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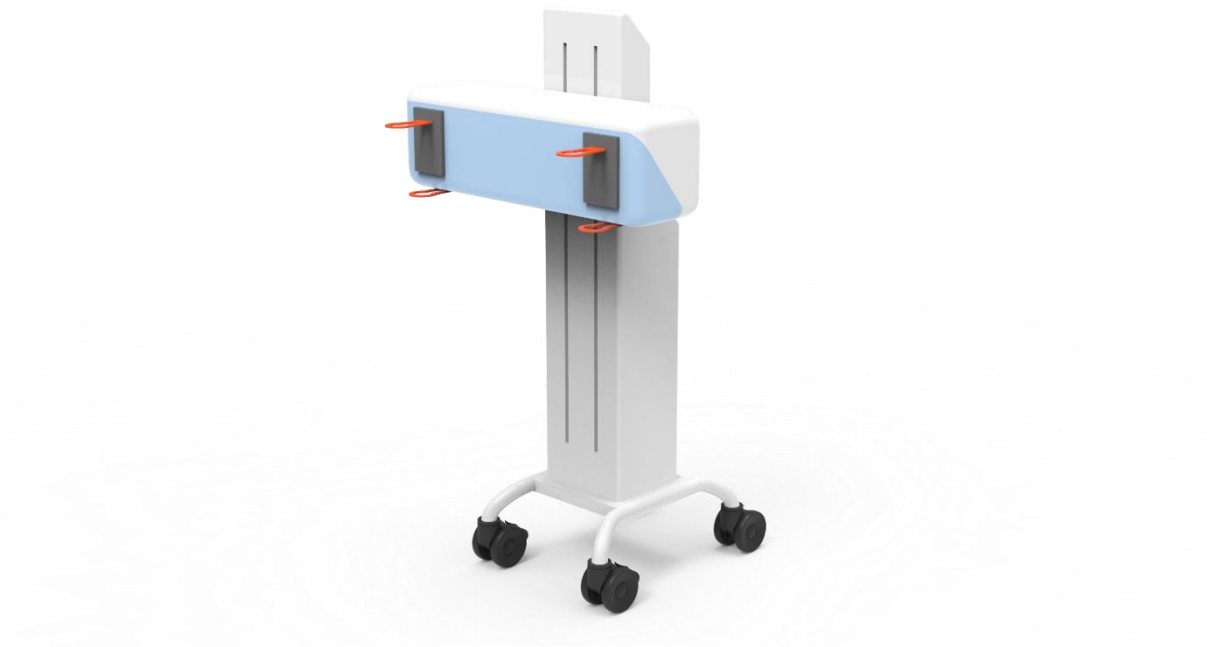

Development of a help tool for moving patients in bed

Master's thesis in Industrial Design Engineering

AGNES SÖDER AND GEORGIOS ANAGNOSTAKIS

DEPARTMENT OF INDUSTRIAL AND MATERIALS SCIENCE
INDUSTRIAL DESIGN ENGINEERING

CHALMERS UNIVERSITY OF TECHNOLOGY
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Master of Science Thesis

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Cover:
The cover picture shows a visual representation of the final concept of this project, which more information can be found in Chapter 12 and on page 62.

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Acknowledgement

This project has been started in conjunction with the master thesis for the Industrial Design Engineering MSc at Chalmers University of Technology. The course is given on the faculty of Industrial and Materials Science. The course corresponds to 30 credits and extends over the spring term in 2020 and is done by two students from Industrial Design Engineering. The project is done in collaboration with the company Njord Medtech. The project will be carried out mainly at Chalmers University of Technology, but studies and home visits will be done in other places. Chalmers supervisor and examiner is the researcher Lars-Ola Bligård and the supervisor from Njord Medtech is Jacob Ahrnstein.

We would like to thank our client, Njord Medtech for trusting us to drive this project forward. Special thanks to the client's contact and CEO, Jacob Ahrnstein for the great engagement and for always being open for discussion.

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Agnes Söder & Georgios Anagnostakis

Abstract

Humans live longer and thus the number of patients in hospitals is increasing. The healthcare faces major challenges. One task that is time consuming for carers is moving patients in bed. The movements are usually heavy, which leads to work related injuries for the carers. In the long term it results in injury related absence from work, which leads to lack of staff.

This master thesis documents the process and result of a design project executed on behalf of Njord Medtech regarding the development of a help tool for moving patients in bed. The goal is to improve the working environment, which includes reducing the physical demands and the work related injuries, by developing a commercializable help tool.

Plenty of interviews have been held during the project, with interesting and useful insights coming forward. There are several solutions for moving patients in bed already. During the user studies it was realized that developing a help tool used in more than one movement can have higher market potential and be easier commercialized. Throughout the project, numerous concepts were generated and evaluated through several iterations.

The final concept Triaid facilitates in three different movements in bed and can be used by only one carer. Triaid is a motorized device that replaces the human force, which reduces the physical demand. The use of Triaid can be beneficial for the whole healthcare system.

Keywords: help tool, assistance device, patient handling, patient movement, healthcare, staff shortages, work related injuries, industrial design, product design, product development

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1. Introduction

Care is something many people come into contact with at some point of their life, whether it is because of a broken leg, a serious illness or just getting old. Everyone wants the best possible care. However, Swedish healthcare is facing major challenges. The population has steadily increased and is expected to continue growing (World Population Review, 2020). The population is getting older, as can be seen in the population pyramid of Sweden, with an ongoing change for the group of elderly that gets bigger.

The fact that people are living longer is in itself positive, but at the same time poses a challenge for Swedish healthcare, which is already suffering from a shortage of carers. Carers include all the staff in the healthcare, such as assistant nurses, nurses, care assistants, physiotherapists and all the rest healthcare workers. The lack of carers is expected to accelerate even more on the next 40 years, with a need of 50% more carers than today, mostly in the elderly care (around 70%) (Regeringskansliet, 2010).

One of the explanations for the large staff shortage is that many carers perform physically heavy tasks that cause work related injuries, which in the long run leads to sick leave and early retirement. In addition to the injuries of this type causing staff shortages, it also means an unacceptable personal sacrifice for the care workers.

Many tasks are executed by the carers everyday in the healthcare. The difficulty varies from task to task and most of them demand more than one carer to perform the task. For instance, moving the patient in bed is needed to be executed many times a day. Turning the patient to do some daily hygiene activities, assisting the patient getting in and out of the bed, moving the patient from bed to bed or to an operation table and moving the patient higher up in bed after sliding down are tasks that carers have to deal with on a daily basis. There are several help tools that facilitate the aforementioned movements, but moving a patient in bed still seems to be very heavy and requires at least two carers.

Njord Medtech decided to develop a new product to facilitate the task of moving patients in bed, which has been seen as an issue for the past 10 years in the healthcare. The company contacted a team of students to execute some research among the problem, confirm it and bring forward ideas for a commercializable product solution.

1.1 Company background

The CEO of Njord Medtech, together with the Research and Development Evangelist of the company, who is also vice deputy head of the Sahlgrenska Radiology department, and the chief of product office of Njord Medtech, saw a potential area to develop more products in the field of healthcare. Njord Medtech aims to secure a patient and user-centric healthcare system via fit for purpose product- and service development. The company has been incubated within the Sahlgrenska University Hospital since 2016, and incorporated in 2019.

1.2 Aim

The primary aim of the project will be to explore the problem area and confirm the existence of the need for a new product design. Then there is a need to understand the context and the user needs before bringing forward the development of a help tool for moving patients in bed that will be commercially viable.

1.3 Objectives

The objective of the thesis work is to explore, ideate, conceptualize, and bring forward product drawings for improved handling of patients. The thesis is about designing a commercializable solution for use in the healthcare. The solution should facilitate executing the tasks related to moving patients in bed with the help of one nurse or independent. The goal is to improve the working environment, by developing a commercializable help tool for carers, which aims on reducing the physical demands of moving patients in bed and the work related injuries.
The level of detail of the final design must be such that a first prototype can be produced, while it is more important to come up with future advice for a good solution that can potentially be commercialized, instead of ending the thesis with a prototype.

1.4 Limitations

Some limitations have been identified, which affected the process and influenced the outcome of the project. As the objective of the project is to come up with a commercializable solution, the feasibility aspect was very strong and important throughout the idea generation and the evaluation phase. In addition with the product that the client has already developed, the outcome of the project has been influenced, since it has been the most feasible and safe way to base the new product on the existing one. Moreover, because of the time limitation for the project the final concept will not be on a fully detailed level, including detailed 3D modelling and a detailed analysis of the production.

The healthcare is a special area as it comes to accessibility and information. The exploration of the context was limited, with a difficulty to reach the target group. The patients form a sensitive target group because of privacy aspects.

1.5 Report Layout

In the first instance, the Methods and Theory used throughout the project are described. Then, the Procedure part describes a summary of the execution of the project's phases as subchapters. Furthermore, these phases are analyzed and discussed in separate chapters. These are step by step leading to the final result. Finally, the Discussion and Conclusion parts are completing the report. The whole report layout can be seen in the figure 1 below.

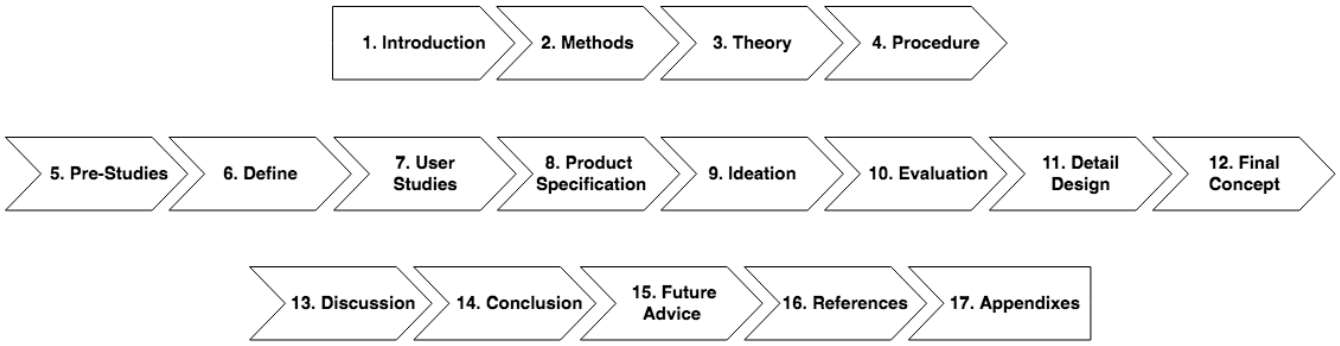


Figure 1 - Report Layout

2. Methods: Information about the methods used for the planning, the data collection, the analysis, the representation, the ideation and the evaluation
3. Theory: Gained theoretical knowledge that was essential for implementing the project
4. Procedure: description of the process from the beginning until the end of the project

The following chapters constitute the result

5. Pre-studies: Pilot test, Market research, Client's product, Study visit
6. Define: Research questions, Pressure cooker, Wwwwwh, How-Tos
7. User Studies: Interviews, Observation
8. Product Specification: Interviews insights, Requirements list
9. Ideation: Team ideation, Workshops
10. Evaluation: Performed in different stages
11. Detail design: Focused ideation and Lo-fi prototypes
12. Final Concept: Design output and Visualization
13. Discussion
14. Conclusion
15. Future advice
16. References
17. Appendix

2. Methods

The methods chapter presents the methods and tools used in the implementation of planning, define, data collection, analysis, representation, concept development and evaluation.

2.1 Planning

The design approach that will be followed among this topic is based on the human centered design. It is a creative approach to problem-solving that starts with the people end ends with innovative solutions (UserTesting, 2020). In order to find a solution that suits the needs, the designers observe and frame the **context**. The stages that are followed include among others brainstorming, modeling, prototyping and implementation of the design solutions (Pittsburgh, 2012).

2.2 Define Methods

The defining methods allow the team to better define the problem and understand the involved stakeholders. Using the defining methods, useful and necessary details come up and help the team gain complete control of the situation at the beginning of a design project.

2.2.1 Pressure Cooker

The Pressure Cooker is a method that puts teams in a situation of executing a whole project in a short amount of time. The goal is to stimulate the brains of the team members in order to start thinking amount a framework related to the project. The method aims in building a good basis of information and thoughts already from the beginning of the project, when the method is usually being used. The Pressure Cooker makes the participants experience a lack of time and a lack of information, takes them out of their comfort zone and enables them to learn. The method puts the participants in a condition they don't know and where their soft skills must be objected. During the pressure cooker the participants experience a substantial amount of stress, which is representative of a complex situation (Kulcsar, 2013).

2.2.2 WWWWWH

The method WWWWWH (Who, what, where, when, why and how) is a checklist of the most important questions to be asked to analyse the design problem, to obtain an understanding and define the problem (DDG, 2017). This method helps to formulate and structure in a complete way. Trough asking multitude of questions the problem can be systematically deconstruct.

2.3 Data Collection Methods

There are plenty of methods for collecting data and measuring information on variables of interest, such as context and user related information. The methods are used to get a better understanding of the situation and identify both stated and non spoken requirements and needs. In the design process, the collected data are used as a decision basis for the rest of the process.

2.3.1 Pilot test

In order to enable a beneficial data collection process, insights for the interview structure is needed. This is achieved through a pilot test, a type of explorative study, which most often includes unstructured interviews with people with knowledge in the field. After the pilot test, the interview content can be designed in a way that relevant data on the task is highlighted (Wallgren, 2012).

2.3.2 Interviews

In order to gain insights and enlarge the understanding about the users environment, some interviews can be done. A type of interview structure is semi-structured interview format , in order for the participants to feel comfortable, by perceiving the interview more as a conversation, rather than a “questioning”. Interviews allow users to describe their own situation from a perspective that is relevant for the study. For the understanding of the user needs, 10-15 interviews reveal about 80% of the needs (DDG, 2017).

2.3.3 Observation

Observation is a way of collecting data through observing. There are two types of observation; open, when the participants are aware that they are being observed, and hidden, when the participants are not aware. The observation method helps to gain a better understanding of the design problem. Observing people in their daily routines leads to a better understanding of problems, requirements and desires that people themselves are not aware of (Wallgren, 2012; DDG, 2017)

2.4 Analysis Methods

In order to compile the collected data some analysis methods can be used. The analysis methods aim at extracting useful information by structuring and analyze the data. The aim is to get a deeper understanding for the situation, the context and the user.

2.4.1 KJ-analysis

The method KJ-analys is developed by the japanese Jiro Kawakita to analyze a large amount of gathered data. By putting the information on post-it papers and organising the information with the others that relate to it, in the end it will be different categorisation with titles. The purpose is to compile an overall picture and to communicate the result effectively (Karlsson, 2007 ; Spool, 2004).

2.5 Representation Methods

Representation methods are used to process and visualize the identified ideas and thoughts. Through different methods or tools, the generated ideas are expressed in order to illustrate and enable the communication of the results.

2.5.1 Expression board

An expression board is a collection of images to visualize and provide a desirable expression of the product’s desired design language. It may work as a inspiration and guide through the

design process. The collages includes images symbolizing colours, shape, material and existing products (Karlsson, 2007 ; Wikström, 2012).

2.5.2 Sketching

Sketches are an easy and quick method to shape thoughts and ideas. Sketching is one traditional technique that is used in the design process to represent and visualize the ideas and the product's current stage. The method enhances the communication between the team and the stakeholders. The sketches give a clearer picture and understanding of the perception of the ideas's forms (Karlsson, 2007)

2.5.3 Lo-Fi Prototype

A low fidelity (lo-fi) prototype is a representation of an idea with little resemblance to the final design in the form of tangible and testable artifacts. It can take on a lot of different forms, from simple sketches to mockups. The most important role of a lo-fi prototype is to explore and test functionality rather than the visual appearance of the product. The goal is to explore different aspects of the idea and communicate it in a simple way (McElroy, 2016).

2.6 Ideation Methods

The ideation methods support the generation of ideas to solve a specified problem. The methods enable the design team to translate their knowledge acquired during the preceding phases into a tangible outcome. The tools and methods vary depending on the desired type of the end result.

2.6.1 How-Tos

How-Tos is a method to write questions that support the idea generation. It is a method to help in the start of the ideation and it stimulates the team to come up with ideas. The goal is to create a wide variety of problem descriptions, which gives different perspective of the problem (DDG, 2017).

2.6.2 Brainstorming

Brainstorming is a method that can be used to encourage creative thinking in the ideation phase. It is used to stimulate and motivate people to quickly generate many ideas. The participants, preferably having different backgrounds and competence, meet and get informed about the current problem and they are then allowed to come up with ideas. During the brainstorming no criticism of the ideas should occur (MindTool, 2014).

2.6.3 Braindrawing

Braindrawing is a method used in the beginning of the ideation phase. Braindrawing is usually carried out in a group of four to eight people. The created ideas from one participant are passed to the next participant and this person gets inspired from the sketches, either doing something related or something new. Like brainstorming, this method is based on the principle of avoiding criticism (DDG , 2017).

2.6.4 Co-design workshops

Co-design refers to a collective creativity of collaborative designers. The co-design approach involves a range of people in the contribution of problem solving. Often, the participants of the co-design process come from different disciplines with different roles and goals (Pirinen, 2016 ; Sanders & Stappers, 2008). Having a co-design approach would benefit a project in many ways, by getting others perspective among the problem.

2.6.5 Fish trap model

The fish trap model is a form generation method that supports to generate and develop ideas in more detail. The method starts by defining the structural concept and ends up to the detailed definition of the morphology of the variants. The method is prescriptive, meaning that it shows how to develop a concept (DDG, 2017).

2.6.6 Morphological chart

The Morphological chart method divide the overall function of a product to sub-functions and helps in a systematic way to generate ideas on the sub-functions. The methods enable to come up with a principal solution by combining ideas on the sub-functions (DDG, 2017). The goal is to get a more concrete idea by breaking down the overall product in parts.

2.6.7 1000 uses of an object

1000 uses of an object is a warm-up exercise that is used to break the ice and facilitate the creative thinking. The purpose is to stimulate the brain, to think outside the box and to encourage wild ideas. It helps on getting better results from the rest of the exercises at the start of team design sessions and workshops, as well as to create a high energy situation among the participants. The participants are divided into two teams and every team is coming up with as many uses of two particular objects in the room as possible, in a very small amount of time. The team that comes up with the most uses wins (Smashing Ideas, 2017).

2.6.8 Character drawing

The Character drawing is a warm-up exercise that aims on quick creative thinking and fast sketching. It is used at the beginning of the team design sessions and workshops to stimulate the brain and get better results from the rest of the exercises, as well as to create a fun and relaxing mood between the participants. The Character drawing exercise is individual and is about drawing another participant with a specific role. The participants are assigned a paper with a name of another participant and a paper with the assigned role. When the sketching time passes, the rest of the participants have to guess who is represented on the drawing and what is the role.

2.7 Evaluation

The ideas or concepts can be developed, sorted and evaluated with using a number of methods. Concept selection is a process for evaluating the concepts according to the needs of the customers and other criteria, compare the concept's relative strengths and weaknesses, and choose one or more for further investigation, testing or development (Ulrich & Eppinger,

2012). A systematic and objective evaluation process is used in assessing the concepts developed.

2.7.1 Grading method

The grading method is used for evaluating and eliminating concepts during the product development process. Each concept is compared against predetermined selection criteria to figure out which idea best fits the criteria (Ulrich & Eppinger, 2012). The aim of the method is to evaluate a variety of concepts.

2.7.2 Three Dots

The three dots is a simple, fast and effective way of evaluating ideas (Österlin, 2016), where participants vote on ideas that they think are best, based on three criteria. This method is used to get a quick selection of ideas according to predefined criteria.

2.7.3 Multivoting

In the multivoting method each member of the team votes for several concepts. The aim of the method is to take decisions and limit down the number of concepts. The concept that is mostly voted moves further (Ulrich & Eppinger, 2012).

3. Theory

This chapter presents the theoretical knowledge relevant to the development of a help tool for moving patients in bed in the healthcare. Different ways of moving patients in bed have been explored, as well as hygiene aspects in the healthcare and ergonomic related aspects.

3.1 Higher up in bed

Carers execute many tasks during a day. One of the tasks is higher up in bed. The task can be done in several ways and with different help tools. Some different cases are explored to understand the possible outcomes and how it is executed today. Below are the cases as described in Vårdhandboken, which is a guideline book for the healthcare (Vårdhandboken, 2018).

Case 1: The patient moves higher up himself/herself
The carer encourage the patient to bend his legs, lift his head, take support with his hands and forearms, lift his pelvis and push away with his feet. The carer puts any anti-slip under the feet. If the patient is unable to lift the pelvis, an aid is used that reduces friction and facilitates the movement.

Case 2: With the help of one person
The carer encourage the patient to lift his head, lift his pelvis and push with his feet. If the patient is unable to lift his head, a pillow may facilitate. It is also possible to use an aid that reduces the friction under the pillow, for example a sliding mat, which should then be placed under the pillow and a bit below the shoulders. If necessary, the carer supports the patient's feet with straight wrists. The carer should work with the arms next to the body, the shoulders lowered, the back in an upright position and with the feet in walking position.

Case 3: With the help of two people - without draw sheet (draglakan)
The patient lies with bent knees and with an anti-slip surface under the feet. The carer places his/her hands under the patient's shoulders-bone to reduce friction under the shoulder. The carer asks the patient to raise his head, lift his pelvis and push with her/his feet. If the patient is unable to lift the head, the carer places a pillow under the head, possibly with an aid that reduces friction. For example, a sliding mat can be used which should then be placed under the pillow and slightly below the shoulders. The carer should work with the arms next to the body, the shoulders lowered, the back in an upright position and with the feet in walking position.

Case 4: With the help of two people and helping tools
There are various tools to facilitate the movement, such as draw sheets (draglakan), glide sheets (glidlakan) and sliding mats (glidmatta). The carers instruct and inform the patient clearly, adjust the working height and have eye contact with the patient. The carers should inform the patient when they will drag. The task should be executed calmly, preferably in stages and always at the same time.

Case 4.1: With the help of two people and draw sheet (draglakan)

The patient lies with bent knees and with anti-slip surface under the feet. The carers grasp the draw sheet with straight wrists. The carers ask the patient to push away with both feet. The carers should work with the arms next to the body, lowered shoulders, upright back and feet in walking position with slightly bent knees. They should use their own body weight as they pull, while the dragging should be done in stages. If necessary, an extra draw sheet should be placed around the patient's buttocks and a sliding mat under the patient's shoulders. The carers should bring both hands in the draw sheet around the buttocks and pull the patient higher up into the bed using a weight transfer backwards.

3.2 Turn on the side

Another task is to turn a patient on the side. The task can be done in several ways. Some different cases are explored to understand the possible outcomes and how it is executed today. Below are the cases as described in Vårdhandboken, which is a guideline book for the healthcare (Vårdhandboken, 2018).

Case 1: The patient turns on the side by himself/herself
The carer moves the pillow to the bed edge and instructs the patient to move the butt towards the side and then turn on the side. A “glidmatta/glidlakan” can be used to facilitate for the patient.

Case 2: With the help of one carer
The carer moves the pillow to the bed edge and encourages the patient to bend his legs and then move the butt towards the side. The movement can be facilitated by using e.g. a glidmatta (sliding carpet) under the patient and then doing the movement in different segments. For the carer it is important to be aware of the posture, stand in a stable position with the arms close to the body, lowered shoulders and the back in a upright position. The carer asks the patient to turn on the side while supporting the movement.

Case 3: With the help of two carers and helping tools
The carer encourages the patient to bend one knee and if possible tells the patient to move the butt towards the side. If not, the movement will be executed in two steps. The first carer gives the dragging sheet (Draglakan) to the second carer, then the patient turns to the side with the help of the dragging sheet. The carers should be aware of their posture. They should stay in a stable position, the arms close to the body, lowered shoulders and the back in a upright position. After the execution of moving a patient to the side with a dragging sheet, it often requires an extra movement to place the patient further into the bed. The first carer place the hands under the patient's hips and place himself/herself to the patients along direction. The second carer stands on the opposite side and helps to push the patient. The first carer follows the movement without lifting. In this way the shear forces that can occur are minimized. Also, one extra help tool can be used to minimize the force. The carer should be aware of the posture in this movement too.

3.3 Hygiene aspects

In the healthcare there are basic routines and rules for hygiene and they must be applied to work that involves care. Hygiene aspects are about how to handle the hair, hand hygiene,

workwear, face protection and personal protective equipment. The hygiene is very important to prevent health-related infections. The best and easiest way is to have a good hand hygiene, “Clean hands saves lives”. Some other basic rules are change workwear daily which is stored at the work and that the hair must be pinned up. Find more routines in the Figure 2 (Folkhälsomyndigheten, 2019 ; Socialstyrelsen, 2019 ; Vårdhandboken, 2019).

Figure 2 - Hygiene aspects mind map

3.4 Ergonomics

In order for people to feel good and for performing a good quality work, there must be enough of variations of movement and also the possibility to recover. The human body needs to have variation of movements to feel good and to perform a good quality work, but it is also important to have the possibility to recover in order to prevent injuries. The body needs a good balance and not too much of load to be healthy.

Physical overloading for the muscles, joints and skeleton caused by product use is in the same ergonomic category, loading ergonomic. Arbetsmiljöverket has formulated some recommendation and regulations about loading and working positions. According to the regulations, the carers should not do heavy loads and too many repetitions because it can lead to long-term problems. Arbetsmiljöverket also gives advices to avoid work in positions that are heavily bent, twisted or overstretched, since the joints are loading in their outer positions and increase the risk of injuries (Arbetsmiljöverket, 2019).

Ergonomic means adapting work to humans to prevent risks of injuries and accidents. It is important to plan and organise the work to prevent injuries, it requires a holistic view.

Apart from the physical aspect of ergonomics, cognitive ergonomics is also very important for healthcare workers. The medical assistive devices, the help tools and other products that are used in the healthcare should be designed to minimize the risk of doing tasks wrong, which can lead to work related injuries or uncomfortable and unsafe treatment of the patients.

To minimize doing the tasks wrong and risk getting injures the function and the design of the product should facilitate. The task should be easy to learn and execute. The user should have access to instruction and be given the opportunity to learn. A professor in Human Machine systems mention that the functions and the design of the products used in healthcare, should be designed in a way to give the healthcare workers the opportunity to perform the tasks in the right way.

4. Procedure

This chapter presents the implementation of the project step by step, from the planning until the final concept. At each phase, the way in which the methods were performed is explained, describing the aim of every action.

4.1 Project Planning

The approach consist of the phases: Pre-studies, Define, User studies, Product Specification, Ideation, Evaluation, Detail Design and Final concept. Some of the phases are done in parallel to each other and there are several iterations and evaluation stages in combination with some milestones during the phases. See the different phases and what each phase includes in Figure 3.

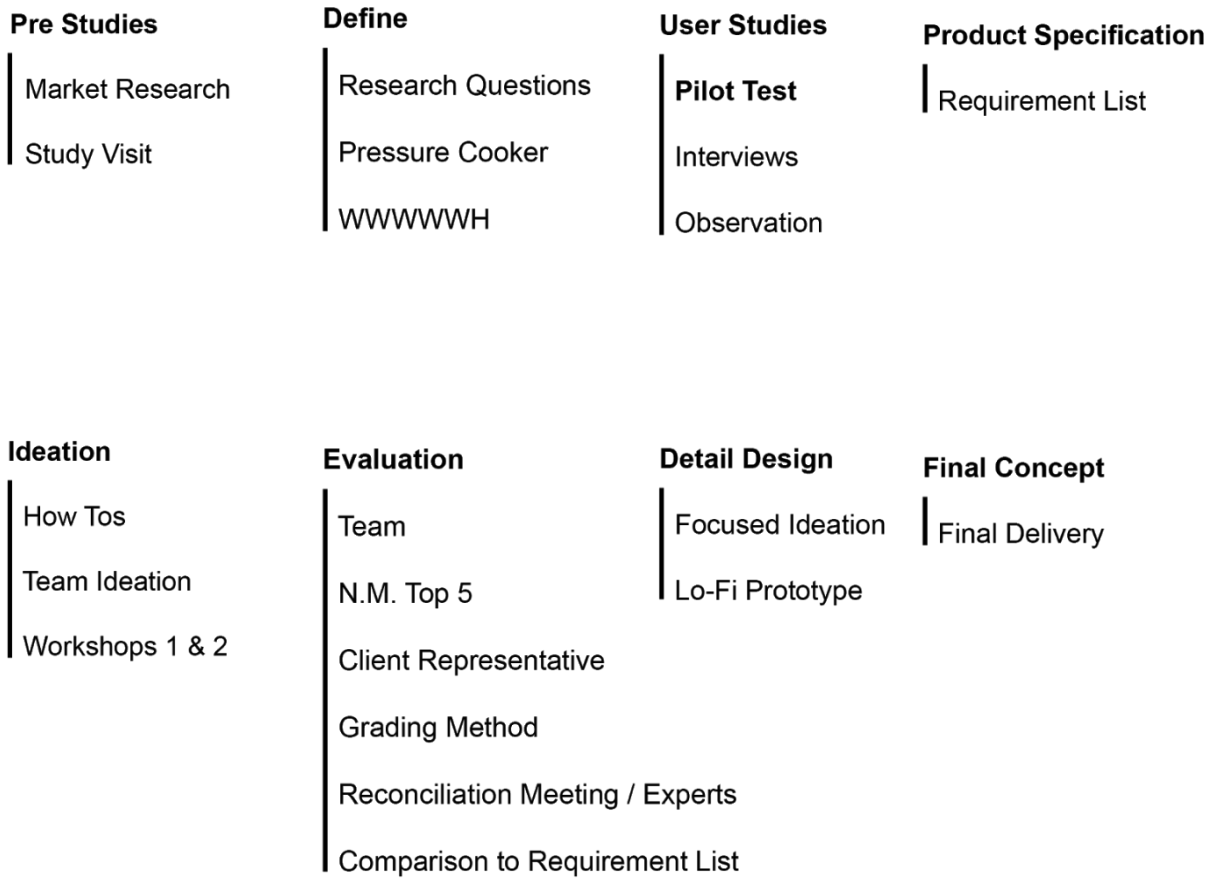


Figure 3 - Project Phases

The process that has been followed for the implementation of this project was based on the human centered design process with adaptations according to the aim of each phase. The project has been executed following a basic procedure that included some iterative phases for the ideas generation and evaluation, while some of the phases were implemented in parallel. During the project, there have been followed two main iteration loops, the first included co-

design workshops and the second included team ideation and evaluation with the client. The whole process can be seen in Figure 4.

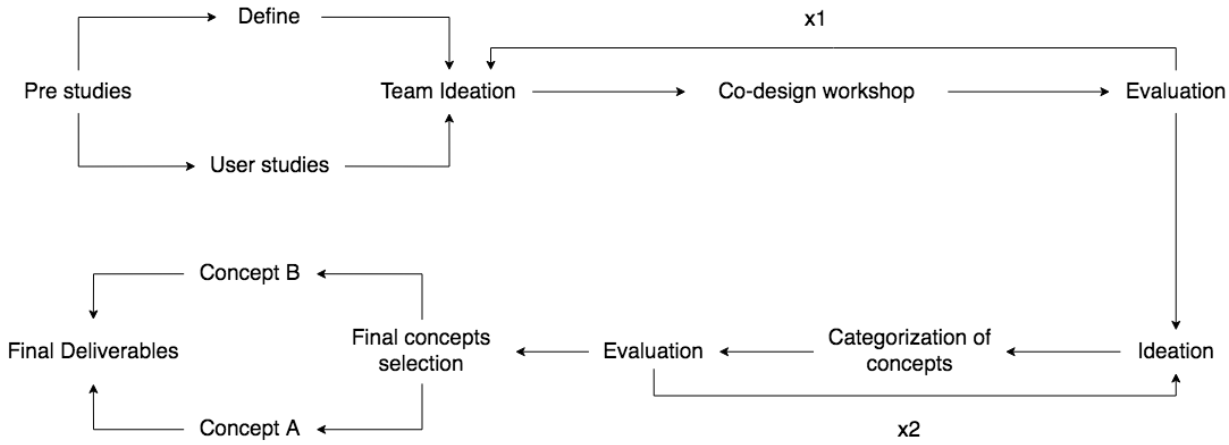


Figure 4 - Project Process

Starting with the Pre-Studies phase, an attempt was made to understand the relative market by doing some market research about competitive and substitute products. Additionally, a study visit was done with an intention to understand better the tasks and the problematic aspects of them. During the Define phase some methods were used that helped determine more the study area, such as designating the research question and grasp the project context and stakeholders. At the same time, the User Studies phase was running, with the implementation of a range of interviews and observation, which then got analyzed to bring forward useful insights. The Ideation phase started already when the first insights from the interviews has been understood, and lasted for several weeks. It consisted of various methods, in a form of team ideation and co-design workshops. The outcome of the Ideation got evaluated several times during the Evaluation phase which was running in parallel. Many different ways of evaluation had been held and led to several iterations of idea generation. When all the insights from the user studies has been gathered, the Product Specification phase was started, when a requirement list has been created and used as a guideline for the rest of the ideation, an evaluation mean, as well as a guide for the client for future development. The outcome of the Evaluation phase was used during the Detail Design phase, when the concepts had been explored on a more thorough level. The project ended with the Final Concept phase, which included the defining of the final product and the creation of the deliverables to the client. A timeline of the different phases can be seen in the Figure below.

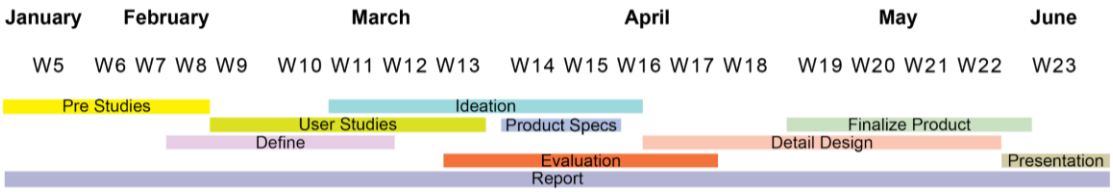


Figure 5 - Time Plan of the project

Furthermore, an additional goal has been set, to meet Njord Medtech's sustainability profile and two of the goals of sustainable development of the United Nation that they aim to meet; good health and well-being, and gender equality. Moreover, throughout the project all the actions were planned and executed following good ethical and moral principles.

4.2 Pre-Studies

On the beginning of the project, Pre-Studies were carried out on the initial and basic aspects of the project. The problems were investigated, as well as the available competitive products today. The Pre-Studies were done to get a first clear picture of the project's environment and to set the ground of what was coming. The outcome of the Pre-Studies can be found in Chapter 5.

4.2.1 Market Research

During the market research, a list has been created, with the most important competitive or substitute products and some basic information about them, such as the product's use, the product's producer, as well as a link directing to the product's webpage. The aim of the market research was to get to know and understand what is available in the market and where is more space in the market for a new product.

4.2.2 Study Visit at Sahlgrenska University Hospital

The first visit was done at Sahlgrenska University Hospital, after consultation with the client and with the assistance of the vice deputy head of the Radiology department. The intention of the visit was to test the particular task of moving a patient higher up in bed, which was the initial movement in focus, and to experience the movement from the perspective of both carers and patients. The aim was to make the process more comprehensible through its practical implementation, to get useful insights that will help in the execution of the project, as well as to better understand the user experience and the relationship between the staff and the patients. The visit was attended by the two team members, the vice deputy head of Radiology who gave a brief on the use of the tools, and two other Industrial Design Engineering master students who helped both by participating in the process and by taking useful photos and videos to analyze later. These particular participants were chosen in purpose so that there is a variety on height from 169 cm to 198 cm and on weight from 52 kg to 82 kg.

4.3 Define

The define phase consists of methods that help designate key aspects of the project as well as directions to be followed during the project. The methods used in this phase are considered fundamental to the proper organization and handling of the project. The outcome of the Define phase can be read in Chapter 6.

4.3.1 Research Questions

At the beginning of the projects some research questions were formulated to meet the goal and the wishes that the client thought were most relevant. Since there are two different directions, one for solving and one for preventing the problem of sliding down in bed, two main research questions were made with common sub-research goals.

MRQ1: How can a commercializable solution be formed and supported to facilitate the task of moving people with disabilities higher up in bed?
MRQ2: How can a commercializable solution be formed and supported to prevent sliding down for people with disabilities in bed?

SRG3: The patient experience a safe and comfortable transfer with improved integrity.
SRG4: The carers operate in an improved working environment with reduced physical demands.
SRG5: The healthcare centers will have the opportunity to improve the efficiency and prevent work related staff injures

Final research questions
During the way the team agreed with the client to update and change the focus because of the insights gotten throughout the project. To have higher market potential the product should be able to be used for more than only one movement in bed. Since the project's goal is to develop a commercializable solution, these insights had strong influence on the continuation of the project. Hence, the research questions were formulated as followed:

MRQ: How can a commercializable solution be formed and supported to be used for more than one movement of patients with disabilities in bed?
SRQ1: How can a commercializable solution be formed and supported to prevent sliding down for people with disabilities in bed?
SRQ2: How can the solution facilitate for the carers for an improved working environment, with reduced physical demands and preventing work related injuries?

4.3.2 Pressure cooker

To start thinking and to understand the assignment, the method pressure cooker was used. In one day, several steps have been held, such as brainstorming, ideation and discussion around the topic and the ideas, as response to the design brief of the client. The goal of the day was to get a better understanding of all the stages of the project, to get the brain start with the creative process and to ideate before starting the in depth research to facilitate thinking of the research question. This method is solely meant to be explorative, there is no right and wrong.

The method started with creating a mind-map by sketching, using only grey & black markers. Dive into the assignment: What are the different contexts? Who are the stakeholders and users? Which technologies are interesting? From the mind-map, the ideation started and some ideas were sketched on the same paper but in colour. By ending this stage an overview of all the stakeholders and their vision/wishes was done. The final step was the vision presentation, in which the first ideas were discussed and more ideas came up. The outcome was hung up in the studio.

4.3.3 WWWWWH method

To get a thorough understanding of the problem the method WWWWWH was used. The team stated multiple questions related to the problem and then gave answers to each one of them.

The questions were related to the context, the stakeholders and the possible solution for the problem. For instance, “Why is it a problem?” and “Who has an interest in finding a solution?”.

4.4 User studies

The user studies are about getting into the user and getting an understanding of the target group, which is carers and patients. Furthermore, they are about gaining insights and increasing understanding about how it looks like today. The user studies have included both interviews and study visits to get a better holistic picture, of which the results can be found in Chapter 7.

4.4.1 Pilot test

A pilot test was executed to test the interview structure and see how long the interview would last. It was held with a student at the Chalmers University of Technology with some experience in the field, in order to get feedback about the content of the interview, the structure of it and see if the outcome can indeed give relevant insights. The interview took place under normal circumstances, recording the interviewee and taking notes on both the answers and possible problems in the structure of the interview.

4.4.2 Interview

Through the interviews that have been performed, there was an intention to explore and investigate the main problem in general, instead of focusing only on a particular aspect and semi-structured interviews would give the possibility for alteration according to the answers. The interview structure was developed and updated during the time and adapted to the interviewee and his/her role.

Participants
The participants of this study were consisted of nurses in hospitals, carers in elderly-care, physiotherapists, movement instructors and researcher. A list of the participants role can be found in Appendix 1.

Interviews have been conducted with nurses and carers working in different healthcare centers, such as Våxnäs retirement home in Karlstad, Huddinge Hospital, and Änggårdsbacken elderly-care in Göteborg.

Procedure
The research location for the study was at different places depending on the interviewed person. Participants were asked if they were willing to do a interview that would last for approximately 30 minutes, through email, phone or physical meeting, where physical meeting was preferred. One researcher asked questions and the other recorded the interview with the phone and took notes. A consent form was used for the participants to agree on their participation.

Data collection
The nature of this research was more explorative and required qualitative data to understand the reasoning of the participants. Therefore, a semi-structured interview, where the

researchers and participants were able to talk face-to-face was used. This allowed the researcher to react to physical reactions and ask for clarifications or go more in-depth if necessary. The answers were recorded by an iPhone XR. The important and useful insights of the recordings were transcribed by the two researchers using a text editor on their personal laptops, by playing the recordings.

The first set of questions were relatively closed-ended questions that provided information about role, experience in field and age. The next questions were open-ended questions and probed the participants on task, ergonomics, context, user and future related questions. If the answers provided were surprising, further questions were asked to explore the topic and give more context. The full interview format can be found in Appendix 2.

The task that was in the main focus during the interviews, is the task of moving patients higher up in bed, when they have slided down and got dispositioned on bed. The answers of the participants were summarized. The important insights were gathered following a KJ analysis and clustered in such a way to get an overview of the data. Raw data was collected in graphs to be clearly displayed.

4.4.3 Observation

A visit to Ängårdsbackens retirement home in Gothenburg is made to observe and get understanding of the users situation and the context. The intention of the visit is to meet and talk with the user, see the movement in a real context, interview staff and see the environment.

4.5 Product Specification

The research phase ends up with the definition of the Product Specification through a requirements list, which is done to specify what the concept must achieve. The criteria matrix is created very early in the process, in order to be used as a basis, and is developed throughout the project as it becomes more concrete and detailed (DDG, 2017). To effectively cover the different aspects of the product development process, requirements and wishes from client and interview insights were compiled according to Olsson's criteria matrix (Johannesson et al. 2013). The criteria matrix should be used as a reference when evaluating the concepts and for the final concept choice (Johannesson et al. 2013). The result of the Product Specification phase can be read in Chapter 8 and the complete requirement list can be found in Appendix 3.

4.6 Ideation

In order to produce as many concepts as possible with information from several different directions, the concept generation is carried out in three stages with iterations, where discussion and creative methods are used as tools. Concept generation is often an iterative process with many loops, discussions and refinements (Johannesson et al. 2013), of which several steps and iterations are done, both in groups and individually. The different ideation stages consisted of team ideations and two workshops with students with different approaches, of which the result can be seen in Chapter 9. The idea is that with the help of the participants and their different backgrounds bring forward new unexpected ideas and views that otherwise may be missed (Johannesson et al. 2013).

4.6.1 How-Tos

The starting point of How-Tos method is to formulate the problem statement, which is a short description of the problem. Since the How-Tos questions are associated with different stakeholders, the stakeholders were defined before stating the questions. The generation of the questions inspired the team and facilitated on broadening the mind and gave more stimuli for the ideation that followed.

4.6.2 Team Ideation

The first stage of the ideation is to individually ideate in the team, coming up with own thoughts and ideas (Figure 6). The two creativity exercises carried out during the team ideation are Brainstorming and 5x5s. During the 5x5s some small iterations were done to develop further on some ideas. Both the methods were done on the problem of sliding down in bed with ideas about how to move the patient back and how to prevent sliding down. Some of the ideas were chosen to be developed further, while some others were directly discarded. Then, the same exercises have been carried out with a focus on the chosen ideas and with an aim to improve them or develop them further (Figure 7).

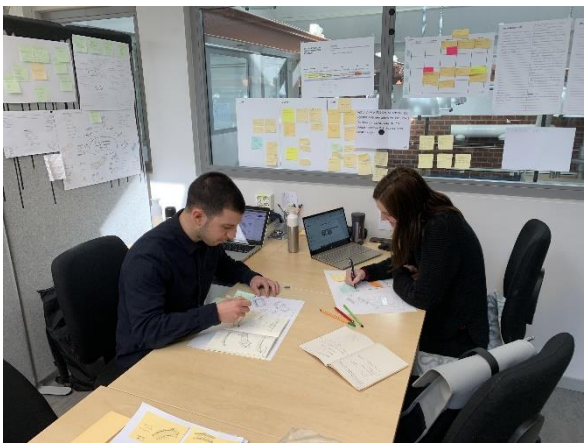


Figure 6 - Team Ideation Session

Figure 7 - Team Ideation Session

4.6.3 Co-design Workshops

It has been chosen to do two co-design workshops in order to get inspired by people with different perspectives among the topic. The variety of views and ideas from people with different experiences and different mindsets helped to think outside the box and see the topic from a different point of view.

Workshop 1

The first co-design workshop has been performed with seven participants, all students from the Industrial Design Engineering master (Figure 8). The workshop lasted 1 hour and 45 minutes and was held in the premises of the IDE master at Chalmers Johanneberg Campus. The aim of the workshop was to gain new insights. Design students were chosen because of their open mind and knowledge about ideation. During the workshop, were conducted two warm-up exercises with an intention to break the ice and start the workshop with some fun. The warm-up included the 1000 uses of an object and character drawing methods. Then, two

ideation exercises followed; 5x5s and braindrawing, which were done on both for moving the patient higher up in bed and for preventing sliding down. Finally, one simple evaluation exercise; three dots, was held to get some first opinions. After the end of the workshop, the results were analyzed and the team performed an additional evaluation among the participant's ideas in order to categorize the best of them.

Figure 8 - Co-Design Workshop 1

Workshop 2

During the second ideation workshop, seven Industrial Design students have been invited to participate in some ideation sessions, as well as the Njord Medtech's CEO (Figure 9). The approach of this workshop was different than the first one, focusing on moving patients in bed in general. The workshop lasted 1 hour and 30 minutes and was held in the premises of the IDE master at Chalmers Johanneberg Campus. The workshop consisted of an introduction video of different movements, the character drawing warm-up exercise, the two ideation exercises 10x10s (based on the 5x5s) and braindrawing and the evaluation exercise, three dots.

Figure 9 - Co-Design Workshop 2

4.7 Evaluation

Through the ideation many ideas were developed. Several steps were needed in the evaluation to reduce the number of ideas. The evaluation took place in different steps, as can be seen in Figure 10, and the result of it can be found in Chapter 10. For the solutions that go from one evaluation stage to another, the concepts can be combined with each other or further developed to be even better if possible (Johannesson et al. 2013).

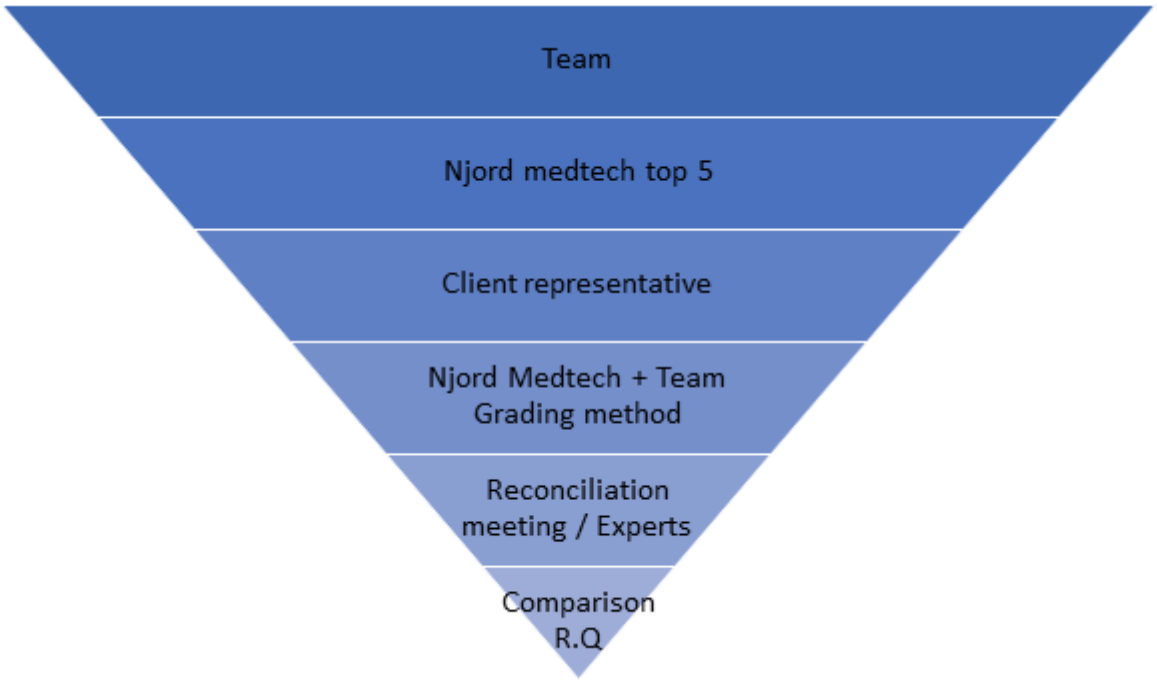


Figure 10 - The different steps in the Evaluation process

4.7.1 Team Evaluation

After the team ideation and the two workshops the ideas that were too similar or totally irrelevant to the goals were discarded by the team. The ideas left were gathered into different categories.

4.7.2 Njord Medtech's top 5

The categories were presented to all the employees of Njord Medtech. After some explanation and discussion the employees commented on them, they multivoted them and ranked them to a top 5. The categories that none of the employees chose or had none comments on, were discarded since they were infeasible, too complex and hard to implement.

4.7.3 Client Representative

For the third evaluation the ideas were categorised more specifically which led to three different directions. Together with the representative of the client some ideas were discarded and some were combined.

4.7.4 Grading Method

The client and the team separately discussed the different concepts and evaluate each one in a matrix according to three aspects; market potential, innovativeness and feasibility. The evaluation was done by assigning to each concept the colours green, orange and red, where green is good, orange is middle and red is bad. The two matrices were combined and the concept with the most greens were ranked as best.

The market potential aspect is defined as a factor that assesses the possibility of each solution to find a competitive place in the market. Aspects that are taken into consideration are potential

price, market competition, existing substitute products and market attractiveness. The innovativeness aspect is defined as a factor that assesses how new and different is each solution in relation to the existing ones. The last aspect, feasibility, is defined as a factor that assesses the level at which each solution can be produced and implemented in a real product. Aspects of feasibility that are taken into consideration are production capability and technology know-how.

4.7.5 Reconciliation Meeting / Experts

A reconciliation meeting was organized with the Njord Medtech. The purpose was to discuss the concepts and take some decisions regarding the concepts that will move further and come up with next steps in the development.

Meanwhile, a survey has been created and sent out to some chosen experts in the field. The purpose was to support and strengthen the concepts going further. The survey included the concepts with descriptions and some following questions, in order to get external opinions on several aspects of the concepts related to the requirements. The experts that answered and gave feedback on the concept were; one person with a long experience in both elderly care and hospitals and one coordinator at a retirement home with broad knowledge.

4.7.6 Comparison to Requirement List

The concepts were compared to the requirement list. A list was created with all the concepts and all the requirements. Each concept was evaluated and remarked if it was fulfilling the requirements. The remarks could have three forms, a check mark if the concept fulfilled the requirement, a dash if it was unclear or difficult to answer, and a cross if the concept did not fulfil the requirement.

After a week a new meeting was organised to see and discuss the further development. The concepts that had too much struggle were discarded and for the others new steps were decided. After the end of the evaluation, some chosen concepts moved further to the detail design phase.

4.8 Detail Design

The concepts that continued into the Detail Design phase were developed further to reach the desired level of detail that the client has set for each concept. In the detail design, the goal was to create a basis that describes the layout, the functions and the use of the product (Johannesson et al. 2013). The aim was to end up with valuable and useful design proposals for the client that will help to achieve the goal of commercialization. The outcome of the Detail Design phase is presented in Chapter 11.

The demand of the Njord Medtech as it comes to the final delivery was an updated requirement list, a visual representation of the final concept proposal and suggestions for future work.

4.8.1 Focused Ideation

Some more ideation was performed, focused on the chosen concepts to get into a more detailed level and explore the parts that have not been so clear. In this phase were explored

and defined aspects such as inner components, measurements and dimensions, forms and materials.

More specifically, the product was deconstructed based on the morphological chart method, and each part of it was defined in detail through some focused brainstorming sessions. In the end all the decided ideas were combined to rebuild the complete product, that was then explored form wise with the use of the Fish Trap Model method. In three different stages, the team explored the structural aspect of the product, the formal aspect and the material aspect, before ending up with a thorough concept proposal.

4.8.2 Lo-Fi Prototype

Throughout the project, some low fidelity prototypes were created to explore and understand the concepts on a better extend. The purpose was to create something that represents the patient, the mattress and the bed, in order to explore different solutions for turning the patient. Some simple materials were used to create solutions, such as fabric, wood and cardboard parts, which were used in different ways to frame some of the ideas.

4.9 Final Concept

The final delivery to the client included three deliverables. The first deliverable, which was the main one, was the final concept in the form of sketches and a storyboard. It included a clear and thorough picture of the concept proposal describing the changes that have been made, the suggested materials and production methods, detailed measurements of the product and the way of using the new functions of the product step by step. The second deliverable was an updated requirement list, which included requirements that were identified throughout the process of the project. The third and last deliverable was recommendations explaining how to deal with the concepts in the future, and some suggestions for the decisions that have to be taken to produce the product. The outcome of the Final Concept is presented in Chapter 12.

5. Pre-Studies

The Pre-studies helped understanding key aspects relevant to the project environment. It has been realized that there are already several help tools in the market, for moving a patient in bed. Additionally, by experiencing the task of moving a patient in bed, the difficulty of the task and the existence of the problem has been better understood.

5.1 Market Research

In the market research, the competitive market has been explored, as well as substitute products in the area of patient handling in relation to bed. During the research, more than 20 different products have been searched. In combination with the interviews insights, which can be read in Chapter 7, it was realized that “Draglakan” (dragging sheet) and “Glidlakan” (gliding sheet) are the most used and how convenient and helpful they are.

The most interesting and most inspiring products were the TurnAid, the RotoCare special bed and the Dormilet Flex mattress (Figure 11). The TurnAid is a patient turning system for healthcare beds. It is used for repositioning patients in the bed. It covers the movement of higher up in bed, moving on the side and turning on the side. The RotoCare special bed, as revealed by its name, it is a special bed that can raise up and turn to a sitting position. It facilitates going out of the bed to a standing position or to a wheelchair. The Dormilet Flex mattress is an innovative mattress for preventing pressure wounds and limiting the shear forces when changing to an upright position. The aforementioned products were chosen as they are different than the common solutions, they are innovative and have affected the development of the project. The whole market research can be seen in Appendix 4.

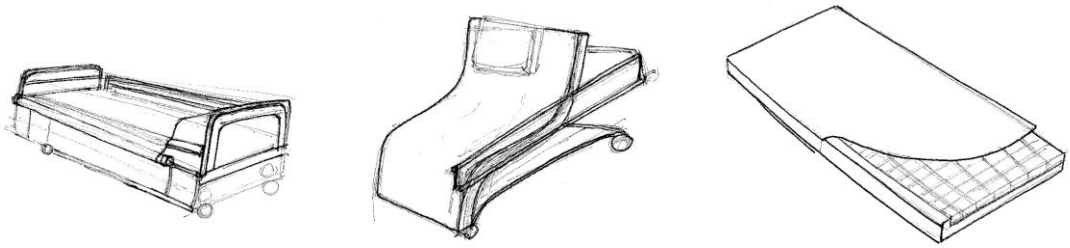


Figure 11 - Examples of competitive products

5.2 Client’s Product Background

Njord Medtech has already developed a product during the past years, named Agilis (Figure 12). Agilis is an assistive device and is going to be produced. Agilis is a motorized lateral patient transfer device that can be used as an external device in hospitals. The device includes two ropes that can be attached on the bed sheet in order to drag the patient horizontally with the help of the motor’s power.

Figure 12 - Visual representation of Agilis

5.3 Study Visit to Sahlgrenska University Hospital

When the visit to Sahlgrenska University Hospital was done and the task of moving a patient higher up in bed was tried, the captured material was analyzed and led to some useful results and insights. It has become clear that it is very easy for carers to deviate from the correct way and either have the wrong posture or make it uncomfortable for the patient, depending of the bed's height (Figure 13). It has also been observed that the draw-sheet is easy to deviate from the correct position that it should be in, while the patient is lying on top of it. This is something that makes it difficult for carers to do the task, as they have to reposition it under the patient's body. Moreover, different force from the carers and unsynchronized movements could result to not perfect repositioning. In addition, it has been observed that it is difficult to calculate the required force in advance, depending on the characteristics of the patient's body (Figure 14). Although this may be an outcome due to the inexperience of the participants. Last but not least, there was a big difference between doing the task when the bed was horizontal and when it was upright positioned. The difference was that the movement was easier and smother when the bed was horizontal. Before ending the visit, the team tried to execute the task with another help tool that is not commonly used Figure 15. Finally, the thought emerged that conscious patients may feel uncomfortable seeing the carers struggling to do the task. More pictures from the visit can be found in Appendix 5.

In addition to the empathy gained by the team members, as well as a better understanding of the process, some problems emerged which were then somehow added to the forthcoming interviews to obtain confirmation from regular users. This visit set the basis for the content of the interviews that followed.

Figure 13 - Example of a bad posture

Figure 14 - The differences between a tall and heavy patient and a short and light patient

Figure 15 - Alternative transferring with an additional tool

5.4 Pre-Studies conclusion

Through the Pre-Studies, several key takeaways were collected. It has been understood that there are many help tools for the healthcare in the market, and more specifically for patient handling. Some of them are used more, such as the dragging sheet (Draglakan), while some others are very interesting and innovative. In addition, with Agilis, the client's product, they set a base for the exploration of new ideas and inspired the rest of the project. Moreover, the study visit at Sahlgrenska gave important insights about the context, the tasks and the existing difficulties that could not be understood otherwise and were very useful. The Pre-Studies added a lot to the project and set a good ground for the continuation of the project.

6. Define

Throughout the Define phase, a holistic view among the problem has been created and deeper knowledge among the context and the stakeholders has been gained. Furthermore, the research questions were answered which supported designing a complete and meaningful product.

6.1 Research Questions

The final concept, which can be seen in detail in Chapter 12, is based on the product that Njord Medtech has already developed. Thus, it is the most feasible way to move to commercialization of the solution, as the know-how is already gained. Additionally, with the improvement of the product throughout this project, it can cover more than one movement of patients with disabilities in bed, which adds on the aspect of having higher market potential.

Apart from the improvement of Njord Medtech's product, an additional concept has been investigated during this project, which can be formed and supported to prevent sliding down for people with disabilities in bed. The prevention can decrease the amount of times that is needed to move the patients in bed.

By developing a concept that turns the task from a two-carers to a one-carer job, the physical demands are reduced and the work related injuries can be prevented. Additionally, with a concept that prevents the problem, an improved working environment for the carers can be facilitated.

6.2 Pressure Cooker

The Pressure Cooker method, enhanced the understanding of the project's different aspects (Figure 16). Through this method, manners such as users and stakeholders have been realized, as well as some important relevant insights that should be explored and researched. Furthermore, some first ideas were put down on paper to start thinking in the desired direction, recognizing more what was coming. With the use of the Pressure Cooker, the vision of the different stakeholders has been discovered, in order to frame the desired outcome. The method helped to open up the minds and start the creative thinking.

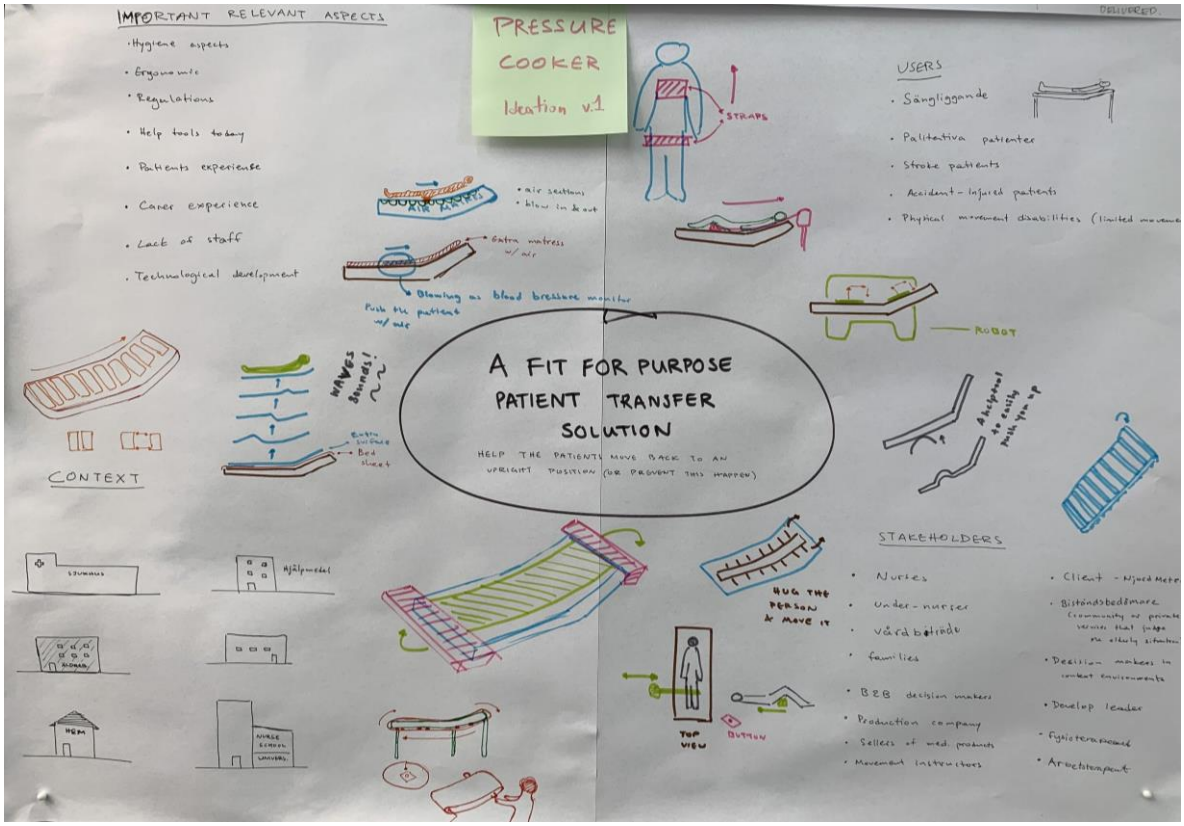


Figure 16 - The Pressure Cooker outcome

6.3 WWWWWH

The WWWWWH method assisted in grasping important sides of the problem in an early stage of the project. The initial design problem was stated as helping patients to have a comfortable upright position in bed and facilitating the carer's working conditions. It was considered that the problem starts from the patient, who is not in a comfortable position, and ends up with the carers, who have to execute a heavy task and end up with work related injuries. The biggest interest in finding a solution lies in the healthcare worker's side. A solution to the problem will encounter the lack of carers and the work related injuries. Moreover, the patients also benefit in a long term as the carers lighter workload will affect the received help.

6.4 Define conclusion

The Research Questions set directions for the project and put the team in a position to answer the questions by implementing the project. They helped the team to be aware of what should be achieved to complete the project. In addition to the Research Questions, the outcome of the WWWWWH method helped building an overall picture of the problem and gave deeper knowledge among the context and the stakeholders. Furthermore, the Pressure Cooker facilitated the thinking in the desired direction and helped to open up the minds of the team. The insights from these methods, were used during the rest of the project and the development of the solution.

7. User Studies

The user studies gave useful insights about important aspects for the development of the project. The user studies were about the work process, the existing products, the patient issues and future thoughts of the participants. More details about the interviews and the observation outcome can be found below.

7.1 Pilot test

Before the interviews, a pilot test was executed. During the pilot test it was realized that not all the questions correspond to all participants and that they should be changed and adapted depending on the participant's role. Furthermore, the order of the questions changed, since the initial order didn't help to have a natural conversation as a semi-structured interview should be. Additionally, it was realized that some questions should be added to get insights about the users, which were lacking from the pilot test. The pilot test lasted for 30 minutes which was less than expected. That helped to give out the right information to the asked participants and made it easier to plan the upcoming interviews.

7.2 Interviews

All the participants were experienced in caretaking field and have experienced the particular task of moving patients higher up in bed. The participants had different nationalities (17 Swedish, one Estonian, one Brazilian, one Norwegian, one Iranian and one American - German). The study was done with 22 participants, of which four were male and 18 were female. The age range of the participants were between 21 years old and 62 years old, with an average of 34 years old. The participants had experience between 6 months to 37 years.

The interview information is gathered in a KJ-analysis and from that the information is divided into seven categories; Why is it happening, Why is it bad, Task Related, Help Tools, Ergonomic Related, User Related and Future Related. From that a summary is done with interview insights.

Interviews insights

During the interviews it has been mentioned that the reason why patients slide down and get dispositioned on bed depends on different aspects. When the back of the bed is raised to an upright position the touching points on the patient's back are increased, which leads to shear forces (Figure 17). In combination with the body weight, the low point of gravity and the low friction because of the bed sheets, the patient slides down. The disability of the patients to use their strength and reposition themselves or stay still, adds to the sliding issue, as well as the fact that there are many extra objects on the bed, such as pillows, layers of sheets, Glidlakan (gliding sheet), etc, which limit the space and the comfort.

Why it is bad?

The repositioning of the patients, when they slide down, leads to a bad and uncomfortable position. The patients sometimes end up very low on bed, which makes the legs not fitting.

Moreover, the pillow does not follow the patient which leads to an uncomfortable and dangerous position for breathing and for the neck, as the upper part of the body is compressed when the body is not aligned with the bed's corner. Additionally, the displacement of the patient can lead to pressure wounds. Reasons for being bad and comfortable can be seen in Figure 18.

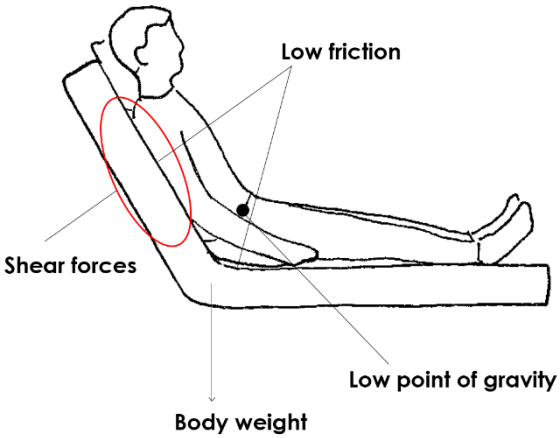


Figure 18 - Reasons for sliding down

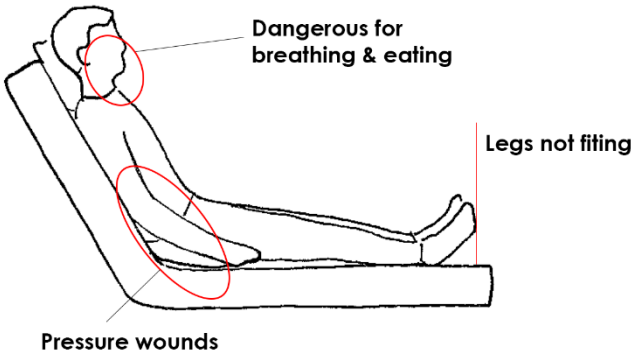


Figure 17 - Reasons for beeing bad and uncomfortable position

Task Related

The task of moving a patient higher up in bed is usually executed by two carers with the help tool dragging sheet (Draglakan). It is a daily task and some of the interviewed carers mentioned that they execute it up to 20 times per day. The carers should be synchronized, have good communication with each other and with the patient, and depends not only on the patient but also on which place the task is executed and on the collaboration between the carers. It is considered as one of the heaviest tasks in elderly care as well as a frustrating task. When questioning about how carers experience is the task, on a scale from one to five, where one was not heavy at all and five was very heavy, almost all of the interviewees chose three to five. Many of the interviewees that chose three, were also mentioning that it depends on the patient and their weight, while there have been cases where the interviewees answered six or seven without it being a choice in the scale. This strengthens the fact that it is a heavy task. The lack of time affects the way the task is executed, as it makes the carers doing it fast and in a bad way. In those cases, the carers think about the patients first of all and not about themselves, leading to injuries and body pain. Also, the task is sometimes done quickly because the carers take away the duvet and the patients feel cold. The interviewees admitted that there is difference between the way they learned how to do the task and the actual way of doing it, mostly because of the lack of time. In order for the carers to be prepared and prevent the problem, it is important to know about the patient's situation (e.g. don't touch their sensitive parts), as well as place the patient correct and in a stable position from the beginning. Additionally, the problem can be prevented by using the bed's benefits, such as tilting it the other way around. Some comments from the interviewees can be read in Figure 19.

Help Tools

During the interviews many help tools were mentioned, but many of them were not used. In the Market Research part, more information can be found about them. The most frequently used ones are Draglakan (dragging sheet) with 20 out of 22 mentions and Glidlakan (gliding sheet) with 13 out of 22 mentions. Additionally, during the interviews it has been pointed out that there are many products for one movement and a product that can help for several movements is more valuable.

Ergonomic Related

As mentioned before, the lack of time affects the way the task is executed, which leads to body pain and stress. It was mentioned during the interviews that 60% of the injuries are in the back, 15% in shoulders and arms and just below that in the neck. One out of three injuries led to sick leave, as 73% of them is due to lifting between transfers. Some actions were mentioned as important in order to execute the task correctly. The bed should be in a correct height for the shortest of the carers participating. It is important to have straight arms, bent knees, straight back and the center of gravity kept in body, while executing the task. Also, the feet should point to the same direction and the lift should be done with the legs and not with the arms and the back.

User Related

The category of users is divided into staff and patients. There is a variety of patients mentioned during the interviews with different ability of movements and levels of independence. A way of categorization is according to cognitive or physical disability. As cognitive disability could be considered dementia or cases that patient's brain forgets how to use the body muscles. As physical disability could be considered many different cases as can be seen in the following scale for the most demanding to the less demanding:

1. Paliativa patients (before death)/ people laying in bed all the time
2. Stroke
3. Amputation
4. Patient with a broken part e.g. hips
5. Some patients can help with the movements

As it can be seen, there are many different cases of patients, which concludes that not everything fits everyone. However, what is common is that patients want to feel that they can do things by themselves and feel independent as long as they can. It is better if patients can do things by themselves because then they don't feel that they are depended on other people. Additionally, it was mentioned that the heaviest part of the patient's body is the lower part, from the center of gravity, which is close to the waist, till the legs.

Future Related

As mentioned before, the task is executed by two nurses, but most of the interviewees mentioned the difficulty for two nurses to be at the same time because of the busy schedule. In addition to that, the change of the population pyramid was mentioned, with more elderly than young people in the future, which adds to problem of not enough carers. If the patient could do the task independent or with the help of only one carer, it would save a lot of time for

the carers, avoid many injuries and enhance their workflow. This brings the need for more technical devices in the future, taking advantage of electricity and mechanical tools in order to help. Although, the task should not become totally automated as it should not be relied only on electricity and the patient should continue using the functions that they still have.

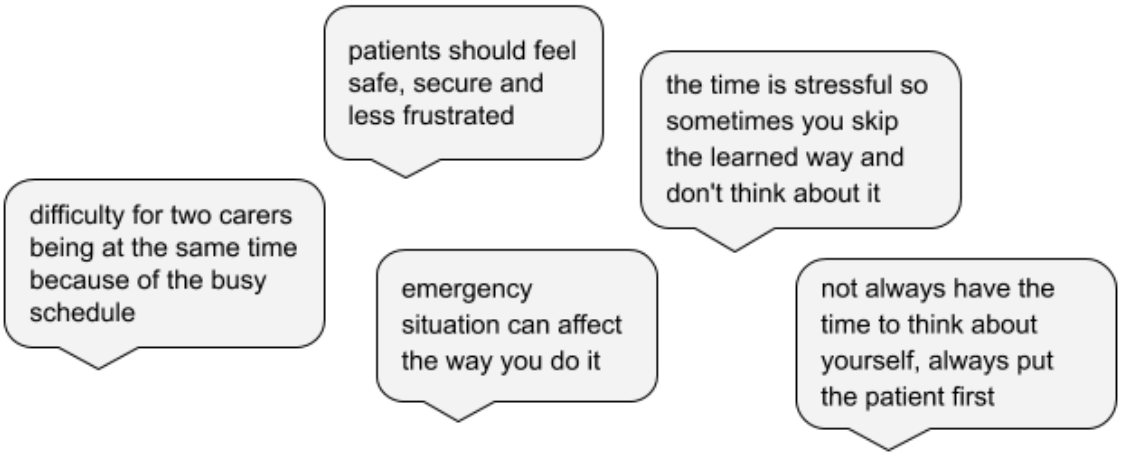


Figure 19 - Comments from the interviewees

7.3 Observation

The visit to Ängårdsbackens retirement home gave a clear picture of the context and reality. The environment has been observed, as well as the behaviour of both the patients and the staff. The high demands needed for executing the task was confirmed, as well as the negative expression from the patients during the task. It was the closest experience with the end users, which helped gaining a feeling and a concrete understanding of what is the problem and who is the design target group.

7.4 User Studies conclusion

Through the interviews and the observation, information about the context and the situation was gathered and gave a clear picture of the problem area. The key takeaways of the User Studies are that the task should be possible to be done independent or with the help of only one carer, the product should be easy to handle and don’t take too much space, the carers and the patients should feel safe, the product should be self-explanatory, and the product should help in several movements in order to have higher market potential.

8. Product Specification

By getting all these insights, some requirements came up for the future solution. The task should save time for the carers, it should be both easy to learn and easy to execute, while it should be easy to handle and don't take too much space. Also for the patients, it should make them feel safe, secure and less frustrated, while it should increase their self-esteem and confidence. As it is hard to change habits, the product should be self-explanatory, reduce the chance of doing the task wrong and it would be good to resemble the human's force. Additionally, it was mentioned during the interviews that it would be nice to make the task less painful for the patient and have a variation on materials. Finally, some very experienced interviewees mentioned that there is more space in the market for a product that helps in more than one task, as well as there are many different movements around this particular task that should be done anyway, so there is more potential for a tool that could help in several movements.

The requirement list is made in an Olsson's criteria matrix based on information from interview insights and requirements and wishes from the client. The criteria matrix consists of 14 requirements and 18 wishes. In the Table 1 the highest ranked requirements are showed, to see the whole requirement list see Appendix 3. In the table, the R stands for Requirement, W for Wish, MF for Main Function, F for Function and L for Limitation.

Table 1 - The highest ranked requirements in the requirement list

Criteria	R or W	weight: 1-5	MF or F or L
Take the patient back up in the bed.	R	5	MF
Reduce the number of carers to 1 or 0.	R	5	L
The task should be easy to execute	R	5	L
Prevent work related injuries.	R	5	L
The maximum weight of carrying should not exceed the 15.8 kg (35 lbs)	R	5	L
Reduce the physical demand of the task/movement.	R	5	L
During the task all the participants should feel and be safe and secure.	R	5	L
The product should meet all the hygiene requirements.	R	5	L
The product should be commercializable.	R	5	L

9. Ideation

Through the ideation phase many ideas were generated among different directions. Some of the ideas were focused on external device solutions, some on bed mattress solutions, some on additional bed sheets and some on combining the aforementioned.

9.1 How-Tos

How-Tos is a tool that helped setting directions for possible solutions and give inspiration to start the ideation sessions. It was a good tool to refresh the minds and broaden the creative thinking. With different perspectives some questions were set, the answers to which could frame a solution to the problem and set the basis for the design of the final product. Such a question is “How to make the task less physically demanding?” or “How to make the product facilitate to the lack of carers?”.

9.2 Team Ideation

The team ideation brought forward some first ideas on how to move the patient and some on preventing the patient from sliding down. The move-related sketches were done in yellow post-it and the prevent-related on green. In Figure 20 can be seen the chosen ones that were used as a base for more ideas in the same direction. The ideas included self-balancing beds, additional dragging solutions, water filled mattresses, electrical moving mechanisms, high friction bed sheets and special mattresses for preventing.

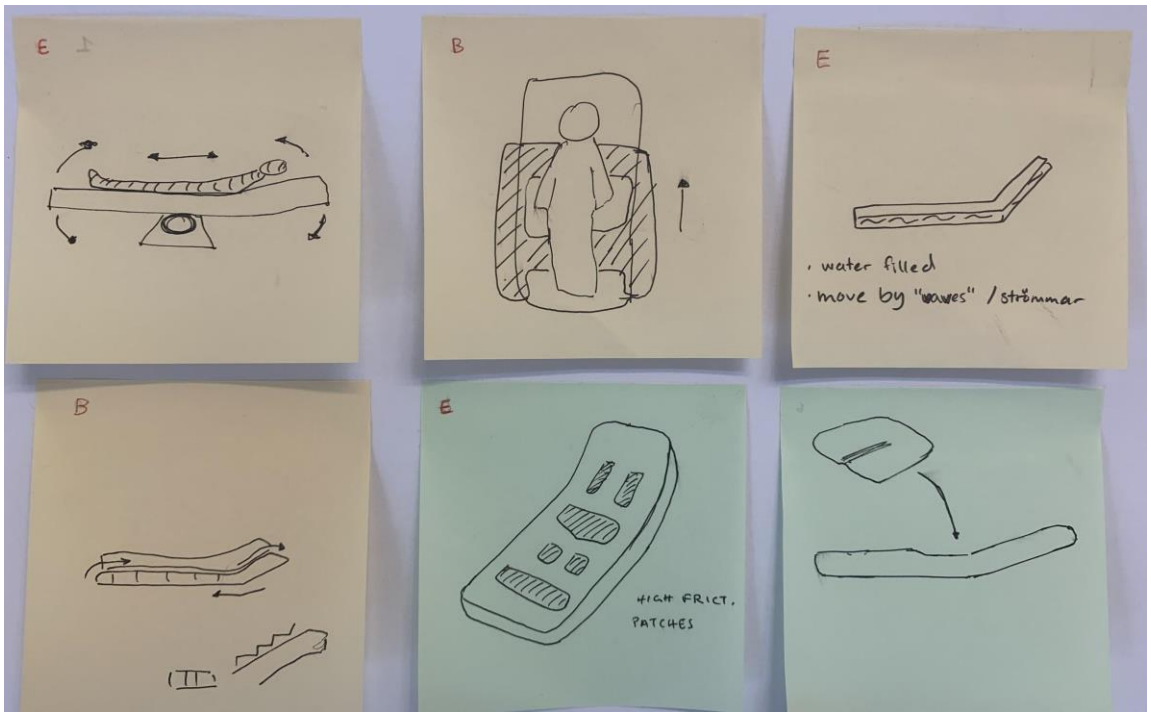


Figure 20 - Chosen ideas from team ideation

9.3 Co-design Workshops

During the co-design workshops, external ideas were put on the table from the different participants. Aspects that had not been considered before have come up and new perspectives among the problem have been discovered. Additionally, some feedback have been gotten for the generated ideas, which gave an initial direction for the evaluation.

9.3.1 Co-design workshop 1

The co-design workshop 1 ended up with a categorization of the ideas. The ones that were not relevant and seemed non feasible were discarded directly, while the rest went further for more discussion. Some of the chosen ideas were also voted from the participants during the evaluation method three dots, while some others were chosen by the team even though they were not voted. The seven categories are listed below and can be seen in Figure 21:

1. Mattress Solutions - Additional Parts / Bumps
2. Mattress Solutions - Curves / Bumps / Fixed Positions
3. Sticking Solutions
4. Mechanical Dragging Solutions
5. Side Rail Help
6. Rolling Around Solutions
7. Air / Wave Solutions

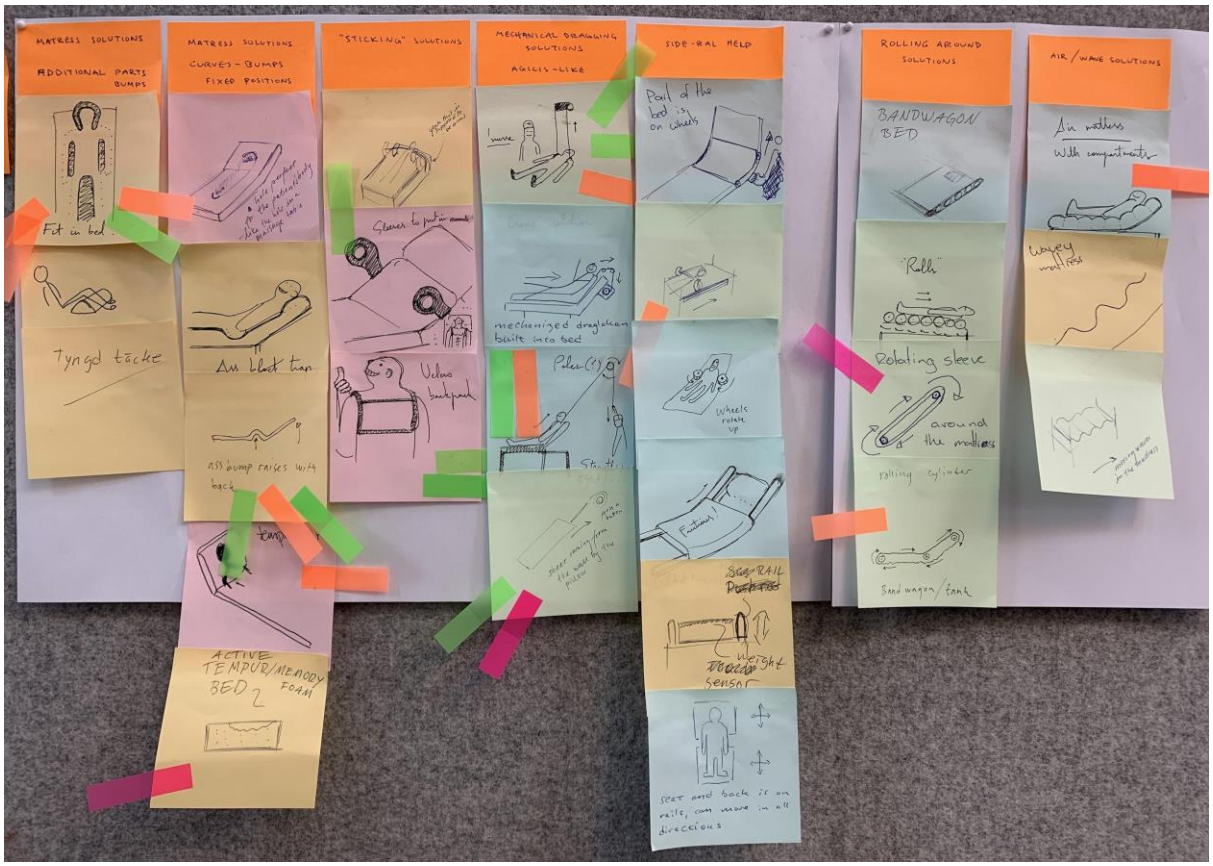


Figure 21 - Co-Design Workshop 1 participant's ideas, chosen and categorized by the team

9.3.2 Co-design workshop 2

By the end of the co-design workshop 2, the ideas were gathered together and were added to the ideas from the categories of the co-design workshop 1. All the ideas together composed a new categorization consisted of 13 categories (Figure 22 & 23). The different categories were: Agilis-like, Bump-preventing, Folding/Bending, Inside Mattress Mechanism, Material Solutions, Mattress - Air Solutions, Rails, Robotic, Rolling Around, Rullgardin-Inspired, Tempur-Ish, Under Thighs and Miscellaneous. In each category there were between four to nine ideas. Since the workshop was held early in the ideation phase, there was an intention to keep every possibly useful idea, only the ideas that were non feasible or the ones that were same as the previously chosen in co-design workshop 1, were discarded and not used further.

Figure 22 - Co-Design Workshop 2 participant's ideas, chosen and categorized by the team

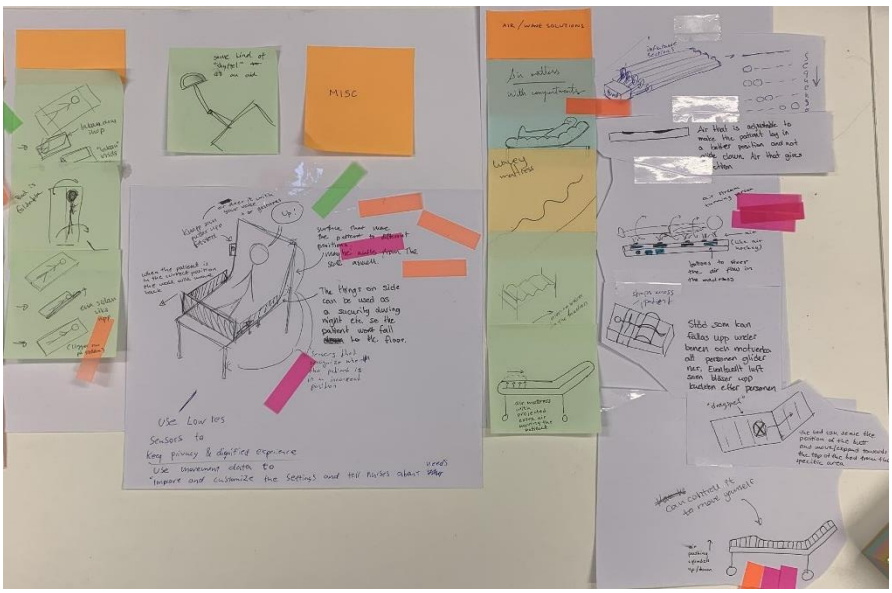


Figure 23 - Co-Design Workshop 2 participant's ideas, chosen and categorized by the team

9.4 Ideation conclusion

Through the Ideation phase, many ideas were generated among different directions, both realistic and nonrealistic. Some of the ideas were focused on a specific movement and some were focused on more. Through the implementation of several creativity methods and a handful of ideation sessions, a reasonable amount of ideas were brought forward to be evaluated, which then set a good ground for the Detail Design phase.

10. Evaluation

The Evaluation phase led to the result that the concepts Agilis-based and Tempur Sections will continue further to the Detail Design phase (Figure 24 & 25). This chapter shows step by step how the concepts have been evaluated and selected to be discarded or move further.

The Agilis-based concept moved to the detail design phase as it was considered the most feasible, most possible to be commercialized. With some further development it can turn to a multitude solution, by being used for more than one movement, which highly increases its market potential. In the next phase, the concept should strive to meet a list of goals prioritized according to the following order: turning on the side, moving higher up in bed and be mobile.

The Tempur Sections concept also moved to the detail design phase even though it does not fulfill all the requirements because it is a preventing mean and not for moving patients. However, all the stakeholders (the team, the client and the experts) considered it as valuable, feasible and novel concept to be explored further.

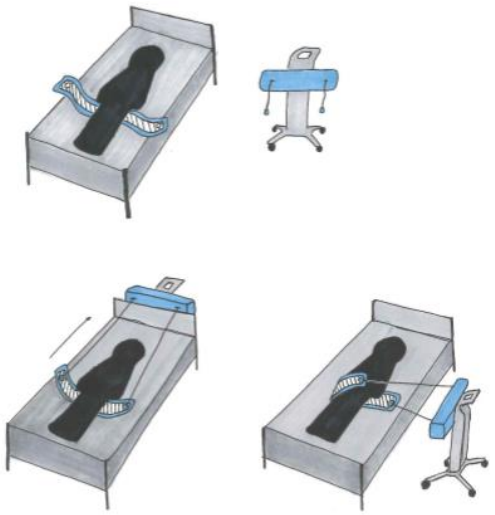


Figure 24 – The Agilis-based concept

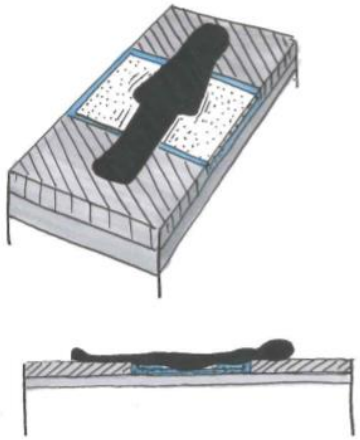


Figure 25 - The Tempur Sections concept

10.1 Team Evaluation

The team evaluation resulted on a new categorization of the ideas. The thirteen categories that can be seen in Figure 26 were, Agilis-like, Bumps-Preventing, Folding-Bending, Inside Mattress Mechanism, Material Solution, Mattress - Air Solutions, Rails, Robotic, Rolling Around, Rullgardin-inspired, Tempur-ish Solutions, Under-thighs and Miscellaneous ideas.

Figure 26 - The categorization resulted from the Team Evaluation

10.2 Njord Medtech's Top 5

The three favorite categories that stood out after this evaluation, with votes from everyone, are the Tempur-ish, the Agilis-like and the Rullgardin-inspired (Figure 27). Right after the 3-most voted categories comes the Inside Mattress Mechanism, with two votes, as even it could be complex, it was seen as interesting and exciting to explore further.

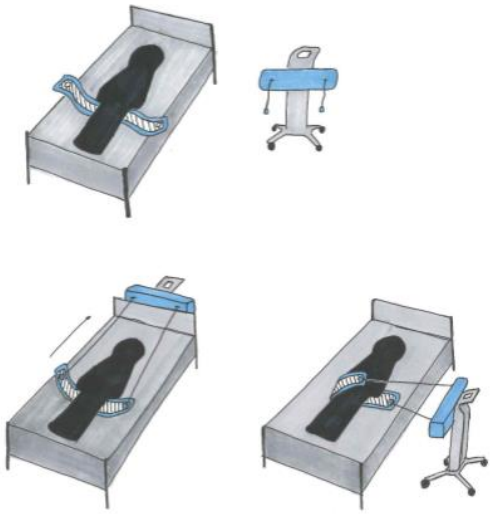
The Folding/bending**,** the Robotic, the Rolling around, and the Misc ideas were discarded since they were infeasible, too complex and hard to implement. The main goal was to come up with a commercializable solution and none of the aforementioned categories met this requirement.

The rest categories were kept in case they could be combined with another idea, or changed in a way, in order to become more feasible and end up to potential concepts. The whole evaluation can be seen in Appendix 6.

Figure 27 - The three favorites from the Njord Medtech top 5 evaluation

10.3 Client representative

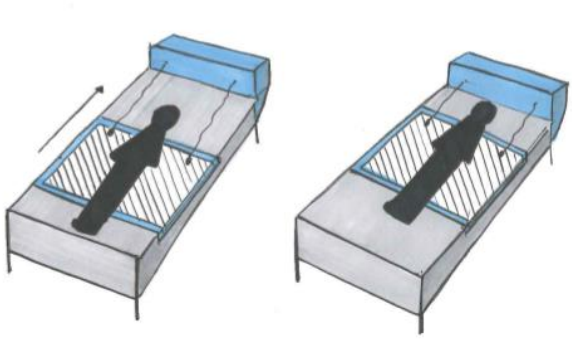
After some discussion with the client representative, three main directions were recognized. The ideas were divided into Agilis-based, Mattress solutions and Additional products ideas. From these three directions, some ideas were discarded and some that had similarities were combined together. See the combined and discarded ideas in Appendix 7. At that stage 17 ideas ended up to eight concepts, as it can be seen in the following eight Figures.



How it works/description
The agilis-based device is free to be used around the bed, it connects with a supportive tool under the patient and does the movement instead of the carers.

What movement
Move upwards
Move sideways
Roll on the side

Figure 28 - Free Agilis-based concept

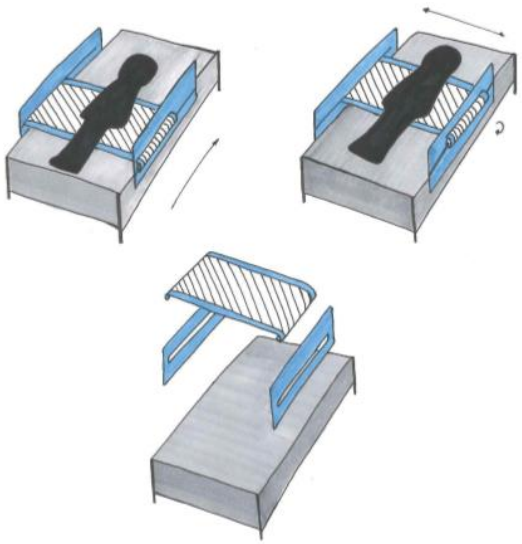


How it works/description
The agilis-based device is attached on the bed, it connects with the draglakan under the patient and does the movement instead of the carers.

What movement
Move upwards

Depending on how it is attached:
Move sideways

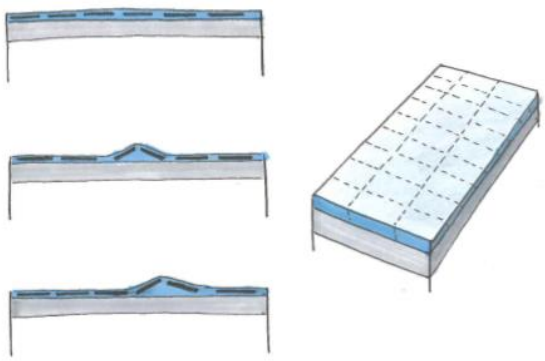
Figure 29 - Attached Agilis-based concept



How it works/description
On the side barriers/gates is integrated a rail/rolling system, on which the draglakan is attached and move the patient with motorized support.

What movement
Move upwards
Move sideways
Rolling on the side (with one carer support)

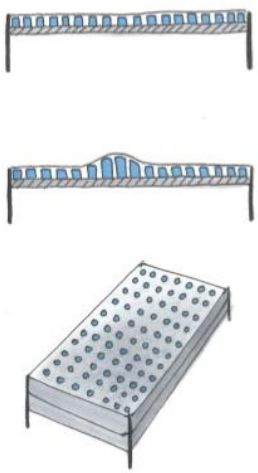
Figure 30 - Side rails concept



How it works/description
An additional mattress is added as a top layer on beds. This mattress has an integrated motorized mechanism with sections, which moves the patient by creating a wave movement with those inner sections.

What movement
Move upwards
Move sideways

Figure 31 - Snake movement concept



How it works/description
An additional mattress is added as a top layer on beds. This mattress has an integrated motorized mechanism with a pattern of expandable cylinders, which moves the patient by creating a wave movement with those inner cylinders.

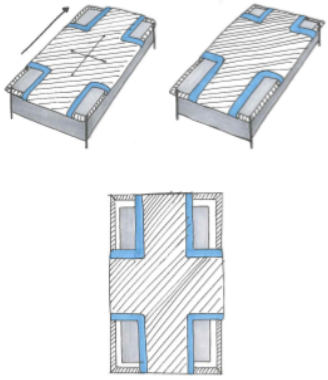
What movement
Move upwards
Move sideways

Figure 32 - Expandable cylinders concept

How it works/description
An additional sheet with high friction is attached on rolling mechanisms at the top and the bottom side of the bed. The mechanism can be manual or motorized and moves the patient with the help of one carer.
There is a lock/stop mechanism to keep the patient still when there is no need for moving

What movement
Move upwards

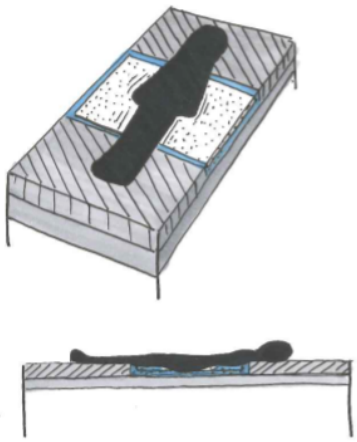
Figure 33 - Rullgardin concept



How it works/description
An additional sheet with high friction is attached on rolling mechanisms on each side of the bed.
The rolling mechanisms are attached on rails.
There are 4 axes of movement for the mechanism. Up-Down, Right-Left
There is a lock/stop mechanism to keep the patient still when there is no need for moving.
The solution can be used with half of the mechanisms (similar to rullgardin solution).
By attaching one side of the sheet on the rolling mechanism of the opposite side, it can roll the patient on the side.

What movement
Move upwards
Move sideways
Roll on the side

Figure 34 - Cross-Rolling concept



How it works/description
An additional mattress is added as a top layer on beds.
This mattress has some sections with different material.
This material could be tempur, or ultra high friction.
This solution can be combined with others.

What movement
Preventing sliding down
Prevent pressure wounds

Figure 35 - Tempur Sections concept

10.4 Grading Method

In order for the team to evaluate the concepts, a table was created with pros and cons for each concept, which was then used to complete the matrix (Table 2), in the same way as the client did. This process led to a discussion around the concepts and below is a summary of the results of this process. The pros and cons table can be seen on the Appendix 8.

Free Agilis-based and Attached Agilis-based: The concepts are very similar. The only difference between them is the aspect of being attached or free, which can easily be explored. This could affect the number of movements that can be done (2 or 3). Rather than that, the know-how already exists for these concepts, which can be combined with other effective help-tools.

Side-Rails: This concept is based on some basic parts that are already on the beds. The solution includes a help-tool such as the draglakan and the side barriers that every hospital bed has. By adding a rolling mechanism on the side barriers, the carers' task can become much easier by just pressing a button and not putting any effort. Even the patient can do it if able. The problematic side of this idea is that the product should be added on each bed and may be costly.

Expandable cylinders - Snake movement: The idea behind these two concepts is the same; having a mechanism inside the mattress which expands or moves in order to move gradually the patient. However, the two concepts are formed in different products, which are considered as very innovative and smart, but the implementation of them and the technology needed, seem to be unknown and could be expensive.

Rullgardin: Even if it is simple to be implemented, there is already an existing similar patent. Additionally, this solution can be used by only one patient and only for one movement, which is higher up in bed.

Cross-rolling: This solution can be used for several movements and it seems to be effective. However, the fact that it should be attached on a frame and be added on each bed separately, seems problematic. Moreover, the product will have some limits for each side of movement and it will not be able to be rolled more. Also, it can be bothering for other everyday activities by the carers because it will be in the way.

Tempur Sections: It is considered feasible and innovative, as the idea is very simple and probably easy to be produced. Considering that there will be only a section of the mattress with tempur, the cost will probably not go very high, which adds on the market potentiality of the product. However, it is not enough to stand as an individual solution to the problem and it has to be combined with something else in order to fulfil the requirement of moving a patient.

Table 2 – The Team grading matrix, where the green colour stands for good, the orange stands for middle and the red for bad.

Concept name and description	Market Potential	Innovativeness	Feasibility
Free Agilis-based Portable Agilis combined with a supportive tool			
Attached Agilis-based Attached Agilis combined with a Draglakan			
Side Rails Rolling System on rails integrated with the gates			
Snake movement Mattress with an integrated motorized mechanism			
Expandable cylinders Mattress has an integrated motorized mechanism with a pattern of cylinders			
Rullgardin Rolling mechanism attached to the sheet			
Cross-Rolling Rolling mechanism attached to the sheet in all directions			

Tempur Sections Mattress with sections with different material e.g tempur			

The client used the same matrix to express their opinion about the different concepts. In Table 3 the grading for each concept among the three criteria can be seen, market potential, innovativeness and feasibility. About the Free Agilis-based concept, the client believed that it can be valuable if it can be used also for the movement of turning the patient on the side, considering that the concept is based on the client's existing product.

The Attached Agilis-based concept is considered valuable for the home care if it can be mobile.

The Side Rails concept is considered cumbersome because it is limited to one movement and it can be problematic when reaching the highest point of the rails, which makes it not very flexible.

The Snake Movement concept can be combined with a pressure wound mattress, however the technology seems very complex and the level of help is unclear.

Moreover, it is not considered as useful as the Expandable Cylinders concept, which can be combined with pressure wounds mattresses and be used as a massage tool also. Although, the massage aspect could be problematic for newly operated patients.

The Rullgardin concept can only be used for one movement, and the fact that there is an existing similar patent made the concept being the least favourite.

The Cross Rolling concept seemed to be technically hard to produce, the fact that there is a maximum point of movement is a limitation and there is a competitive product (Vendlet) that is very similar.

Lastly, the Tempur Sections concept was considered novel, a good preventing mean and interesting to explore further.

Table 3 - The client grading matrix

Concept name and description	Market Potential	Innovativeness	Feasibility
Free Agilis-based Portable Agilis combined with a supportive tool			
Attached Agilis-based Attached Agilis combined with a Draglakan			
Side Rails Rollingsystem on rails integrated with the gates			

Snake movement Mattress with an integrated motorized mechanism			
Expandable cylinders Mattress has an integrated motorized mechanism with a pattern of cylinders			
Rullgardin Rolling mechanism attached to the sheet			
Cross-Rolling Rolling mechanism attached to the sheet in all directions			
Tempur Sections Mattress with sections with different material e.g tempur			

From the grading matrices and with additional discussion, the decision is made that the two Agilis-based are combined to one concept that should meet a list of goals prioritized according to the following order: turning on the side, moving higher up in bed and mobile, which cover both the free and the attached Agilis-based versions. The turning on the side is prioritized due to COVID-19 pandemic that is going on during the execution of this project, as turning the COVID-19 patients is crucial for increasing the chance of surviving the virus. Furthermore, Tempur Sections, side rails and expandable cylinders also fulfil the criteria better and these are the four ones that go further.

10.5 Reconciliation Meeting / Experts

During the meeting, several aspects related to each concept came up. About the Agilis-based concept, most of the discussion was focused on the form it could have and the level of mobility. The weight of the device was also put on the table as an important aspect of the design, as carers will have to lift or carry the device a lot and in case it weighs too much it may occur even more fatigue or injuries. Another aspect that was mentioned is about the motor and the two ropes, and how they can be formed in order for the device to be used for turning on the side. Moreover, it was clarified that it is more interesting for Njord Medtech, from a market potential perspective, to explore the area of hospitals more than elderly care, while the area of home care is the least interesting. The reason is that one of the company's employees is working in the hospital area, which makes it easier to connect and build a distribution network.

About the Expandable cylinders concept it has been discussed that the feasibility of the concept is questionable, and it is unknown if the wave movement can be effective enough to move a human body in a safe way.

The Side Rails concept has been discussed around the way it can be integrated on beds and how each movement can be executed. The conclusion was that the concept is very similar to a competitive one, which means that Njord Medtech should compete directly to that company.

The Tempur Sections concept was considered as interesting to be explored as a side solution in parallel. The main goal for this concept is to gain knowledge about the material, the ways of production, as well as the available mattress producers.

The conclusion of the meeting was that the focus of the project will be narrowed down to the Agilis-based concept and the Tempur Sections concept, as the Expandable Cylinders and the Side rails concepts do not go further and stay at this stage.

The expert insights from the concept feedback survey strengthened the outcome of the meeting. Both the experts agreed with the decision taken in the meeting, since the Agilis-based concept and the Tempur Sections concept were ranked top. Both concepts were considered as easy and safe ways to move the patients, with market potential if they are not too expensive. About the Agilis-based concept, it was mentioned that it needs little physical demand, as it needs only one carer to use it. Especially with the COVID-19, there are more bedridden patients that need to stay in bed for long and most of them require abdominal turning, which enhances the need for more caregiving. About the Tempur Sections concept it was mentioned that it can be a good preventing mean for sliding down and for pressure wounds.

The Expandable Cylinders and the Side Rails concepts were not considered good enough and very safe. It was believed that both concepts need more support from carers and don't have market potential. More specifically, for the Side Rails concept it was mentioned as an obstacle, the fact that one of the side gates should always be sealed, which makes the concept less usable. The full comments of the experts can be found in Appendix 9.

10.6 Comparison to requirement list

After going through the requirement list, checking if each concept meets each requirement, the result is that the free Agilis-based and the Attached Agilis-based meet most of the requirements. The free Agilis-based meets totally 21 out of 28 requirements and partially four out of 28, so only three requirements were not met, of which two were about efficiency that is difficult to be evaluated at this stage, and the last one is preventing which was not the focus of the design anyway. The attached Agilis-based comes second, right after free Agilis-based, with only two more requirements partially met.

This evaluation stage, in addition to the reconciliation meeting and the experts evaluation formed the final decision that the Agilis-based concepts went further to the detail design phase. Moreover, the Tempur Sections concept was decided to move further, even though it does not meet all the requirements. However, the positive comments and feedback about it, made it go further to the detail design phase.

11. Detail Design

To summarize the outcome from the two chosen concepts from the evaluation stages, different deliverables were made for each concept. For the Tempur Sections concept, the final deliverable has the form of advice for further work, which can be seen in Chapter 15 - Future Advice. For the Agilis-based concept, one flow chart (Figure 36) was made. The flow chart was made to organize the rest of the project regarding the Agilis-based concept and to show the different directions that had to be followed and covered. The three goals: turning on the side, moving higher up in bed and a mobile version were explored in the focused ideation.

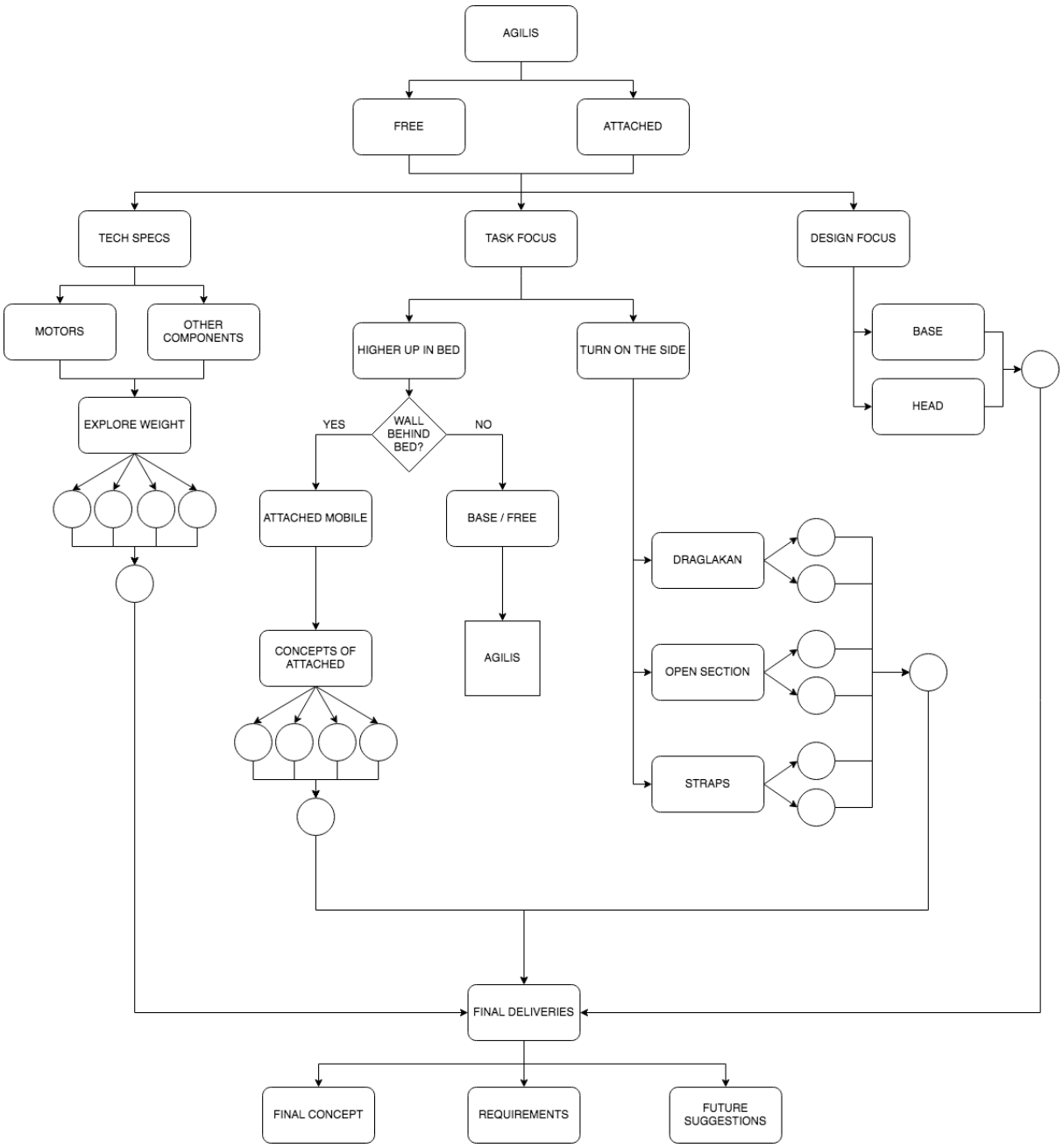


Figure 36 - The flow chart of the different directions for the Agilis-based concept

11.1 Focused Ideation

The different directions of the flow chart started to be explored. First, the goal of developing a solution for turning on the side was achieved. The turning of the patient will be done by using two fabric straps that are attached on the Agilis-based device (Figure 37). On one side of the straps, a part made of a material with low friction (like Glidplatta/Glidbräda) can be connected (Figure 41), which will make it easy to go under the patient (see more details in 11.2 Lo-Fi Prototype). After putting the straps under the patient, the low friction part is removed and the fabric part is attached to the Agilis-based device ropes. The other side of the straps, that should be stable, is attached to the Agilis-based device mechanisms housing part (mentioned as “head” for the rest of the report) in the same way as it is attached to the ropes with the fastener (Figure 38 & 39).

The total strap length will be 2000 mm, considering that a bed is 900 mm wide and half of the bed’s width should be added on each of the sides to cover the distance between the patient and the Agilis-based device and to have a part over the patient. Additionally, 100 mm is added on each side for the attachment. The width of the strap will be 250 mm, in order to be enough for supporting the body, but not too big to be in the way while doing the task (Figure 40. The dimensions for the low friction part should be 500 mm long in order to be enough to be passed underneath the patient’s body.

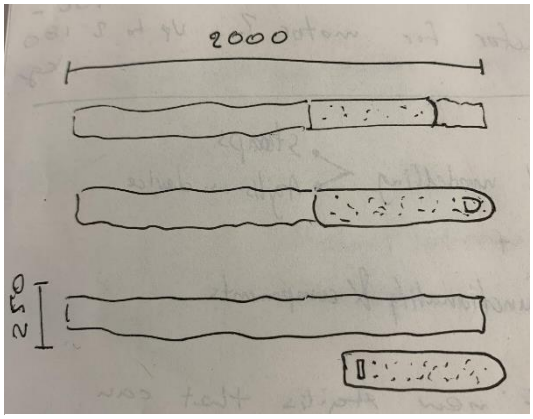


Figure 37 - Sketches of the straps solutions

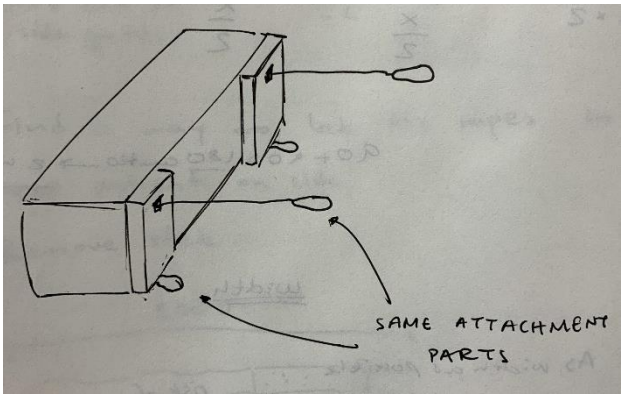


Figure 38 - The attachment points on the Agilis-based device

Figure 39 – The fastener that is connected with the ropes

Figure 40 - Exploring the necessarly dimensions

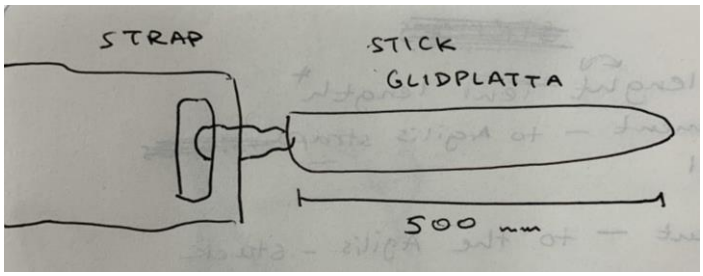


Figure 41 - A sketch of the straps connection

To keep the patient on the side, the ropes should be blocked and kept stable, in order for the patient to stay still. This can be done with an addition of a brake to the device. The brake should ideally be electrical and controlled by the hand controller. An alternative way for the brake would be to be mechanical with a button on the Agilis-based device head, like the dog leash brake mechanism that can be seen in Figure 42 and Figure 43.

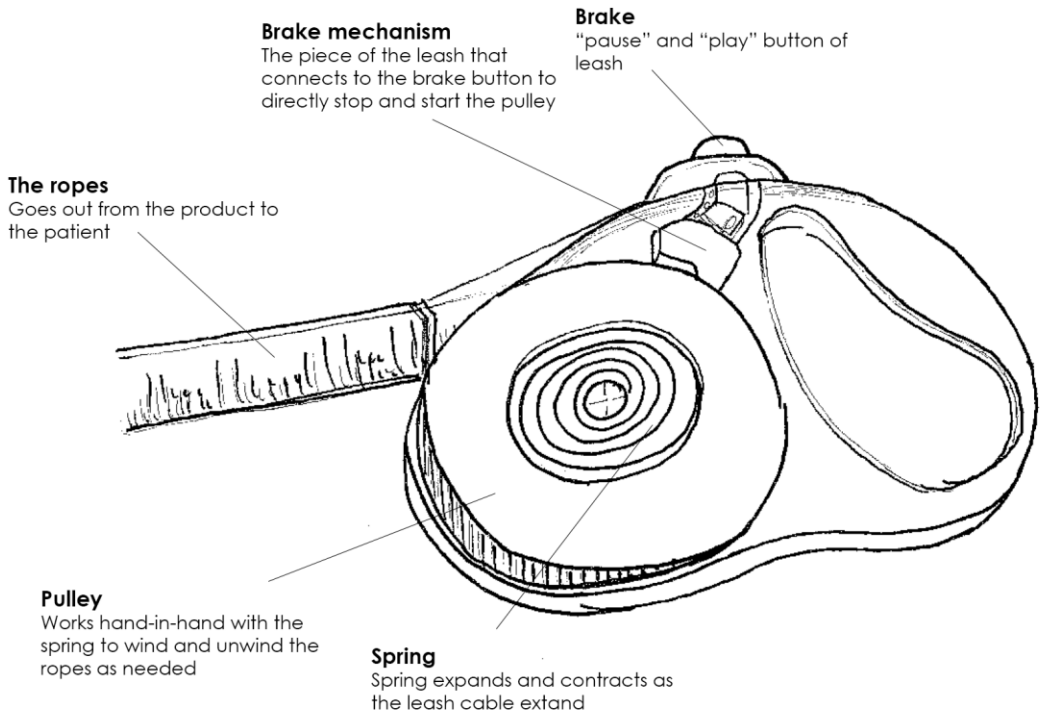


Figure 42 - The suggested brake mechanism

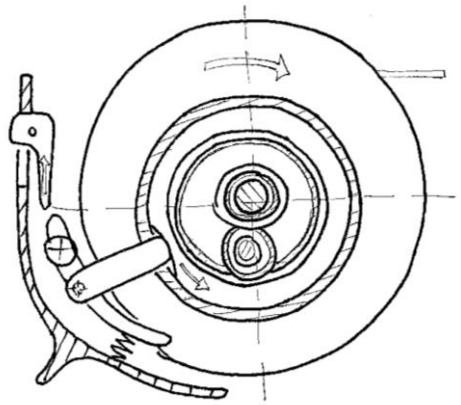


Figure 43 - The inner part of the suggested brake mechanism

The Agilis-based device should be able to reach a level higher than the bed's side gates and the patient's body (see Figure 44). By doing that, the friction between the ropes and the patient's body will be avoided and the movement will become smoother and more comfortable.

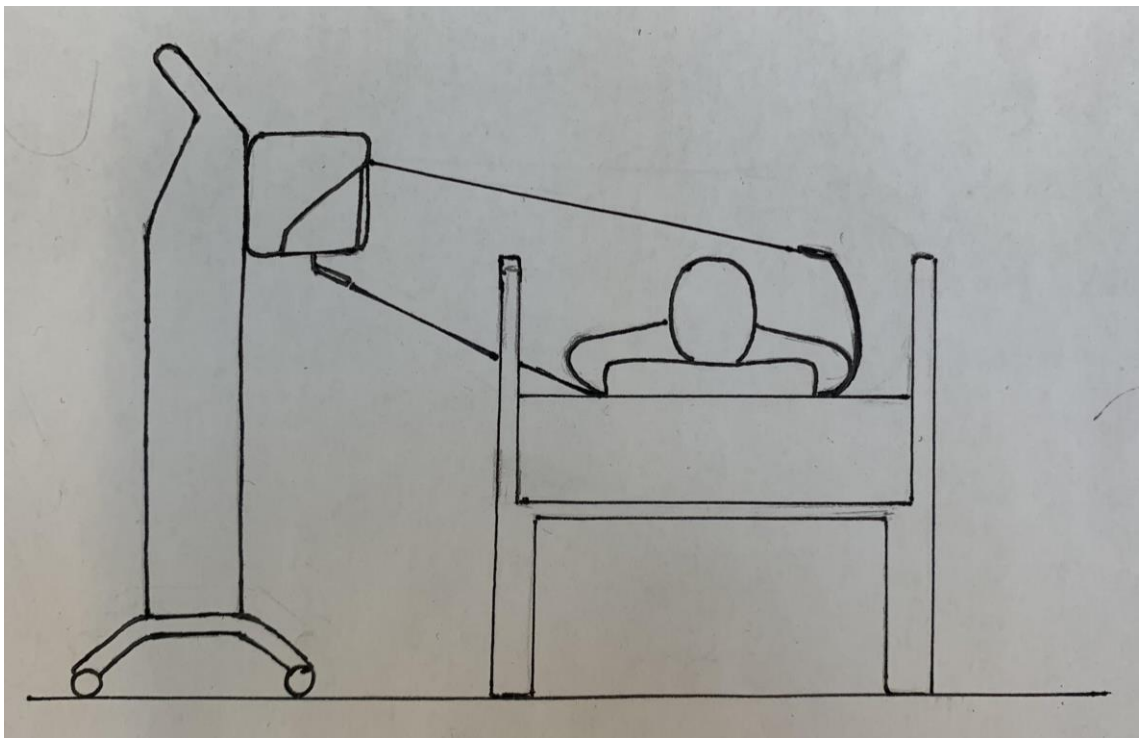


Figure 44 - The relation of the height between the Agilis-based concept and the patient

Redesign

For defining the new design of the device, the Morphological chart helped coming up with variations for each part separately and exploring different ways and forms. Then, the Fish Trap model (Figure 45) was used to determine the final form of the product. During the Fish Trap model, aspects such as production methods and materials were considered, since the goal is a commercializable product. The chosen production method for most of the parts that the product consists of is injection molding, because it is an appropriate method for durable plastic parts. Another aspect that was considered during the method, is that of assembling and

disassembling the device. The way that parts will be connected was taken into account during the defining of the final concept.

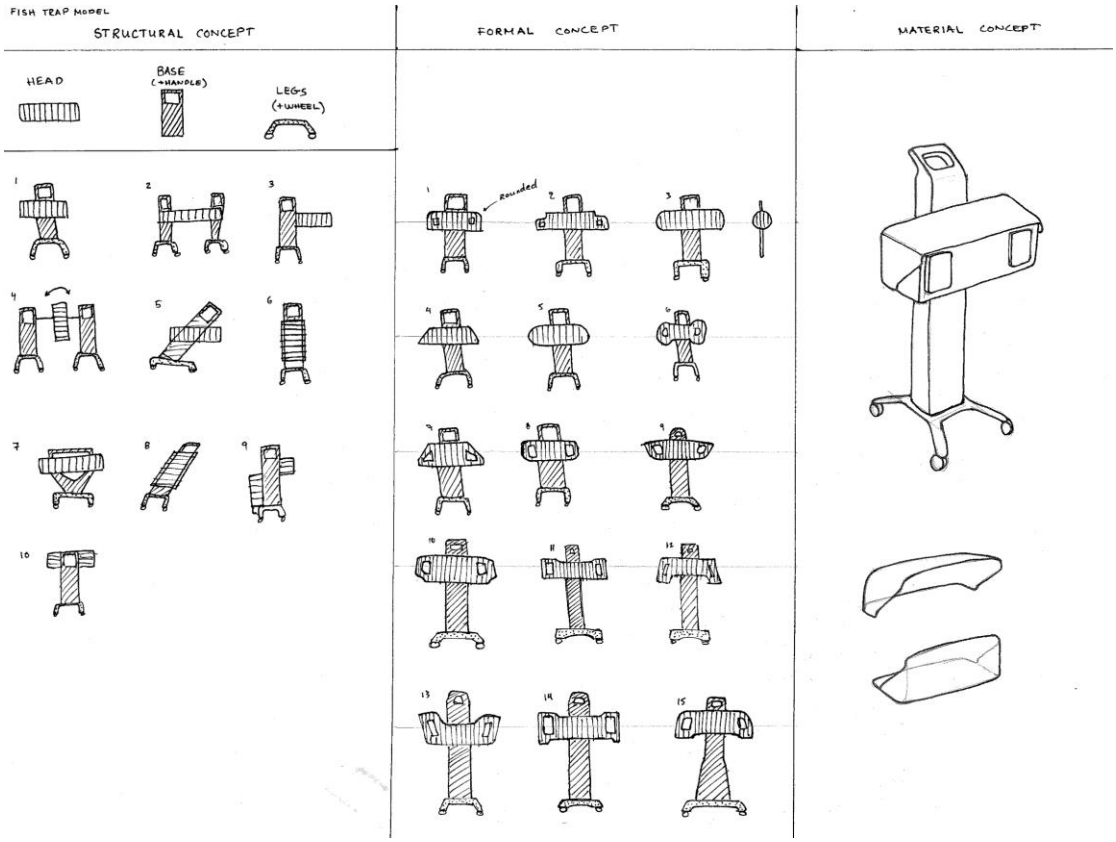


Figure 45 - Fish Trap Model sketches

Higher up in bed

Apart from turning on the side, in detail design, the task of moving a patient higher up in bed has been explored. For this task, two cases have been identified; if there is a wall behind the short end of the bed or not, as placing the beds next to the wall is a common situation in the healthcare. In case of not having a wall next to the bed, the Free Agilis-based device can be placed and used behind the bed. In case that there is a wall, this is not possible. In this case, an Agilis-based device attached on the bed can be an alternative. Thus, some focused ideation was done for the attached Agilis-based, with the use of brainstorming (Figure 46).

During this focused ideation, some ideas regarding possible attachment mechanisms were generated. For instance, a mechanism similar to the TV wall-mounting mechanism that could go above and behind the bedhead with an extendable arm. Some other ideas were dealing with different ways of attaching the head of the device on the bed frame, with the device weight being the biggest issue at that stage. For this reason, the concept of attached agilis stopped at this level, as more work needs to be done as it comes to the weight. Today the head of Agilis weighs around 15-16 kg, without including the cleaning system and the plastic covers. For safe lifts the maximum weight should not exceed 15.8 kg (Relias Media, 2007). See recommendations for how to make it lighter in Chapter 15 - Future Advice.

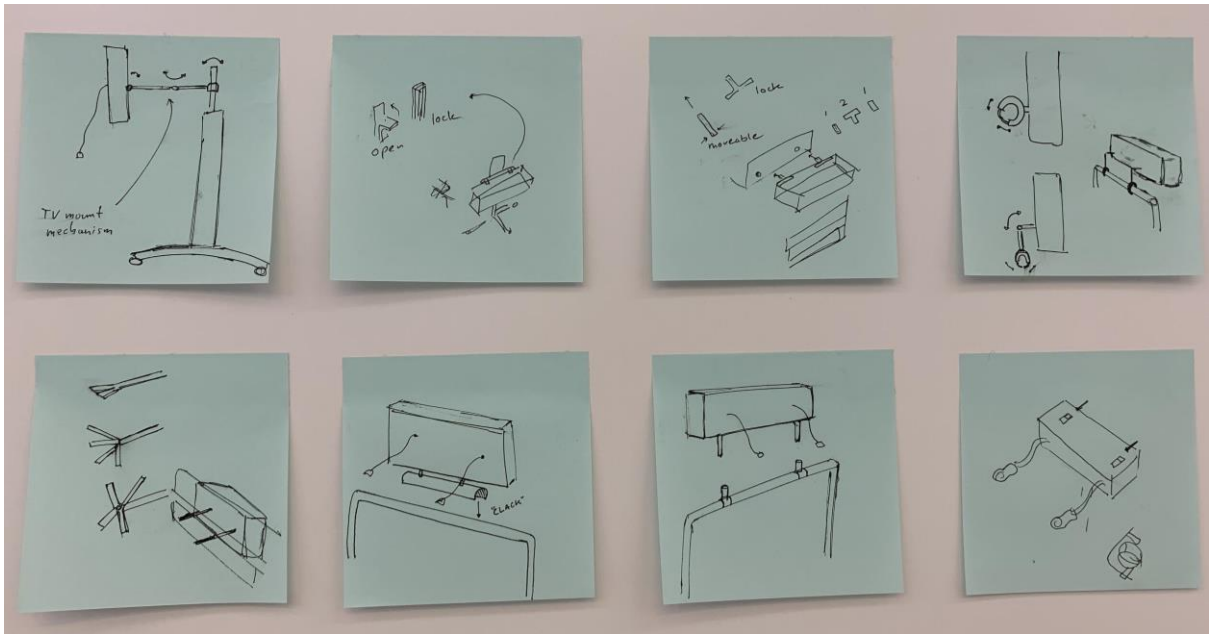


Figure 46 - The brainstorming about the attachment of the Agilis-based concept

11.2 Lo-Fi Prototype

For the two chosen concepts; Tempur Sections and Agilis-based, low fidelity prototypes were created to facilitate the understanding of the different solutions. The prototypes were used as a communication mean between the team members and the client, as the prototypes could show the general picture of the concepts on a better extent than simple sketches and express the ideas more thoroughly.

For the Tempur Sections concept, a basic wooden bed prototype was built to understand the relation between the bed frame and the mattress, as well as the way of bending in different ways. To imitate the Tempur mattress, a sample of viscoelastic foam was used (Figure 47), in combination with two normal foam parts (Figure 48). The Tempur sample gave a clear perception on how viscoelastic material works, what the density of it is, how the temperature affects it and the pace of recovery when no pressure is exerted.

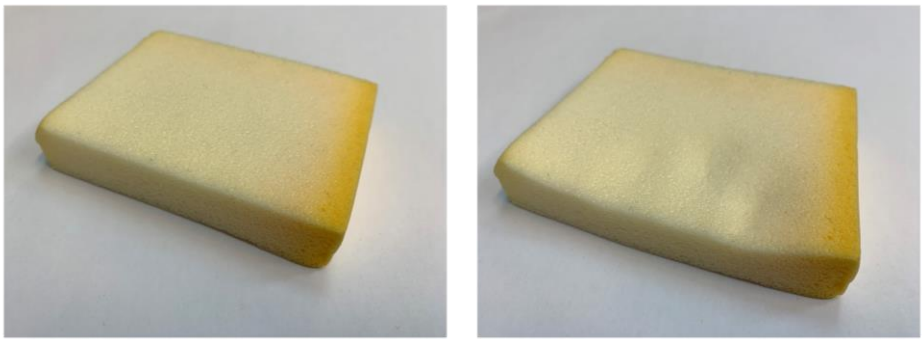


Figure 47 - The tempur sample

Figure 48 - The prototype of the Tempur Sections concept

For the Agilis-based concept, the low fidelity prototype was focused on the way to turn the patient on the side, creating different straps solutions. A patient figure had been created by the client's R&D evangelist, in combination with a mattress replica, which were used as a basis for the straps exploration (Figure 49). The main goals of this prototype were to explore and define in detail the size and the shape of the straps, as well as to confirm that the ideas were possible to be executed.

Figure 49 - Lo-Fi prototype of the straps solution

11.3 Detail Design conclusion

The Detail Design phase included some further exploration of some parts of the chosen concepts through some focused ideation among several aspects. Such aspects that were defined during this phase were the increase of the height of the device, the way to turn on the side with the design of a straps solution, the addition of a brake for the ropes, the general redesign of the device's form that turned it into a more rounded and eye pleasant product, as well as some additional details for the Tempur Sections concept. The mobile version of the Agilis-based concept and the Tempur Sections concept stopped at this phase, while the rest of the aspects of the Agilis-based that were defined in this phase went further to build the final concept in the next chapter.

12. Final Concept

The final delivery of this project consists of the final concept of the Agilis-based, which can be seen in this chapter, an updated requirement list, which can be found in Appendix 10, and future advice which can be found in the homonymous Chapter 15.

The final concept, which is named Triaid, is a development of the product that the client has already produced, Agilis, which has been presented on Chapter 12. Agilis was designed to be used for moving a patient from one bed to another. This project started with a focus on moving a patient higher up in bed, which is a task that Agilis can be used for, as realized throughout the process of the project. Thus the focus changed to develop a help tool that can be used for more than one movements. Triaid, which is the new version designed during this thesis work, has small changes and additions. It can be used for moving a patient from bed to bed, higher up in bed and turning a patient on the side. The biggest additions regard the task of turning on the side, as moving from bed to bed and higher up in bed can be executed on the same way with the help of Draglakan (dragging sheet), depending on the positioning of the device. For bed to bed movement, the device can be placed on the side of the bed, and for higher up in bed it can be placed behind the head side of the bed (Figure 50).

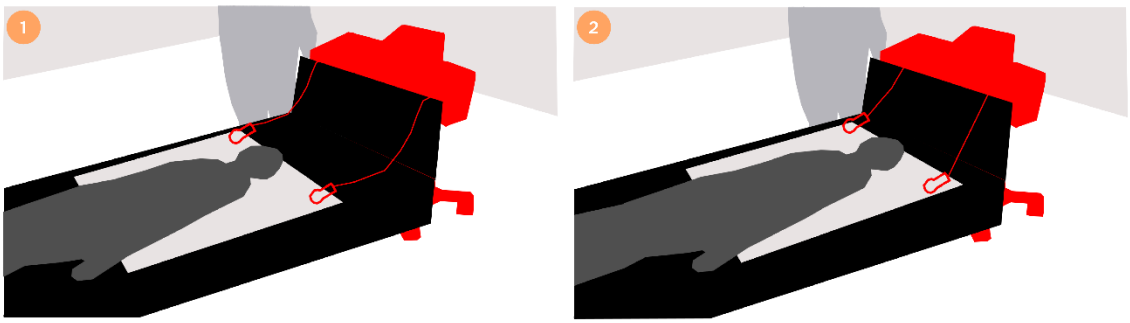


Figure 50 - An illustration of moving a patient higher up in bed with Triaid

For the task of turning the patient on the side, some additional accessories should be added (Figure 51). Such accessories are two straps that will enable turning the patient on the side, and at the same time they will not be in the way, making it easier for the carers to execute the necessary hygiene activities. These activities cannot be executed as the product is today. A storyboard showing the way of using the straps, can be seen in Figure 52 and 53. Additionally, the height of the product has been increased, as the straps and the ropes have to be on the highest point possible, without touching the gates, which might slow down the movement, and without touching the patient, which might make the task uncomfortable.

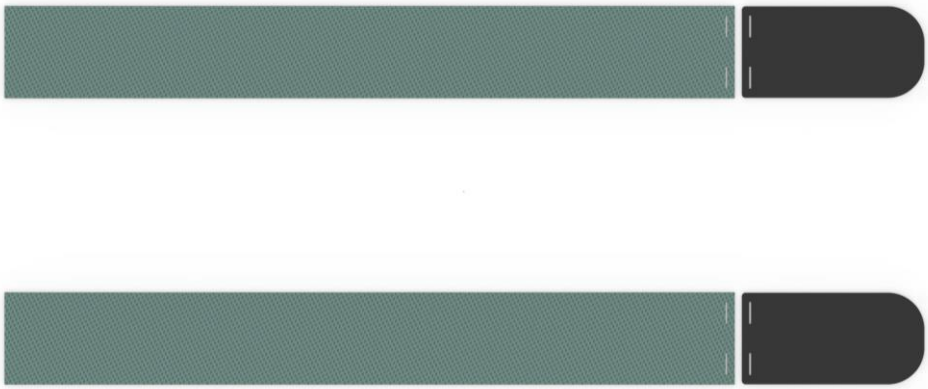


Figure 51 - A visual representation of the straps solution

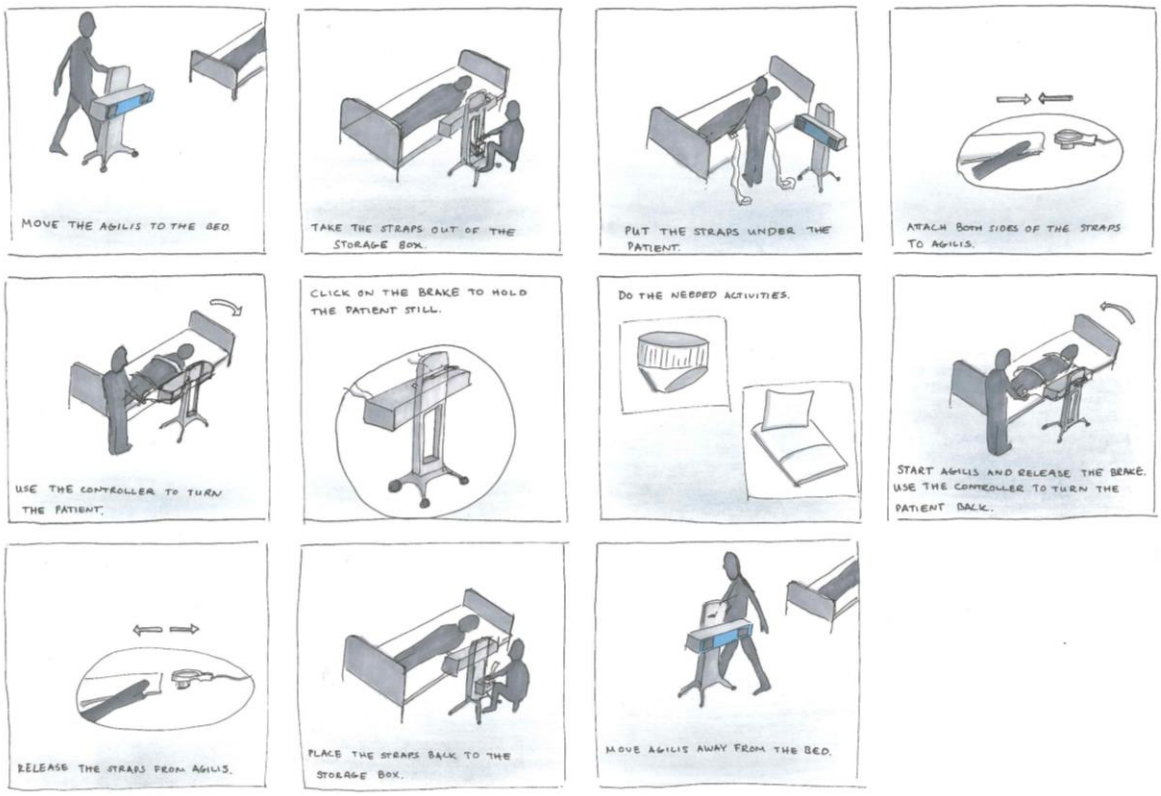


Figure 52 – A Storyboard sketch for turning the patient on the side

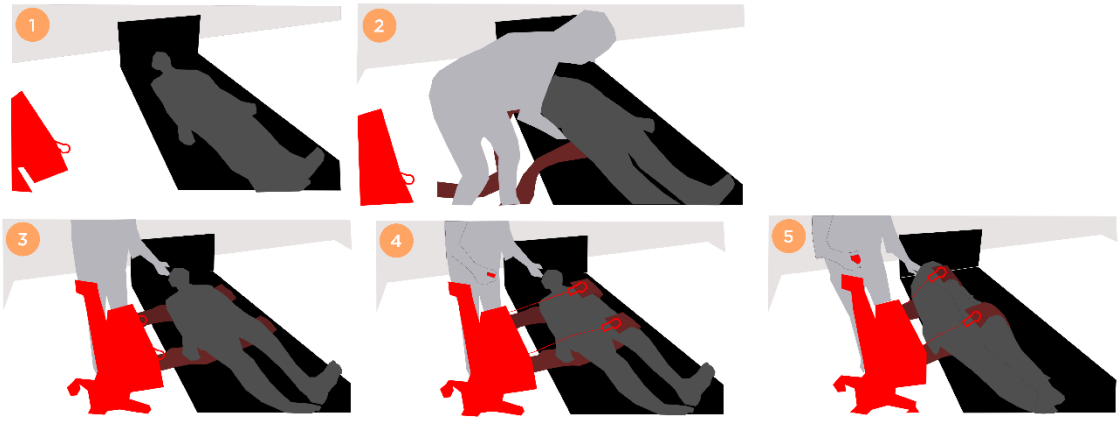


Figure 53 - An illustration of step by step turning the patient on the side

To make the turning on the side and the execution of the hygiene activities possible, the patient has to stay still when turned on the side. To achieve that, the addition of a brake was necessary, in order to stop the rotation of the motor and to keep the ropes secured. Today, Agilis is programmed to release when the movement is finished, so with the addition of an electrical or a mechanical brake on Triaid, the movement can be possible. An electrical brake can be connected to the other electrical parts of the device and can be controlled via the hand controller. A mechanical brake can be directly connected with the ropes, which will be blocked with the push of a button on the device.

Triaid

Triaid, which is a redesign of the Agilis, consists of the same basic elements but has a more rounded shape. Starting from the bottom to the top, the device stands on four wheeled legs, which have an angle for more stability and durability. The base is higher, as the device should reach a higher level, so the form has changed a little bit. As the handle should stay on the same height, which is ergonomically correct, an additional volume has been added above that, to extend the moving rail of the head of the device. Moreover, on the back side of the base has been created a recess (Figure 54), which makes the base lighter because of the absence of material and creates a storage place integrated with the product. This storage place can be used for storing the straps when not used, as well as for hanging the controller in a specially designed hook.

Furthermore, the head device has been redesigned with more round edges, and divided into two parts. The first and main part covers the upper and back side of the device made by white plastic, while the second part covers the front and lower surface made by light blue plastic. On the left and right side of the device, the two colored parts are connected creating a diagonal border on each side. The light blue color has been chosen since it stands for calm and relaxing, and the redesign of the shape has been done to make the device more eye pleasant. Visual representations can be seen in Figure 54 and 55.

The main parts of the device are made by injection molded plastic ABS. ABS has been chosen as it is one of the most versatile plastics, which in addition with its low cost, makes it a good

choice for many applications. It is easy to process and extremely tough with good impact resistance. It remains stable during processing and is very straightforward to exactly match colors. It can be rigid, colorful and shiny, and it achieves an extremely high degree of manufacturing tolerance (Lefteri, 2013).

The production method injection molding has been chosen, as it is the most common to produce ABS housings that are mass produced. It is inexpensive to mass produce injection molded ABS parts, as the main cost is for the tool and the molds. Injection molding is a versatile method of producing plastic parts in general. It is known as the most common and most efficient form of molding and it can handle extremely complex parts, many different materials and colors. What is more, with injection molding it is easier to reduce waste, as companies have system in place to recycle its excess plastic. Last but not least, labor costs are typically relatively low in plastic injection molding, in comparison with other types of molding, and the ability to produce the parts at a high level with a high output rate, helps with its cost efficiency and effectiveness (Swift & Booker, 2006).

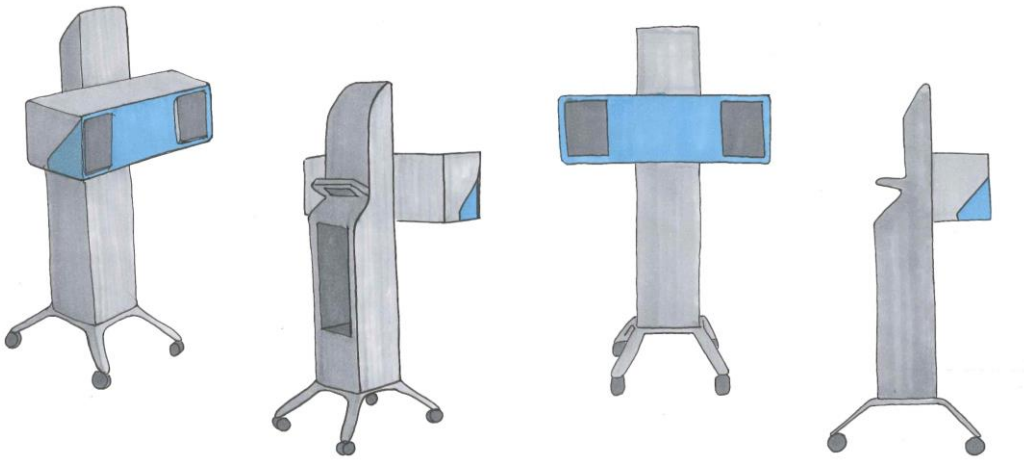


Figure 54 - Sketches of the final concept Triaid

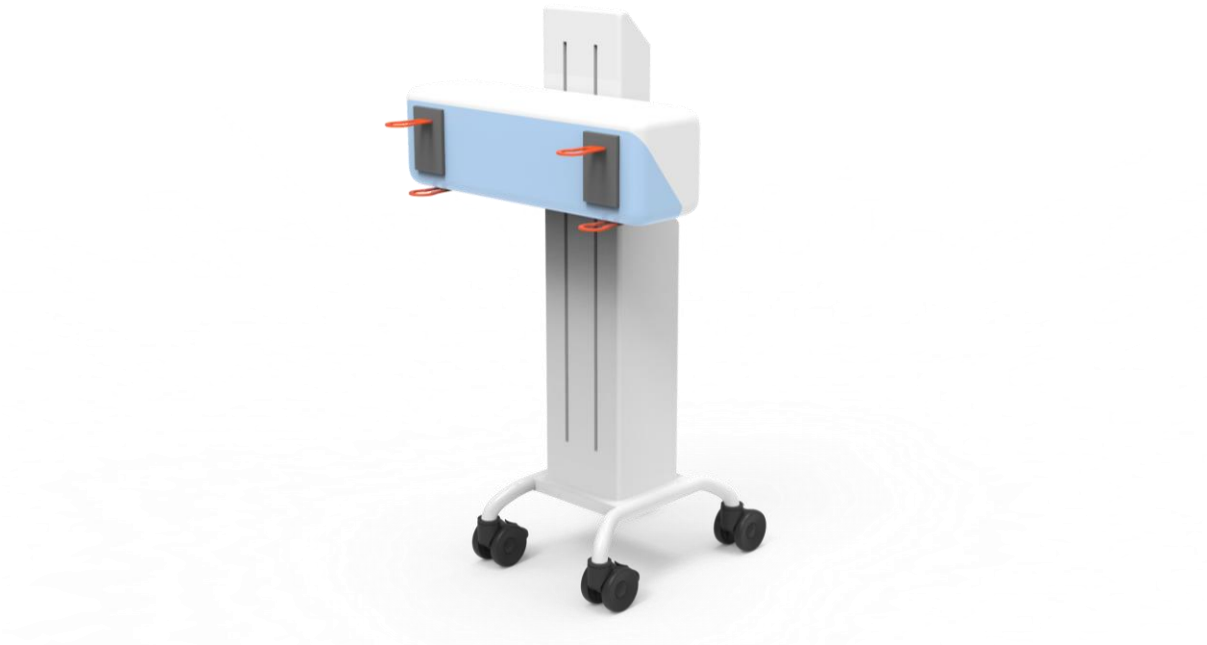


Figure 55 - Visual representation of the final concept Triaid

13. Discussion

In this chapter, some thoughts and reflections will be mentioned about taken decisions during the project and things that could have been done differently. Aspects that influenced the project, as well as issues that led to particular acts, are described below.

Planning

Before the beginning of the project, a planning had been made including all the desired phases that were considered necessary for delivering the asked outcome. The time assigned for each phase, had been decided under ideal circumstances with some extra time in the end of the project, in order to be able to overcome unexpected obstacles and make changes needed. However, during the execution of the project, it had been realized that some phases needed to be overlapped or merged together, while some tasks needed more time than planned. Additionally, more iterations than planned have been done during the ideation phase, which was directly connected with the evaluation stages.

Focus

The initial focus of the project was the task of moving a patient higher up in bed. The focus has been stated by the client, who asked to confirm it first, before trying to create a solution for facilitating it. It has been also mentioned that the focus should be open and adapt according to the users insights. Therefore, during the user studies phase, the main focus was around moving a patient higher up in bed, but with a small trigger for getting information about other problematic movements too. During this phase, the underlying problem was moving higher up in bed, but a secondary plan was always on the background ready to be brought on the foreground. At some point, when the market potentiality was taken more into account, the focus became broader. From only one movement, the focus changed to facilitate several movements with the same product, which would have higher market potential and would meet the goal of a commercializable solution better.

User Studies

A difficulty during the user studies has to do with the hard to reach target group. As the users in interest were both carers and patients, it was a sensitive task to arrange meeting them in the context of work. For the carers, their busy schedule makes it difficult to find a time, as for the patients the privacy aspect is important and demands a lot of planning to manage to come in contact. Additionally, the hospitals, the retirement homes and the other healthcare centers have a peculiarity in terms of ease of visiting them. Apart from that, the project took place in a special period, as COVID-19 pandemic turned the world upside down with unprecedented conditions in all sectors. This affected the user studies phase, as some of the planned interviews were not able to be done because of the situation. Some of the potential interviewees got sick and some others had to work more. Moreover, a planned visit to a retirement home could not be performed as planned, because of the restriction for visits in retirement homes. Although, the visit was modified and adapted to the situation, by performing the interviews outside but without being able to observe and talk with patients in the real context.

Because of the COVID-19 situation, the user studies phase had to be extended and be done in parallel with the beginning of the ideation phase. Fortunately, the good planning of arranging interviews and visits very early in the process, helped with getting enough data for the rest of the project. Even though almost half of the interviewees were not very experienced, the user studies ended up with 22 interviews, which is a good amount for getting qualitative data.

Ideation

The ideation phase was also affected by the COVID-19. The second co-design workshop was supposed to be done with a mix of students and experienced people in the field, but because of the situation that was not possible. The initial plan was to hold the workshop at the Chalmers University of Technology facilities, but as it was forbidden to bring external people there, some tries have been done to change the location. Finally, the workshop ended up with only students, as the first one, because then it could be held at Chalmers with the client representative participating digitally. Since the focus of the project changed between the two workshops, it has been decided that the approach of the second workshop can change to several movements in bed. Thus, it was fine to hold two workshops with students, as the approaches were different.

The ideation phase was done in many sessions and ended up with many ideas. Together with the evaluation phase, that was performed in parallel, the two phases lasted longer than planned. This was necessary to narrow down the ideas, to select and discard some of them and iterate more until reaching a satisfying level. Therefore, the detail design phase was affected, as well as the final concept phase. However, it ended up fine, as it was decided from the beginning that the final deliverables are open and depended on the time.

Evaluation

The evaluation phase was not fully structured from the beginning, but when the first evaluation stage started, everything became clearer. If the whole phase had been structured and fixed from the beginning with more concrete steps and predefined stakeholders, the evaluation phase would have looked different and maybe the same for the outcome. In the way the evaluation was actually performed, with the desired stakeholders and in many steps, the decisions taken are still considered trustful. An issue during one stage of the evaluation had to do with external stakeholders, who in order to participate had to sign a non disclosure agreement (NDA). This made some of the participants hesitant resulting in having only two external stakeholders at that stage.

Agilis influence

Another topic for discussion is the influence from the client's already developed product; Agilis. At first it had been tried not to let Agilis impact the project's outcome. However, during the procedure of the ideation phase, it has been realized that many of the new ideas were connected with Agilis resulting in creating a specific category of concepts, called Agilis-like. Furthermore, there was a feeling that the client believed more in the Agilis-like concepts, probably because of the existing know-how, which made it safer compared to other more outside the box ideas that could be less feasible. As a result, it could be said that the project

outcome was very influenced by Agilis, but indeed it has been understood through the evaluation that the Agilis-based concepts have more potential to be commercialized and meet the project's goal better than any other concept.

Besides, during the project and because of the COVID-19 pandemic, it has become a bigger need for hospitalization and more patients need to be bedridden. This strengthens the demand for an immediate development of a product to facilitate the higher workload in the healthcare. Thus, a commercializable solution became even more relevant.

Final Concept

Due to the longer duration of the previous phases, the detailed design phase was not as long as initially estimated. As a result, there was not enough time to develop the final concept on a fully detailed level, including detailed 3D modelling, as well as detailed analysis of the production. However, this decision has been taken in agreement with the client.

The result of the project is considered satisfying, as it meets the project's goal and requirements. Triaid is possible to be used by only one carer, which compared to the existing solution, Draglakan (drawing sheet), makes the work easier. The communication between the carers can be problematic when using the Draglakan and it is very easy to use it unsynchronized, which has an impact on the patient. With Triaid this is not a problem, as only one carer is needed. Additionally, with Draglakan it is very easy for the carer to have a bad posture while using it, or use more strength than it should. As Triaid is a motorized device, the carer does not need to put much effort on the task, since the device does the job instead. Even if the Triaid needs a few more steps to be used by the carers, in a long extend it can be very valuable for the healthcare system. For the carers, it will mean less injuries and will support an efficient work for the future. For the whole healthcare system, Triaid will help with the problem of lacking carers.

Even if COVID-19 pandemic had a big role in the implementation of this project, the process went well and the final outcome is considered fulfilling. If commercializable was not set as a key aspect on the beginning of the project, the final result could have been different and more innovative, in a conceptual level. Considering the commercialization, it is believed that the project could not have any better result. With some more development of the details, Triaid can go soon out in the market.

Relation to COVID-19

The majority of the COVID-19 patients require intensive care and have been affected by Acute Respiratory Distress Syndrome, ARDS, that is acute respiratory failure or shock lung. By abdominal turning, gas exchange in the lungs can be improved increasing the chance for the patient to survive the virus. Today, abdominal turning is performed with a coordinating anesthesiologist, as well as another three to six people depending on the patient's weight and sensitivity. The large amount of carers required to perform this task means that there is a difficulty to do it as often as desired, and the large amount of people increases the risk of infection. As another option, the carers choose to perform the task with a fewer amount of people, which lead to a risk of work related injuries and sick leave. With a partially motorized procedure of abdominal turning the hospitals and especially the intensive care department, that have a continuous flow of COVID-19 patients will benefit on several different levels.

Sustainability aspect

Since the beginning of this thesis, while planning the project with the client, an additional goal has been set to meet Njord Medtech's sustainability profile. Njord Medtech aims to have an impact that targeting the goals of sustainable development of the United Nations, and the design decisions taken throughout the project strived to follow these objectives. Sustainable development includes supporting healthy lives and enhancing well-being at all ages. Triaid is a product that can be helpful in the healthcare to support both the patient's situation and the carer's healthy working environment. Considering that Triaid will be used in hospitals and healthcare centers, which are humanitarian aid areas, as well as that Triaid will enhance the human experience, it can be said that there is a social contribution behind this project. Additionally, Triaid is a simple to use device, which can be used by any worker in the healthcare, contributing like that to the gender equality.

Ethical aspect

During the project, there had been followed actions that fit the ethics and values that the team members believe in as designers and as human beings. There has been a great and honest cooperation between the team members, the team and the client, the team and the supervisor, as well as between the team and the external stakeholders.

Especially when contacting users and third parties, the communication has always been based on ethical interaction with transparency and full respect for their personal data and wishes. Before every interview the participants have been given a consent form to sign, in order to agree on the participation. Also, the team members signed a consent form declaring that all information given during the interviews will be respected, according to the GDPR laws.

14. Conclusion

Patient handling in the healthcare is an everyday routine. Several movements are done depending on the patient and the needs. Today these movements are often done manually, which demand high effort from the carers. In many cases, the tasks are patient-focused, often resulting in bad working conditions for the carers and work related injuries.

This project strived to create better conditions for the carers, by bringing forward a help tool for several patient movements in bed. Triaid can be used for moving a patient higher up in bed, moving a patient from bed to bed and turning a patient on the side, which due to COVID-19 pandemic is more frequently needed in hospitals. Introducing Triaid in the healthcare will have a big impact since it will help with reducing work related injuries for the carers and support the efficient workflow. The lack of carers in the healthcare system will be helped to be reduced.

By developing Triaid, which is a help tool that can be used for more than one movement, the project results to a high market potential product, which can become very valuable and meaningful for the future of the healthcare.

15. Future advice

After this project, the concepts are not in a level to be produced and some more steps are needed to be done in order to put the concepts out in the market. In this chapter, some advice about the steps that can be followed are described.

Tempur Sections concept

For the Tempur Sections concept some information was gathered regarding Tempur as a company, the material of viscoelastic and producers of similar products. The information was given from a Tempur bed store in Gothenburg. The advice given to the client for future work with this concept is that Tempur company seems very hard to reach, as they collaborate with huge companies for big projects and they don't do small series of products. For instance, Tempur is collaborating with Koenigsegg for producing the car seats. However, there are many producers of products similar to Tempur, with some differences in the consistency of the material and the thickness of it. The recommendation is to find a company that produce memory foam mattresses and explore the market potentiality of such a material in the healthcare, considering that Tempur is already producing solution for the healthcare. Such solutions are mattresses for operations, supportive pillows and wheelchair cushions. Throughout the project, it has been obvious in many steps of the process, that Tempur Sections concept has a lot of potential and it is seen as a good solution for preventing sliding down, which can facilitate a lot for the carers and their workflow in the healthcare.

One next step that needs to be done in relation to the memory foam producers could be to contact Jysk, since they have a foam memory series called Wellpur and is a local brand from Scandinavia. However, more research for the producers needs to be done in order to get in touch and find out the possibility of creating a new product for the healthcare together.

Mobile version of Agilis

In order to change Agilis into a mobile version it is necessary to minimize the total weight, especially of the head of the device. The two components that are the heaviest in the head are the brake (4.2 kg) and the motor (7.9 kg). A first step could be to find a lighter brake or a lighter motor. Additionally, there should be explored the possibility of placing the components closer to gain space and decrease the size of the head even more. The weight is vital for the way of attachment, as it should not be any risk of tipping or falling. It is also important to manage to meet the requirement of 15.8 kg as maximum lifting weight, in order to be able to make the device portable.

More in detail for taking the decision about a new motor some other specifications should be taken into account. First, a torque test needs to be done to explore the amount of torque needed, which is crucial for the choice and the speed that can be reached. Another aspect to be explored is the noise level of the motor, as this device will be used in the healthcare it would be preferably with an as quiet motor as possible. To conclude with, the different aspects of the motors should be evaluated and prioritized in order to make the best choice out of it.

Triaid

For the proposed design of the straps for turning the patient on the side, the way to connect the two part that the concept consist of should be explored further, as the proposed way consists of simple tying with ropes. As the straps concept was prototyped in low fidelity and small scale, to ensure that it is appropriate for the task, it should be tested in full scale with a human body in real context. With this the dimensions of the straps will become clearer, the ease of going under the patient and the level of comfort for the patient.

Last but not least, information about the resistance of the bed sheets used in the healthcare should be collected. As it was mentioned during the user studies by an expert in the field, some tests should be performed to explore the impact of the proposed solutions on the sheet, ensuring that it can handle the force. This is a crucial aspect, as the patient and the device are not the only important parts of this task. If the proposed solution occurs damage to the bedsheet it should be redesigned.

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Figures references

All the figures included in the report are illustrations made by the team or photos taken by the team.

17. Appendixes

Appendix 1 - Interviewees participants

Role	No. of interviewees
Vårdbiträde	8
Assistant nurse	3
Nurse	4
Nurse students	4
Movement instructors	2
Physiotherapist	1

Appendix 2 - Full Interview Structure

Interview

Presentation about us
We are Agnes and Georgios, industrial design students at Chalmers. We are doing our master thesis.

Consent Forms

Introduce the task
We are currently exploring the problem of patients that are in an upright position on beds (in hospitals, elderly care, etc.) and after some time they slip into a bad more laid position. We aim to design a solution so that patients can get back to an upright position independently or with the help of only one nurse.

Have you experience it?
yes ◯ No ◯

Introduction Questions
Education

Nationality

Age

Female ◯ Male ◯ Other ◯

Where do/did you work?

Role

Years of experience

Task Related Questions
How is the task executed today?

What helping tools are there available in the work?

How many people are involved in the execution of this task?

How often do you do the task?

How do you experience it? (Does the problem exist?)
Very heavy ◯ ◯ ◯ ◯ ◯ Not heavy at all

What is the learned way to do it?

Is there difference between the way you learned & the way you do it?

Are there particular parts of the patient's body that you should/should not touch?

How do the patients feel while the task is executed?

Are there cases that the force put by the nurses is unequal, so the patient ends up in a wrong position?

Is it easy to estimate the force needed, depending on the patient's body, to do the move smoothly?

What problem do patients usually have and how does this affect the way you treat them?

Ergonomics Related question
Do you have any pain problem in general?

Do you think that this task is giving you pain?

What is important to think about (ergonomic perspective) when doing this task?

Show us how is the task executed if possible

What would be important from an ergonomic perspective, when designing a new product for this task? (material, shape, movement)

Future Related Questions
How would you like to do it in the future?

Have you ever thought of a way to solve the problem or make it easier?

Do you have any suggestion of improvements?

What do you think it will mean for both carers and patients if the task could be executed independently or with the help of only one person?

Additional Questions
Is it okay if we contact you again?
yes ◯ no ◯

Appendix 3 - Requirement List

Criteria	R or W	weight: 1-5	MF or F or L
Function			
Take the patient back up in the bed.	R	5	MF
Move the patient sideways	W	5	F
It should enable to be used for more than one movements.	W	5	F
Prevent the patient from sliding down	W	4	F
Roll the patient on the side (changing sheet, changing clothes)	W	3	F
Move the patient from bed to bed.	W	1	F
Task			
Reduce the number of carers to 1 or 0.	R	5	L
The task should be easy to execute	R	5	L
Enable the task to be fast in order to gain time for the carers.	R	4	L
The task should always be able to be done manual / one carer.	R	4	L
The task should be easy to learn & self-explanatory.	W	5	L
Make (enable) the task steps for all the conscious participants.	W	3	L
Do not hinder other everyday activities.	W	3	L
Ergonomic			
Prevent work related injuries.	R	5	L
The maximum weight of carrying should not exceed the 15.8 kg (35 lbs)	R	5	L
Reduce the physical demand of the task/movement.	R	5	L
Encourage the carers to use the body in an ergonomic way	W	4	L
Participants			
During the task all the participants should feel and be safe and secure.	R	5	L
During the task all the participants should feel and be comfortable (less frustrated).	W	4	L
Prevent pressure wounds.	W	3	L
Product			
The product should meet all the hygiene requirements.	R	5	L

The product should be commercializable.	R	5	L
The product should be easy to clean.	R	4	F
The product can take a patient with a maximum weight of 180 kg	R	4	L
The product should be possible to be replaced or fixed.	R	3	F
The product should meet the sustainability objectives of the client.	W	5	L
The product should meet the client's vision and design language.	W	4	L
The product should be adjustable in order to be used by all the variety of disabilities.	W	3	L
The product should be used on all beds.	W	3	L
The product should be able to be used in combination with other help tools.	W	3	L
The product should encourage the patients to use as much effort as they are able to.	W	3	L
The product should be free-movable.	W	2	L

Appendix 4 - Market Research

What	Link	Material - Basic Function	Additional information	What is it used for?
Glidmatta	etac	Nylon slide sheet with low-low friction	- minimize friction under pressure points - easy to apply & remove - should always be removed after use	for turning and positioning
Glidmatta	etac	Nylon tubular slide sheet with high-low friction	- ultra low friction inside, high outside - suitable for minimizing friction under pressure points - should always be removed after use	transfering & turning in bed, bed to wheelchair or operation table
Draglakan & Glidlakan	etac	reduces the friction in 2 or 4 directions, can be used with and without Draglakan depending on how much help the user needs.	- helps reducing strain on the carer back - helps to save time	facilitate to: reposition transfer turn
	etac	incontinence pad with a low friction backside	- reduces friction side-to-side, suitable for turning an incontinent user with reduced mobility	turning user
	Vendlet or TurnAid		- reduces strain on the back for carers - easy to install on all commercially available nursing beds	repositioning and turning a patient in the bed
	etac	Nylon sheet high-low friction with integrated handles	- minimise friction under pressure points - tubular slide sheet with high friction on the outside and ultra low friction inside	facilitate transfers up and down in bed
Padded turning mattress	etac	It is placed in bed and the user remains on top of it	- The ultra low friction inside may facilitate a user with reduced mobility to turn independently in bed.	suitable for turning in bed
Padded glide cushion	etac Handicare		- support independent movement or to aid assisted movement - reduces friction on the shoulders and hips, which in turn reduces the risk of pressure wounds.	turning in bed moving up or down a bed and transfer from bed to wheelchair

	Hillrom		- is placed under the patient and can be used either in combination with or instead of a regular bed sheet during the entire care period.	turning and repositioning
Glindcylinder	Hillrom	made of high-quality, low-friction textiles	- Reduce friction during manual movement	between two beds higher up in bed turn a patient
Readyslide	Handicare	- reducing friction under the user - thin, flexible, and very easy-to-use	Reducing friction under the user, and with very little force and without unnecessary lifting, facilitates simple and safe movements.	positioning in a sitting position applying a lifting harness in a sitting position.
	etac	Anti-slip surface: Nylon with polyurethane coating	Open slide sheet with handles, suitable for wheelchair and bed transfers or in and out of car.	Bed to wheelchair Wheelchair to toilet or shower chair
Glidbräda	Handicare Swereco	-Strong polyethylene (polyeten) -anti-slip tape on the underside	- Easy to transport and place - Polypropylene plastic which provides low friction	From one bed to another Higher up in the bed
Segelduk / spilerdug	karlstad kommun Spilerdug etac	decreasing of friction	- Prevents pressure wounds - It is easy to place and remove. - It decrease the friction, which means that the user can be more active and use their own resources - suitable for extremely heavy and difficult movements.	Covers a very large area of use in movement and dressing e.g. Higher up in bed and turning in bed
Platta under the feet		higher friction under the feets		The patient can easier help when moving higher up in bed
Hävert/ Dävert	Comfortsystem	adjustable handle makes it easier for people to sit up and move in bed	Help and facilitate disabled people in the beds	Sit up and move in bed
Lift	Guldmann	- Used with harness	-Are controlled with a control box or control panel and the smooth wheels and ergonomic push handles make them extremely easy to operate.	Takes care of most of the lifting and moving needs eg. lift users from the floor if they have fallen
	Humancare Guldm	- Used with rails, harness and accessories.	-A roof lift is the best possible aid to safely and conveniently move a patient in a care environment. - Having all the necessary tools for	

	ann Pernova		heavy lifting on hand saves a lot of time, enabling better and more cost-effective nursing.	
	picture Vårdhandboken	If the patient is in need of more assistance, a care belt can be used.	Easier to grab the patient	Facilitate to rise from a sitting position to a standing position
Mattress	vendlet	DORMILET Flexi consists of 2 different foam types. The mattress base and side construction are made of solid foam. This foam frame has specially developed cutouts that allow the mattress to follow the bed when eg. the back and leg supports are raised.	provides great comfort for the bed reclining with good pressure relieving properties DORMILET Flexi has a very special gliding zone. The sliding zone is located throughout the upper body and is designed to eliminate shear and friction between the bed and the mattress when the backrest is raised	prevent pressure wounds
special bed	youtube able	Different angles/positions	- 0-10 ° side tilt function for both sides for easy and gentle rearranging, transfer, care and boarding. - Pre-programmed dining position for better intake and digestion. - Pre-programmed seating and rest positions.	The bed can raise up and turn to a sitting position

Appendix 5 - Visit to Sahlgrenska University Hospital

When the visit to Sahlgrenska University Hospital was done, the captured material was analyzed and some parts were isolated leading to useful results. The following are the isolated examples followed by comments:

In this example it can be seen that both carers have a bad posture. Even though their legs are bended, the bed is too high so their arms are not in a right position.

In this example it can be seen that the starting and ending position have different orientation because of the different force the two carers used during the task.

In this example it can be seen that the carer on the right is having a very bad posture, leaning backwards.

In this example it can be seen that the carers are struggling because of the big weight of the patient.

In this example it can be seen that the draw-sheet has not been placed correctly under the body of the patient.

In this example it can be seen that the carers are not synced on the movement.

In this example it can be seen that the starting and ending position are different with the patient ended up closer to the one side of the bed.

 In this example it can be seen that is a difference on the level of lifting from the two carers.

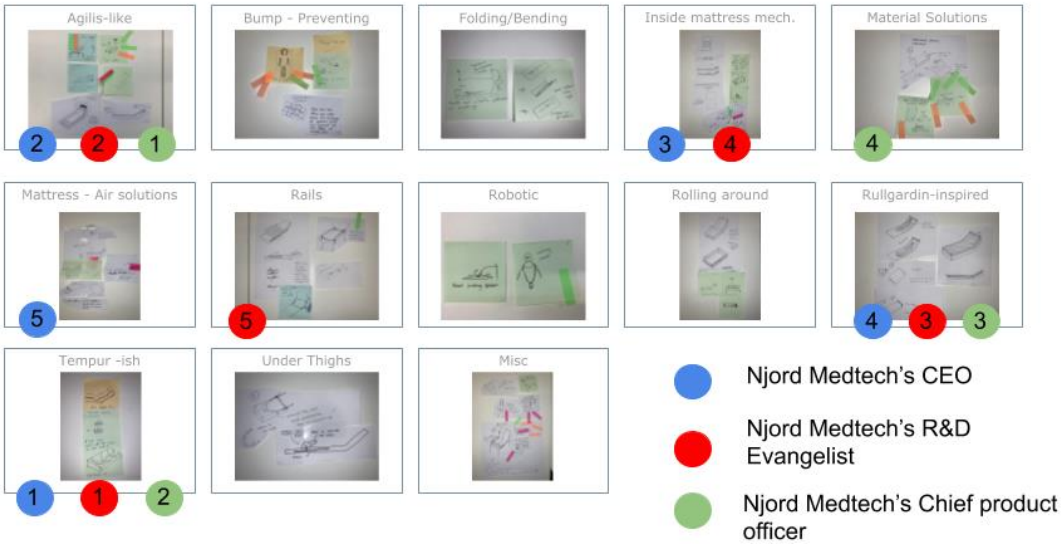
 In this example it can be seen that the ending position is very high on the bed because of the low weight of patient, which made the task very easy and light.

In this example it can be seen that the movement has been done perfectly, as the patient is light, the dragging has been done horizontally and the bed is in a flat position.

In this example it can be seen that even the patient is heavy, the bed is in a flat position and at an appropriate height, which made the movement more effective.

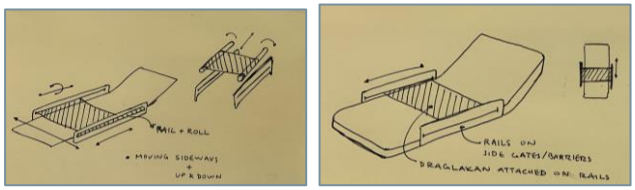
In this example it can be seen an alternative transferring with an additional tool, which felt easier for the carers and comfortable for the patient.

Appendix 6 - Njord Medtech Top 5

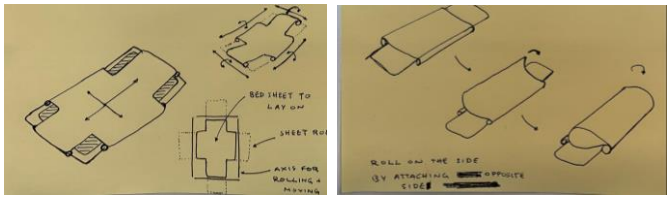


Appendix 7 - Client Representative

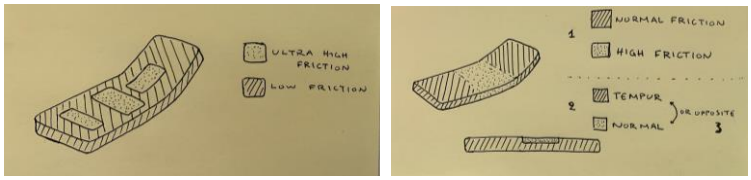
Combined ideas



These ideas were combined because both of them are based on rails.

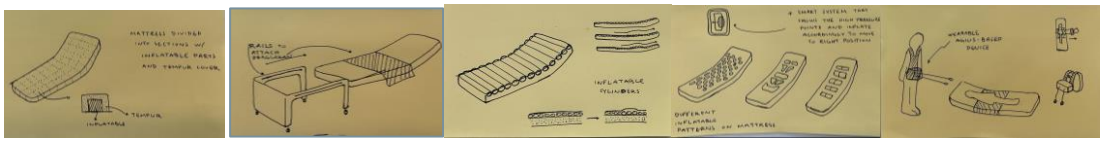


These ideas are combined since the second idea is an extension of the first one, so they could be merged.



These ideas were combined because they both are based on sections with different material.

Discarded ideas



These ideas were discarded because of two reasons. The first reason is that they were similar to other ideas, which went further because they had better details. The second reason is that some of the ideas were not feasible enough.

Appendix 8 - Pros and cons of concepts

Concept name and description	Pros	Cons
Free Agilis-based Portable Agilis combined with a supportive tool	- Already have the know-how - Can be combined with tools that are already there (draglakan) - Can be used for 3 movements: If redesigned, it can be used for both on-bed and from-bed-to-bed movement - Effective	- Expensive - If there is a wall behind the bed it is harder to use on that side - Quite big and Take space on the floor - Many steps need to be taken - Need one carer
Attached Agilis-based Attached Agilis combined with a Draglakan	- Already have the know-how - Can be combined with tools that are already there (draglakan) - Smaller in size? - Effective - Mobile	- How to attach? Needs something extra on bed - If there is a wall behind the bed it is harder to attach on that side - One for each bed - Need one carer
Side Rails Rollingsystem on rails integrated with the gates	- Very low effort from carer - Can be combined with tools that are already there (draglakan) - The patient can use it if able - Can be attached to the gates - Can be used for three movements - Can be taken down and not in the way for carers	- Need for changing the side barriers or it can be added on them? - Where is the motor part? Underneath the bed? - One for each bed - Hard to move
Snake movement Mattress with an integrated motorized mechanism	- Very low effort from carer - Can move the patient to all directions - The patient can use it if able - Very innovative - Comfortable for the patient to be moved like this	- Expensive - Unknown technology - Will it work? - Need to change or add extra mattress on all beds - Can only be used by one patient at a time
Expandable cylinders Mattress has an integrated motorized mechanism with a pattern of cylinders	- Very low effort from carer - Can move the patient to all directions - The patient can use it if able - Very innovative	- Expensive - Unknown technology - Will it work? - Need to change or add extra mattress on all beds

	- Massage at the same time?	- Can only be used by one patient at a time
Rullgardin Rolling mechanism attached to the sheet	- Simple technology - Easy to use, could be manual	- Already existing patent - Moves only upwards - Can only be used by one patient - Need one carer
Cross-Rolling Rolling mechanism attached to the sheet in all directions	- Simple way to move to all directions - Effective - Can be used for three movements	- Need to add the additional frame on bed - One for each bed - It has a limit/ending point - can't move more than that - In the way for the carers work
Tempur Sections Mattress with sections with different material e.g tempur	- Can be very innovative - Adds on right-posture when laid on bed - anatomic - Simple idea - Tempur mattress is comfortable	- Should be combined with something more - Not enough to prevent 100% - Only preventing a bit for sliding down - Only be used by one patient

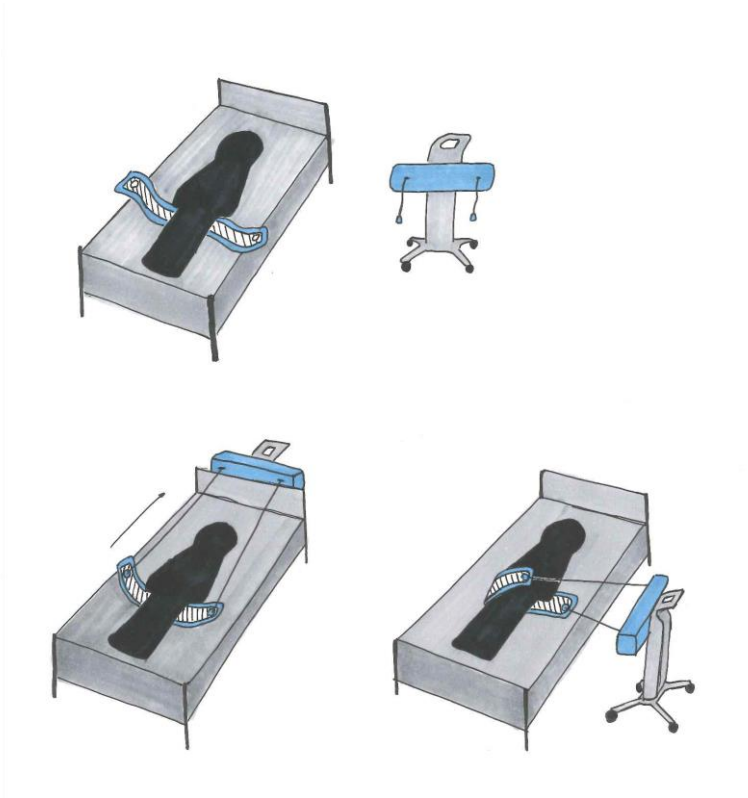
Appendix 9 - Experts insights

Experts:

1. Expert 1 - Nurse with a long experience in both elderly care and hospital
2. Expert 2 - Coordinator at a recruitment home

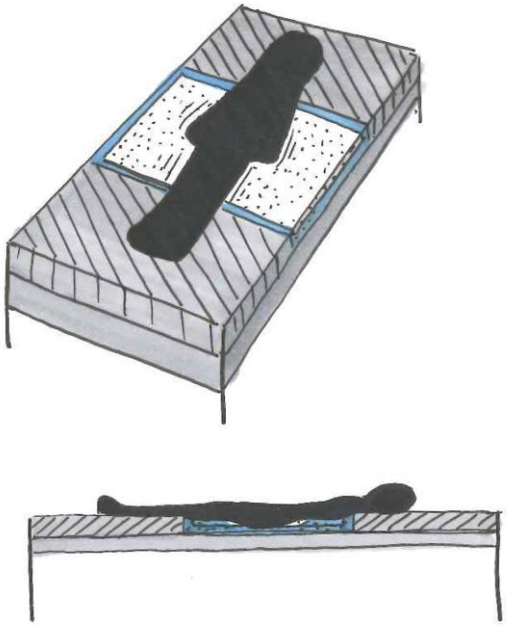
Agilis-based

The Agilis-based concept is considered as an easy and safe way to move the patient. The fact that there is low friction is good because it hurts the patient's skin less, thinking about pressure wounds. With this concept, the task is very little physical demanding, as it needs only one carer. They believe that it has market potential, but considering that it is not too expensive. Especially nowadays with COVID-19 pandemic, there are more patients that need to lay on bed. It seems nice and easy to use, as it can be used on many places-sides of the patient-bed. It shouldn't be too heavy and it should have good brakes and big wheels, which are better for smoother moving.



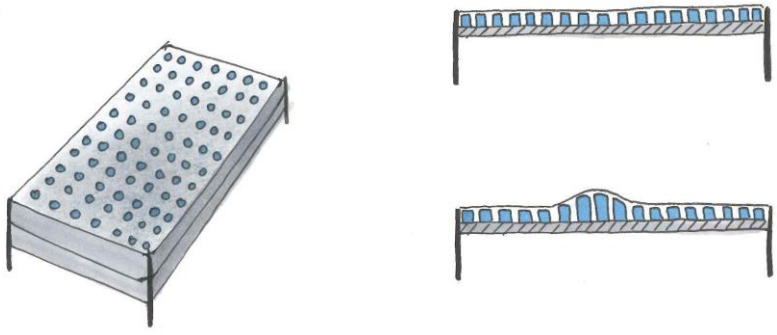
Tempur Sections

Both of the experts liked the Tempur Sections concept. They think that it is easy to move the patient with this concept and they considered it as very safe. It was mentioned that it can be a good preventing mean for sliding down and for pressure wounds. Additionally, they both saw high market potential on this concept.



Expandable cylinders

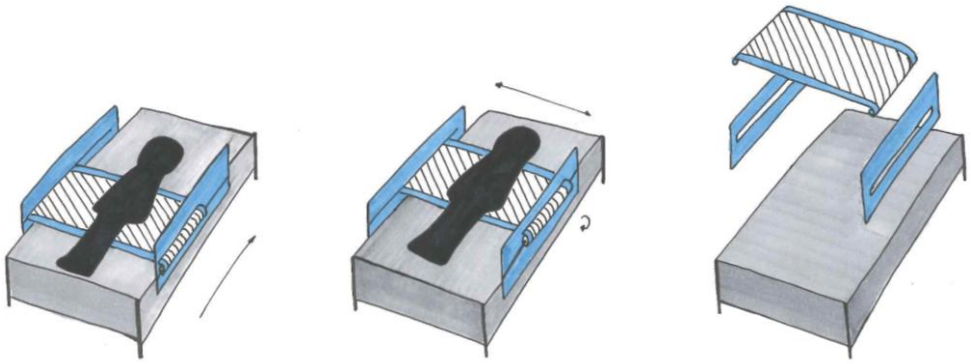
The expandable cylinders concept is considered as medium to hard moving a patient with this concept. It is thought that it can be helpful but there should be 1 to 2 carers to support, so that the patients don't turn around, fall down, or end up on a hurtful position. It is considered as medium safe and not so physical demanding, as the mattress is doing most of the moving. The carer should facilitate in order to have a correct body position while moving (legs, arms, head). They saw low market potential. It can be hard, many patients will feel unsafe, they could be scared to fall. It does not seem very trustful. There are mattresses in healthcare that have inflatable sections to help with pressure wounds, but they don't help on moving. The cylinders version is better because it is easier to steer the movement as you move smaller areas.



Side Rails

There are contradicting opinions for the side rails concept. One thought that it is quite easy to move the patient with this concept and the other thought that it is quite difficult. It is mentioned that maybe it can help with the movement but 2 carers are needed to support the head and the shoulders. It is considered as medium to quite safe. One thinks that it is physical demanding as there is extra support needed for the head and the shoulders, but the other one

thinks that it is not so physical demanding. They didn't see so much market potential, because it demands a lot of support from carers. It is mentioned that one side gate must be sealed (plomberad) and must not be raised unless the customer has both up at night. So, this can only be used on them. Also, one thinks that looks good, but compared to Agilis, it has higher friction and it can add on getting more pressure wounds.



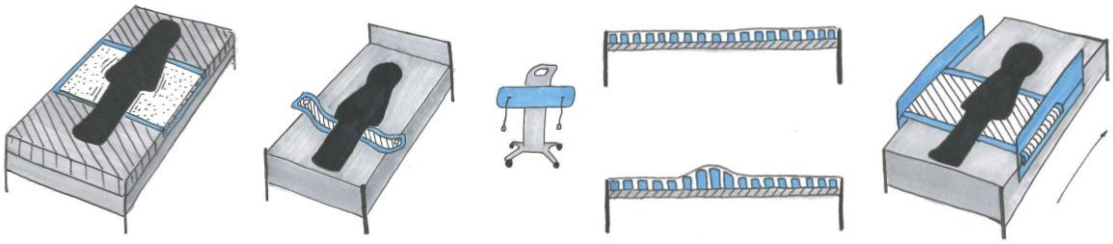
Concept Ranking

	Agilis-based	Tempur Sections	Expandable Cylinders	Side Rails
Ease of moving the patient	8	9	5	6
Safe	8	9	7	7
Not Physically Demanding	8	7	8	6
Market Potential	7	9	4	5
SUM	31	34	24	24

Ranking

1. Tempur Sections
2. Agilis-based
3. Expandable
4. Side Rails*

*Side rails is ranked last because of the comment that if the patient in elderly care do not need to have the both gates up during the night one of them should be always down and stuck (plomberad)



1. 2. 3. 4.

Appendix 10 - Updated Requirement List

R: Requirements
W: Wish
MF: Main Function
F: Function
L: Limitation

Criteria	R or W	weight: 1-5	MF or F or L
Function			
Take the patient back up in the bed.	R	5	MF
Move the patient sideways	W	5	F
It should enable to be used for more than one movements.	W	5	F
Prevent the patient from sliding down	W	4	F
Roll the patient on the side (changing sheet, changing clothes)	W	3	F
Move the patient from bed to bed.	W	1	F
Task			
Reduce the number of carers to 1 or 0.	R	5	L
The task should be easy to execute	R	5	L
Enable the task to be fast in order to gain time for the carers.	R	4	L
The task should always be able to be done manual / one carer.	R	4	L
The task should be easy to learn & self-explanatory.	W	5	L
Make (enable) the task steps for all the conscious participants.	W	3	L
Do not hinder other everyday activities.	W	3	L
Ergonomic			
Prevent work related injuries.	R	5	L
The maximum weight of carrying should not exceed the 15.8 kg (35 lbs)	R	5	L
Encourage the carers to execute the task in a right way.	R	3	L

Reduce the physical demand of the task/movement.	R	5	L
Encourage the carers to use the body in an ergonomic way	W	4	L
Participants			
During the task all the participants should feel and be safe and secure.	R	5	L
During the task all the participants should feel and be comfortable (less frustrated).	W	4	L
Prevent pressure wounds.	W	3	L
Product			
The product should meet all the hygiene requirements.	R	5	L
The product should be commercializable.	R	5	L
The product should be easy to clean.	R	4	F
The product can take a patient with a maximum weight of 180 kg	R	4	L
The product should be possible to be replaced or fixed.	R	3	F
The product should meet the sustainability objectives of the company.	W	5	L
The product should meet the company's vision and design language.	W	4	L
The product should be adjustable in order to be used by all the variaty of disabilities.	W	3	L
The product should be used on all beds.	W	3	L
The product should be able to be used in combination with other help tools.	W	3	L
The product should encourage the patients to use as much effort as they are able to.	W	3	L
The product should be free-movable.	W	2	L
The speed of the execution of the task should be smooth.	R	3	F
The hand controller should be able to be hanged on the product.	W	3	F
The product should indicate when needs to be charged and while charging.	W	2	F
The product should be able to stay still during the use.	R	3	F
The product should be easily-movable.	W	3	L
The product should express stability and safety.	W	4	L
The parts of the product that get in touch with the bed, should be easily disinfected after every use.	R	4	L

All the parts that compose the product, should be able to be kept/stored together.	W	3	L
The product should be able to be stopped in case of emergency.	R	4	F
The product should avoid touching sensitive parts of the patient.	R	4	L
The product should be placed easily in relation to the patient before the use.	R	4	L

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