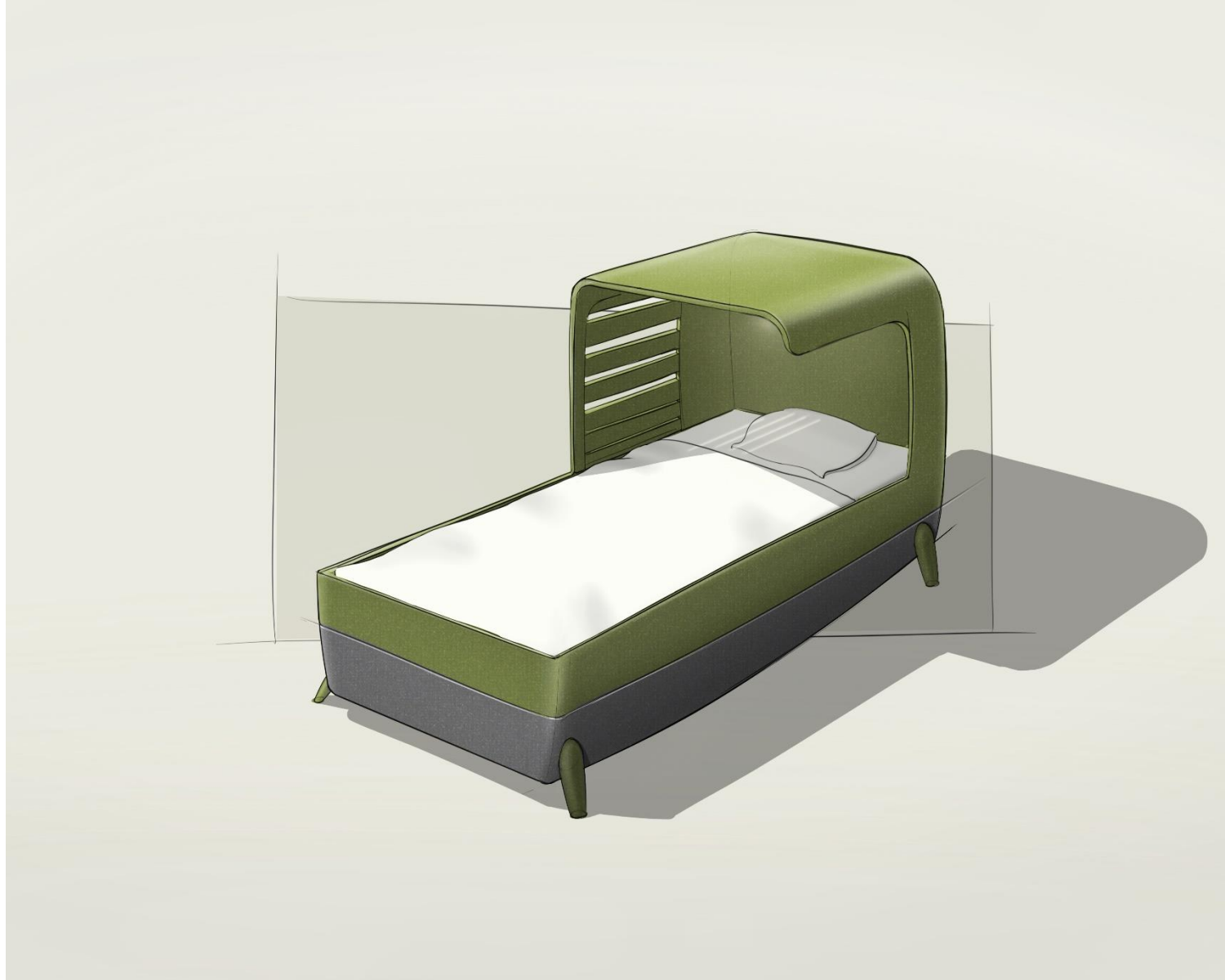


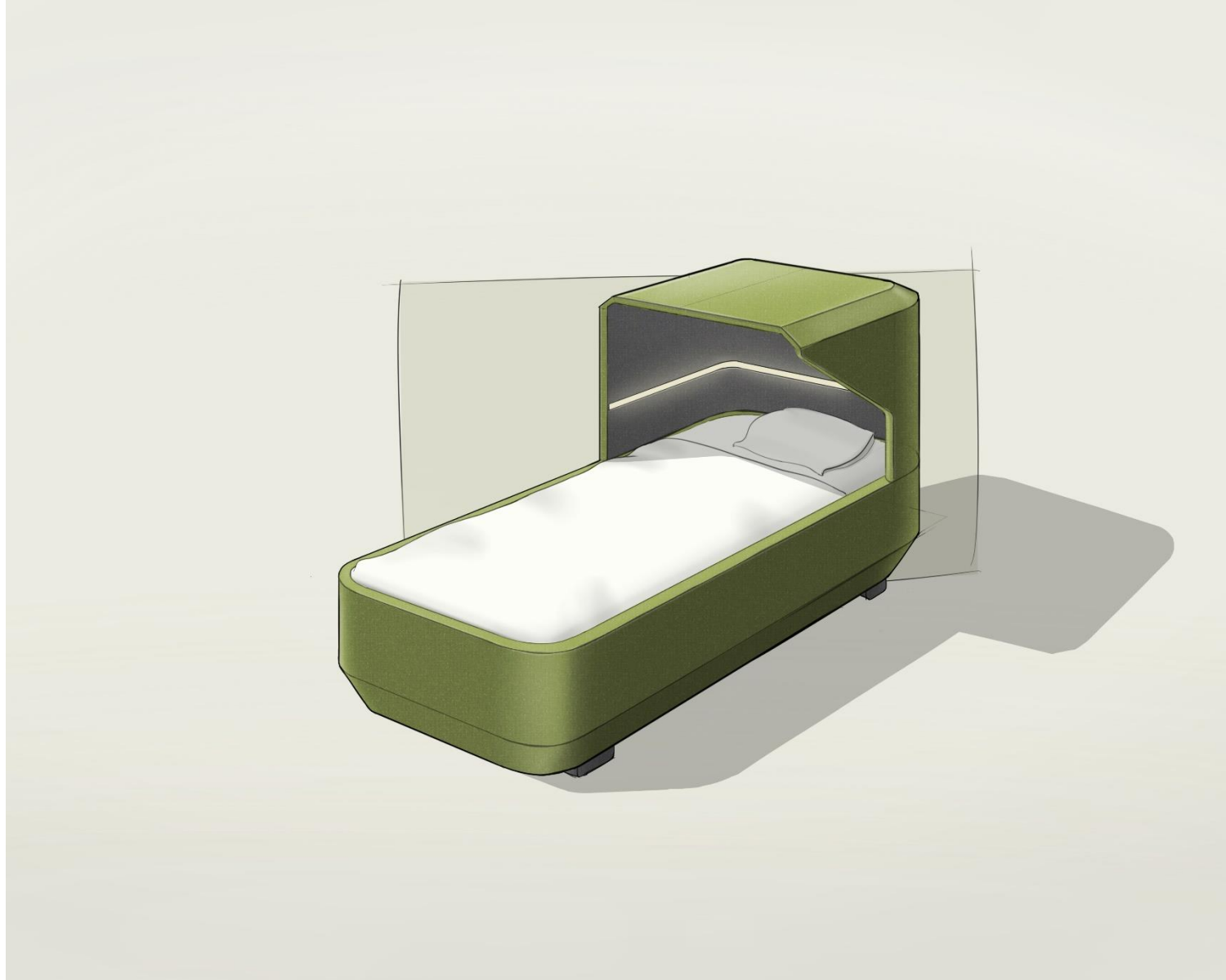


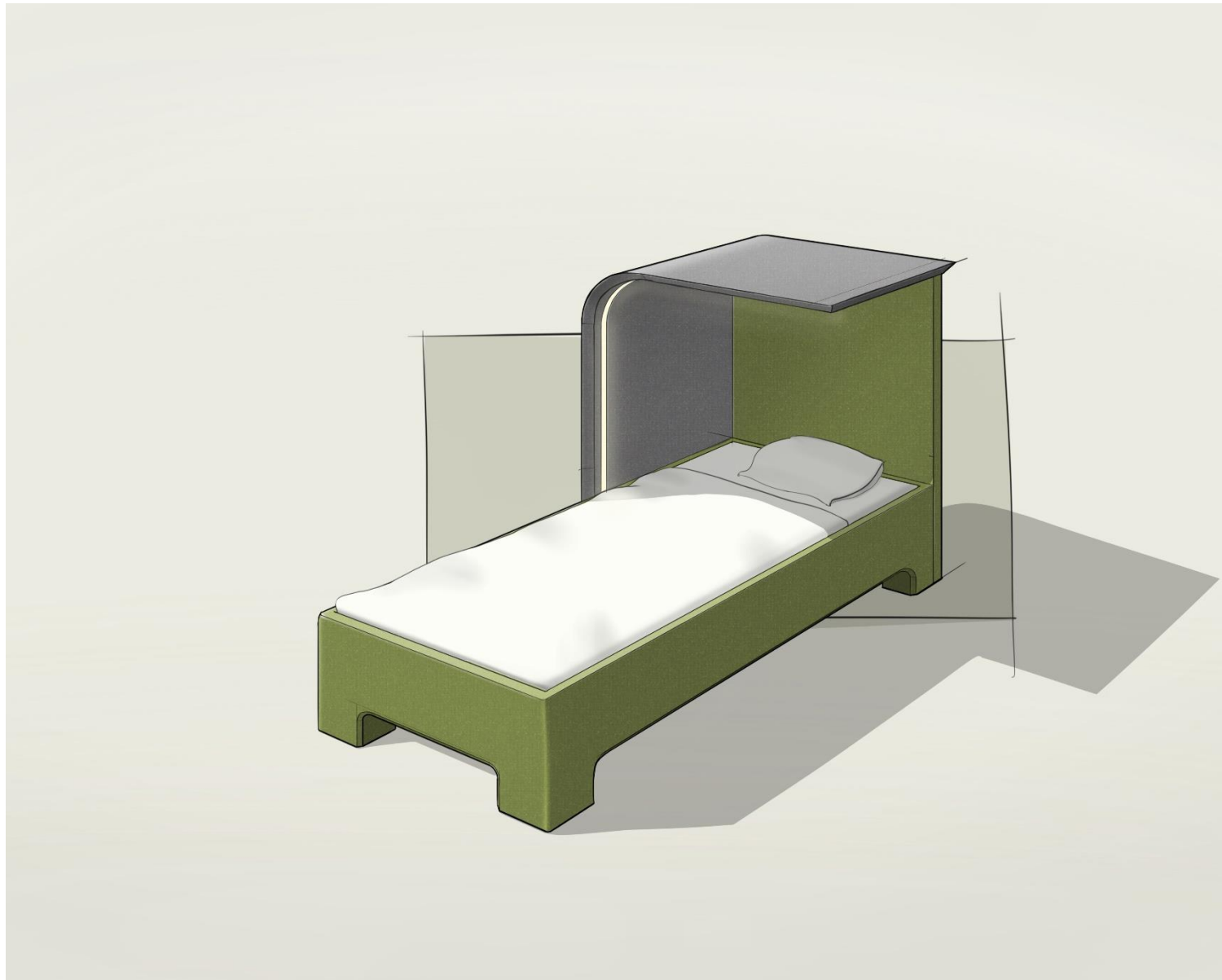


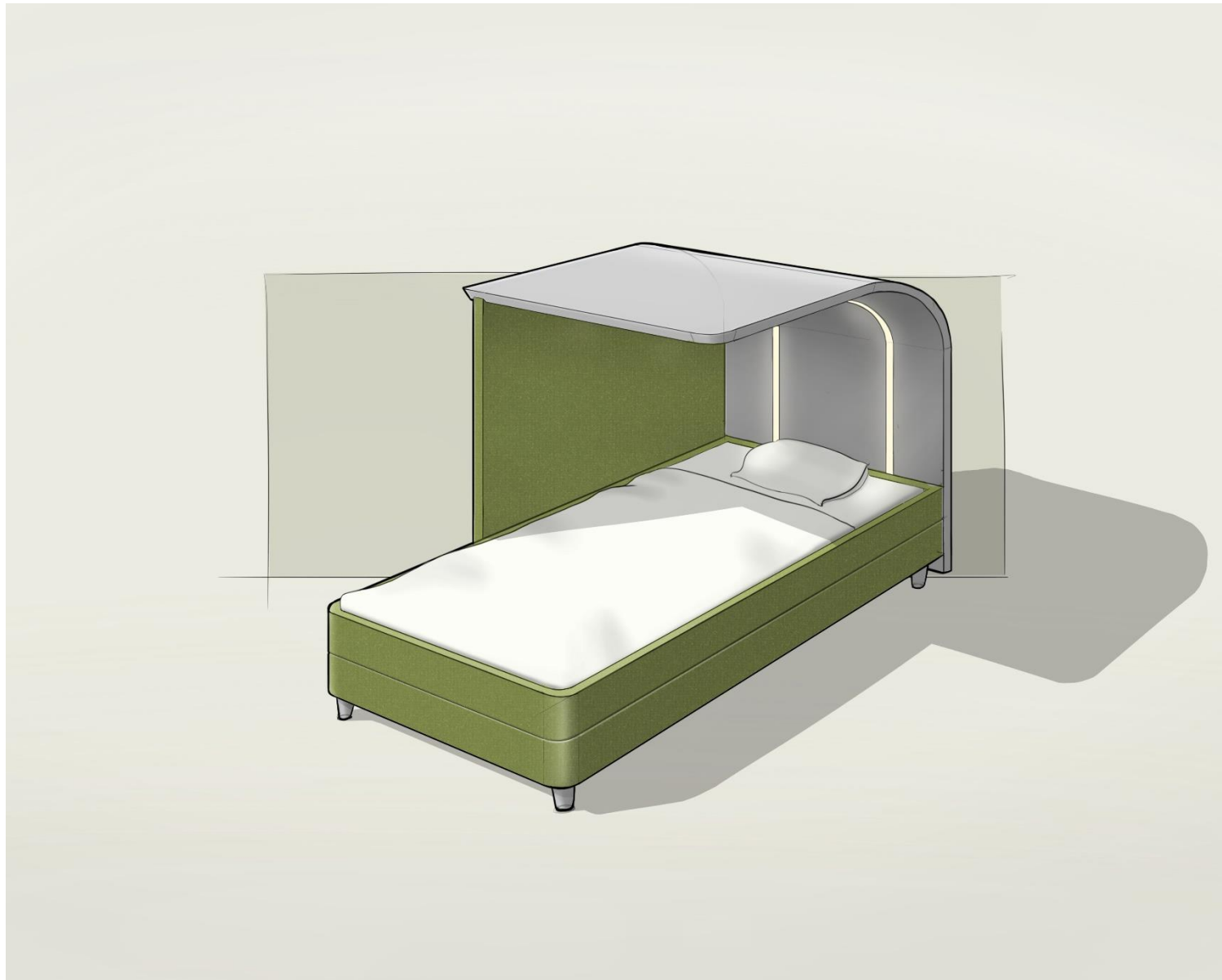


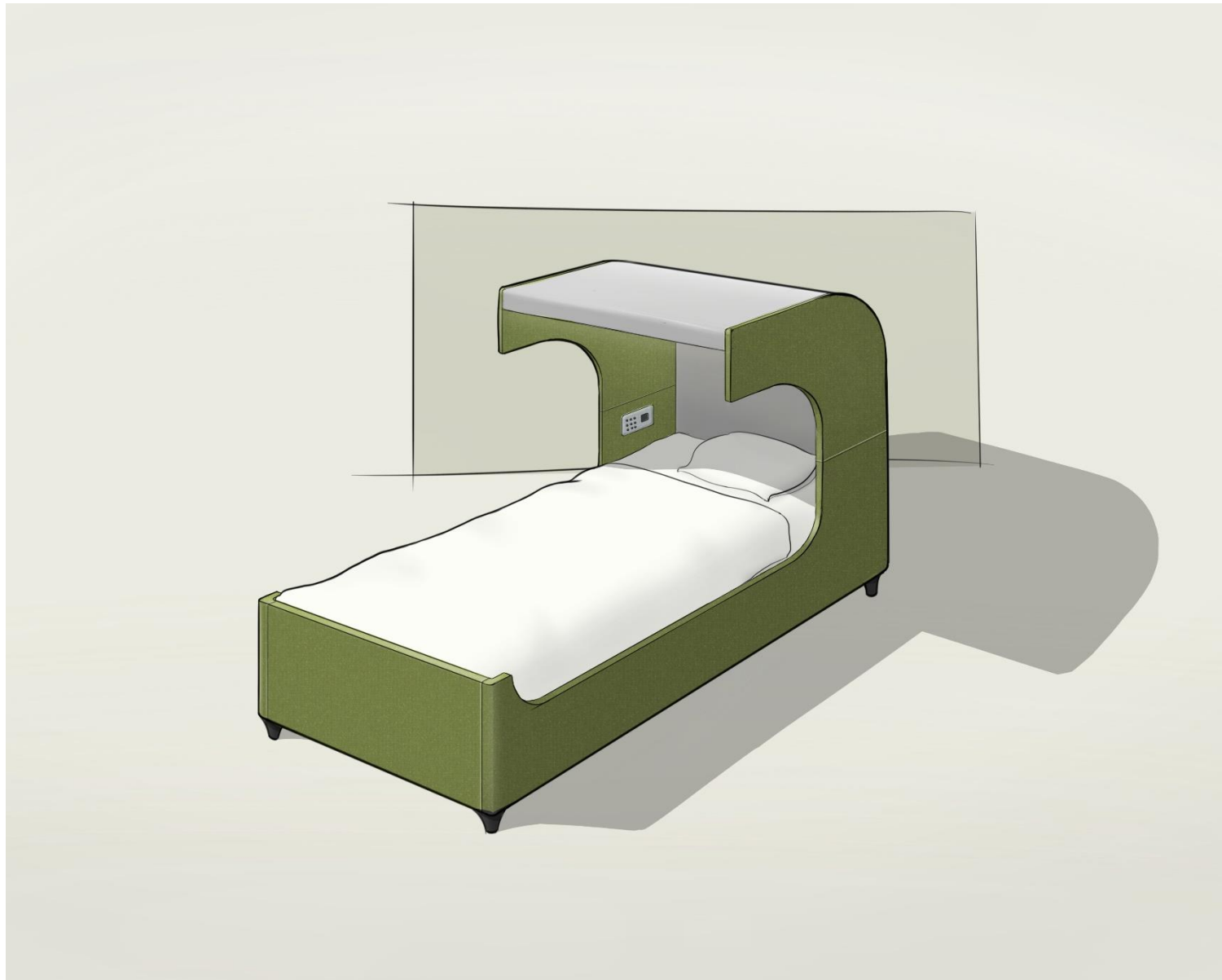




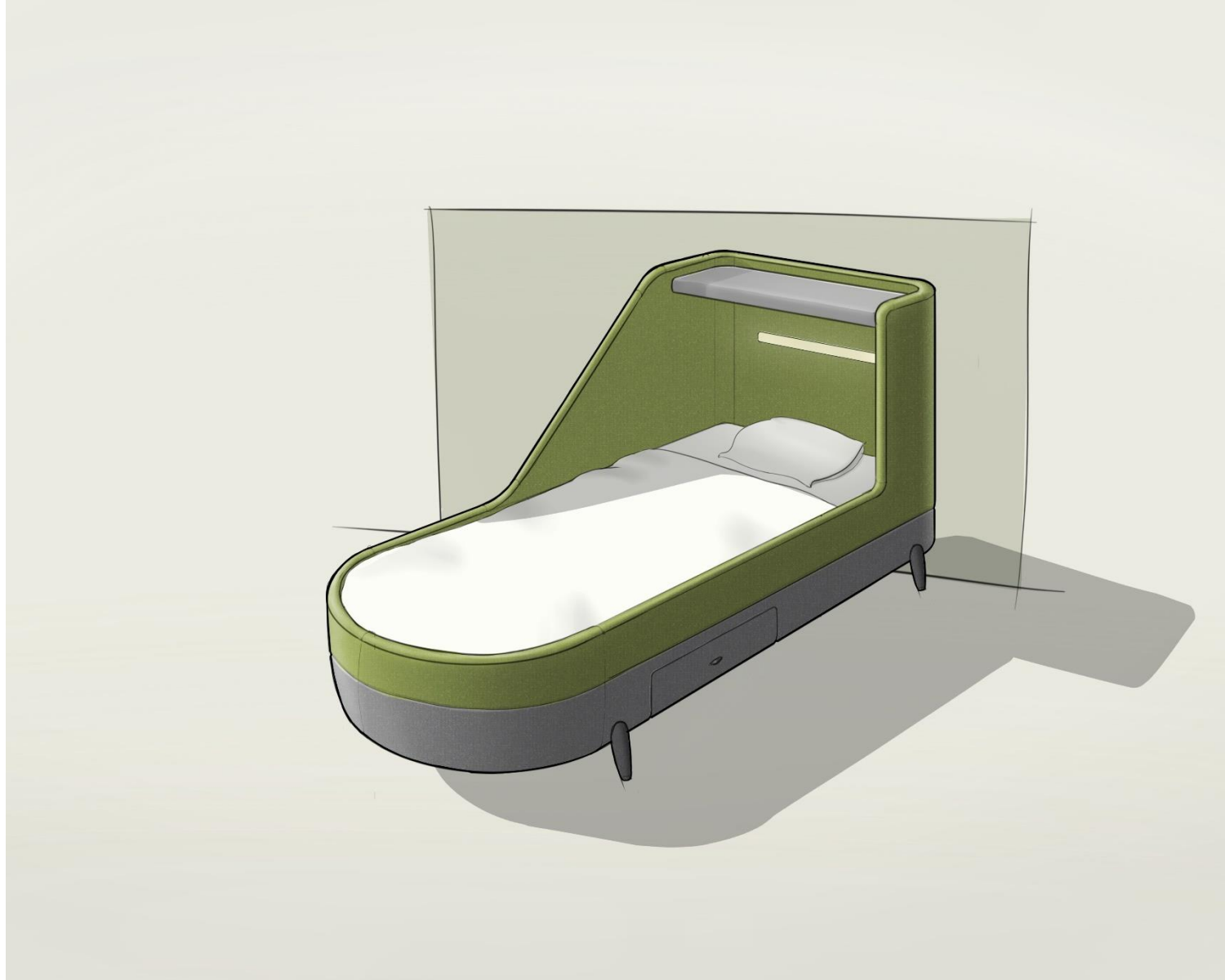




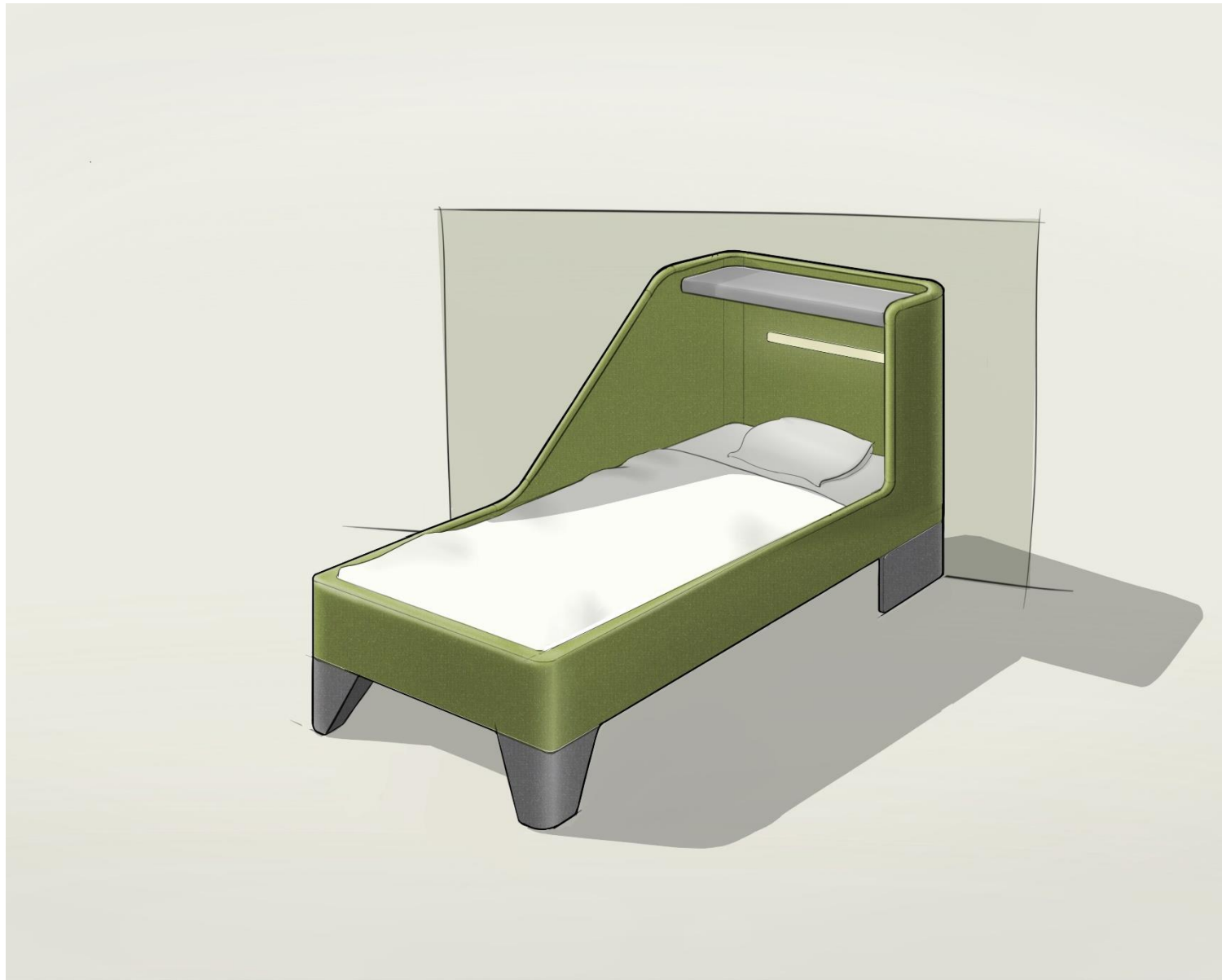






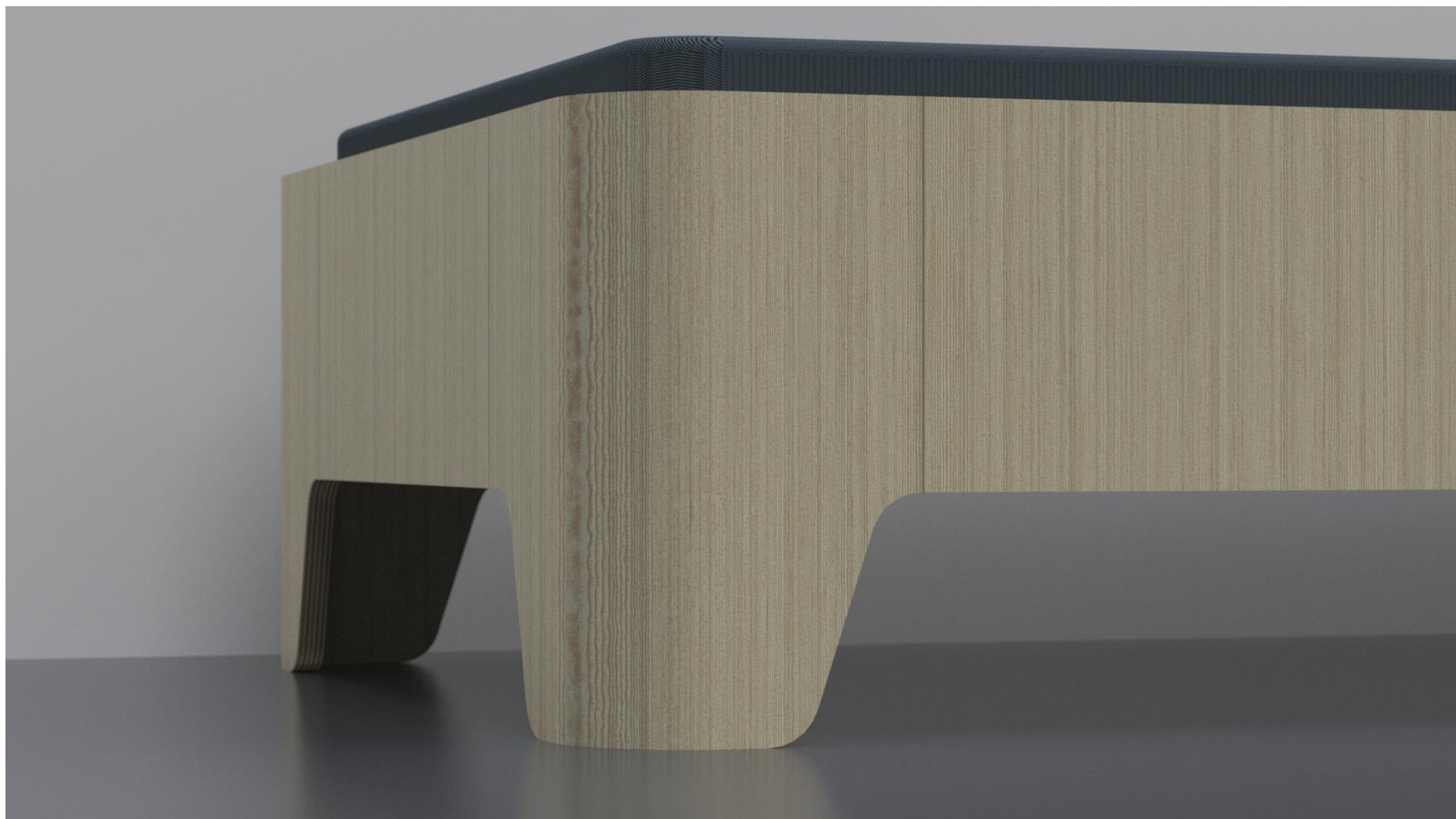


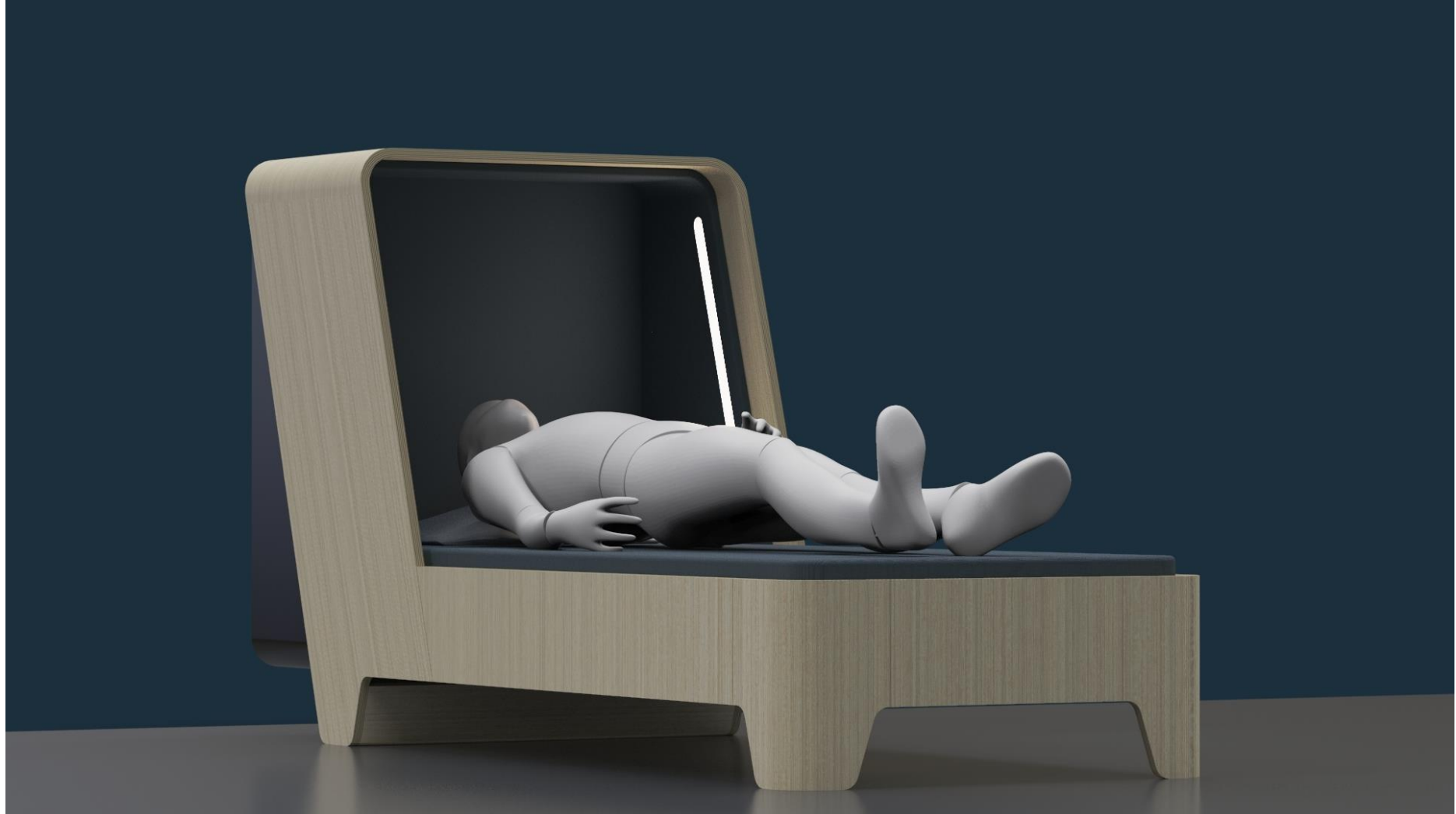




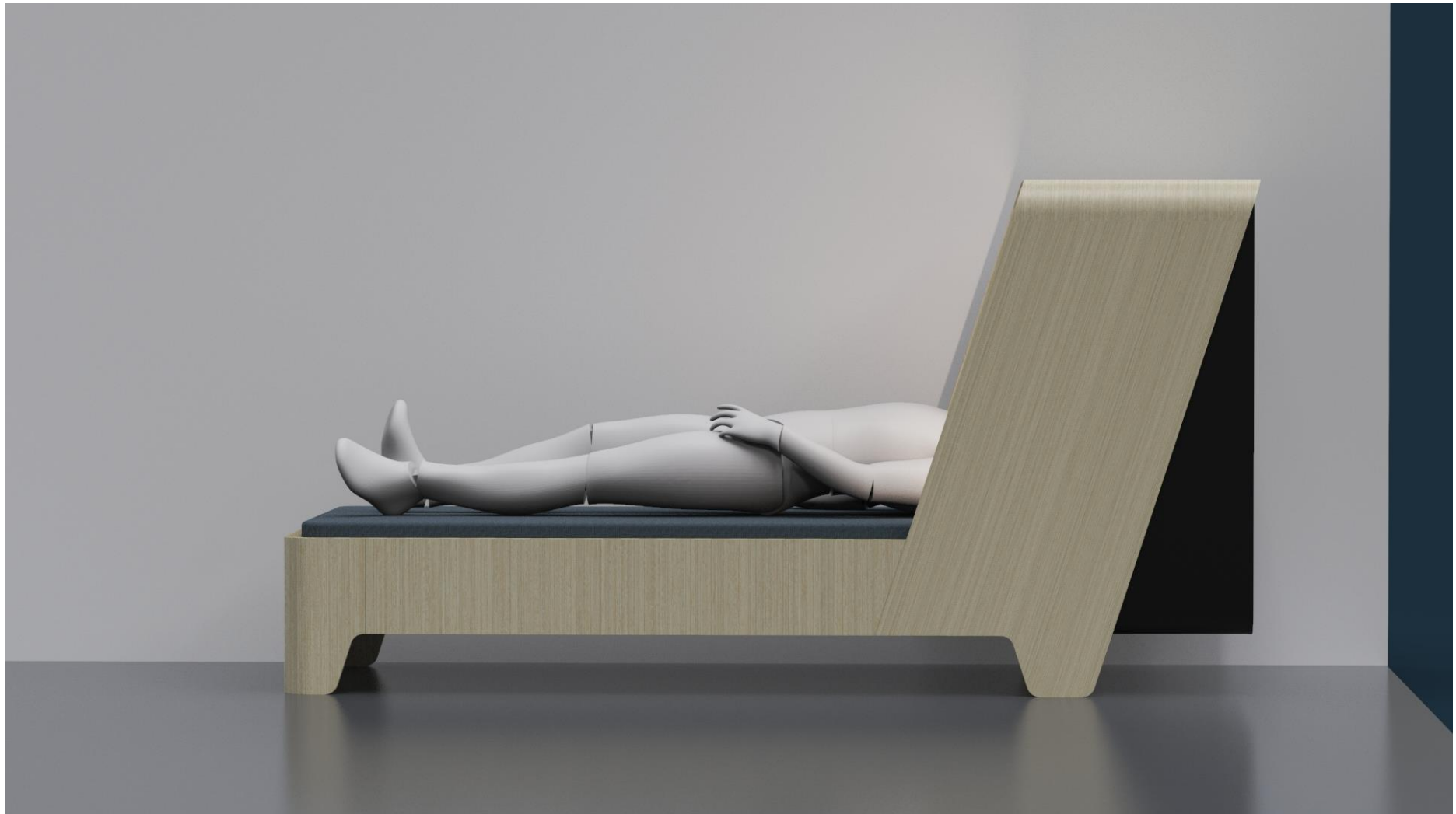
**Appendix I - Full resolution images of 2<sup>nd</sup> iteration concepts**

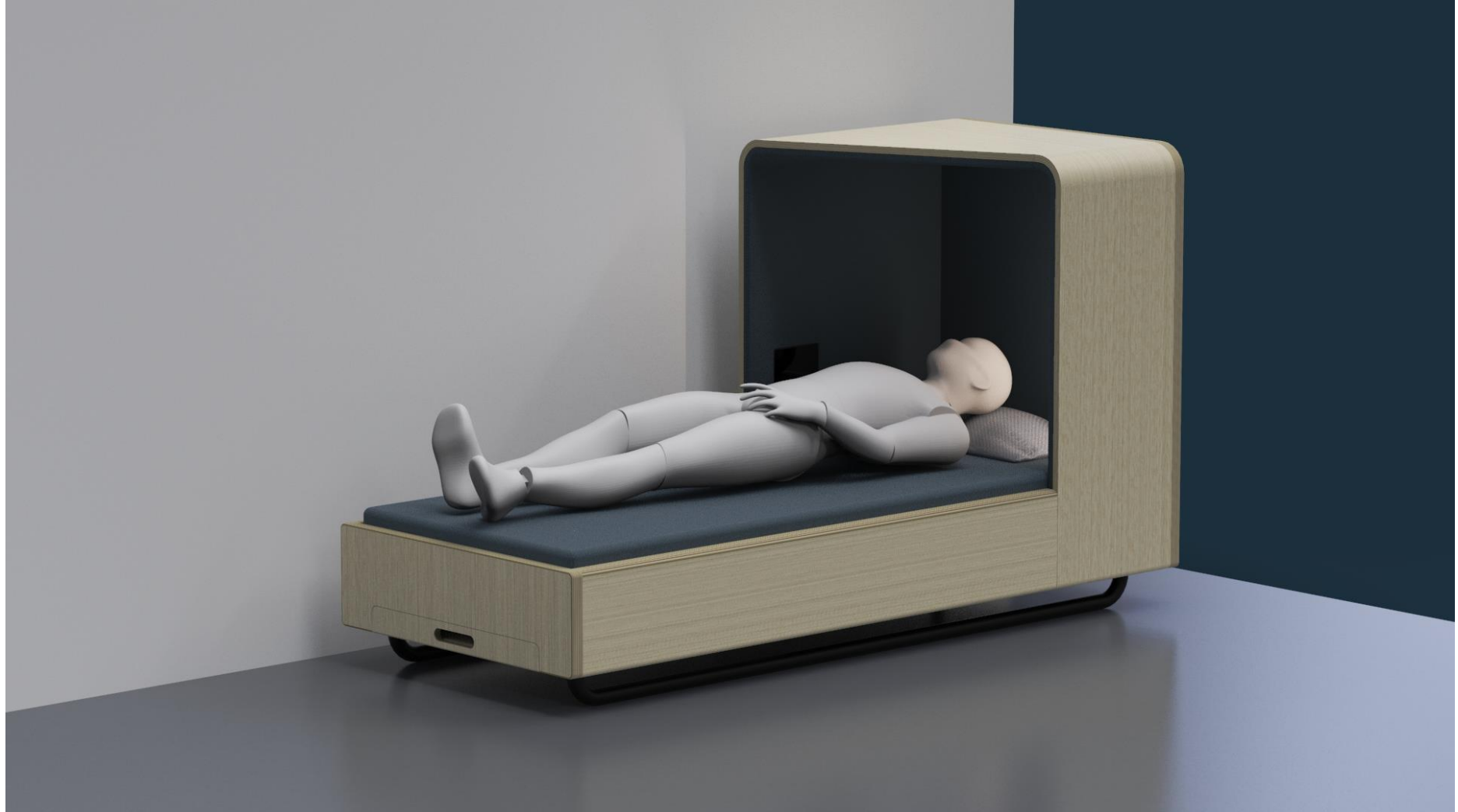






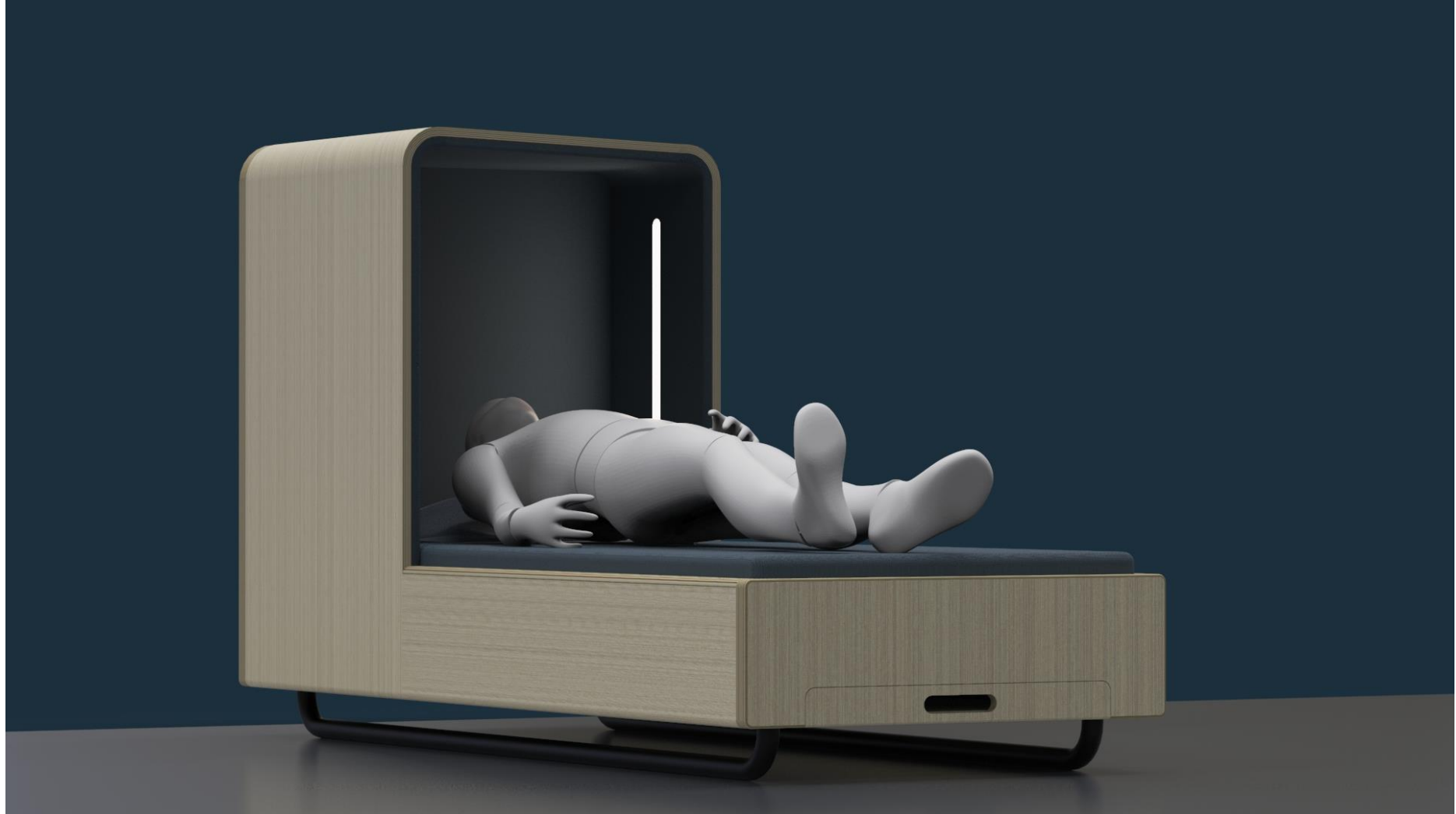




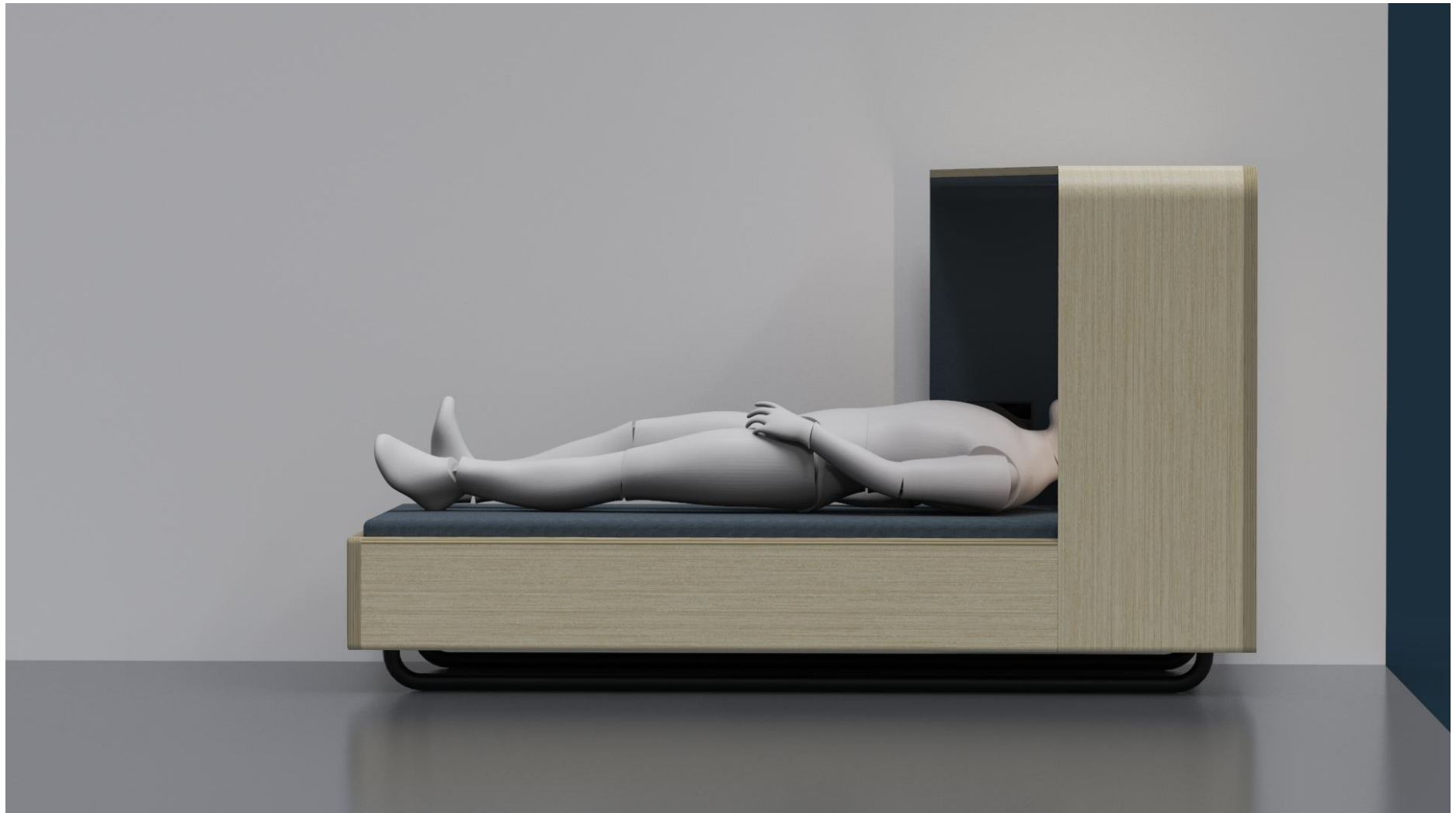


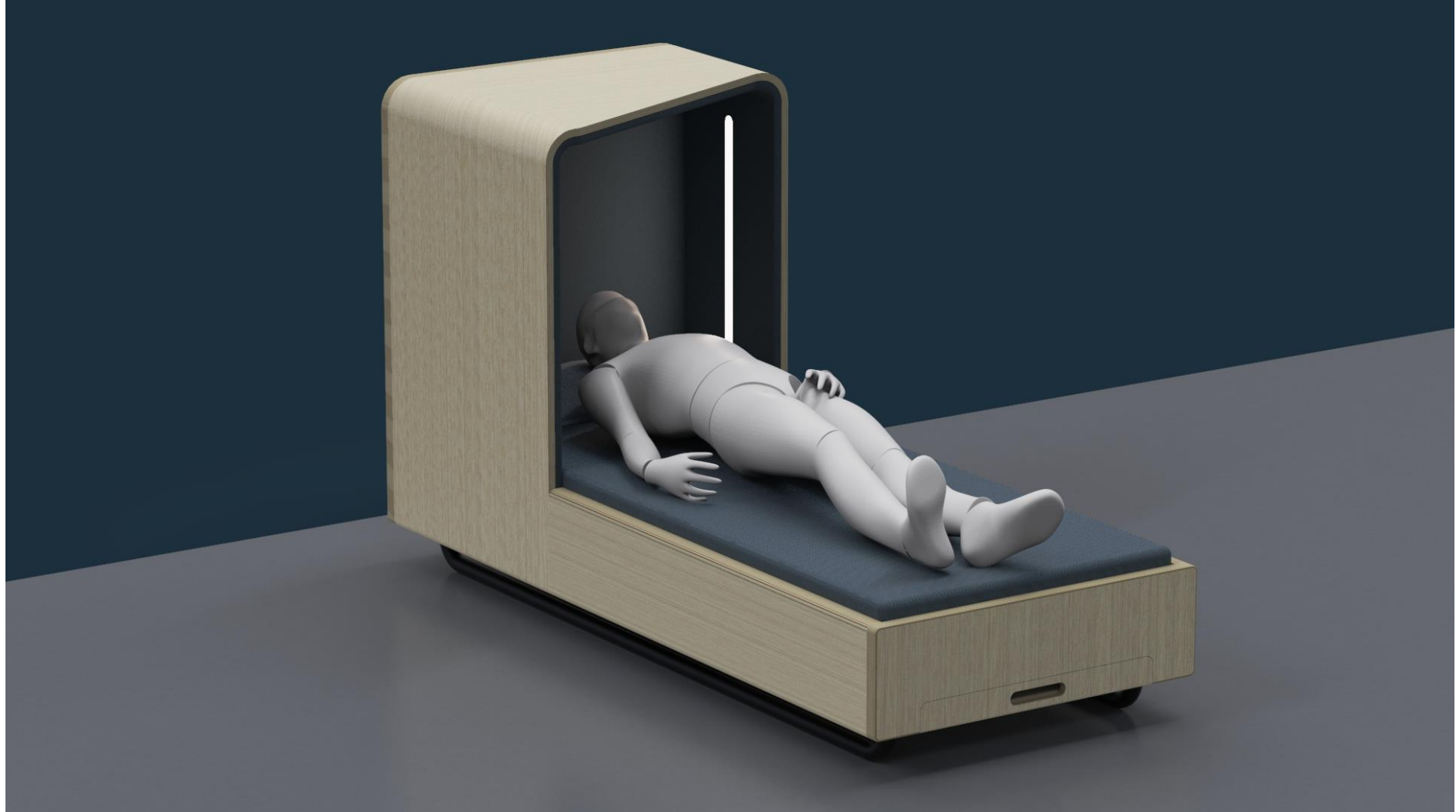




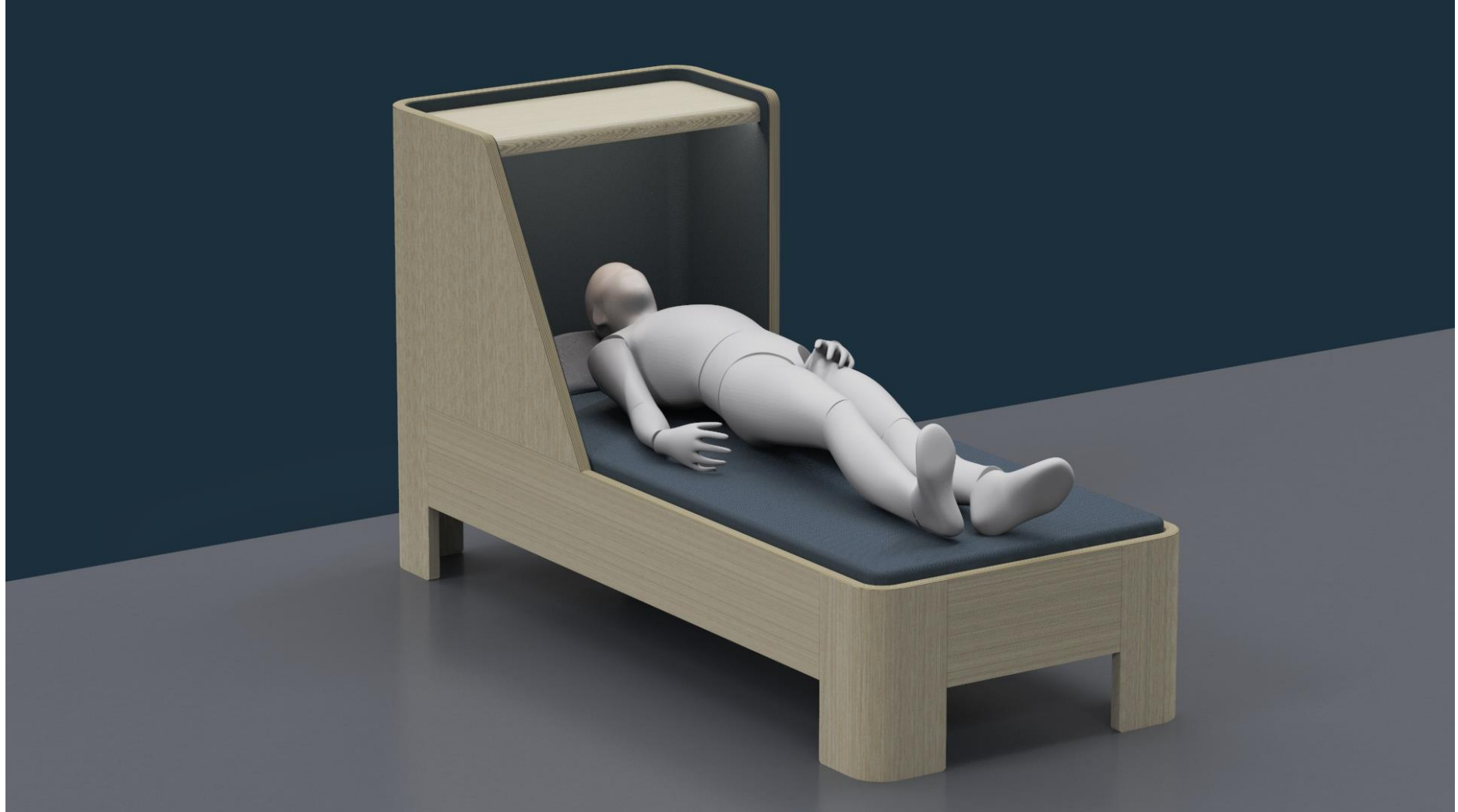




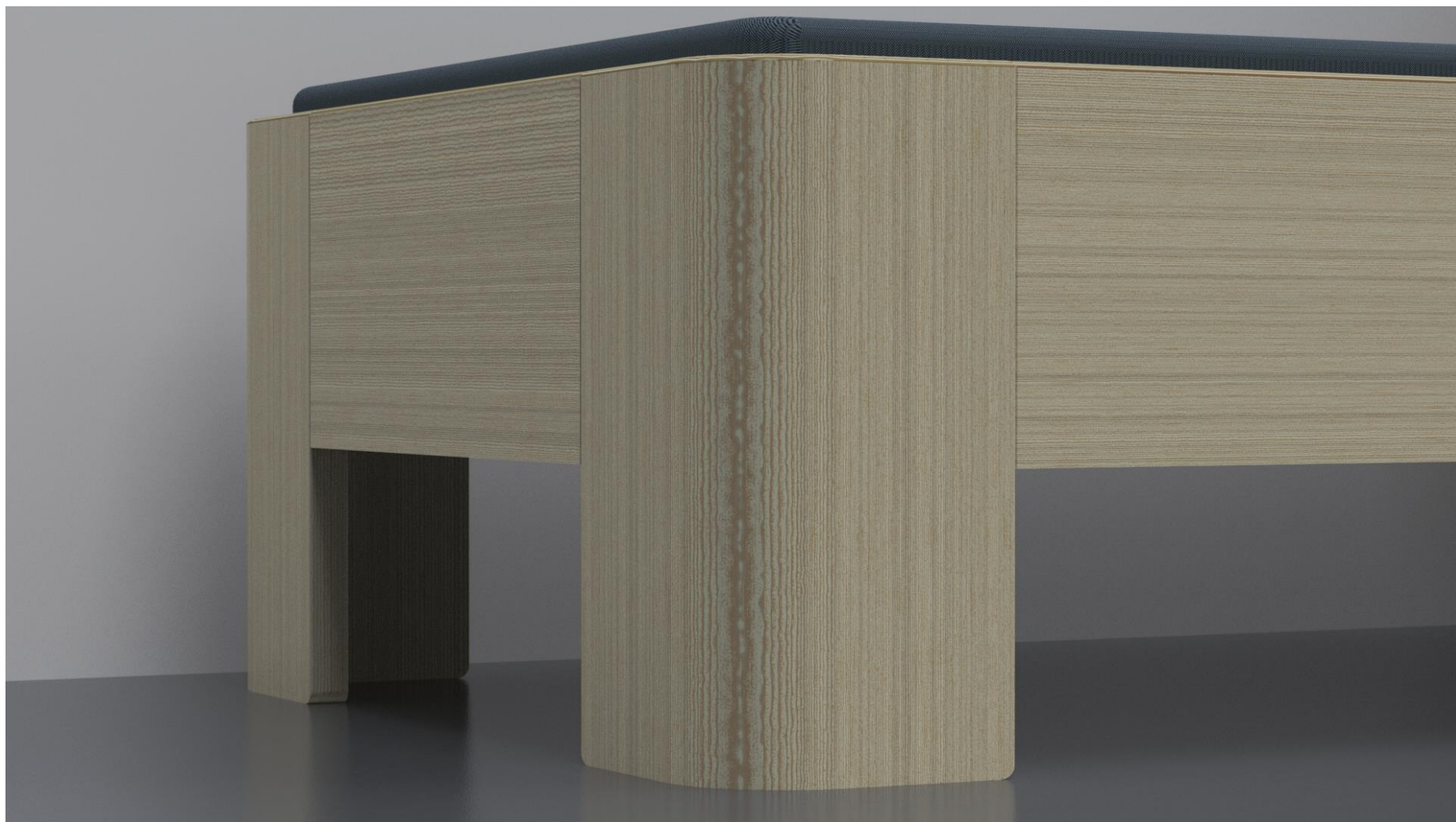




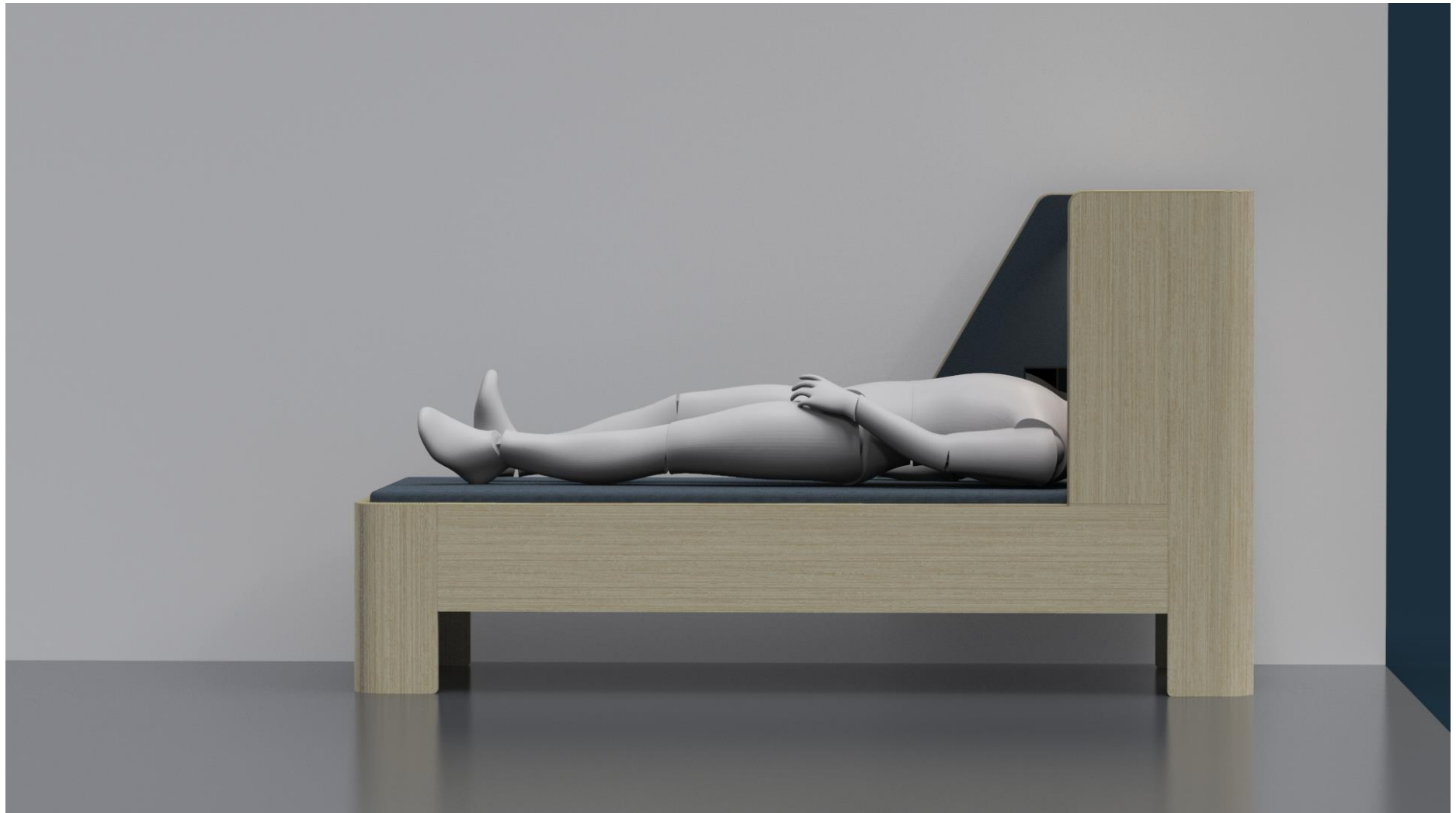










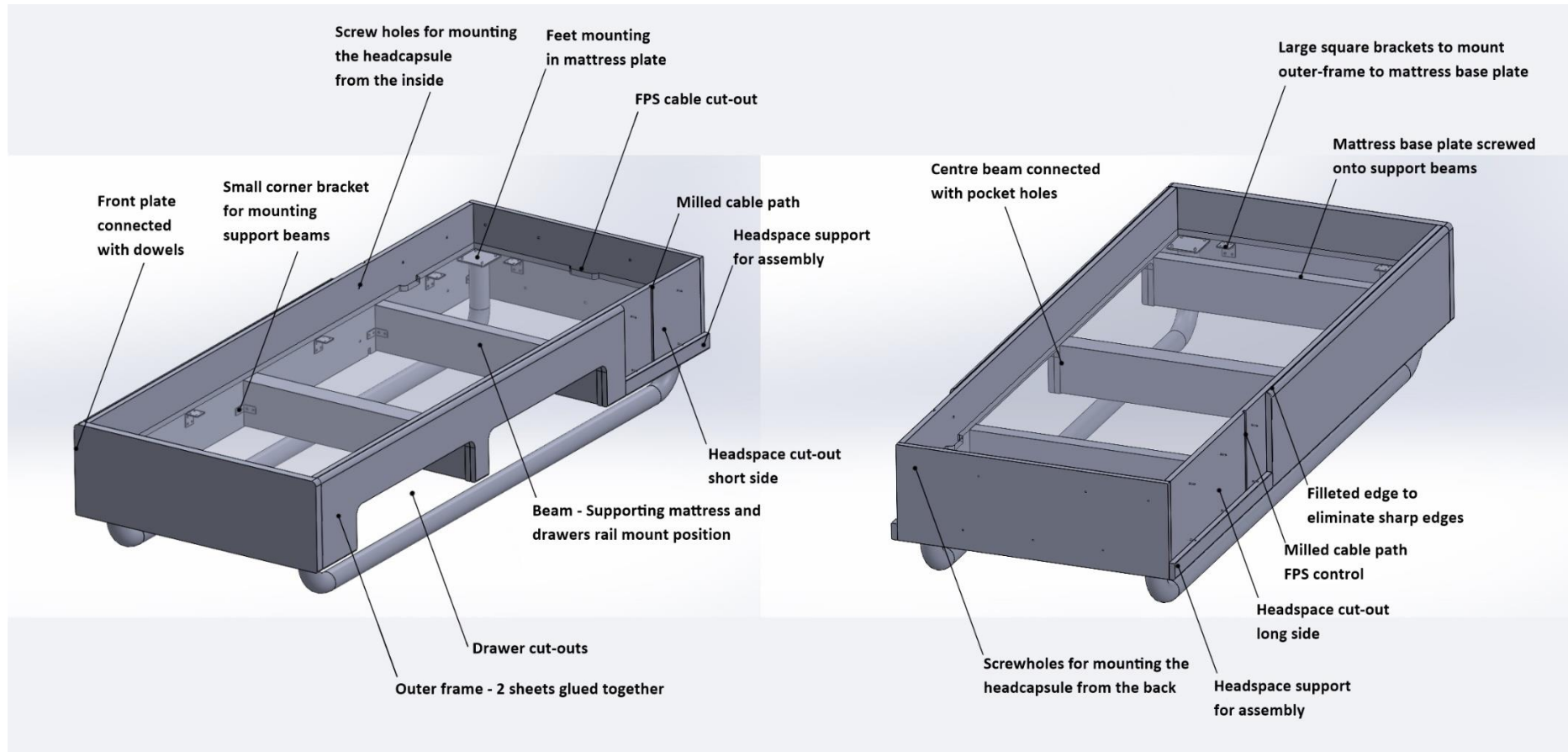


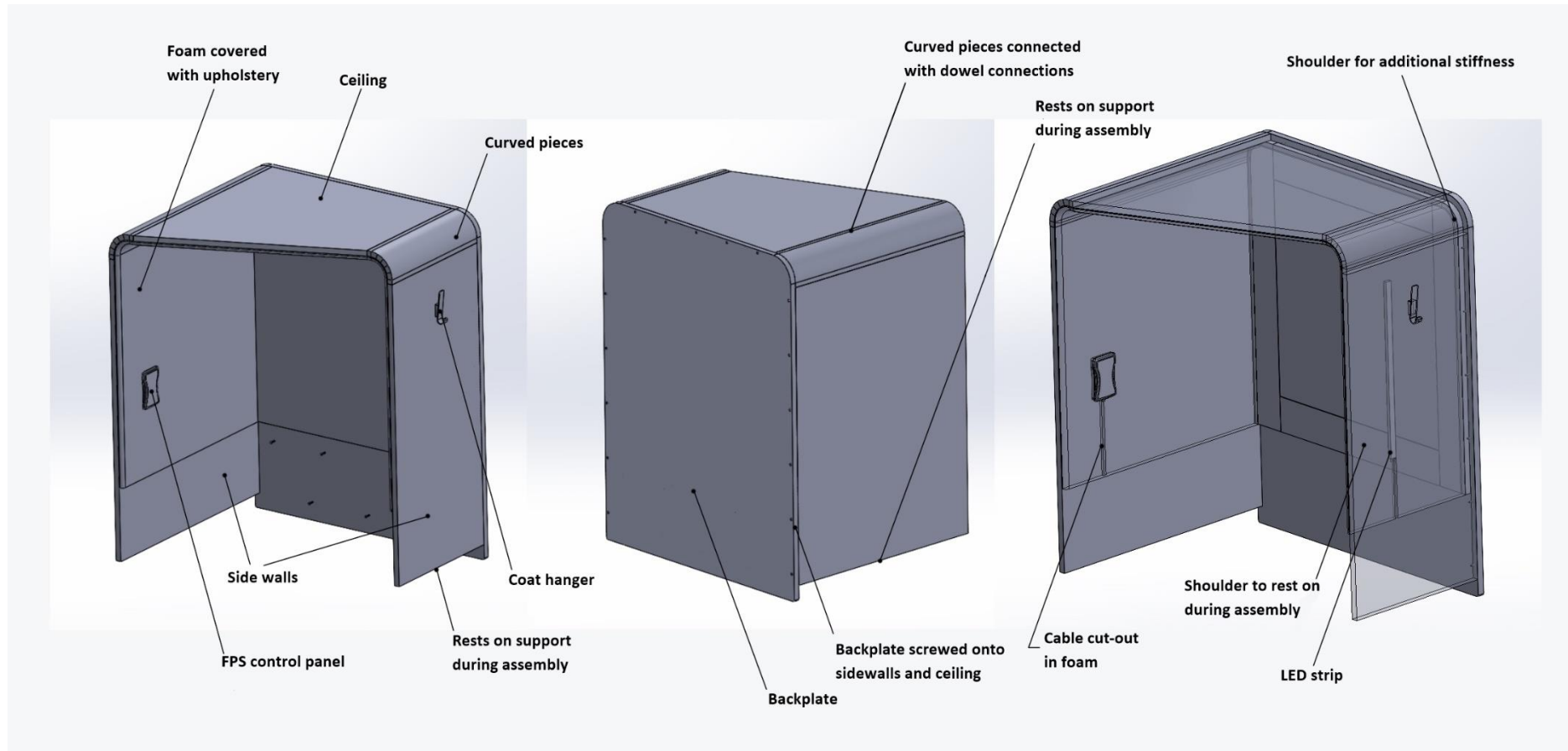


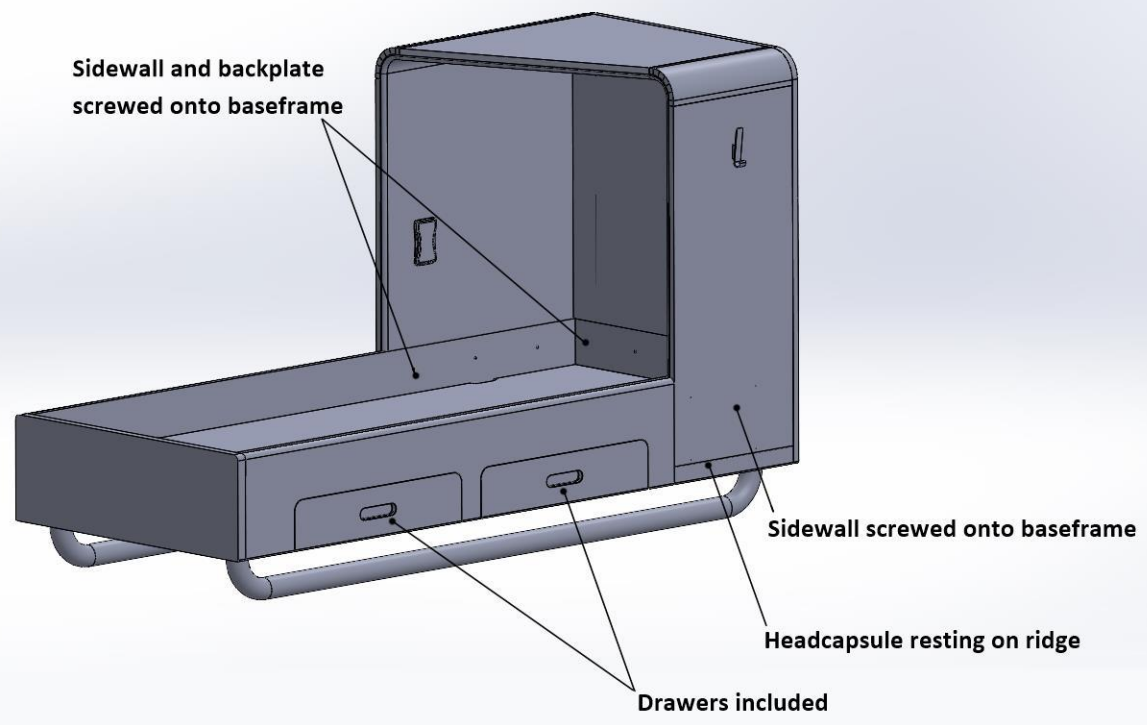
Total costs		1358,40					
Materials		575,87					
Operations		542,53					
Assembly		240,00					
<b>Materials</b>							
Part #	Part name	Part outer dimensions (mm)	Part size (m Quantity)	Material	Estimated cost/part	Total cost	Source
1	Zijkant_Kort	1600*260	0,416	1 Beech plywood 18 mm 88/8	18,89	18,89	zagenzagen.nl
2	Zijkant_Lang	1300*260	0,338	1 Beech plywood 18 mm 88/8	15,35	15,35	zagenzagen.nl
3	Kast_Lang	721*1021	0,736141	1 Beech plywood 18 mm 88/8	33,42	33,42	zagenzagen.nl
4	Kast_Kort	721*421	0,303541	1 Beech plywood 18 mm 88/8	13,78	13,78	zagenzagen.nl
5	Achterkant	1115*1021	1,138415	1 Beech plywood 18 mm 88/8	51,68	51,68	zagenzagen.nl
6	Bovenkant	692*721	0,395132	1 Beech plywood 18 mm 88/8	17,94	17,94	zagenzagen.nl
7	BinnenkantLang	2000*260	0,52	2 Beech plywood 18 mm 88/8	23,61	47,22	zagenzagen.nl
8	BinnenkantKort	842*260	0,21892	1 Beech plywood 18 mm 88/8	9,94	9,94	zagenzagen.nl
9	Voorkant	880*260	0,2288	2 Beech plywood 18 mm 88/8	10,39	20,78	zagenzagen.nl
10	Buigdeelkort	60*421 (R*Length)	-	1 Beech plywood	25,8	25,80	biegeholz.com
11	BuigdeelLang	60*721 (R*Length)	-	1 Beech plywood	44,2	44,20	biegeholz.com
12	SchuimenBekleding_Wanden	2400*700*20	1,342	1 Polyether foam	9,48	9,48	Schuimwinkel.nl
13	SchuimenBekleding_Achter	850*720*20	0,612	1 Polyether foam	4,6768	4,68	Schuimwinkel.nl
14	Stalen_voeten	60*240 (D*Length)	-	2 Steel	34,82	69,64	Bouwbuis.nl
15	StoffenBekleding_Totaal	700*2500 + 850*720	2,36	1 WetCare cloth	52	52,00	Paint.com
16	VerstevigingsBalken	44*44*2700	-	2 Spruce	4,5	9,00	Hornbach.nl
17	Ledindbouwbak	600 mm	-	1 -	8,28	8,28	ledstripkoning.nl
18	Ledstrip_voeding	-	-	15	15,00	15,00	ledstripkoning.nl
19	Hoekanker_nil	60*60	-	4 Steel	1,45	5,80	gb.nl
20	Plaat_verbinding	100*60	-	2 Steel	1	2,00	gb.nl
21	Schroeven/bouten	-	-	60 Steel	0,1	6,00	Hornbach.nl
22	Deuvels/Lamello	-	-	50 Wood	0,1	5,00	-
23	Draagplank_Matras	2000*80	-	1 Wood	40	40,00	-
24	Overigen	-	-	1 -	50	50,00	-
						<b>Total</b>	575,87
<b>Operations</b>		Based on an hourly rate of 40 euro	40	<a href="https://www.mijnzpp.nl/Beroep/664-Interieurbouwer/Salaris-en-tarief#:~:text=Een%20interieurbouwer%20factureert%20onges">https://www.mijnzpp.nl/Beroep/664-Interieurbouwer/Salaris-en-tarief#:~:text=Een%20interieurbouwer%20factureert%20onges</a>			
Part #	Operation #	Operation	Quantity in Estimated time in seconds / m, m*2, feature or par	Quantity (part)	Total cost	Source	
1	1	Rounding edges	3,2 60	1	2,13	-	
	2	Drilling dowel/lammelos holes	6 15		1,00	-	
	3	Inserting and glueing dowels/lammelos	6 10		3,33	-	
	4	Glueing and clamping to part 7	1 300		3,33	-	
	5	Sanding edges flat	1 300		3,33	-	
	6	Spraying coat/paint*	0,5 37,5 * Coating is calculated in price/m*2		18,75	<a href="https://sputerij-jansse">https://sputerij-jansse</a>	
2	7	Rounding edges	2,6 60	1	1,73	-	
	8	Drilling dowel/lammelos holes	6 15		1,00	-	
	9	Inserting and glueing dowels/lammelos	6 10		0,67	-	
	10	Glueing and clamping to part 7	1 300		3,33	-	
	11	Sanding edges flat	1 300		3,33	-	
	12	Spraying coat/paint*	0,35 37,5 * Coating is calculated in price/m*2		13,13	-	
3	13	Rounding edges	0,7 60	1	0,47	-	
	14	Predrilling mounting holes	12 15		2,00	-	
	15	Drilling dowel/lammelos holes	7 15		1,17	-	
	16	Inserting and glueing dowels/lammelos	4 10		0,44	-	
	17	Predrilling mounting holes for control inter	4 15		0,67	-	
	18	Sanding	1 420		4,67	-	
	19	Spraying coat/paint*	0,8 37,5 * Coating is calculated in price/m*2		30,00	-	
4	20	Rounding edges	0,4 60	1	0,27	-	
	21	Predrilling mounting holes	12 15		2,00	-	
	22	Drilling dowel/lammelos holes	6 15		1,00	-	
	23	Inserting and glueing dowels/lammelos	3 10		0,33	-	
	24	Sanding	1 360		4,00	-	
	24	Spraying coat/paint*	0,45 37,5 * Coating is calculated in price/m*2		16,88	-	
5	25	Rounding corners	4 180	1	8,00	-	
	26	Predrilling mounting holes	18 15		3,00	-	
	27	Setting screws to mount backplate	18 10		2,00	-	
	28	Sanding	1 480		5,33	-	
	29	Spraying coat/paint*	1 37,5 * Coating is calculated in price/m*2		37,50	-	
6	29	Drilling dowel/lammelos holes	7 15	1	1,17	-	
	30	Inserting and glueing dowels/lammelos	7 10		0,78	-	
	31	Sanding	1 240		2,67	-	
	32	Spraying coat/paint*	0,45 37,5 * Coating is calculated in price/m*2		16,88	-	
7	33	Predrilling holes for corner brackets	8 15	2	2,67	-	
	34	Screwing on corner brackets	8 10		1,78	-	
	35	Predrilling holes for mounting part 3/4	8 15		2,67	-	
	36	Sanding	1 240		5,33	-	
	37	Spraying coat/paint*	0,55 37,5 * Coating is calculated in price/m*2		41,25	-	
8	38	Predrilling holes for corner brackets	8 15	1	1,33	-	
	39	Screwing on corner brackets	8 10		0,89	-	
	40	Predrilling holes for mounting part 5 (backs	8 15		1,33	-	
	41	Sanding	1 200		2,22	-	
	42	Spraying coat/paint*	0,25 37,5 * Coating is calculated in price/m*2		9,38	-	
9	43	Rounding corners	4 180	1	8,00	-	
	44	Drilling dowel/lammelos holes	6 15		1,00	-	
	45	Predrilling holes for corner brackets	8 15		1,33	-	
	46	Screwing on corner brackets	8 10		0,89	-	
	47	Sanding	1 300		3,33	-	
	48	Spraying coat/paint*	0,3 37,5 * Coating is calculated in price/m*2		11,25	-	
10	49	Drilling dowel/lammelos holes	6 15	1	1,00	-	
	50	Predrilling holes bracket strengthening	4 15		0,67	-	
	51	Mounting strengthening bracket	2 60		1,33	-	
	52	Sanding	1 300		3,33	-	
	53	Spraying coat/paint*	0,1 37,5 * Coating is calculated in price/m*2		3,75	-	
11	54	Drilling dowel/lammelos holes	8 15	1	1,33	-	
	55	Predrilling holes bracket strengthening	4 15		0,67	-	
	56	Mounting strengthening bracket	2 60		1,33	-	
	57	Sanding	1 300		3,33	-	
	58	Spraying coat/paint*	0,15 37,5 * Coating is calculated in price/m*2		5,63	-	
12	59	Cutting foam to size	1 420	1	4,67	-	
	60	Glueing foam to boards	1 300		3,33	-	
13	61	Cutting foam to size	1 180	1	2,00	-	
	62	Glueing foam to boards	1 180		2,00	-	
14	63	Bending to the required shape**	1 30	2	60,00	-	
	64	Welding on mounting plate	2 7,5		30,00	-	
	65	Making mounting plate	2 5		20,00	-	
	66	Powdercoating	1 20		40,00	-	
	67	Screwing on Feet	8 10		1,78	-	
15	68	Cutting fabric to size	1 600	1	6,67	-	
	69	Sewing/making the upholstery	1 3000		33,33	-	
16	70	Predrilling holes for mounting	20 15	1	3,33	-	
	71	Cutting to length	4 30		1,33	-	
	72	Mounting and screwing in	20 10		2,22	-	
	73	Cutting into a circular profile	2 120		2,67	-	
17	73	Cutting to the right length	1 150	1	1,67	-	
	74	Mounting with clips	3 30		1,00	-	
18	75	Mounting LED strip and wiring it up	1 600		6,67	-	
	76	Mounting power source	1 240		2,67	-	
23	78	Predrilling mounting holes	14 15	1	2,33	-	
	79	Screwing baseplate	14 10		1,56	-	
						<b>Total</b>	542,53
<b>General assembly</b> Based on the general complexity of the concept							
Hour rate (euro/hour)	Total expected hours	Total assembly costs					
40	6	240					<b>Total</b> 240,00

Total costs		1203,80							
Materials		596,63							
Operations		367,17							
Assembly		240,00							
<b>Materials</b>									
Part #	Part name	Part outer dimensions (mm)	Part size (m²)	Quantity	Material	Estimated cost/part	Total cost		Source
1	ZijkantPlank	1675*250		0,419	2 Beech plywood 30 mm BB/B	32,45	64,91		zagenzage
2	VoorkantPlank	475*250		0,119	1 Beech plywood 30 mm BB/B	9,22	9,22		zagenzage
3	AchterkantPlank	475*970		0,46	1 Beech plywood 30 mm BB/B	35,63	35,63		zagenzage
4	ZijkantKort	720*230		0,166	1 Beech plywood 30 mm BB/B	12,86	12,86		zagenzage
5	ZijkantSchuin	700*720		0,36	1 Beech plywood 30 mm BB/B	27,88	27,88		zagenzage
6	BovenPlank	815*360		0,295	1 Beech plywood 30 mm BB/B	22,85	22,85		zagenzage
7	HoekenVoor	440*50*120*30 (Height*IR*Length*Thickne		-	2 Beech plywood	48,00	96,00		biegeholz
8	HoekenAchter	1160*50*120*30 (Height*IR*Length*Thickn		-	2 Beech plywood	88,00	176,00		biegeholz
9	Schuimenbekleding	1990*965*10		-	1 Beech plywood 18 mm BB/B	9,00	9,00		Schuimwi
10	StoffenbekledingTotaal	2250*1100		-	1 Wetcare cloth	58,5	0,00		Pintail.cor
11	VerstevigingsBalken	44*44*2700		-	2 Spruce	4,5	9,00		Hornbach.
12	VerstevigingsBalken	44*44*2700		-	2 Spruce	4,5	9,00		Hornbach.
13	Ledinbouwbak	600 mm		-	1 -	8,28	8,28		ledstripko
14	Ledstrip + voeding	-		-	1 -	15	15,00		ledstripko
15	Schroeven/bouten	-		-	60 Steel	0,1	6,00		Hornbach.
16	Deuvels/Lamello	-		-	50 Wood	0,1	5,00		-
17	Draagplank_Matrass	2000*80		-	1 Wood	40	40,00		-
18	Overigen	-		-	1 -	50	50,00		-
							<b>Total</b>	596,63	
<b>Operations</b>									
	Based on an hourly rate of 40 euro	40	https://www.mijnzpp.nl/Beroep/664-Interieurbouwer/Salaris-en-tarieff#:text=Een%20Interieurbouwer%20factureert%20ongeveer%20€2%82%AC%2030%2C						
Part #	Operation #	Operation	Quantity in m, m², feature or part	Estimated time in seconds / m, m², feature or part	Quantity (part)	Total cost			Source
1		1 Rounding edges	1,67	60	2	2,23			-
		2 Drilling dowel/lammelos holes	8	15		2,67			-
		3 Inserting and glueing dowels/lamellos	8	10		0,00			-
		4 Screwing on support beam	4	15		0,00			-
		5 Sanding	1	360		8,00			https://sp
		6 Spraying coat/paint*	0,45	37,5 * Coating is calculated in price/m²		33,75			-
2		7 Rounding edges	0,47	60	1	0,31			-
		8 Drilling dowel/lammelos holes	6	15		0,00			-
		9 Inserting and glueing dowels/lamellos	6	10		0,67			-
		10 Screwing on support beam	3	15		0,50			-
		11 Sanding	1	240		2,67			-
		12 Spraying coat/paint*	0,15	37,5 * Coating is calculated in price/m²		5,63			-
3		13 Rounding edges	0,47	60		0,31			-
		14 Drilling dowel/lammelos holes	12	15		2,00			-
		15 Inserting and glueing dowels/lamellos	12	10		1,33			-
		16 Screwing on support beam	3	15		0,50			-
		17 Milling support groove for top	0,4	12		4,80			-
		18 Sanding	1	480		5,33			-
		19 Spraying coat/paint*	0,5	37,5 * Coating is calculated in price/m²		18,75			-
4		20 Rounding corner	1	180	1	2,00			-
		21 Rounding edges	1	60		0,67			-
		22 Drilling dowel/lammelos holes	6	15		1,00			-
		23 Inserting and glueing dowels/lamellos	6	10		0,67			-
		24 Milling support groove for top	0,4	12		4,80			-
		25 Sanding	1	180		2,00			-
		26 Spraying coat/paint*	0,2	37,5 * Coating is calculated in price/m²		7,50			-
5		27 Rounding corner	1	180	1	2,00			-
		28 Rounding edges	1,2	60		0,80			-
		29 Drilling dowel/lammelos holes	7	15		1,17			-
		30 Inserting and glueing dowels/lamellos	7	10		0,78			-
		31 Milling support groove for top	0,4	12		4,80			-
		32 Sanding	1	300		3,33			-
		33 Spraying coat/paint*	0,4	37,5 * Coating is calculated in price/m²		15,00			-
6		34 Glueing parts together	3	200	1	6,67			-
		35 Milling out groove and corner	1	18		18,00			-
		36 Glueing in place	1	200		2,22			-
		37 Sanding	1	360		4,00			-
		38 Spraying coat/paint*	0,7	37,5 * Coating is calculated in price/m²		26,25			-
7		39 Drilling dowel/lammelos holes	6	15	2	2,00			-
		40 Rounding edges	0,8	60		1,07			-
		35 Screwing on support beam	4	15		1,33			-
		36 Sanding	1	300		6,67			-
		37 Spraying coat/paint*	0,2	37,5 * Coating is calculated in price/m²		15,00			-
8		38 Drilling dowel/lammelos holes	12	15	2	4,00			-
		39 Rounding edges	0,8	60		1,07			-
		40 Screwing on support beam	6	15		2,00			-
		41 Sanding	1	420		9,33			-
		42 Spraying coat/paint*	0,5	37,5 * Coating is calculated in price/m²		37,50			-
9		43 Cutting foam to size	1	420	1	4,67			-
		44 Glueing foam to boards	1	300		3,33			-
		45 Creating cut-out	1	120		1,33			-
10		46 Cutting fabric to size	1	600	1	6,67			-
		47 Sewing/making the upholstery	1	5200		57,78			-
11 & 12		48 Cutting to the right length	6	30		2,00			-
		49 Predrilling holes	24	15		4,00			-
13		50 Cutting to the right length	1	150	1	1,67			-
		51 Mounting with clips	3	30		1,00			-
14		52 Mounting LED strip and wiring it up	1	600	1	6,67			-
		53 Mounting power source	1	240		2,67			-
17		54 Predrilling mounting holes	14	15		2,33			-
							<b>Total</b>	367,17	
<b>General assembly</b>									
	Based on the general complexity of the concept								
<b>Hour rate (euro/hour)</b>	<b>Total expected hours</b>	<b>Total assembly costs</b>					<b>Total</b>		
40	6	240					240,00		

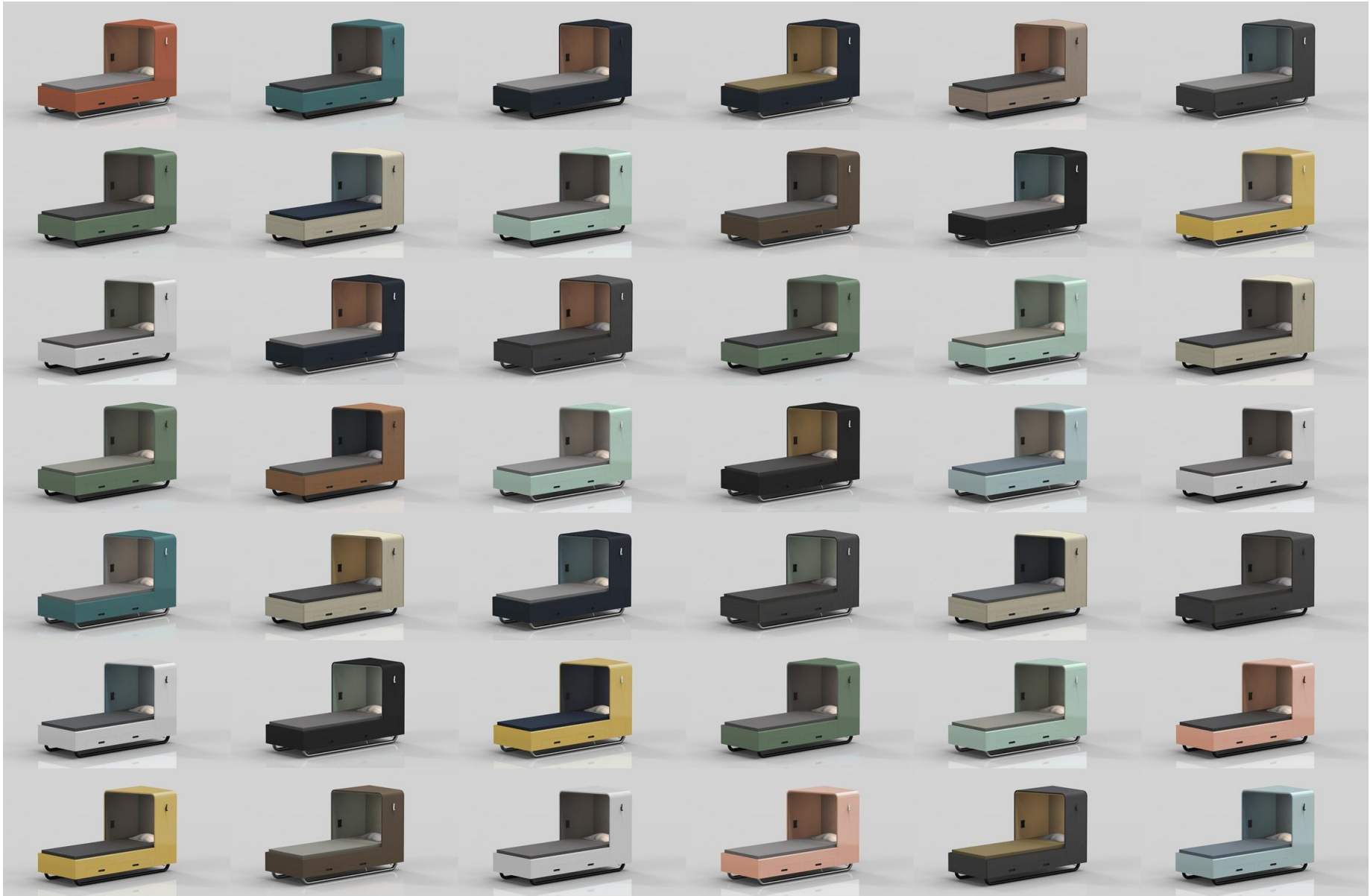
## Appendix K - Full resolutions images construction iteration 3







# Appendix L - Full resolutions images colour study







Black varnish



Deep brown varnish



Transparent varnish





Salmon coat - Petrol coat



White coat



Olive coat



Ocher coat





Navy coat



Light green coat





Black coat



Light blue coat



## Appendix M prototyping process

The prototyping of the concept was done in the following steps. Images of the steps can be found in the next pages.

1. All parts were cut to size with a circular saw and a guide.
2. The base frame was assembled with screws, brackets and wood glue.
3. Then, drawers were built and attached to the base frame.
4. Meanwhile, 40 kerfs were cut into both bends. These were backfilled with wood filler and left to dry.
5. After drying, the head capsule was assembled with dowels.
6. The base frame and head capsule were attached and got their first coat of primer.
7. Last, the feet were painted and attached to the wooden structure.



















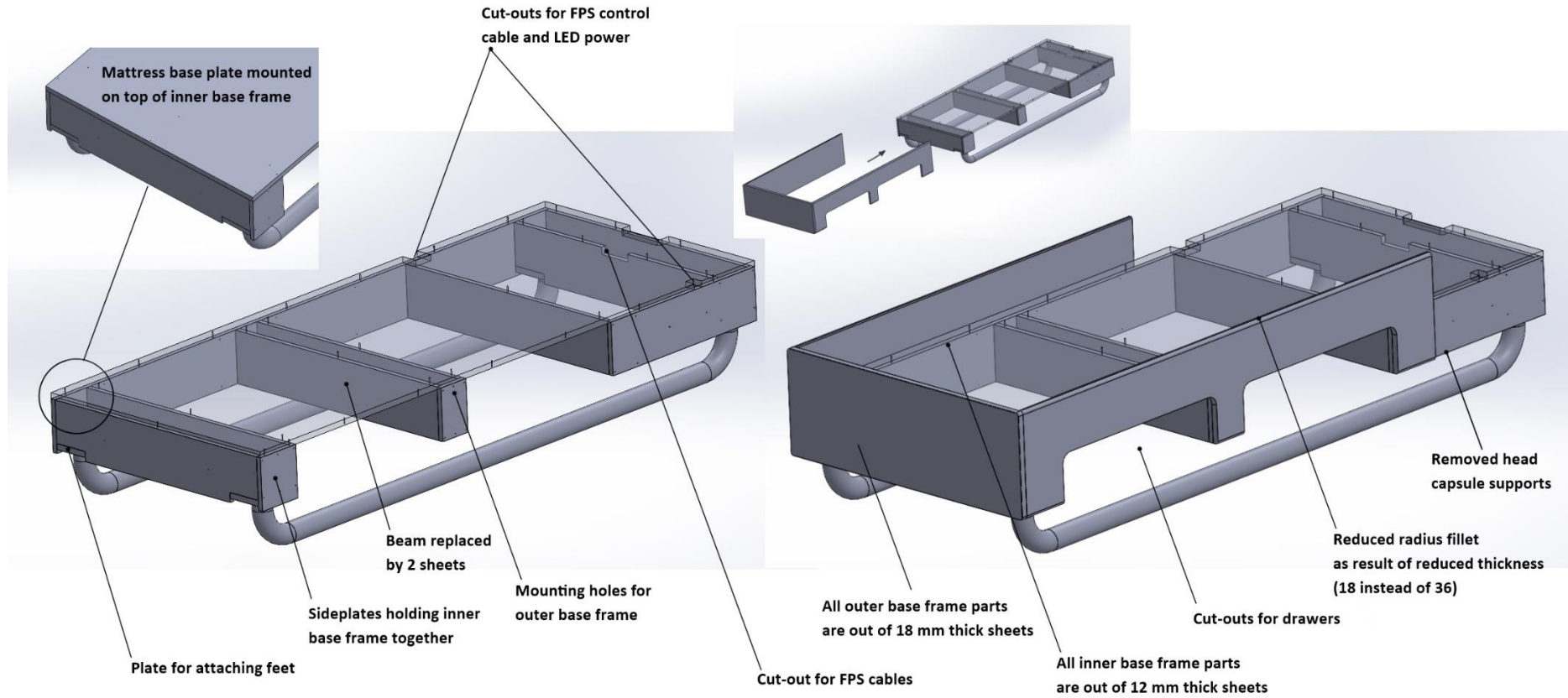


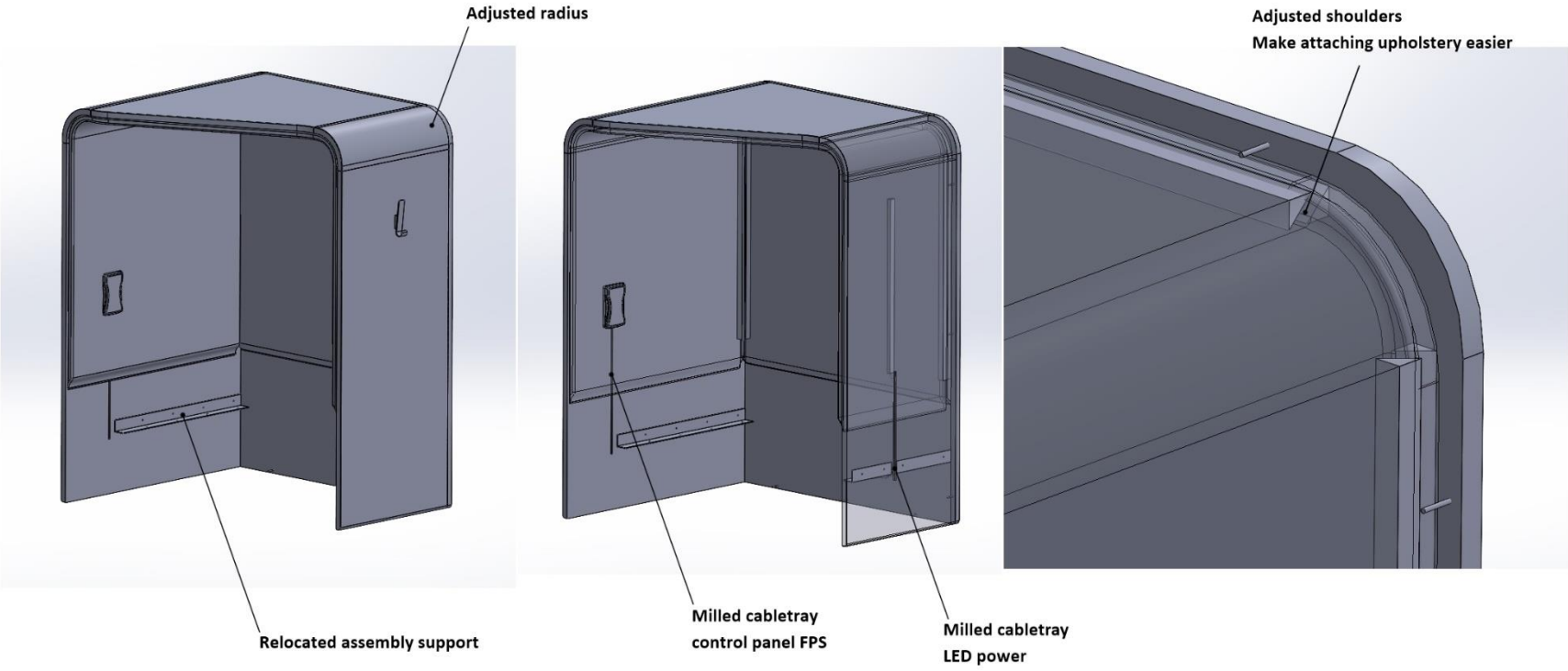






# Appendix N - High resolution images construction iteration 4





# Appendix O - User validation research

6/14/2021

Powernap bed enquete

## Powernap bed enquete

Deze enquete is bedoeld om het ontwerp en de gewenste eigenschappen van het powernapbed te valideren. De enquete bestaat uit een aantal onderdelen. De eerste paar vragen gaan over jou, de deelnemer. De vragen daarna zijn schaalvragen over de uitstraling van het concept. Tot slot zijn er een aantal ja/nee- en open vragen. Eventuele opmerkingen kun je aan het einde van deze enquete kwijt.

**\*Vereist**

### Vragen over jou

1. Hoe oud ben je? \*

\_\_\_\_\_

2. Wat is je geslacht? \*

*Markeer slechts één ovaal.*

Man

Vrouw

Anders: \_\_\_\_\_

3. Werkt u in ploegendienst of nachtdiensten? \*

*Markeer slechts één ovaal.*

Ja

Nee

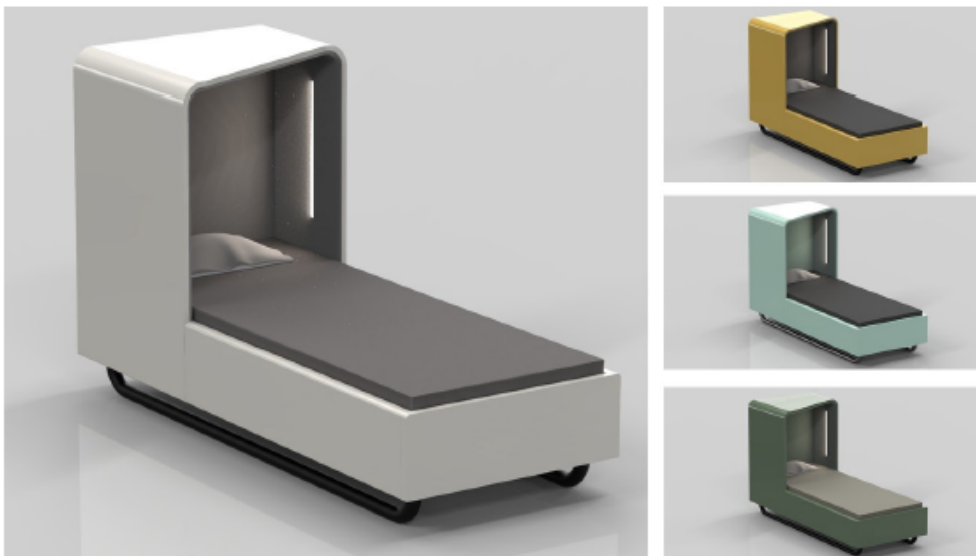
### Informatie over het powernap bed

Het powernap bed is gemaakt voor mensen die tijdens hun nacht-, vroege ochtend- of late avonddienst even willen uitrusten. Het doen van een powernap tijdens deze diensten is een goede manier om veel voorkomende problemen van irreguliere diensten, zoals slaap- en gezondheidsproblemen, te bestrijden en voorkomen. Daarnaast zorgt een powernap tijdens een dienst voor minder fouten en ongelukken op de werkvloer en verlaagt een powernap de kans op ongelukken gedurende de reis naar huis na een dienst.

Het powernap bed is ontworpen om de ideale powernap op te doen en de gebruiker te ondersteunen bij dit belangrijke rustmoment. De belangrijkste features/functies die zorgen voor deze ondersteuning zijn:

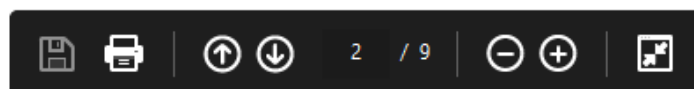
1. Het bed bevat FPS technologie. FPS technologie genereert lichte trillingen in het matras, deze trillingen versnellen het ontspanningsproces en daarmee het in slaap vallen.
2. De kap over het bed schernt de gebruiker af van direct licht van boven, absorbeert geluid en bied privacy voor de gebruiker.
3. Het bed gebruikt licht om de gebruiker aan het einde van de powernap te wekken en om een lichtje te bieden bij het gebruik van het product in een donkere ruimte (om bijv. de deur of lichtknop te vinden na gebruik).

### Het powernap bed in verschillende kleurencombinaties



### Uitstraling van het powernap bed

Hieronder staan een aantal stellingen. Deze kun je beoordelen op een schaal van 1 tot 7, waarbij 1 helemaal mee oneens is, en 7 helemaal mee eens. Ook staan de vier verschillende kleurencombinaties op deze pagina, zodat je ze nogmaals in detail kunt bekijken.





4. Het powernap bed heeft een rustgevende uitstraling. \*

Markeer slechts één ovaal.

	1	2	3	4	5	6	7	
Helemaal mee oneens	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Helemaal mee eens

5. Het powernap bed ziet er comfortabel uit. \*

Markeer slechts één ovaal.

	1	2	3	4	5	6	7	
Helemaal mee oneens	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Helemaal mee eens

6. Het powernap bed geeft mij voldoende privacy in een powernap ruimte. \*

Markeer slechts één ovaal.

	1	2	3	4	5	6	7	
Helemaal mee oneens	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Helemaal mee eens

7. Het powernap bed heeft een zachte uitstraling \*

Markeer slechts één ovaal.

	1	2	3	4	5	6	7	
Helemaal mee oneens	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Helemaal mee eens



8. Het powernap bed ziet er degelijk en/of kwalitatief uit. \*

Markeer slechts één ovaal.

	1	2	3	4	5	6	7	
Helemaal mee oneens	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Helemaal mee eens

9. Het powernap bed nodigt uit om uit te rusten. \*

Markeer slechts één ovaal.

	1	2	3	4	5	6	7	
Helemaal mee oneens	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Helemaal mee eens

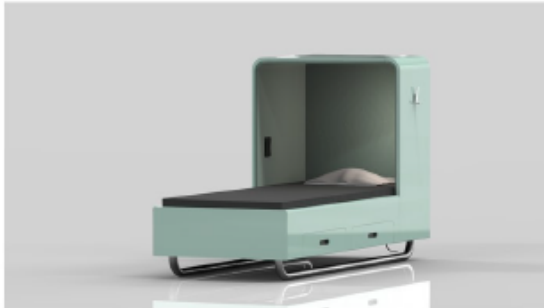
Vragen over jou mening over het powernap bed

Open vragen

10. Als je kunt kiezen tussen de powernap stoel van NEWAS en het powernap bed van NEWAS, welke zou je dan kiezen voor het doen van een powernap? \*

Markeer slechts één ovaal.

- De stoel  
 Het bed



11. En waarom kies je daarvoor? \*

---

---

---

---

---

12. Hoe zou je het powernap bed het liefst gebruiken? \*

---

---

---

---

---

13. Wat vind je van de wekker die je wekt d.m.v. trillingen en licht? \*

---

---

---

---

---

14. Vind je dat de kap bij het hoofdeinde voldoende privacy biedt als het bed in een ruimte staat? \*

*Markeer slechts één ovaal.*

Ja

Nee

15. Waarom vind je dat? \*

---

---

---

---

---

16. Zou je op dit bed een powernap willen en/of kunnen doen? \*

*Markeer slechts één ovaal.*

Ja

Nee

17. Denk je dat je op dit bed tot ontspanning kunt komen? \*

*Markeer slechts één ovaal.*

Ja

Nee

Bedankt voor je deelname!

Mocht je nog iets willen delen, dan kan dat hieronder.

18. Opmerkingen

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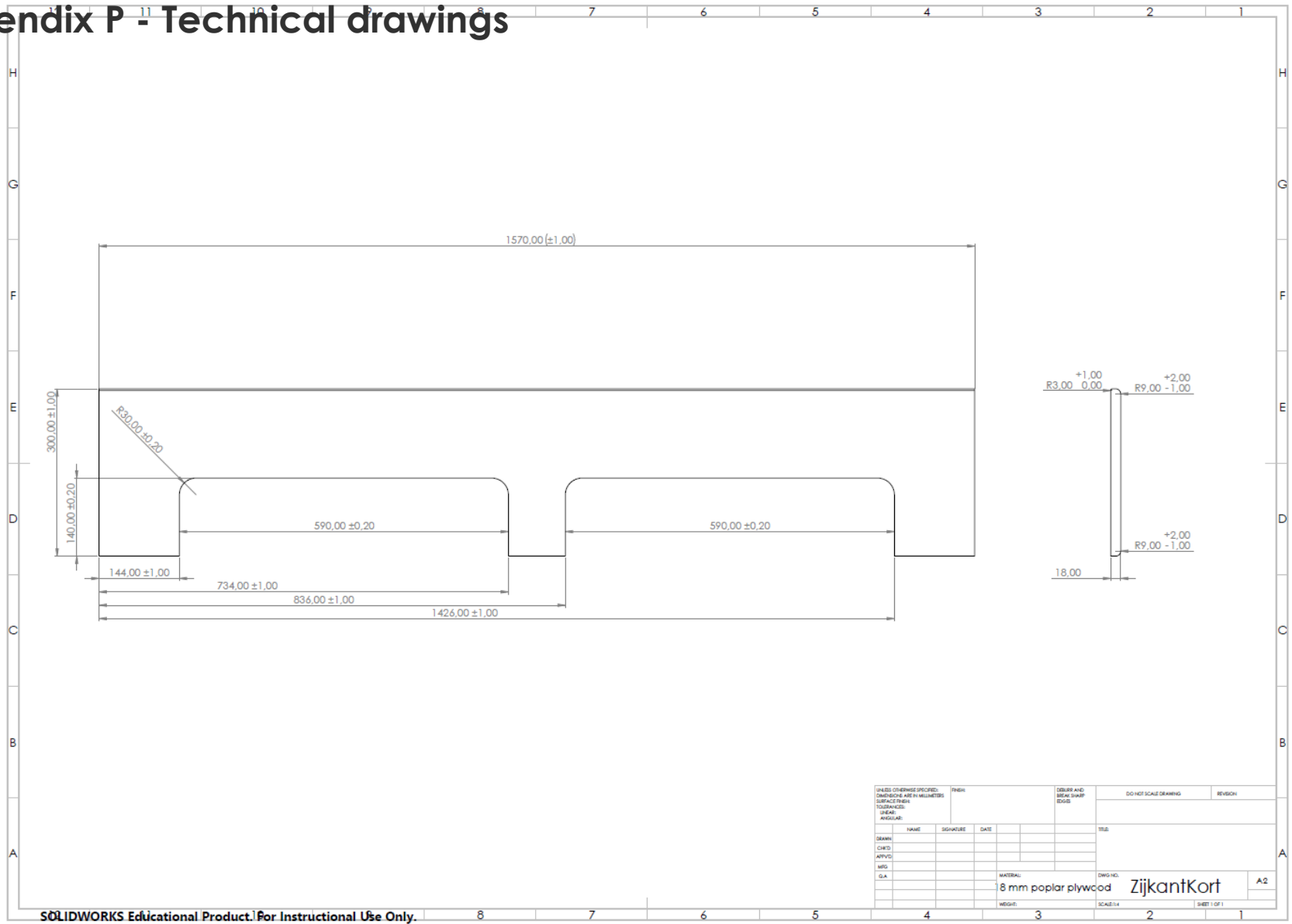
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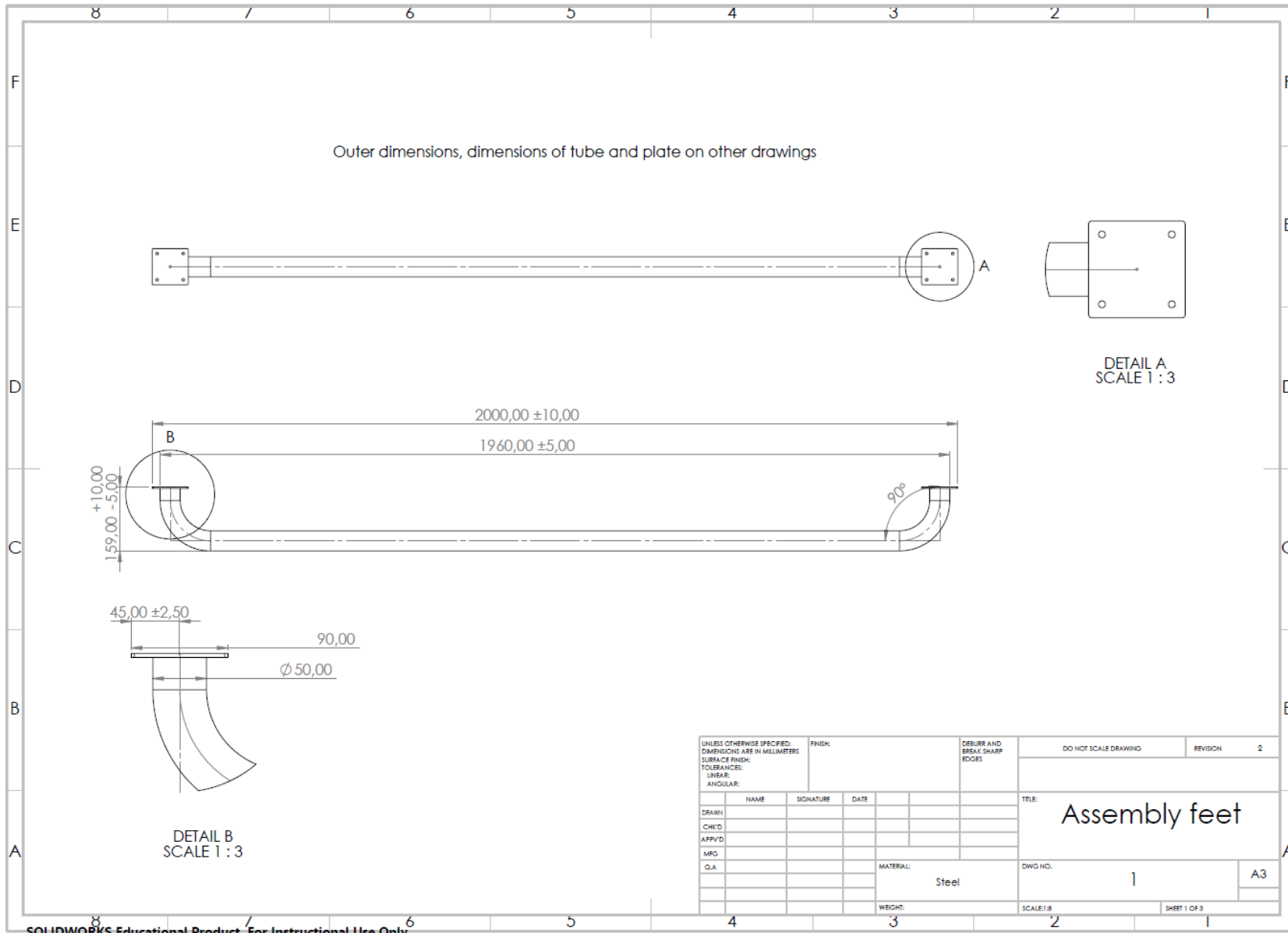
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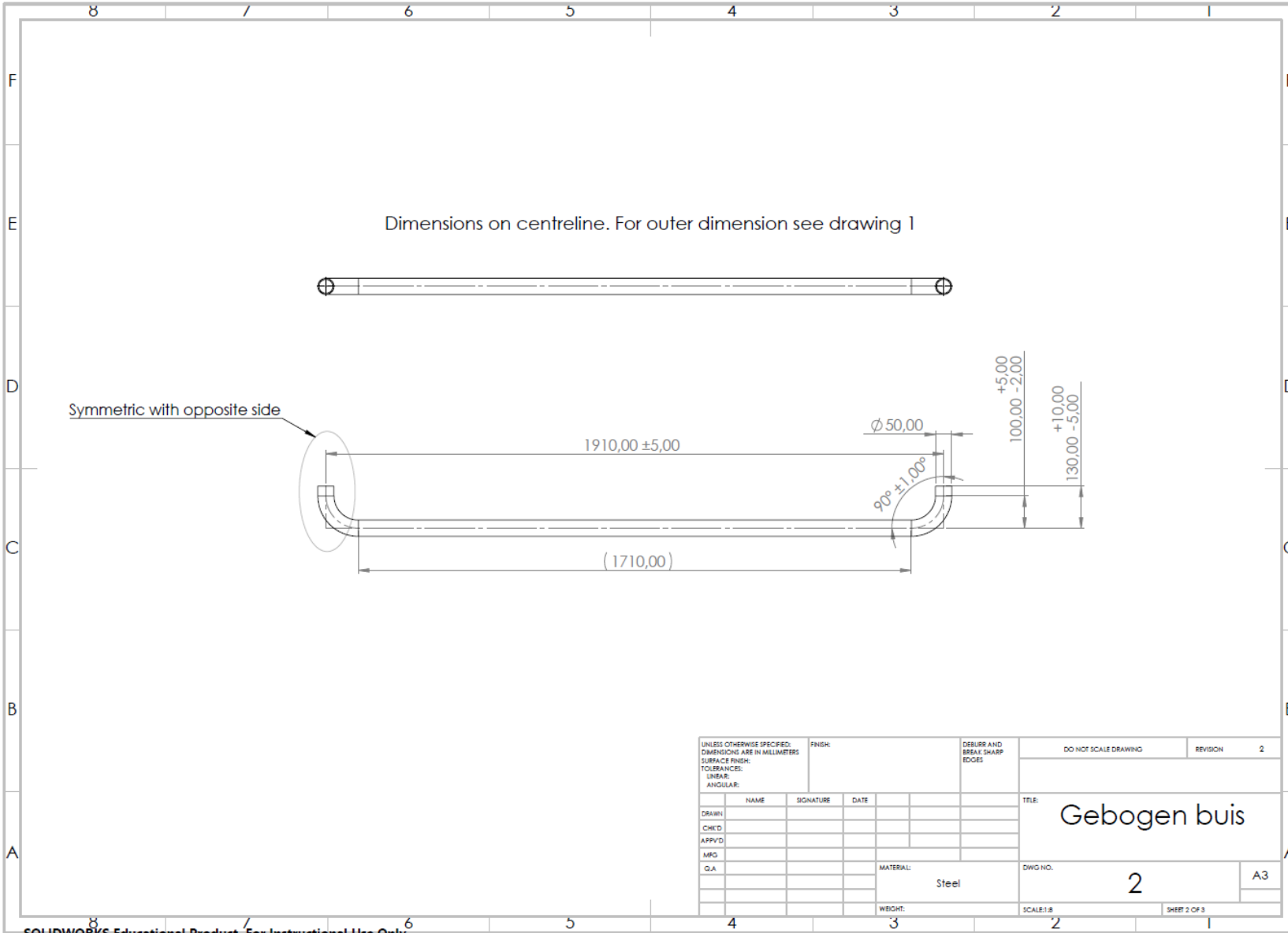
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# Appendix P - Technical drawings

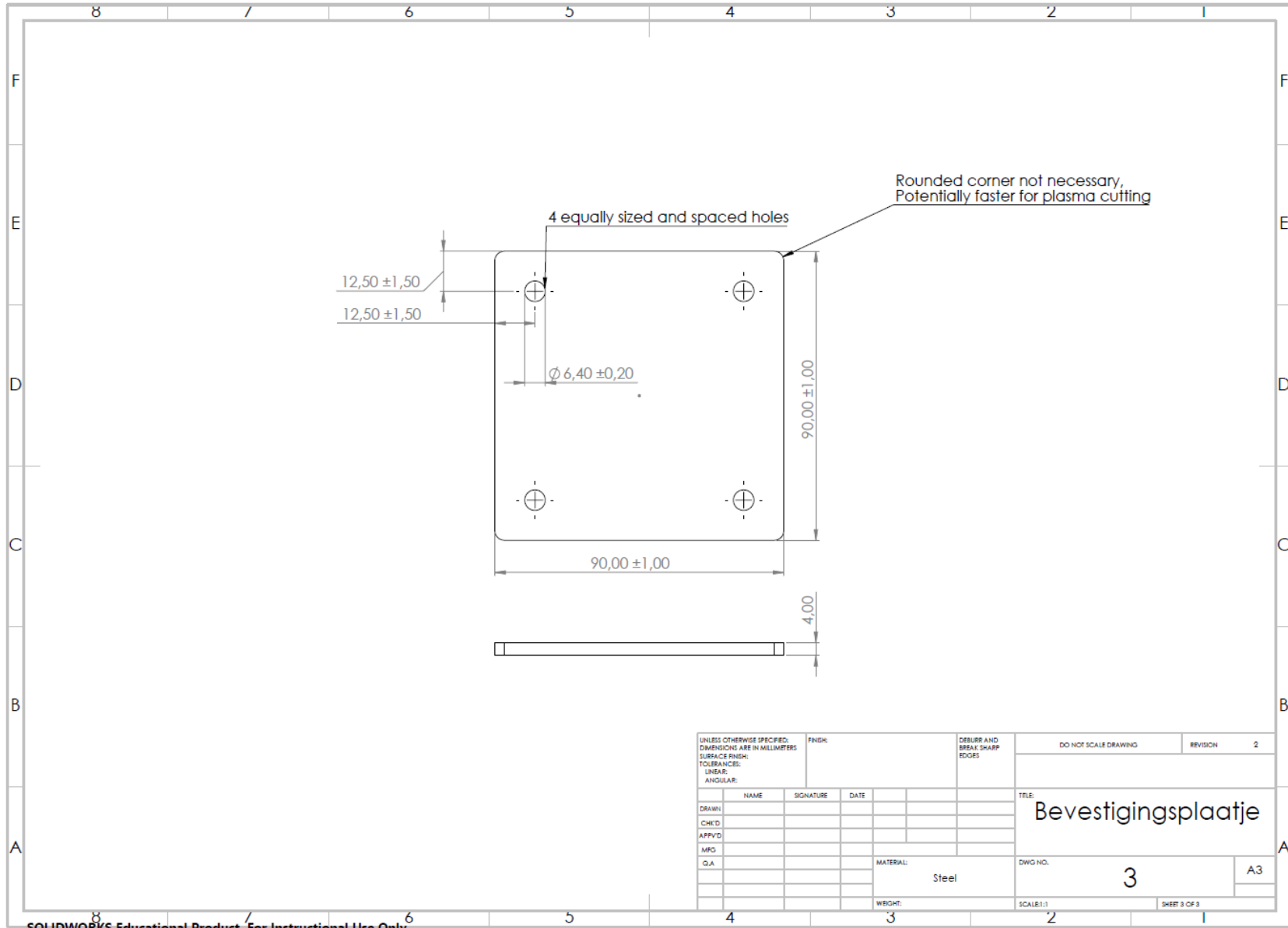




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