

*Master Thesis*

# Development and Design of an Accessory for the Carevo Shower Trolley

*Magnus Leksell & Keyloth Perez*

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*Division of Machine Design • Department of Design Science  
Faculty of Engineering LTH • Lund University • 2013*



**LUND UNIVERSITY**

**ARJOHUNTLEIGH**  
GETINGE GROUP



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## Preface

This report describes the process and result of a Master Thesis Project in Mechanical Design Engineering with Industrial Design at the division of Industrial Design and Machine Design at Lund University. The project was made in collaboration with ArjoHuntleigh AB, under the supervision of Per Henriksson.

We would like to thank Per Henriksson for his excellent guidance and feedback throughout the project, his confidence in our work and the level of involvement at ArjoHuntleigh that he offered us. We would also like to thank the members of the Carevo team: Kajsa Haraldsson, Björn Friberg and Josefine Carlsson for their support and advice during this project, as well as all the other involved employees at ArjoHuntleigh.

We would like to thank Katarina Elnér-Haglund for her time and competent advice regarding producibility of the developed concept.

We would like to thank all the involved caregivers who are not mentioned by name in this report for their time and helpfulness.

Finally, we would like to thank our supervisor at Lund University, Per Kristav, for his guidance and support throughout this project.

Lund, December 2013

Magnus Leksell & Keyloth Perez



## Abstract

This report is the result of a Master Thesis project in Mechanical Engineering with Industrial Design at the Faculty of Engineering LTH at Lund University. The project was conducted in collaboration with ArjoHuntleigh AB, a company based in Malmö, Sweden. ArjoHuntleigh develops integrated healthcare solutions for people with low mobility and thereto related problems.

The report describes the development and design of an accessory for the Carevo shower trolley, a newly launched product in the ArjoHuntleigh product line of hygiene systems. The accessory is intended to facilitate handling of loose objects involved in the showering process using the Carevo.

In order to obtain valuable knowledge about the healthcare business and identify the relevant needs of the Carevo users, research was conducted. The research involved a pre-study, observation and contextual interviews with the caregivers in their environments and interviews with sales representatives of ArjoHuntleigh in foreign countries.

Based on the identified needs, a range of product concepts were generated. Using sketch prototypes the concepts were tested and refined until only one concept was chosen.

The final concept is a holder mainly intended for facilitating the handling of bottles used in the shower process using Carevo. The holder can be attached to different parts of the Carevo, depending on the requirements of the user. When not used, it can be stored on a flat surface, e.g. in a cabinet or on a sink.

A prototype of the final concept was produced and tested in order to evaluate how well the concept meets the needs of the target users. Suggestions for further improvements to the concept are provided, as well as brief discussions about producibility and material choice.

### **Keywords:**

Product Design, Product Development, ArjoHuntleigh, Healthcare, Hygiene System





## Sammanfattning

Denna rapport beskriver resultatet av ett examensarbete inom civilingenjörsutbildningen Maskinkteknik med Teknisk Design på Lunds Tekniska Högskola. Projektet genomfördes i samarbete med ArjoHuntleigh AB, ett globalt företag som utvecklar medicinsk utrustning och integrerade lösningar för vård av personer med nedsatt funktion och därtill relaterade problem. Projektet utfördes under 20 veckor med start i maj 2013. Uppgiften var att utveckla ett tillbehör till företagets nylanserade duschvagn Carevo. Detta tillbehör är tänkt att underlätta hanteringen av lösa föremål som förekommer vid duschprocessen när Carevo används.

Duschvagnen Carevo är en ny produkt i ArjoHuntleighs produktfamilj av hygiensystem. Den är tänkt att ersätta föregångaren Concerto/Basic, som bygger på ett 30 år gammalt produktkoncept. Användningsområdena för Carevo är främst duschning av vårdtagare med mycket låg mobilitet på hälsovårdsmiljöer som vårdboenden av olika slag och sjukhusmiljöer.

För att få en grundläggande kunskap om branschen för medicinsk utrustning och hjälpmedel i vården, utfördes en kort förstudie. En rad fältstudier utfördes för att få en djupare förståelse för det arbetsflöde som används i samband med en duschvagn och de användarbehov som förekommer i samband med detta. Intervjuer och observationer utfördes med vårdgivare på olika typer av vårdboenden och sjukhusavdelningar i södra Sverige. För att få en bättre bild av hur vårdboenden ser ut utomlands, utfördes telefonintervjuer med säljpersonal på ArjoHuntleigh i utlandet.

De data som samlades in under fältstudierna sammanfattades och analyserades för att kunna identifiera de relevanta kraven och behoven, samt för att kunna fastställa vilka önskade funktioner som slutprodukten borde ha. Analysen visade att det fanns behov för att hantera lösa föremål, men att dessa behov kunde se mycket annorlunda ut beroende på typ av vårdanläggning, arbetsflödets utseende, typ av vårdtagare, vårdgivarens preferenser, rutiner och en rad andra faktorer.

De största skillnaderna visade sig bero på om badrummen på de olika typerna av vårdfaciliteterna var centrala eller privata. Ett centralt badrum innebär att vårdtagaren måste transporteras från sovrummet till badrummet och därmed även hans/hennes tillhörigheter som ska användas före, under och efter duschen. Vid användning av privata badrum finns oftast vårdtagarens tillhörigheter redan i badrummet.

Baserat på den analyserade data från undersökningsfasen genererades en rad idéer som i sin tur gav upphov till principiella produktkoncept. Under det som kallades konceptgenereringsfasen användes skisser och skissprototyper för att kontinuerligt

generera och testa produktkoncept. Konzepten delades in i olika kategorier beroende på deras funktionalitet och vilka användarbehov de var ämnade att tillfredsställa.

I en första sällning kvarstod endast produktkoncept inom kategorierna ”förvaring och/eller transport av kläder” och ”hållare för enkel tillgång”. Behovet för hantering av kläder ansågs dock vara sekundärt eftersom behovet inte fanns på alla typer av vårdanläggningar. Som resultat av detta sällades alla produktkoncept inom denna kategori till slut bort.

Två koncept från kategorin ”hållare för enkel tillgång” gick vidare till ytterligare utveckling. För dessa koncept gjordes mer raffinerade prototyper som sedan utvärderades genom egna tester, användartester samt diskussioner med utvecklingsgruppen bakom Carevo. Till slut valdes ett koncept för ytterligare utveckling och vidare design på detaljnivå.

Slutkonceptet är en hållare vars främsta funktion är att hantera flaskor som används under duschprocessen vid användning av duschvagnen Carevo. Hållaren är tänkt att fästas på duschvagnens olika handtag, och vara lätt för användaren att flytta runt så att flaskorna alltid finns nära till hands. När hållaren inte används kan den ställas av på en plan yta, t.ex. i ett skåp eller på en vask.

För att kunna testa och utvärdera slutkonceptet producerades en 3D-utskrivna prototyp. Prototypen testades och utvärderades genom förstahandstester och användartester på tre olika vårdanläggningar. Utvärderingarna visade att hållaren är användbar för de målgrupper som har behov för hantering av mindre föremål, men även att det fanns utrymme för förbättringar inom vissa av hållarens funktioner och delar.



Slutkonceptet, en hållare för flaskor som används under duschprocessen med Carevo

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# 1 Introduction

*This chapter describes the background of the project.*

## 1.1 Background

The average age of the population in Sweden and many other western countries is constantly rising [1]. More and more people live to become of high age. With high age comes often age related medical ailments which in different ways may reduce the ability to carry out everyday activities, such as maintaining one's hygiene. Maintaining one's hygiene is not only a matter of health but also a matter of dignity and life quality. Due to the private and delicate nature of the bathroom situations, it is very hard for some people to accept assistance with hygiene care related activities. Nonetheless, this situation is inevitable for many elderly people and is becoming more and more common.

Subsequently, the demand for people to *give* assistance to the ones who need it is becoming bigger and bigger. The jobs of these people are occasionally very physically demanding and impose risks of work related injuries. For them, it is important that they can carry out their work assignments in a manner that is both safe and ergonomic.

ArjoHuntleigh's motto is to develop products with people in mind. Since the start of the company in 1957 [2], ArjoHuntleigh has been delivering healthcare products with the users in mind, with the aim of contributing to a safer workplace for the caregivers and a more dignifying life for the caretakers.

One of the newest products in ArjoHuntleigh's line of healthcare products is the shower trolley *Carevo*, which is intended to assist when showering caretakers with the lowest levels of mobility.

Before the global launch of Carevo, an extensive field trial was conducted in order to validate the Carevo and obtain real user feedback. During these trials, some users expressed the need of an aid to facilitate the handling of loose objects when using the shower trolley.

This project was started in cooperation with the Carevo development team with the aim of designing and developing a new accessory for the Carevo. The accessory should facilitate the handling of loose objects and belongings that might be present when using the Carevo.

## 1.2 ArjoHuntleigh

ArjoHuntleigh develops healthcare products for people with problems related to reduced mobility, with the purpose of improving efficiency and quality of elderly care, at hospitals and other healthcare situations.

**Form** – The company was established early 2007 through the merger of ARJO and Huntleigh Technology. ArjoHuntleigh brings together two leading groups in the healthcare industry to create a wide range of products and services, with an extensive sales- and service network worldwide.

**About** – ArjoHuntleigh is a global supplier of medical equipment with a turnover of 750 million €, 4500 employees in over 30 countries, and products that are sold in over 100 countries. Research and development is strategically located at five locations in Europe and North America, and production is carried out in ten factories worldwide.

**Focus** – The ArjoHuntleigh product range includes medical equipment and integrated solutions for movement and hygiene care of caretakers, health care beds and preventive/treatment mattresses, wound care, prevention of deep thrombosis/clots (DVT), disinfection and diagnostics.

ArjoHuntleigh also offers several solutions for special applications, such as burn wound care and care of very obese persons. [3]

## 1.3 The Carevo Shower Trolley

The Carevo shower trolley (Figure 1.1) is a newly developed product in ArjoHuntleigh's line of hygiene systems. It is intended for assisted hygiene care, especially showering of patients with very low mobility in care environments such as elderly care facilities, special care facilities and hospitals. The usage areas of the Carevo shower trolley include:

- showering of caretakers
- nursing table
- skin care and inspection
- cleaning of wounds
- transport of caretakers

Carevo was developed to replace ArjoHuntleigh's current shower trolley, the Concerto/Basic (Figure 1.2), which is one of most popular products of the company. However, since the design of Concerto/Basic is built on a very old product platform which was developed almost 30 years ago ArjoHuntleigh [4] consider the Concerto/Basic to be outdated when it comes to design, features and costs.



**Figure 1.1** The Carevo Shower Trolley



**Figure 1.2** The Concerto/Basic Shower Trolley



## 2 Aims

*This chapter describes the brief given by the company, as well as the aims and scope of the project.*

### 2.1 Brief

The following brief was formulated together with ArjoHuntleigh.

ArjoHuntleigh recently launched a new product in their line of hygiene systems - the shower trolley Carevo. It is a successor to the company bestseller Concerto/Basic, which will be gradually phased out.

The aim of the new product is to be more competitive than its predecessor. This means that new accessories need to be developed so that the market needs can be satisfied to a greater extent.

The workflow of showering in the Carevo includes handling of hygiene items (such as shampoo and soap), the clothes of the caretaker, and towels. It has been identified on a higher product level that the market needs an accessory to facilitate the handling items of this nature, thus making the workflow better and more effective, from the perspective of both the caregiver and the caretaker.

On a deeper level the question of which items the accessory relates to and how the accessory should be designed and placed to be both ergonomic and functional. To determine this user studies need to be conducted to identify which needs have to be satisfied. Furthermore, the accessory needs to have an attractive design that harmonizes with the Carevo and the ArjoHuntleigh brand, but also matches the standards and hygiene aspects that the healthcare environments demand. Other aspects that need to be taken into account are choice of material, costs and producibility.

### 2.2 Scope

The master's thesis is executed in collaboration with ArjoHuntleigh in accordance with the brief formulated together with ArjoHuntleigh. The duration of the project is 20 weeks starting May 2013.

The aim of this project is to further investigate the need of a holder for belongings by conducting field studies and identifying user needs on a deeper level. Using this research data, one or more concepts shall be developed to the extent that they can be evaluated. This will be accomplished by producing a prototype that has the desired

## 2 Aims

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design, ergonomics and functions. The necessary standards and requirements of the medical device industry should be taken into account when developing the concept. Furthermore, the project should include discussions about choice of material, costs and producibility. The presented result of the project will be the design of a detailed functional prototype together with evaluation results, as well as suggestions on further development.

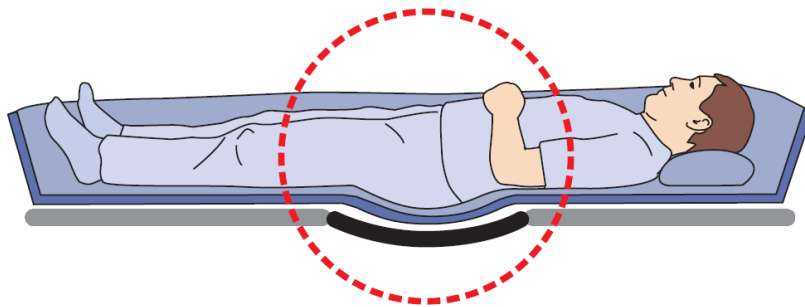
### 3 The Carevo Shower Trolley

*This chapter further describes the Carevo and its target users and environments in order to give the reader a deeper understanding of the given conditions of the project.*

#### 3.1 The Parts and Functions of the Carevo

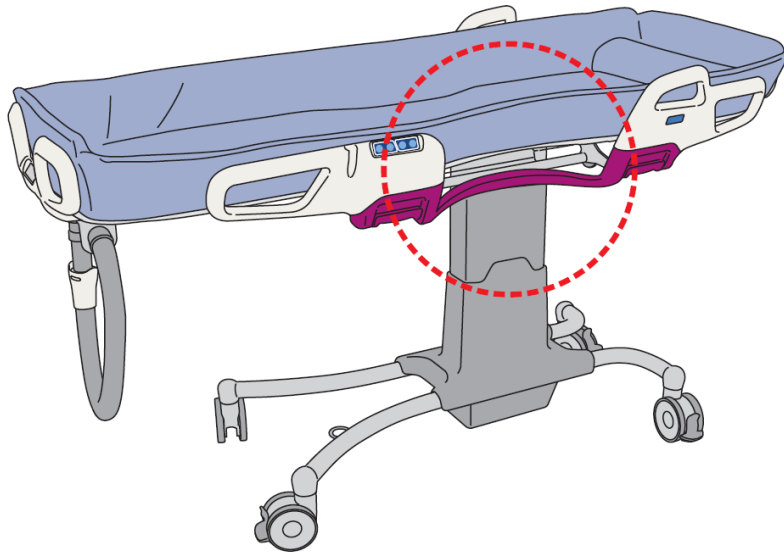
The different parts and features of the Carevo, as well as the thoughts behind them are described below [5]-[7].

The stretcher has a pressure relieving part which is called the *Flexi Zone* (Figure 3.1), which is intended to make the trolley more comfortable to lie on.



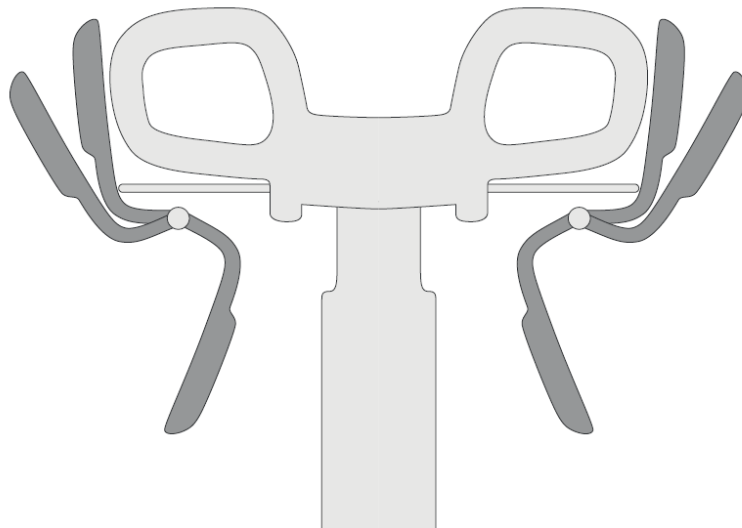
**Figure 3.1** The Flexi Zone

The space where the two side supports are separated (Figure 3.2) is called the *Ergo-Access Zone*. It allows caregivers to work closer to their patients, which is intended to improve the workflow and reduce static loads.



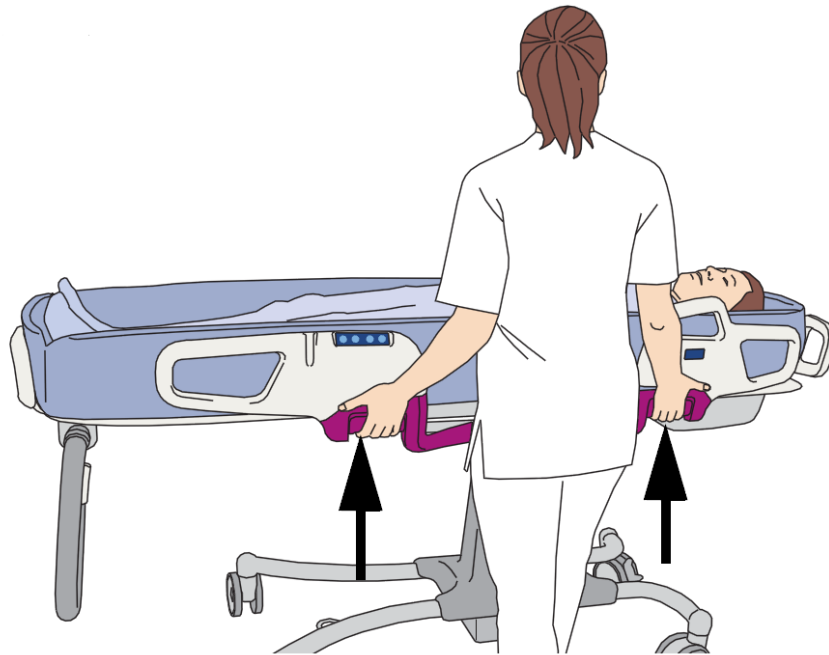
**Figure 3.2** The Ergo-Access Zone

The *Side Supports* have three positions, an inner position, an outer position and a down folded position. The different positions are shown in Figure 3.3. The inner and outer positions are used when the patient is lying in the trolley. The outer position is intended for bigger patients who need more space in trolley. The Side Supports are folded down only during lateral transfers, i.e. when transferring a caretaker from a bed to the trolley. The position of the Side Supports is adjusted by lifting the two opening handles simultaneously, see Figure 3.4.



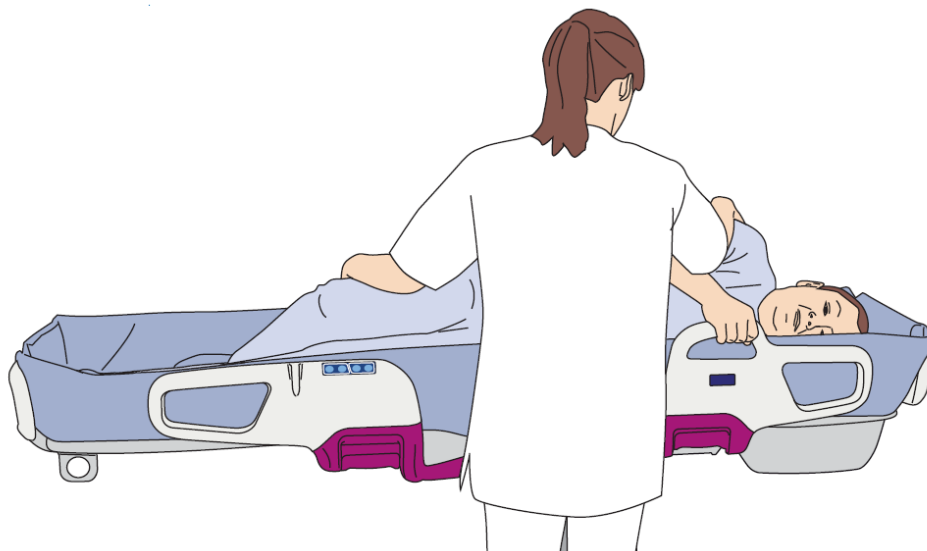
**Figure 3.3** Positions of the Side Supports from a frontal view





**Figure 3.4** Method for folding down the Side Supports

The *Comfort Handles* are placed on the side supports at a higher position, see Figure 3.5. They are intended to provide support and enhance the sense of security for the caretaker. It is placed within reach for the caretaker in order to encourage caretaker participation.



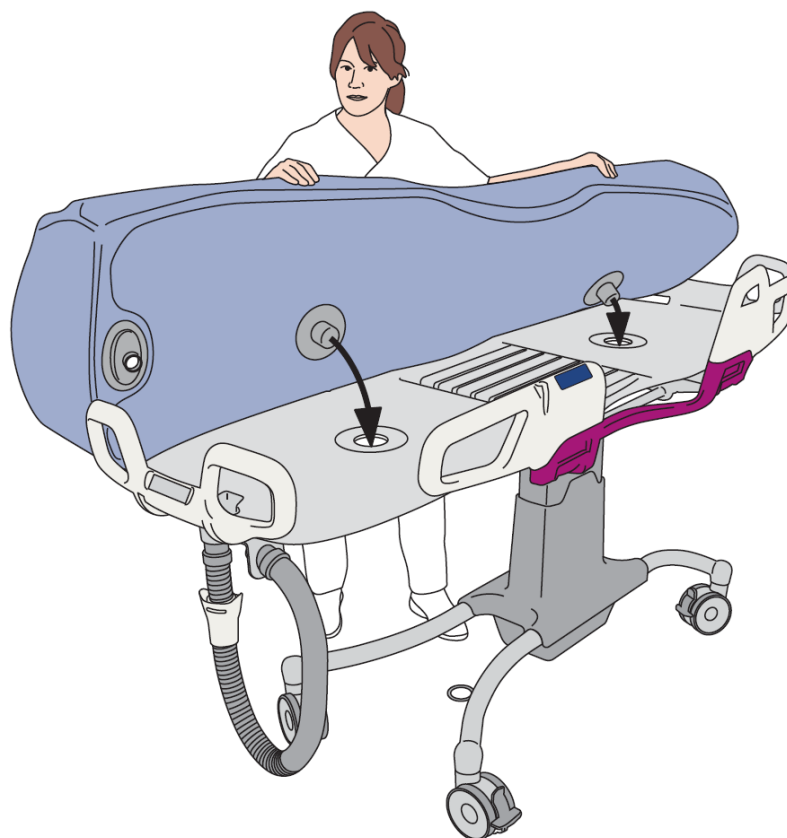
**Figure 3.5** An example of the Comfort Handle in use

The height of the stretcher and the inclination of the back support are electrically adjustable. This is controlled by using the *Integrated Control Panels* (Figure 3.6), which are placed on three locations of the Carevo; the head end and on the two Side Supports, see Figures 3.10 and 3.11.



**Figure 3.6** The Integrated Control Panel

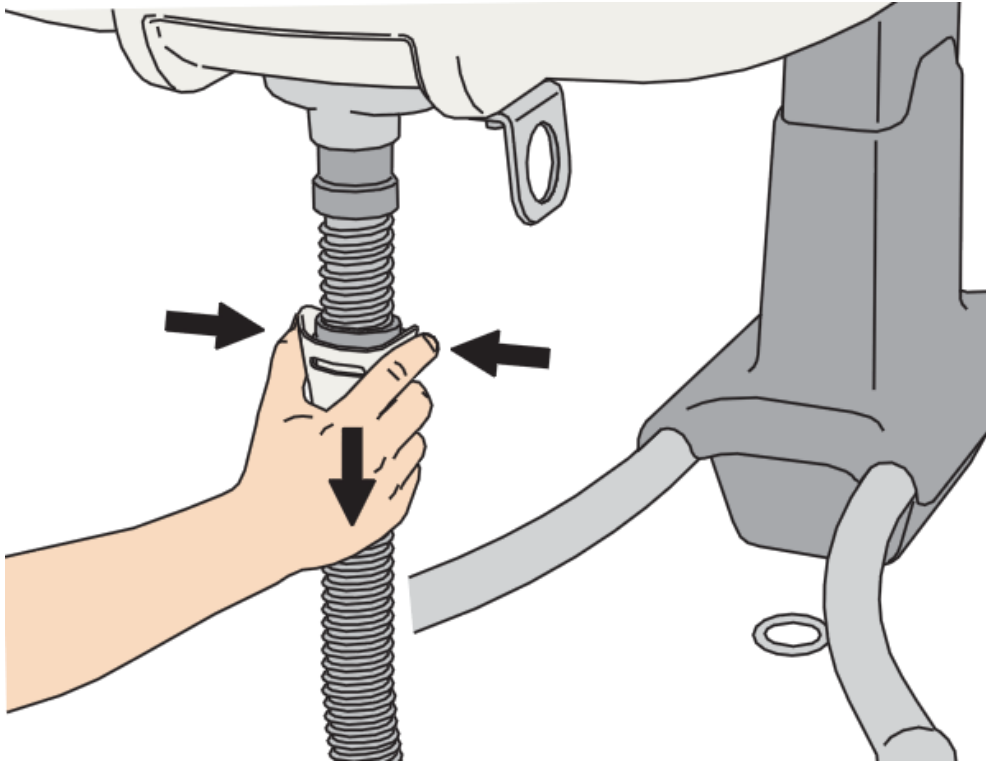
The mattress is designed to provide comfort to the caretaker and guide the water to the drainage outlet located at the foot end of the mattress. The mattress is detachable and kept in place by two guide pins that go into holes in the stretcher, see Figure 3.7.



**Figure 3.7** The mattress and the guide pins

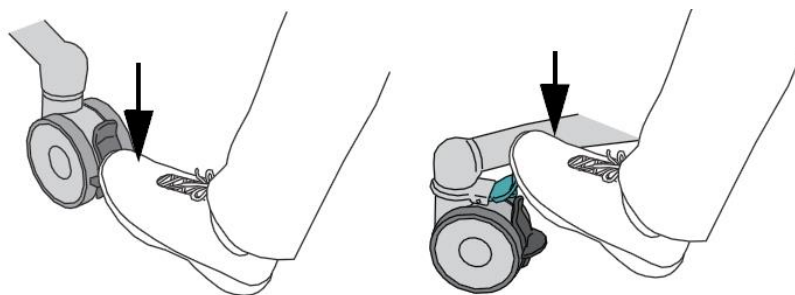
The drainage is placed by the foot end of the Carevo and consists of two parts, an outlet and a removable hose, see Figure 3.8. The purpose of having two parts is to allow users to use it in different ways, e.g. placing the outlet over a toilet or placing

the hose in a floor drain. The drainage can be plugged to allow shallow bathing in the shower trolley.



**Figure 3.8** The detachable drainage hose

The 4 castors can be individually braked (Figure 3.9) and 2 of them can be locked to allow straight steering (Figure 3.9), which is intended to facilitate maneuvering of the trolley in narrow corridors and around corners.



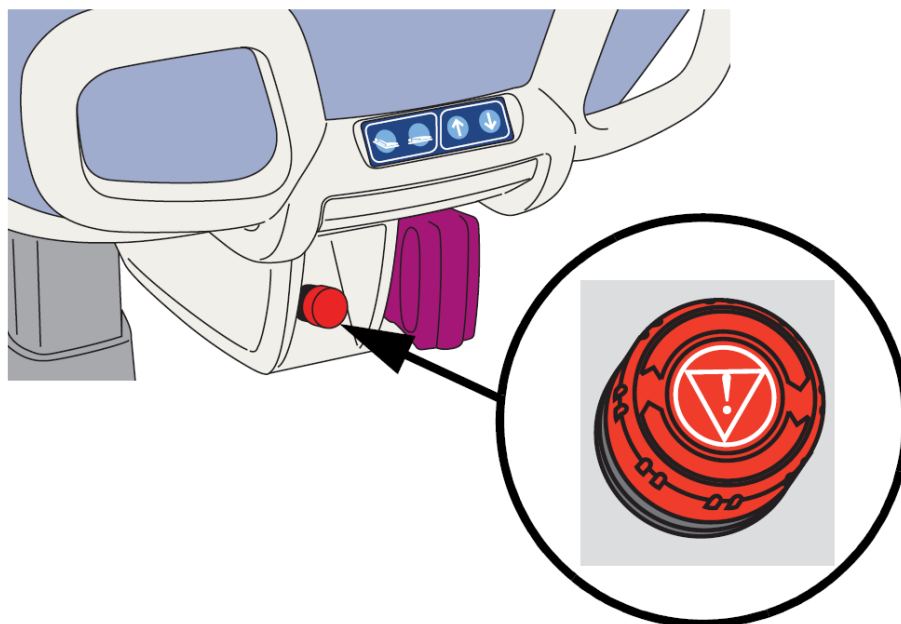
**Figure 3.9** Braking a Castor (left) and activation of Straight Steering function (right)

The battery unit and an emergency stop button are located beneath the head-end part of the stretcher, see Figure 3.10. The emergency stop button shuts off all of the electronics of the Carevo when activated.

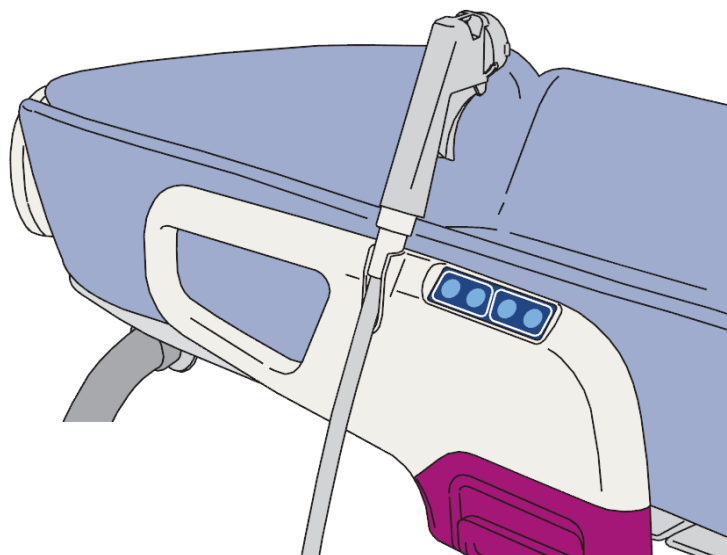
### 3 The Carevo Shower Trolley

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Each side support has a shower handle holder (Figure 3.11) which is intended to give the caregiver easy access to the shower handle when not used.



**Figure 3.10** The Battery Unit and the Emergency Stop Button



**Figure 3.11** One of two shower handle holders

### 3.2 Facilities

The following section is a summary of the general knowledge about the care facilities, which was obtained in the Market Research phase described in Chapter 6.

The Carevo shower trolley is intended for use at care environments such as elderly care facilities, special care facilities and hospitals. The bathrooms at these facilities might be either private or central.

A private bathroom is usually connected to the living space of the resident at the facility and is not shared with other residents. Private bathrooms are often small and not necessarily suitable for use with shower trolleys.

A central bathroom is shared by multiple residents at the facility and might be located in another part of the facility in relation to the room of the caretaker. In this case, the caretakers often need to be transported in the shower trolley from their private rooms to the central bathroom. Central bathrooms are often more spacious than private bathrooms.

Elderly care homes are residences for elderly people who are in need of assistance to be able to carry out their everyday activities, due to different age-related medical conditions. Whether the facility has private or central bathrooms can depend on different factors, such as cultural factors and when the facility was built.

Special Care facilities are either permanent or temporary residences for caretakers of all ages who are in need of assistance in their everyday activities, due to physical and mental disabilities.

Hospitals can serve as a temporary residence for people in need of medical assistance. While private bathrooms are present at these facilities, they are often not adapted for use with a shower trolley. The shower trolley is instead used in a central bathroom.

### 3.3 Users

In this section, the different users of the Carevo are described. They are divided into two main groups: the caretakers and the caregivers. These two main user groups are further described below.

#### 3.3.1 *The Caretaker*

ArjoHuntleigh have developed their own system for categorizing different types of caretakers. It is called the Resident Gallery and is a classification system of five caretaker types, based on their degree of functional mobility, ranging from A to E. The system is based on the functional mobility of the caretakers, and not their underlying specific diseases and their medical diagnoses. [8]

In elderly care, these five categories are described as five characters called Albert, Barbara, Carl, Doris and Emma. They represent the five levels of mobility of caretakers. Since the Carevo shower trolley is intended for caretakers of mobility level D-E (Doris and Emma), only these two caretaker types will be presented.

#### 3.3.1.1 Doris

Doris sits in a wheelchair and is not capable of supporting herself at all. She cannot stand unsupported and is not able to bear weight, not even partially. The caretaker cannot perform daily activities without support and is not able to contribute to these actions in a reliable or substantial way. The assistance in this case is physically demanding for the caregiver, if proper equipment is not used to eliminate physical overload for the caregiver. It is highly important to stimulate the remaining abilities of the caretaker to slow down deterioration of mobility. It is also important to prevent risks associated with immobility, e.g. by providing good skin care.

#### 3.3.1.2 Emma

Emma is not capable of performing daily activities independently or contributing to them actively. She might be completely bedridden and passive. The assistance in this case will result in risk of physically overloading the caregiver, if special precautions are not taken. It is no longer important to stimulate the resident to contribute to the action and become active; promoting and stimulating mobility and activating the caretaker are no longer goals of the care plan. Instead, optimum care and prevention of the complications of immobility are given priority. [8]

#### 3.3.2 The Caregiver

The Caregiver is a term for all the people who assist caretakers, such as nurses, assistant nurses, ancillary staff, physiotherapists, occupational therapist. [8] Approximately 90% of the caregivers are women, ranging from 20 to 60 years of age. [4]

### 3.4 Intended Workflow

To understand how the Carevo is intended to be used during the showering workflow, the *Intended Workflow* is described according to the *Instructions for Use*. [6]

#### 3.4.1 Transfer

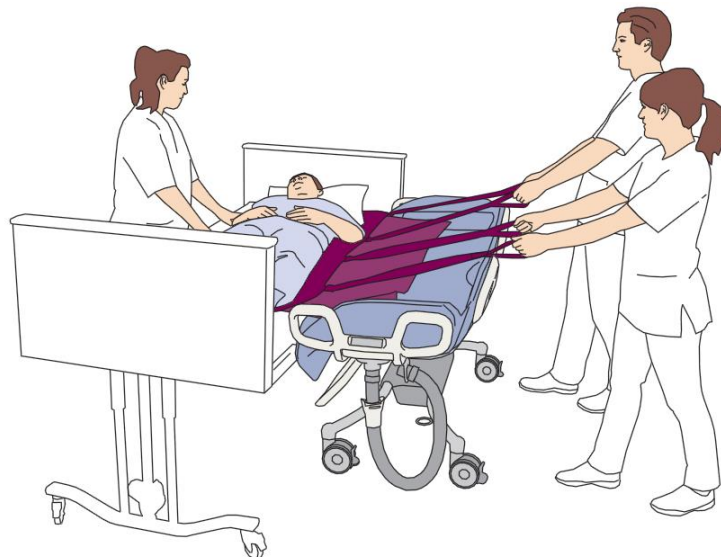
The first step of the intended workflow is transferring the caretaker from his/her bed to the shower trolley. This can be executed in different ways, using different types of aids.

The transfer can be executed laterally using sliding sheets or tubes. The sliding aid is placed under the caretaker by using different lifting techniques, such as the *logroll* technique shown in Figure 3.12.



**Figure 3.12** Two caretakers performing a lifting technique called “logroll”

The side supports and mattress of the Carevo are folded down on one side, and the height of the Carevo is adjusted to be slightly lower than the height of the bed. After the side rail on one side of the bed has been lowered, the Carevo is placed directly adjacent to the bed and locked into position by applying all four brakes on the castors (the bed has to be braked as well). The transfer is then executed by sliding the caretaker across, from the bed onto the shower trolley using the sliding sheets/tubes, as shown in Figure 3.13.



**Figure 3.13** A lateral transfer using sliding sheets

When the transfer is complete, the sliding aid is removed from beneath the caretaker and the Carevo pillow is placed beneath the head of the caretaker. The shower trolley is then carefully moved away from the bed until the mattress and side supports can be folded back up.

The transfer can also be executed using mechanical lifting aids, such as floor lifters or ceiling lifts. The Carevo is then fully braked and adjusted to its lowest position, and the caretaker is transferred into the Carevo using the lifting aid with the side supports folded up and the back support raised up, see Figure 3.14.



**Figure 3.14** Transfer using a mechanical lifting aid

#### 3.4.2 Transport

The length of the transport necessary to get the caretaker from the bedroom to the bathroom varies depending on whether the bathroom is private or central, but some transport is always necessary. The caregiver needs to be positioned at the head end of the Carevo during transport so he/she is able to reach the emergency stop in case of emergency. The maneuverability of the trolley can be improved by using the straight steering function.

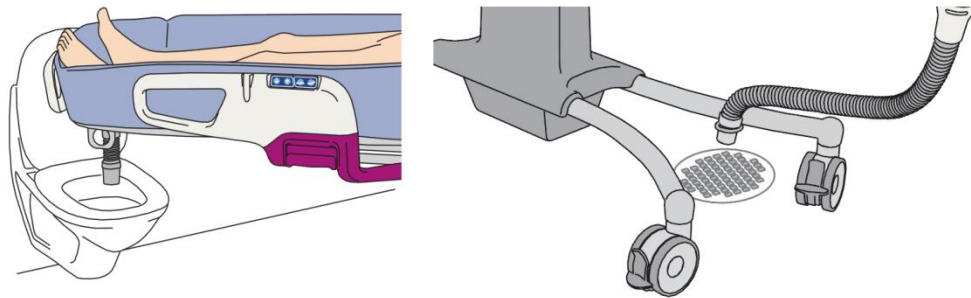
#### 3.4.3 Shower

Before the shower starts, the Carevo is placed over the toilet/flush sink or floor drain, (see Figure 3.15), depending on how the drainage is used (with or without hose). The trolley is then fully braked into working position and adjusted to an ergonomic working height. The caretaker is then undressed and showered. During the shower the caregiver can use the Ergo-Access area to better reach the patient and move around



the shower trolley to avoid non-ergonomic working positions. When not using the shower handle it can be placed in one of the shower handle holders on each of the side supports.

After the shower is completed, residual water in the mattress is drained and the mattress and the caretaker are dried using towels. The caretaker is dressed or covered to keep him/her warm and then transported back to the bedroom, where a transfer from the Carevo to the bed is executed.



**Figure 3.15** Placement for drainage: over toilet (left) or over floor drainage (right)

#### **3.4.4** *Cleaning the trolley*

The last step is cleaning and disinfection of the Carevo. The trolley is transported back to the bathroom where it is thoroughly cleaned and disinfected using disinfectants and cleaning products. Cleaning and disinfection of the Carevo is necessary between every use.

#### **3.4.5** *Storage*

Before and after the shower process, the Carevo is transported to/from its storage location. The Carevo shower trolley should be stored in a dry area with good ventilation.

### 3 The Carevo Shower Trolley

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## 4 Method

*This chapter describes the design and development methodology used in the project.*

### 4.1 Choice of design and development methodology

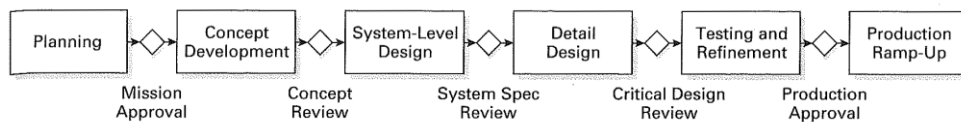
The overall development phases are based on *Product Design and Development* by K. Ulrich and S. Eppinger [9] while the ideation and concept development methodology is primarily based on *Vilda Idéer och Djuplodande Analys* by J. Landqvist [10]

#### 4.1.1 The development process according to Ulrich & Eppinger

*Product Design and Development* [9] provides a generic model for the product development process, and mentions some alternative configurations depending on which kind of product is being developed. Different product categories are suggested, in which the product developed in this project is considered to mainly fall under the category “Generic (Market-Pull) Products”.

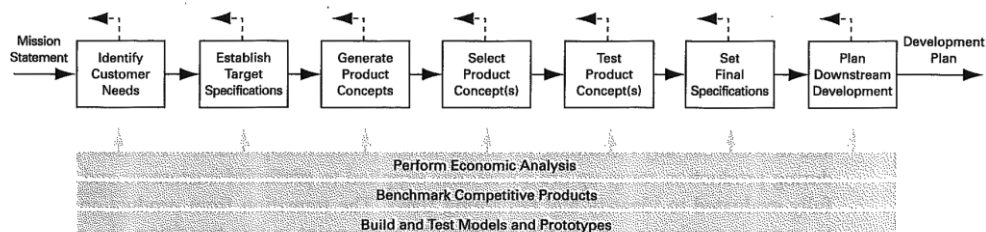
A Generic Product, also referred to as a “Market-Pull” product, is a product that is developed in order to satisfy an identified market opportunity. The technology used by the developed product is selected depending on what best satisfies the market need.

This product category is associated with a generic product development process shown in Figure 4.1.



**Figure 4.1** The Generic Product Development Process

The concept development phase of the generic product development process is further divided into the steps shown in Figure 4.2



**Figure 4.2** The steps of the Concept Development Process

#### 4.1.2 *The development process according to Landqvist*

While *Product Design and Development* [9] provides a detailed process for product development within a company, *Vilda Idéer och Djuplodande Analys* [10] is focused on explaining the parts of the product development process which is performed by the industrial designer. The process described is divided into the following phases:

- Background and goals
- Analysis
- Ideation
- Tests and experiments
- Presentational sketches
- Prototype drawings
- Prototype making
- Evaluation/ Follow-up
- Detail design and drawings
- Prototype manufacturing
- Marketing

The book describes the idea generating phase of the design process in detail, and provides a detailed explanation of the method used when performing a functional analysis.

#### 4.1.3 *The development process used at ArjoHuntleigh*

The ArjoHuntleigh development process is largely governed by the strict directives which apply to medical devices. In order to ensure that the requirements of these directives are fulfilled, quality management systems are used by the organization. The directives regarding medical devices include requirements for the design controls used, which govern the development process used when developing medical device products. For most medical devices, design controls are applied in order to ensure that good quality assurance practices are used during the design and development process.

The requirements regard the following design controls [11]:

- **Design and Development Planning** – Planning of the development process in order to ensure that proper control is maintained of the process and that the device quality objectives are met.
- **Design Input** – The physical and performance requirements of a device that are used as a basis for device design
- **Design Output** – The results of a design effort at each design phase and at the end of the total design effort
- **Design Review** – A documented, comprehensive, systematic examination of a design to evaluate the adequacy of the design requirements, to evaluate the capability of the design to meet these requirements, and to identify problems
- **Design Verification** – Confirmation by examination and provision of objective evidence that specified requirements have been fulfilled

- 
- **Design Validation** – Establishing by objective evidence that device specifications conform with user needs and intended use(s)
  - **Design Transfer** – Translation of the design into manufacturable specifications
  - **Design Changes** – Changes made to the developed design
  - **Design History File** – A compilation of records which describes the design history of the finished device.

## 4.2 The chosen development process

The methodology used in this project is a combination of all three aforementioned development methodologies. *Product Design and Development* [9] describes the concept generation process in a detailed way, with clear divisions of the different phases involved. These phases are the basis of the used methodology, but are not referred to with the same names as in *Product Design and Development* [9], and some modifications to the methodology are made.

The concept generation phase contains an idea generation phase inspired by the methodology described in *Vilda Idéer och Djuplodande Analys* [10]. The analysis phase is also inspired by this methodology, utilizing a modified application of a functional analysis.

Certain aspects of the method used are inspired by the ArjoHuntleigh development process, such as the use of a simplified version of a Traceability Matrix, and certain aspects of the concept evaluation process.

The development project is divided into the phases described below.

### 4.2.1 Project Plan

A Project Plan is made in order to get an overview of the development process and the amount of time which should be invested into each development phase. The Project Plan is based on strategic decisions regarding resource and time investment. The Project Plan is also used as a tool to ensure that all necessary steps of the development process are included, and that they occur in the right order.

The project plan is illustrated in a simple GANTT-schedule, which is a graphical representation of the different project phases in relation to the available time. The initial project plan time span reaches from mid-May to mid-October while the final project plan time span reaches from mid-May to the end of December. The project duration is 20 weeks/800 hours. The final project plan is presented in Appendix A.

### 4.2.2 Pre-Study

A pre-study is conducted in order to obtain basic knowledge regarding the Carevo and its usage. The pre-study includes the following steps:

**Benchmarking** – A brief examination of competing and similar products.

**Medical device requirements** – An examination of the requirements involved in the development due to issued directives.

**Physical restrictions** – An examination of the physical restrictions implied by the Carevo shower trolley.

**Transfer and shower simulation** – An arranged simulation intended to provide understanding of the experience of using the Carevo shower trolley, from both a caretaker and caregiver perspective.

#### *4.2.3 Field Research*

Field research is conducted in order to obtain valuable information which will later be used in the Research Analysis phase. The field research includes the following steps:

**Contextual interviews** – Interviews conducted in the environments of the users.

**Observed simulation** – Simulation performed by caregivers in their working environment, providing a first-person experience from the caretakers perspective and information regarding the behavior of the caregivers during actual usage of the shower trolley.

**Telephone interviews** – Interviews with foreign sales representatives.

#### *4.2.4 Research Analysis*

The Research Analysis is performed in order to interpret the research data and specify which functions the developed product must provide in order to satisfy identified user needs.

The Research Analysis is divided into the following phases:

**Workflow analysis** – A workflow analysis is performed in order to get an overview of the workflows used by the caregivers, and to visualize the flow of objects and potential time savings.

**Identification of needs** – Research data is examined and user needs are identified and documented in a traceability matrix. In order to get a good overview of the collected data and the conclusions made in the analysis, a *Thick Description* is created which summarize the findings and conclusions drawn.

**Functional analysis** – The listed user needs are translated into product functions which would satisfy these needs. These functions are then graded depending on their relative importance, supported by the information given by the thick description and workflow analysis.

#### *4.2.5 Concept Generation*

During the concept generation phase different ideas and solutions are generated in order to create product concepts. These concepts can later be compared and evaluated, and through iteration and combination of different partial concepts, lead to a solution which will be developed further.

The concept generation is further divided into the following phases:

#### 4.2.5.1 Ideation

During the ideation process ideas are generated through a systematic approach. This allows a wide spectrum of ideas to be evaluated regardless of their initially perceived feasibility; hence the process assures that as few as possible, potentially promising, solutions are left undiscovered. A range of ideas are then combined or selected, and are further developed in the following phases.

#### 4.2.5.2 Prototyping and Testing

During this phase simpler prototypes are built in order to test and evaluate the quality of the ideas from the previous phase.

#### 4.2.5.3 Evaluation and Screening

Concepts are evaluated and compared in order to phase out the least promising alternatives. The screening process is done systematically by evaluating the concepts according to different aspects and criteria.

#### *4.2.6 Concept Refinement*

The most promising concept(s) developed during the concept generation phase are further refined and developed during the Concept Refinement phase. Compared to the concept generation phase, the development is focused on one or few concepts. Material selection and production techniques are considered during this phase, as well as economic aspects and market aspects. The remaining concepts are evaluated and screened until only one concept is chosen for further detail design.

#### *4.2.7 Concept Detail Design*

The final chosen concept is further developed in the concept detail design phase. Design details such as exact dimensions and form are decided, as well as methods for manufacturing and material selection.

#### *4.2.8 Final Concept Evaluation*

The final concept is evaluated by testing a detailed prototype. The results of the evaluations are meant to indicate how well the concept meets the needs of the users and how it can be improved.

## 4 Method

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## 5 Pre-Study

*This chapter describes how the pre-study phase of the project was conducted. The Pre-Study included benchmarking, gathering knowledge about the Medical Device classification, defining the physical restrictions and conducting first-hand simulations of the workflow.*

### 5.1 Purpose and Method

The purpose of the pre-study was to gain an understanding on the different conditions that would have a direct impact on the project. First of all, it was necessary to explore the market and the competitors in order to determine if similar solutions exist.

Most ArjoHuntleigh products are certified Medical Devices. Another purpose of the pre-study was to determine if and how the Medical Device classification would affect the result of the project.

During the pre-study phase, the Carevo and its functions were further explored in order to obtain an understanding of the physical restrictions of the trolley and its intended usage environments. A simulation was also conducted in order to get familiarized with the intended workflow when using the Carevo, and also in order to improve the quality of the market research.

### 5.2 Benchmarking

Around 50 competing products to the Carevo were examined in order to find accessories which related to loose objects. None of the competitors offered such a solution.

Instead, a market research regarding existing products which perform a similar function was conducted. The gathered information mostly served as inspiration during the ideation process and as a checklist of possible technical solutions applicable to developed concepts.

### 5.3 Medical Device

The Carevo (and many of the products manufactured by ArjoHuntleigh) falls into a product classification category called *Medical Device*. This section describes the definition of a medical device, how medical devices are classified, and the requirements which are applied to medical devices.

### 5.3.1 Definition

According to *Council Directive 93/42/EEC* [13], which applies to Medical Devices sold in Europe, a medical device is defined as:

*“(a) [...] any instrument, apparatus, appliance, software, material or other articles, whether used alone or in combination, including the software intended by its manufacturer to be used specifically for diagnostic, and/or therapeutic purposes and necessary for its proper application, intended by the manufacturer to be used for human beings for the purpose of:*

- *diagnosis, prevention, monitoring, treatment or alleviation of disease,*
- *diagnosis, monitoring, treatment, alleviation of or compensation for an injury or handicap,*
- *investigation, replacement or modification of the anatomy or of a physiological process,*
- *control of conception,*

*and which does not achieve its principal intended action in or on the human body by pharmacological, immunological or metabolic means, but which may be assisted in its function by such means;*

*(b) ‘accessory’ means an article which whilst not being a device is intended specifically by its manufacturer to be used together with a device to enable it to be used in accordance with the use of the device intended by the manufacturer of the device”* [13]

The definition goes on to further describe and define what constitutes a medical device, but the section above is considered enough to understand why the Carevo and its accessories are classified as medical devices.

### 5.3.2 Classification

Medical devices are classified according to their use characteristics and their potential harm if misused. This classification differs in different countries and regions. In the European Union medical devices are classified according to the rules defined in the ‘Classification Criteria’ (Annex IX) section of the *Council Directive 93/42/EEC* [13].

Class I medical devices are non-invasive and non-active devices which can be described as the most basic type of medical devices. After discussions with personnel from the ArjoHuntleigh quality assurance department it was assumed that the holder would be classified as a Class I Medical Device.

### 5.3.3 Requirements

Different countries have different directives containing requirements which must be met in order for a product to be certified as a medical device. In Europe, these directives are published by the European Parliament. The corresponding directives in the United States are issued by FDA, the U.S. Food and Drug Administration. The requirements included in these directives assert the product quality relating to areas

such as risks, patient and user safety, performance, packing, cleanliness, infection/contamination control, material properties, and ergonomics.

Some of the relevant essential requirements derived from the *Council Directive 93/42/EEC* [13], are summarized and listed below:

- The device must not be designed for patient safety and not compromise the clinical condition or safety of patients when used for the purpose intended.
- The devices must be designed in such a way as to reduce as far as possible the risk of infection to the patient, user and third party. The design must allow easy handling and minimize contamination of the device by the patient or vice versa during use.
- Choice of material in the device must be paid attention to in regards of toxicity and flammability.
- When intended for use in combination with other devices (in this case the Carevo), the whole combination (including the connection system) must be safe and not impair functions of any of the devices. Any restrictions must be indicated on the label or in the Instructions For Use.
- The risk of injury from physical and ergonomic features must be removed or minimized as far as possible. [13]

#### **5.4 Physical Restrictions**

In this section, the physical restrictions implied by the Carevo shower trolley and its intended usage environments are explained and described.

##### *5.4.1 Dimensional Restrictions*

The dimensions and measurements of the Carevo have been carefully selected and tested to fit the needs of the users and should not be altered by the use of an accessory in such a way that it makes the trolley harder to use or less functional.

An accessory which is transported with the Carevo need should not compromise the maneuvering capability. The Carevo has been validated to fit in corridors and doorways of specific minimum values. If the accessory is developed in such a way that it permanently alters the dimensions of the trolley, these validations would have to be remade.

The inner dimensions of the Carevo mattress have been chosen to meet a certain percentile of the user population. An accessory should not compromise the space inside the mattress taken up by this group of users.

##### *5.4.2 Functional Restrictions*

It is important that the functions of the Carevo are impaired or hindered as little as possible by an accessory. Because of this, there are certain parts of the trolley which are not suitable to cover, or for something to be attached to:

- The emergency stop button, located at the head end of the trolley (see Figure 3.10). Covering or hindering the button from being pushed in case of

emergency would lead to additional risks and hazards. The emergency button must therefore not be made less visible or accessible by the accessory.

- The shower handle holders, located on the side gates, see Figure 3.11. The accessory should not cover or make the handle inaccessible, and if it does it should compensate for this.
- Anywhere where the ability to adjust and lower the side gates is impaired, see Figure 3.3 and Figure 3.4.
- Anywhere where the ability to raise or lower the stretcher is impaired.
- Anywhere where the ability to raise or lower the back support is impaired.
- In the Ergo-Zone (Figure 3.2), since it would impair the ability of the caregiver to get closer to the caretaker and work in a more ergonomic working position.
- Inside the mattress. This might be uncomfortable for the caretaker and it puts higher hygienic demands on the accessory if it makes direct contact with the caretaker.
- The castors have two functions that cannot be hindered: the ability to be braked individually and the ability to lock the wheel into straight steering. Figure 3.9 shows how these functions are activated.
- The drainage located at the foot-end of the stretcher should not be blocked. It is also important that the drainage hose can be attached and detached easily, see Figure 3.8 and 3.15.
- The three control panels that are located on the side supports and the head-end should not be covered or made less accessible.

In addition to this, the use of an accessory with the Carevo should not impair its ability to function together with other supported ArjoHuntleigh equipment, such as lifting aids and sliding sheets.

All of these restrictions are not necessarily absolute, but should be taken into careful consideration when designing an accessory for the Carevo.

## 5.5 Transfer & Shower Simulation

A first hand test was performed in order to gain understanding of the Carevo and its intended workflow. This insight was believed to be important in the following steps of development, especially in preparation of the next research phase.

The simulation included simulated transfers with sliding sheets and a mobile lift. The functions of the Carevo and the workflow was tested, but in intervals. A showering simulation was performed, where bathing suits were worn, and no scrubbing or shampooing was performed. No shower articles were involved except towels and the shower handle. Thoughts about the experience of being transferred and showered, as well as transferring and showering a patient were noted after the simulation.

## 6 Field Research

*This chapter describes the method and execution of the market research conducted at care facilities and through telephone interviews. A brief summary of findings is included.*

### 6.1 Purpose and Method

Research is conducted in order to gain an understanding of the user and the environment in which the product is intended to be used. The ultimate goal of the research is to provide the data needed to identify the needs of the product users and to translate these into necessary and desirable functions of the product.

The method used during the market research phase was based on the methods described in *Identifying Hidden Needs* by K. Goffin, F. Lemke and U. Koners. The methods described in *Identifying Hidden Needs* [12] are used in order to be able to detect so called *hidden needs*, which are defined as: “Needs that have not been previously identified, either by market researchers or customers themselves“.[12]

The benefits of being able to detect hidden needs are potentially great; when identified, they can be satisfied by product functions, which leads to a product that differentiates itself from market competition [12]. Even though no competing shower trolley solution provide an accessory similar to the one being developed in this project, the functions of an accessory could potentially lead to a stronger differentiation of the Carevo itself. In The Kano Model, described in *Attractive Quality and Must-Be Quality* [14], hidden needs are referred to as “excitement needs” and the features which satisfy these needs are referred to as “excitement features”. These excitement features are described to bring high customer satisfaction, and may be attractive out of proportion to the objective extra benefits they give [14].

*Identifying Hidden Needs* [12] describes three techniques used in leading-edge market research:

- Ethnographic market research
- Repertory grid interviewing
- Involving the user

Ethnographic market research is further divided into the techniques *systematic observation* and *contextual interviewing*. Variations of these two techniques were used during the market research conducted in this project.

## **6.2 Contextual Interviews**

Interviewing the end-users in the environment where the product ultimately will be used provides an insight beyond the perceived experiences of the interviewed subjects. Compared to surveys or traditional interviews it also allows for the observer to gather additional information that might contradict the verbally expressed opinions and explanations given by the interview subjects. Such information might consist of body language and tone of voice, but also environmental factors. [12]

The questions asked during the interview are semi-structured, which allows for flexibility in the questions asked, and the possibility to further investigate certain areas of interest with follow-up questions.

### *6.2.1 Structure*

In preparation of the interviews, a document with semi-structured questions was prepared. The insights acquired in the pre-study phase were helpful in the process of formulating relevant questions.

The main focus of the interviews was to gather information about the workflow used by the caregivers, the items used during this workflow and the handling and transportation of these, and the environments in which the workflow is performed.

During the interview, the interviewed subjects were asked to explain the different steps of the workflow used when showering a caretaker with the shower trolley. While being interviewed, the subjects were asked to show the environments where the different parts of the workflow are performed. They were also asked to demonstrate some parts of the workflow physically. The interview was recorded digitally, and photographs were taken of the environment and objects used during the workflow.

### *6.2.2 Target Facilities*

The contextual interviews were conducted at six different facilities. The facilities were selected to include all of the three main target groups of care facilities: Elderly care, special care, and hospitals.

Since the biggest market for the Carevo is elderly care facilities, these were prioritized. Beyond these criteria, the facilities were chosen due to accessibility within project time restrictions. Since the Carevo shower trolley was not yet launched on the Swedish market at the time of the interviews, all of the facilities were using an older version of the shower trolley. The workflow used when working with an older shower trolley was believed to be very similar compared to the one used when working with the Carevo shower trolley. The visited facilities were the following:

#### **6.2.2.1 Elderly Care Facility A**

Elderly care facility in southern Sweden with 37 apartments.

Area manager and two Caregivers with shower trolley experience interviewed, all female.

Shower trolley not present during interview, no demonstration possible.

#### 6.2.2.2 Elderly Care Facility B

Elderly care facility in southern Sweden with 70 apartments.

Female Caregiver with shower trolley experience interviewed

Shower trolley present during interview, demonstration of trolley mobility and working positions possible

#### 6.2.2.3 Elderly Care Facility C

Elderly care facility in southern Sweden with 23 apartments.

Area manager (male) and caregiver with shower trolley experience (female) interviewed.

Shower trolley present during interview, demonstration of trolley mobility and working positions possible.

#### 6.2.2.4 Special Care Facility A

Youth special care facility with short term residency and after-school care center. Capacity of 30 residents

Female Area manager with shower trolley experience interviewed.

Shower trolley present during interview, demonstration of trolley mobility and working positions possible.

#### 6.2.2.5 Hospital A

Hospital in southern Sweden, Orthopedic Unit.

Female Area manager with shower trolley experience interviewed.

Shower trolley present during interview, demonstration of trolley mobility and working positions possible.

#### 6.2.2.6 Hospital B

Hospital in southern Sweden, Intensive Care Unit.

Female Assisting nurse with shower trolley experience interviewed

Shower trolley present during interview, demonstration of trolley mobility and working positions possible.

### 6.3 Observed Simulation

The main focus of the observation was to gather data about

- movement and mobility of caregivers
- accessibility and handling of objects
- experience of the workflow from a caretakers perspective

- actual workflow execution (which might contradict the workflow explained in interviews)
- caregiver reactions and emotions
- caretaker contact during shower (eye contact, physical contact, occurrences when caregiver leaves trolley)
- cleaning and disinfection process

The preferred method of observation for this project would be to be able to observe the tasks performed before, during and after a real showering of an immobile caretaker at a healthcare facility. Unfortunately, this is difficult to achieve since personal hygiene is a very delicate and private matter; the caretaker would most likely feel uncomfortable if being observed during a shower.

Instead a simulation of the shower process was arranged, where the caregivers of the chosen facility were instructed to simulate a shower where one of the observers took the role as a caretaker. This also allowed the observer to gain insight into the caretaker experience during showers.

Only one observed shower simulation was conducted due to the limited time frame. The simulation was conducted at an elderly care facility since this is the biggest market for the Carevo shower trolley.

### *6.3.1 Execution*

The observed simulated shower was performed at an elderly care facility which was visited during an earlier performed contextual interview, Elderly Care Facility C. Two caregivers were participating in the simulation (none of which were interviewed at the earlier visit) which was performed inside an empty apartment. The simulated workflow included the following tasks:

- Transportation of the shower trolley into apartment
- Lateral transfer of caretaker from bed to trolley using sliding sheets
- Transportation of caretaker into bathroom
- Showering (observer wearing bathing shorts)
- Drying
- Transportation of caretaker into bedroom
- Transfer of caretaker from shower trolley to bed using a mechanical lift
- Cleaning and disinfection of shower trolley
- Transportation of shower trolley to storage location

During the observation the caregivers were asked to perform each task normally performed during showers, without any further instructions. The simulation was documented by a video recording.

## **6.4 Telephone Interviews**

All research was done at facilities in southern Sweden, which does not reflect the international markets where Carevo is sold [4]. None of the elderly care facilities visited used central bathrooms for showering; this was believed to have an impact on



the used workflow. Cultural differences were also believed to have an impact on the workflow. Therefore telephone interviews were conducted in order to collect information regarding these differences. ArjoHuntleigh sales representatives were contacted since they work in close contact with the purchasers and end-users, and visit many care facilities. Three Sales representatives from France, the Netherlands, and Germany were contacted.

Questions were asked regarding the workflows, the frequency of central bathrooms, cultural differences, and related customer feedback.

## **6.5 Field Research Results**

In this section, the findings from the Market Research phase are briefly summarized according to their respective source; Elderly Care, Special Care, or Hospitals.

### *6.5.1 Elderly Care*

At all three facilities visited, residents live in small apartments within the facility with their own private bathrooms. The showering process using a shower trolley is carried out in the private bathrooms of the caretakers. The bathrooms are not spacious; maneuvering and fitting the trolley in the bathrooms is often troublesome. At one of the facilities there was only space for one caregiver when the trolley was placed in the working position. The other two facilities provided enough space for two caregivers, but the layout of the bathroom prohibited one of the caretakers to move freely around the shower trolley.

At the visited care homes, objects used during the shower process are stored in cabinets or on the surfaces of the wash basin inside the private bathrooms. During showers these objects are either placed on surfaces close to the shower trolley or placed inside the mattress of the trolley.

In addition to showering the caretakers, some body care is also performed, such as nail care, brushing teeth, skin care and barbering. Additional objects are required when performing body care, such as razors, nail clippers, toothbrush and toothpaste.

In the telephone interviews it was reported that central bathrooms are very rare in Sweden, and that the trend is going towards every resident having a private bathroom. In other European countries central bathrooms are still common, but reducing in numbers. In Germany, a recent law requires elderly care facilities to develop a plan to arrange for private bathrooms. In the Netherlands it is becoming more common for two residents to share a private bathroom.

### *6.5.2 Special Care*

Much like the situation at elderly care facilities, the objects used in the shower process are owned by the caretaker. At Special Care facilities, central bathrooms are generally used with the shower trolley. Objects used during showers are stored in a cabinet. Using small baskets, the personal objects are organized according to which resident they belong to. During showers, the objects are accessed either by placing them on available surfaces close to the shower trolley, or by placing them inside the

mattress of the shower trolley. In addition to showering, body care and toilet assistance is performed in trolley.

Caretakers at special care facilities have different needs than caretakers at elderly care homes or hospitals. These caretakers often have more mobility, and can suffer from spasms and uncontrolled movements. During interviews it was stated that caretakers occasionally throw objects around if they are able to access them.

### *6.5.3 Hospitals*

Hospitals generally use a central bathroom when showering patients with the shower trolley. The objects used in the shower process are normally not owned by the patients, but personal objects may be used if requested by the patients. Patient clothing is normally not owned by the patients. Objects used during showers are stored in the central bathrooms in cabinets or on available surfaces. During the shower the objects are accessed either by placing them on available surfaces close to the shower trolley, or by placing them inside the mattress of the shower trolley.

Hospitals have different requirements on the products used when it comes to hygiene. Equipment and products that have been in direct contact with the caretaker have to be thoroughly cleaned and disinfected after each use.

The hospital environment involves additional medical equipment compared to elderly care homes and special care homes. Examples of equipment which occasionally need to accompany a patient during showers include breathing devices, oxygen tanks, catheters and IV-equipment. The required equipment depends on the medical condition of the patient being showered.

## 7 Research Analysis

*This chapter describes the different steps performed in the analysis phase of development, and includes a summary of the conclusions drawn from the research data.*

### 7.1 Purpose and Method

The purpose of the research analysis was to review the collected data gathered during the research phase and process it into a more manageable and concentrated form. The result of the analysis was intended to be the basis for further development in the Concept Generation phase.

The research analysis phase consisted of several steps: workflow analysis, identifying needs from collected data, translating the needs into desired functions and rating the importance of the functions in the functional analysis.

The method used in the analysis phase was based on *Identifying Hidden Needs* [12], with elements based on *Vilda Idéer och Djuplodande Analys* [10] and the development strategy used at ArjoHuntleigh.

### 7.2 Workflow Analysis

Using the collected data from interviews and observations, the workflows from the different visited facilities were visualized in flowcharts. The purpose of the Workflow Analysis was to gain an understanding of the similarities and differences in workflows between the different types of care facilities and interpret the needs that shape their workflows. The flowcharts were also intended as an aid to pinpoint where and how a holder could optimize the workflow or even eliminate steps and to explain the involvement of the objects used during the shower process.

An example of a workflow flowchart can be seen in Appendix B.

#### 7.2.1 Conclusions

The results showed great variations in workflows, not only between the different types of facilities but also within different facilities of the same type. It was discovered that the workflows often deviated from the Intended Workflow described in Chapter 3.4.

A typical workflow for using shower trolleys was not possible to define, since the workflow has to be adapted to the caretaker. The shape of the workflow is also influenced by other factors, such as number of caregivers, preferences of the

caregivers, size of the bathroom, cultural factors etc. This puts high demands on an accessory to be adaptable and flexible to meet the needs of all the different users and workflows.

One apparent difference between hospitals and the other types of facilities was the amount of preparation needed before transporting the caretaker to the bathroom. The workflows at the hospital had less activities and time spent in the preparation category, due to the bathroom being a central bathroom and being equipped with dispensers, towels, aids etc. Since the shower objects were not belongings of the patient but of the hospital, less time was spent on preparing and transporting these objects. At elderly care and special care facilities on the other hand, each resident have their own set of shower objects. These need to be taken out of cabinets so they are available and easier to reach during shower.

### **7.3 Identification of needs**

The collected raw data was analyzed and summarized in order to interpret needs and find relationships and contradictions in the research data. The needs were listed in a matrix, and then translated into desired functions of the product. A Thick Description of the conclusions as well as the contradictions and relationships in the collected data was generated.

#### *7.3.1 Thick Description*

In *Identifying Hidden Needs* [12] the Thick Description is described as a distilled summary of the relationships and contradictions in data generated from ethnographic studies. The Thick Description is meant to provide insights to the culture of the actors, and should consist of a summary of what was observed and conclusions drawn from the research data.

In this project a simplified version of a thick description was used. The most relevant and important findings of the thick report are summarized in Section 7.5 of this chapter.

#### *7.3.2 Traceability Matrix*

A document called *Traceability Matrix* is a quality management tool used in the development process at ArjoHuntleigh in order to trace all functions, requirements and specifications throughout the entire process. In this project a simplified version of this document was used, but is still referred to as a Traceability Matrix.

The identified needs and requirements from the research phase were listed in the Traceability Matrix, as well as the statements or observations which indicated these needs and requirements. In order to further understand the differences between different types of facilities, the traceability matrix states in which of the visited facilities the need in question was present. This allowed each need or requirement to be traced back to the data it originated from. Table 7.1 shows an example of a row from the Traceability Matrix.

Statement or Observation	Interpreted Need	Function	Category	Elderly Care A	Elderly Care B	Elderly Care C	Special Care A	Hospital A	Hospital B	Simulated Observation
"Objects are out of reach and must be fetched by leaving the trolley"	Easy access (mentally and physically) to desired object	Allow easy access to desired objects	Objects	X	X	X	X	X	X	X

**Table 7.1** An example showing the structure of the Traceability Matrix used.

## 7.4 Functional Analysis

The functions from the Traceability Matrix were listed and categorized in a Function Analysis document, where the different needs were rated as a Main Function (MF), Necessary Function (N), Desired/Necessary Function (D/N), Desired Function (D), Desired/Unnecessary Function (D/U), or Unnecessary Function (U). This was conducted in order to determine the relative importance of the functions and was later used in the ideation process. The relative importance of the different functions was based on the conclusions made when analyzing the research data, as well as the Traceability Matrix.

The Functional Analysis was inspired by the method described in *Vilda Idéer och Djuplodande Analys* [10], where the idea of the Functional Analysis is described as a way to learn to express and think in functions instead of finished solutions. The Functional Analysis is an aid to facilitate the work of reviewing and analyzing the requirements and desires that are applied to the product in question. The finalized Functional Analysis should act as a summary of all the information and knowledge that has been gathered through previous research. [10]

The Functional Analysis used in this project is a simplified version of the method described in *Vilda Idéer och Djuplodande Analys* [10] and is mainly intended as an aid for the concept generation and refinement phases, since these are the phases that are most emphasized within the project scope. Therefore, the Functional Analysis does not include areas such as production, costs, marketing and construction. The Functional Analysis can be viewed in Appendix C.

## 7.5 Interpreted Needs

Below follows a summary of the findings and conclusions stated in the Thick Description.

### 7.5.1 Specific Needs

This section summarizes the identified needs and analysis conclusions which were unique to a specific target facility.

#### 7.5.1.1 Elderly Care

Due to the limited space and mobility offered by the private bathrooms used during showers, it is important for an accessory to the shower trolley to be space efficient and to have the ability to be placed as needed.

The private bathroom is a part of the home of the caretaker and should feel like a part of the home in order to preserve the dignity of the caretaker. Objects used during showers are usually stored in cabinets in the bathroom, and it is presumed that an important reason for this is to keep the bathroom tidy. Also, the bathroom is used for other activities than showering, such as going to the toilet, dental hygiene, barbering and other body care. The showers occur more seldom than these other activities. These activities require objects in addition to the objects used during showering.

Central bathrooms put different demands on a holder since the objects used for showering often need to be transported from the bedroom of the caretaker to the central bathroom. This also indicates the need to transport clothes and towels with the Carevo. Since these needs concern the main functions of the developed product, elderly care homes were divided into two categories of target facilities: elderly care facilities with and without central bathrooms.

#### 7.5.1.2 Special Care

The results of the research regarding Special Care facilities shows a need for organizing the belongings of individual caretakers in the bathroom; this was interpreted from the fact that each caretaker have a personal basket or shelf in the central bathroom where his/hers belongings are stored.

#### 7.5.1.3 Hospitals

A clear difference seen at the Hospitals compared to the other facility types is the fact that the caretaker is normally not the owner the shower articles; in other words, the same shower articles are used for all caretakers. This eliminates the need of transporting shower articles between the caretaker rooms and the bathrooms. This was interpreted as a need for storage and organization of shower articles in the bathroom at all times, as well to accessibility to the shower articles when they are needed.

At one of the hospitals visited, a small cart was used during the shower process as a storage surface. The cart was moved depending on the working position of the caregivers. This indicates the need for temporary storage during the shower process which is easily adaptable.

The amount of specialized medical equipment and devices used at Hospitals also indicate needs that differ from those of the other facility types. These objects put restrictions on the working space and the ability to move around for the caregivers. From this it was interpreted that the caregivers at Hospitals are in need of space efficient and flexible aids.

### 7.5.2 Common Needs

This section summarizes the identified needs and analysis conclusions which are shared by several target facilities.

#### 7.5.2.1 Easy Access to objects

Both interviews and observations at the special care and elderly care facilities shows that the phenomenon of putting shower articles such as shampoo and shower soap in the mattress next to the caretaker is common. This indicates the need for easy access to these objects.

#### 7.5.2.2 Flexibility

The studies showed that the workflows can look quite different depending not only on the type of facility, but also on the caretakers, caregivers, environments, cultural aspects, routines etc. Therefore it is important that the holder is adaptable and flexible to meet the needs of the different users. There are also many different objects used in the shower process that need to be taken into consideration.

#### 7.5.2.3 Caretaker Contact

The caregivers at the Hospitals and Special Care facilities stated that they sometimes had to deal with caretakers who are very unpredictable and move around a lot in the shower trolley when showered; this is due to the caretakers being spastic, suffering of dementia or simply because the experience of being showered in the trolley makes them anxious. Therefore it is important for the caregiver to have full focus on the caretaker at all times in order to keep him or her safe in the shower process. Reaching for objects by turning around or walking away from the trolley might result in moments where the caretaker is left completely unsupervised and vulnerable. If this is avoided by having all the necessary objects used in the shower process accessible without having to turn away focus from the caretaker, one could make the argument that it makes the shower process safer.

#### 7.5.2.4 Single Caregiver

2 out of 5 of the facilities visited stated that caretakers are on occasion showered by a single caregiver. In one of the interviews it was stated that she would perform a logroll in order to wash the back of the caretaker, only to realize that the soap was out of reach. In that case, the caretaker had to fetch the soap and start over. If the objects needed are within reach at all times these types of time-consuming mishaps can be reduced or eliminated.

It is also safe to assume that it is harder for the caregiver to maintain a constant focus on the caretaker when he/she is performing the shower process single-handedly. If the caregiver has to turn away or walk away from the trolley to fetch something, it is inevitable that the caretaker is left unsupervised for a moment. As mentioned above, by reducing or eliminating these occurrences with a holder, one could argue that the workflow becomes safer, especially when only one caregiver is present.

### 7.5.2.5 Towels

Caretakers at all of the facilities visited claimed to use many towels in their workflow, often up to 5-6 towels. There are also occasions when towels need to be transported between the bedroom and the bathroom. The size and weight of 5-6 towels is presumably more than that of the shampoo bottles and other shower products used during showering.

### 7.5.2.6 Waste

Caretakers at all of the facilities visited showed needs of temporary waste handling during the shower process. Some of them had met the need by having a waste bin close to the trolley during the shower process. Waste is generated during practically every shower due to the use of disposable hygiene articles such as washcloths, protection gloves and diapers. At some facilities waste was left on the floor or on the sink until the bathroom was cleaned up after the shower.

### 7.5.2.7 Water Protection

The market research showed that some of the objects present in the shower process, such as towels and clean clothes, should not be exposed to water and moisture. In order to be able to store these objects close to the trolley (i.e. within accessible reach) they need to be protected from water or moisture.

### 7.5.2.8 Transportation of Objects

The need for transportation of objects was not present at any of the facilities visited, but is assumed to be more common in foreign countries where care facilities are equipped with central bathrooms. A holder solution that is meant to assist during transportation as well as during the shower process would presumably look different than a holder which is just intended to assist during shower alone.



## 8 Concept Generation

*This chapter describes the concept generation phase of the project. It explains how ideas were generated and formed into product concepts which were prototyped and tested.*

### 8.1 Purpose and Method

The methodology used during the concept generation phase was based on *Vilda Idéer och Djuplodad Analys* [10] but with several adjustments.

Since the result of the functional analysis was derived from all the needs discovered during the research, every function that the product *could* provide in order to satisfy these needs is listed there. Only the functions rated as necessary were certain; the other functions were decided to be implemented only if a good solution gave the opportunity to do so. It was believed that this would lead to fewer compromises between the desired functions and thus to a product with higher quality in the functions provided.

### 8.2 Ideation

To be able to tell which functional direction of the product and which solution is the most promising, ideas regarding these have to be compared. More ideas and concept solutions were believed to lead to a greater probability of ideas with higher potential.

#### 8.2.1 Categorization of Needs

In order to structure the first steps of the ideation phase, the ideation was divided into several different brainstorming sessions. The needs listed in the functional analysis were sorted into categories, and each functional category was the basis of a separate brainstorming session.

The requirements listed in the functional analysis were not considered during the first steps of the ideation process since they were believed to hinder creativity instead of inspire new ideas and solutions. The focus of this approach was to generate a big quantity of ideas.

One reason for the categorization of needs was to make the functional analysis comprehensible when creating ideas; the traceability matrix included over 200 formulated needs. Another reason was to allow a wider scope for the ideas, instead of being too focused on a specific attribute or function of the product.

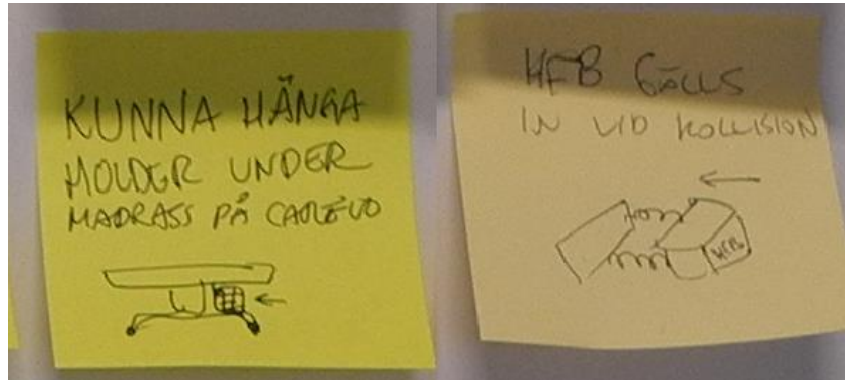
#### 8.2.2 Brainstorming Sessions

## 8 Concept Generation

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In the brainstorming sessions *conceptual ideas* were generated within each functional category.

These ideas were not evaluated during the sessions. No requirements regarding manufacturability or feasibility were implied; the ideas could be of any nature as long as they intended to provide functionality within the category to which they were assigned. An example is seen in Figure 8.1.



**Figure 8.1** Two ideas generated in the brainstorming session for the functional category *Mobility*. The post-it note to the left describes a holder attached beneath the stretcher of the Carevo, which does not compromise the mobility of the trolley during transports. The post-it idea to the right describes a holder that somehow retracts when colliding with walls or doorways.

The first brainstorming session was however not based on any of the functional categories, but focused on fundamental questions asked from a holistic perspective of the product function. The generated conceptual ideas could regard functions such as keep caretaker hygienic.

### 8.2.3 Idea Selection

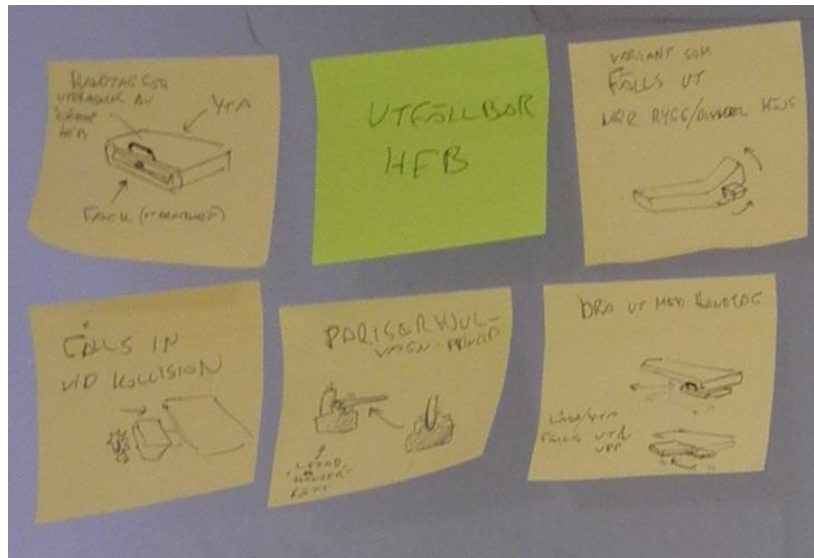
The conceptual ideas which were generated in these brainstorming sessions were not ranked or screened. Instead promising and interesting ideas were selected as the basis of the next concept generation phase. This was partly due to the great amount of ideas generated during the sessions; about 500 ideas were generated. The ideas which were not explicitly selected were still used as inspiration during the following development.

## 8.3 Idea Development

During this phase of the ideation, the selected ideas from the brainstorming sessions were developed into product concepts.

### 8.3.1 Idea Generation Session

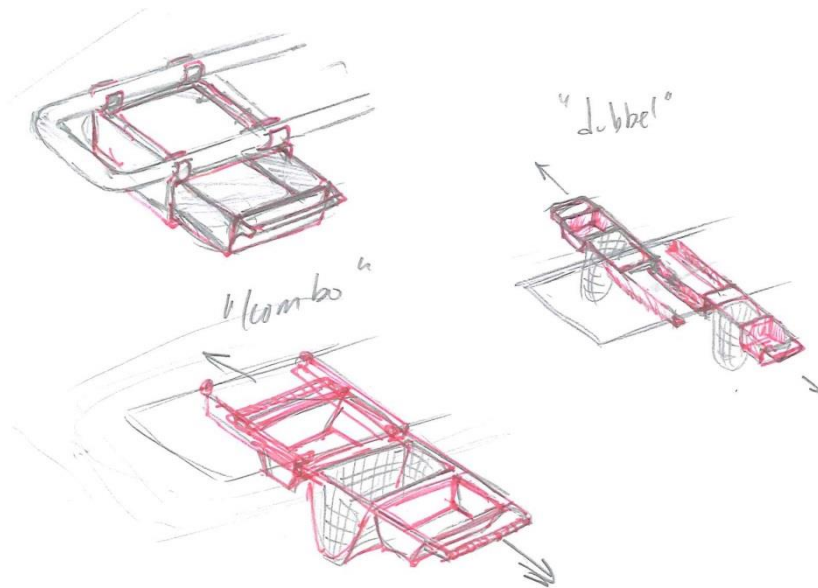
Another idea generation session was conducted. Each conceptual idea selected from the previous brainstorming sessions represented the basic thought, which further defined product concepts would revolve around. The ideas generated in this session further developed these basic thoughts, and gave examples on technical solutions and concrete examples of design. An example of this is seen in Figure 8.2.



**Figure 8.2** An example of a basic thought, represented by a green post-it note. It describes the idea of a retractable holder. The yellow post-its describe design ideas associated to the basic thought.

### 8.3.2 Sketching and Prototyping

Using sketches and sketch prototypes, these basic thoughts were developed into product concepts. During this phase of development, many iteration cycles were performed, and the basic thoughts were combined and modified. The sketch prototypes were tested continuously, and were either improved or discarded after each iteration cycle. An example from this process is shown in Figures 8.3 and 8.4.



**Figure 8.3** An example of sketches of a product concept based on the basic thought described in Figure 8.2. It describes a holder which is pulled out from underneath the stretcher



**Figure 8.4** A sketch prototype made of the product concept described in Figure 8.3

#### 8.4 Concept Categories

The concepts were divided into categories, depending on their functionality. These different categories satisfy different needs, some unique to a certain category of target facilities. The concept categories are listed below:

**Clothing storage and/or transportation** - The concepts were able to store and/or transport clothes and towels as well as other items. The need for transportation and handling of clothes was identified for elderly care facilities with central bathrooms, and for special care facilities.

**Holder for easy access** - Concepts which allow easy access to objects used during showering of caretakers. The need for this was identified for all target facilities.

**Furniture** - Concepts which are stored in bathroom and are in functionality more similar to furniture than an accessory.

The furniture concepts were believed to satisfy the needs of all target facilities except for elderly care facilities with private bathrooms, where they were considered inappropriate considering their unwieldiness.

**Eliminate Objects** - Instead of storing and allowing access to objects used in the shower process, the concepts in this category intends to eliminate the need for loose objects by replacing their function. These concepts were intended to mainly target hospitals, since none of the objects involved in the shower are owned by the patients.

#### 8.5 Concept Screening

When the deadline for the concept generation phase was reached, a concept screening was performed in order to narrow down the concept alternatives, and to focus further development on the most promising concepts in the Concept Refinement phase. Because of the many restrictions and the vast difference between the concepts, the ranking of the concepts was made through discussion and reasoning. Discussions with the Carevo development team were continually conducted throughout the project in order to gain valuable feedback for the concept screenings.

No concepts within the categories “Furniture” and “Eliminate Objects” qualified to the concept refinement stage.

Since only part of the target users were in need of clothing storage/transportation, this functionality was decided to be optional. The functionality was however considered important for those who were in need of it, therefore it was decided that parallel concepts were to be developed. The separation of the parallel concepts was considered as following:

1. One product which combine handling of clothes and smaller objects. A compromise solution which works for all target users, even if all of its functions are not used by all.
2. One product which combine handling of clothes and smaller objects, and an additional product which only offers handling of smaller objects. The target

## 8 Concept Generation

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users who do not need the combined solution are assumed to opt for the separate simpler product.

3. One product for handling of clothes/towels, and one product for handling of smaller objects. Users who are in need of clothes/towels handling use both products, while users who only are in need of the handling of smaller objects use solely the product intended for doing so.

8 concepts were chosen in the screening process, and were evaluated in order to determine which features were good enough to be kept, and which areas of concern that would needed to be addressed in order to refine the concepts.

## 9 Concept Refinement

*This chapter describes the Concept Refinement phase of the project, where the concepts remaining from the Concept Generation refined and improved. After further screening, only one concept was for design finalization.*

### 9.1 Purpose and Method

After the screening performed at the end of the concept generation phase, the passing concepts were further developed in order to be improved or combined with other concepts.

Two iterations of concept refinement were performed. When the first iteration had been completed, a concept screening was performed (referred to as Iteration Screening 1) where the resulting concepts and improvements were discussed, compared and evaluated in order to terminate concepts that were not considered good or feasible enough.

After this screening, the refinement process was iterated once again with the few remaining concepts. At this point the focus was completely directed towards improving the existing concepts, and no new concepts were generated.

The concepts were then taken to a final screening (referred to as Iteration Screening 2), which consisted of comparisons, discussions with the company, and feedback from the target users. A final concept was chosen for further development.

### 9.2 Refinement Iteration 1

During the first iteration many sketch prototypes were built in order to continuously test and improve concept designs. At this point in the project, there were 8 concepts to be further combined and refined into more complete concept solutions. These concepts were in the previous phase of the project divided into the categories *Clothing storage and/or transportation*, and *Holder for easy access*.

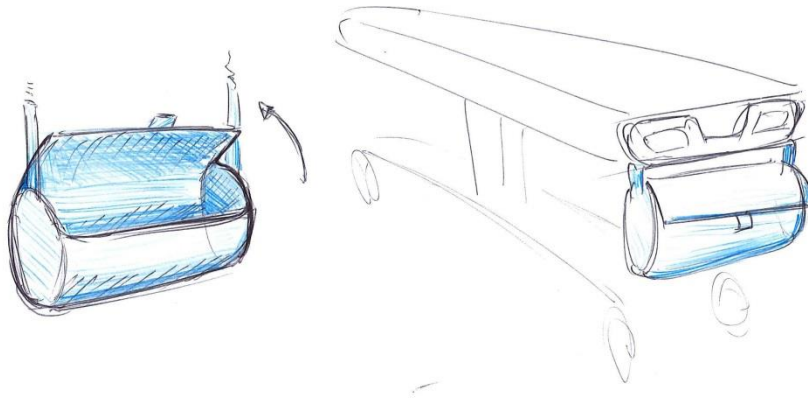
#### 9.2.1 Clothing Storage and/or Transportation

The concepts developed within this category could be summarized with the following three concepts.

##### 9.2.1.1 Concept C1

Concept C1 is a relatively large holder which in functionality is similar to a messenger bag. Intended to be made of a water resistant fabric with additional

structural reinforcements in a plastic material, this concept can be collapsed and folded in order to only occupy only as much space as the objects it contained. This concept is intended to be attached to the handles of the Carevo when stored during showers. This concept idea is intended to be used with a separate holder for easy access. Figure 9.1 shows a sketch made of Concept C1.



**Figure 9.1** Sketch of Concept C1

### 9.2.1.2 Concept C2

Concept C2 is a retractable holder which is mounted under the stretcher of the Carevo. When not accessed, it does not add to the width of the Carevo, and the contained objects are protected from water. When accessed during showers, the holder is retracted from under the Carevo at the desired side. The holder is not intended to be detached from the Carevo unless when cleaned and disinfected. Two versions of this concept was considered: one version which is intended to be used with a separate holder for easy access, and one version which combines the functionality of clothing storage and/or transportation with the functionality of a holder for easy access. A sketch prototype of concept C2 is shown in Figure 9.2.

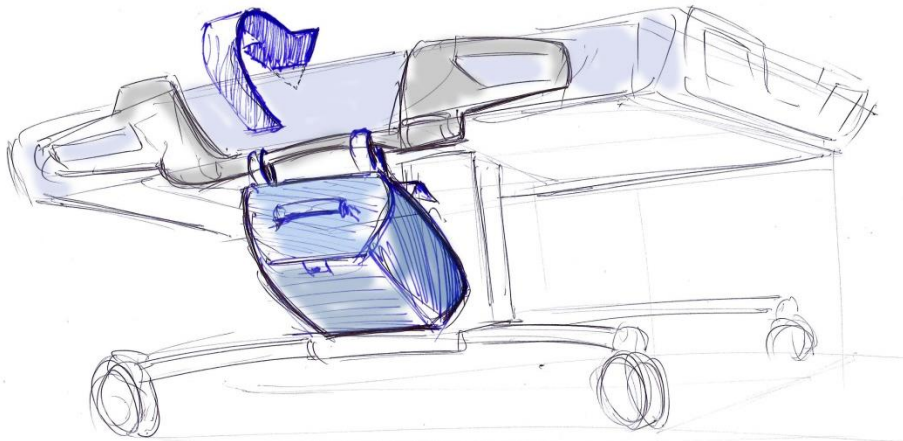




**Figure 9.2** Concept C2, sketch prototype

### 9.2.1.3 Concept C3

As seen in Figure 9.3, Concept C3 is a combination of both above mentioned concepts; a soft holder made of fabric which could be stored under the stretcher of the Carevo when not used. When accessed during showers, this holder is moved to a more accessible position on the Carevo. When transported, it is possible to detach the holder from the Carevo, enabling it to be carried separately.



**Figure 9.3** A sketch of Concept C3, showing the intended use with the Carevo

### 9.2.2 Holder for Easy Access

During the first concept refinement iteration, several concepts within this category were discarded throughout the ongoing prototyping and testing. The three concepts which remained in development at the end of this iteration cycle are presented below.

#### 9.2.2.1 Concept E1

Concept E1 is a holder which can be attached on the Carevo by sliding it onto the handles. The holder provides two compartments at different levels of height, with the

## 9 Concept Refinement

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purpose of organizing objects by the frequency of which they are used. A handle at the top part of the holder enables users to carry it with one hand. The holder is intended to be hung on the wall of the bathroom in which it is used when not attached to the Carevo, providing access to the objects it contains at all times.

The compartments were designed to be made out of a flexible material in order to allow support for different types of objects and to enable the user to turn the compartments inside out when cleaning the holder. Further functionality of the separated compartments, such as water protection, was examined in different prototypes. Figure 9.4 shows one of the sketch prototypes made of concept E1 attached to the Carevo.



**Figure 9.4** A sketch prototype of Concept E1

### 9.2.2.2 Concept E2

A simple holder designed to assist in the handling of the bottles included in the showering process. This concept was developed in order to address problems identified while testing the above mentioned concept. These problems regarded functions such as cleanability, manufacturability, and ease of use.

The holder can be attached to the different handles of the Carevo, as well as to the edge of the Carevo mattress, and is intended to be easy to move between these different attachment locations. This is enabled by a flexible back attachment wall, which also allows the holder to stand upright on a flat surface. The bottles contained in the holder is held in place by the front wall of the holder, which is flexible and

tilted inwards in order to apply pressure against the side of the bottles. The simple and open shape is intended to simplify the cleaning of the holder. Two sketch prototypes of this concept can be seen in Figure 9.5.



**Figure 9.5** Sketch prototypes of Concept E2, attached to the Carevo

### 9.2.2.3 Concept E3

Concept E3 has the functionality of a holster, inspired by similar solutions used by hairdressers and craftsmen. Providing compartments for objects, the holder is attached around the waist of the caregiver, giving constant access to objects within reach regardless of the working position used. Figure 9.6 shows the sketch prototype of concept E3 being tested.



**Figure 9.6** Concept E3, also referred to as *The Holster*

### **9.3 Screening of Iteration 1**

After the first refinement iteration, the concepts were evaluated and screened as described below.

#### *9.3.1 Clothing storage and/or Transportation*

At this stage of the project it was determined that further development and refinement of the concepts within the category clothing storage and/or transportation would not continue. This decision was taken due to the following reasons:

- No developed concept was considered to provide an adequately satisfying solution for this need; the functionality of these concepts was not on par with the functionality of concepts developed within the holder for easy access category. The physical restrictions, described in Chapter 5.4, proved to be difficult to overcome.
- The concepts in the holder for easy access category satisfies needs identified at all the target facilities, whereas the concepts intended to facilitate handling of clothes satisfies needs only seen at two of the four target facilities: elderly care facilities with central bathrooms and special care facilities.
- Due to the limited time available for this project, focusing all development on the holder for easy access category meant that the final concept could be more refined.

As described in the Concept Screening section, Chapter 8.5, three different options for the separation of the two functional categories were identified. The decision to terminate continued development of the clothing storage and/or transportation category meant that the first of these options were excluded. This option involves a product concept combining the handling of clothes with the handling of smaller objects. This does however not mean that the other two options are excluded entirely, only that they are excluded from the scope of this project. This is further discussed in Chapter 12, Further Development.

#### *9.3.2 Holder for Easy Access*

Since several concepts were discarded throughout the prototyping and testing performed during the first iteration of concept refinement, only three concepts were still in development at this point. These were the concepts previously mentioned in Section 9.2.2. During the screening, concept E1 and E2 were selected for further development, and concept E3 was discarded.

### **9.4 Refinement Iteration 2**

Much like the first iteration of the concept refinement process, the aim of the second iteration was to add functions to the two concepts and/or to combine them into a concept that had the best features of both concepts. This proved to be a difficult task due to Concept E2 already being a very refined concept and due to the relatively large differences between the two concepts.

At this stage an ideation session was conducted regarding each area of concern for both concepts in order to improve the concepts. These variations of the concepts were then tested using sketch prototypes. This did unfortunately not lead to any major improvements on any of the concepts.

## **9.5 Screening of Iteration 2**

In this second screening of the concept refinement phase, a single concept was to be selected.

Since potential was seen in both concepts, and since each concept had unique advantages, this screening was performed more methodically than previous screenings.

### *9.5.1 Comparison*

The two concepts were compared in a table in order to get a better view of the upsides and downsides of each concept. The comparison shows that there is a relatively large difference between the holder concepts, and that the positive aspects of each concept depend on the situation of the end-user. The result is seen in Table 9.1

9 Concept Refinement

	<b>Concept E1</b>	<b>Concept E2</b>
<b>Producibility</b>	Potentially harder to manufacture, more material used.	Assumed to be easier to manufacture.
<b>Cost/price</b>	Presumably more expensive to manufacture, but easier to justify a high price due to more functions.	Presumably less costly to manufacture, however it could be harder to justify a high price due to its simplicity.
<b>Viability as personal holder</b>	Could be big enough to fit all of the caretaker's personal objects, but could also be too big. Not adapted to special care due to the requirement of several holders in the same bathroom if personal.	Possibly not big enough to fit all objects that are needed during the shower, hence potentially less time saving. Easy to store in cabinets (standing).
<b>Use with trolley</b>	Less attaching options, only on the long sides of the Carevo. Could potentially be adjusted to work on short sides. The attaching method could possibly be difficult to understand.	Considered easier to place where needed. Attachment method considered easier to understand.
<b>Use "outside" of trolley</b>	Can be hanged on wall and allow easy access to the objects it contain. Not able to stand on flat surface.	Can be put on a flat surface, such as on the sink, on shelves, cabinets etc. Can be hanged on towel racks and other bars in the bathroom if they are situated with the right distance from a supporting wall.
<b>Transport</b>	Can possibly be placed on head of foot-end during transport, if the width is adjusted.	Can be placed on head or foot-end during transports. However, if attached on the head-end, the control panel is covered, and it could potentially be in the way if caretaker is tall.
<b>Capacity</b>	Can fit shower articles, body care products, dental care products etc. at the same time. Capacity could possibly be superfluous in some situations.	2-3 bottles depending on size. Capacity might not be enough in some situations.
<b>Handle/Grip</b>	Easy to understand, comfortable and ergonomic.	The grip might be hard to understand and less ergonomic.
<b>Water protection</b>	Lower compartment could be made watertight, though a potentially superfluous function.	No protection from water.
<b>Most negative aspects</b>	Big, not as easy to move around on the trolley, attaching method is less intuitive.	Few functions, less compatible with different objects.
<b>Most positive aspects</b>	A lot of functions, more flexible in compatibility with objects.	Simple, easy to understand how it is attached to the trolley.

**Table 9.1** Comparison of Concepts E1 and E2

### 9.5.2 End-user Tests

The two concepts were brought to two of the facilities visited during the research phase in order to obtain direct feedback from the end-users. Caretakers at these facilities were shown the prototypes and were asked about how they thought the concepts worked, and which one they preferred. The results from the end-user tests are summarized in the following points:

- None of the interview subjects understood how to attach Concept E1 to the trolley. However both of the facilities used an older model of the shower trolley (ArjoHuntleigh Concerto/Basic) which has drastically different looking side supports (see Figures 1.1 and 1.2). Concept E2 received positive feedback for its ability to be attached anywhere on the rails of the side supports, and for being easy to move around.
- The ability to store Concept E2 on a flat surface was preferred to the ability to hang Concept E1 on the wall. At the special care facility it was stated that they would not keep the personal belongings of the residents out where everyone can see them.
- None of the interview subjects expressed the need for a water protected compartment.
- The preferred placement of the holders during transport would be on the head-end, which Concept E2 is best suited for.
- Concept E2 was considered a bit too small, the subjects states that they would like to be able to fit one more bottle.
- The additional compartment of Concept E1 was considered to be redundant at the elderly care facility, but would be of use at the special care facility according to the interview subjects.
- Both concepts were considered easy to clean, but this was not considered necessary if the holder was to be personal.

In conclusion, the field studies showed that Concept E2 was considered more useful than Concept E1 for these caretakers and their respective facilities.

### 9.5.3 Discussions with ArjoHuntleigh

The two concepts were presented for the Carevo development team at ArjoHuntleigh in order to obtain their opinions regarding which of the two concepts that would pass and be further developed. Concept E2 was considered as the more feasible concept due to its simplicity and intuitive functionality. There was however some concerns about the producibility of the concept, which is further discussed in the next chapter.

## 9.6 Selection of Final Concept

Based on the results of the above mentioned screening, Concept E2 was chosen as the final concept to be further refined, designed and developed into a fully working prototype for testing and evaluation.





## 10 Final Concept Design

*This chapter describes the development phase in which the final prototype is designed and produced.*

### 10.1 Purpose and Method

The goal of the Final Concept Design phase was to create a fully functional prototype and to further investigate the intended production method and material selection for the final concept. Further refinement to the design was made in this phase.

The concept was modeled in CAD software in order to visualize aesthetic design decisions, provide geometrical data for 3D printing, and to enable simple finite method analyses to be performed. The final prototype was produced by 3D printing.

### 10.2 The Final Concept

A 3D printed model of the final concept can be seen in Figure 10.1.



**Figure 10.1** The 3D printed model made of the final concept design

Its main function is to assist with the handling of bottles used during the shower process. The holder is attached on the handles of the Carevo and is intended to be

easily moveable, allowing the user to attach it where it is most convenient for him/her.

### 10.3 Detail design

This section describes the detail design of the different functional parts of the holder.

#### 10.3.1 Supported Storage Capacity

Since the most commonly used bottles during the shower process contain shampoo, hair conditioner, soap, and lotion, the holder is designed to be able to contain up to four bottles.

The inner length dimension was set to 230 mm. This means that four bottles of the maximum supported size will not fit into the holder, but the user is never believed to use four bottles of the maximum supported size at once when using the holder, as shown in Figure 10.2. This dimension was set after testing different dimensions on prototypes, and was believed to be a good compromise between holder size, supported bottle capacity and proportions.



**Figure 10.2** Supported storage capacity of the holder

#### 10.3.2 Supported Bottle Size

The supported bottle size was limited to a cylindrical bottle with the diameter of 60 mm. This dimension was found on a bottle used at one of the visited hospitals in the market research phase. Since this bottle was a bulk product not available for retail, it was believed that bottles with similar dimensions could be found at other hospitals as well.

Dimensions of shower product bottles at a super market in southern Sweden were also examined prior to setting this restriction. Bottles with bigger dimensions were found, but the 60 mm diameter restriction allowed the majority of bottles in the store assortment to be used with the holder.

Supporting bottles with larger dimensions would mean a holder with larger dimensions. This would affect mobility when working around the shower trolley. Prototypes of different sizes were made in order to test how the dimensions of the holder affected the mobility, and to confirm that the 60 mm restriction allowed tolerable mobility restrictions. In addition, since the flexible front wall of the holder is designed to allow a sturdy fitting of smaller bottles, the negative angle of the front wall would have to be increased if bottles of larger dimensions were to be supported.

### 10.3.3 Fit for Bottles

Since the final holder concept is designed to contain and manage the shower bottles used during showering, it is important that these bottles are contained and held in place in a satisfactory way. The ability to comfortably place and remove bottles into and from the holder is also vital for the basic functionality.

During the earliest prototypes of what would become the final concept, bottles did not stand firm in the holder. This was due to the coarse nature of these prototypes and the undefined bottom of the holder; see Figure 10.3.



**Figure 10.3** An early sketch prototype of what would become the final concept

A more detailed prototype, made of bent sheet metal covered with a thin polyurethane sheet, was built. This prototype provided an improved bottom for the bottles to stand

on. The bottom was tilted in order to make the bottles lean towards the front wall of the holder, which is especially useful when a small bottle is used together with a bigger bottle (see Figure 10.4). The friction of the polyurethane material kept the bottles in place and prevented them from sliding, without compromising the ability to easily lift out bottles from the holder.



**Figure 10.4** A side view of the polyurethane-coated prototype showing the tilted bottom.

Since a plastic material was considered for this concept, another prototype was made by heat forming a plastic sheet. In this prototype the bottles did not stand firm; the low friction of the used plastic material caused the contained bottles to slide against the bottom of the holder. For this same reason the front wall of the holder did not keep the contained bottles in place, failing to prevent the bottles from falling over when the holder was moved. The prototype made of a heat formed plastic sheet can be seen in Figure 10.5.



**Figure 10.5** A prototype of what would become the final concept, made of a 2 mm thick plastic sheet. The prototype was made by heating up and forming the sheet.

Another issue with the plastic prototype was the fact that the function of the flexing front wall did not work when using multiple bottles of varied size. The wall flexed out due to the largest bottle it contained, which meant that smaller bottles were not held in place by the wall (see Figure 10.6).



**Figure 10.6** A picture of the plastic prototype, highlighting the problem of using the prototype with multiple bottles of different sizes.

Several modifications to the prototype were tested in order to address these issues. The solution which was considered to be the most promising meant attaching flexible tabs to the front wall, see Figure 10.7. Used together with the tilted bottom of the holder, this prevented bottles from sliding and falling sideways in the holder. Due to the flexibility of the tabs, bottles of varying size were able to stay in contact with the tabs and therefore benefit from the stabilization these provided.



**Figure 10.7** Functional prototype of flexible, separating tabs

In the more detailed prototypes of the concept, the top section of the front wall is protruding at an angle, in order to provide a surface for the thumb to press against when gripping the holder. This also allows for the front wall to flex out when bottles are placed in the holder (see Figure 10.8).



**Figure 10.8** The protruding top section of the front wall functions as a guide when bottles are placed in the holder, and allows for the front wall to flex.

In the final prototype this protruding section was divided into 2 parts, one with the angle allowing bottles to flex out the front wall, and one flat section for the thumb grip. The flexible material of the tabs and the grip only cover the flat part of the protruding section in order to allow bottles to slide across the angled surface. The function of the angled part of the protruding section can be seen in Figure 10.9.



**Figure 10.9** The function of the angled part of the protruding section, guiding bottles when they are placed in the holder and allowing for the front wall to flex.

The rounded corners where the tabs meet the thumb grip are designed to indicate the four sections of the holder constituted by the negative space between the tabs (see Figure 10.10), and highlight its intended use with bottles.



**Figure 10.10** Highlights of the negative space between the tabs which constitute the four sections of the holder.

### 10.3.4 Grip

The intended grip for holding the holder is shown in Figure 10.11. The thumb is placed on a protruding edge on the holder, while the rest of the fingers are supporting the weight from the holder by grasping the bottom. This grip allows the user to move the holder using only one hand.



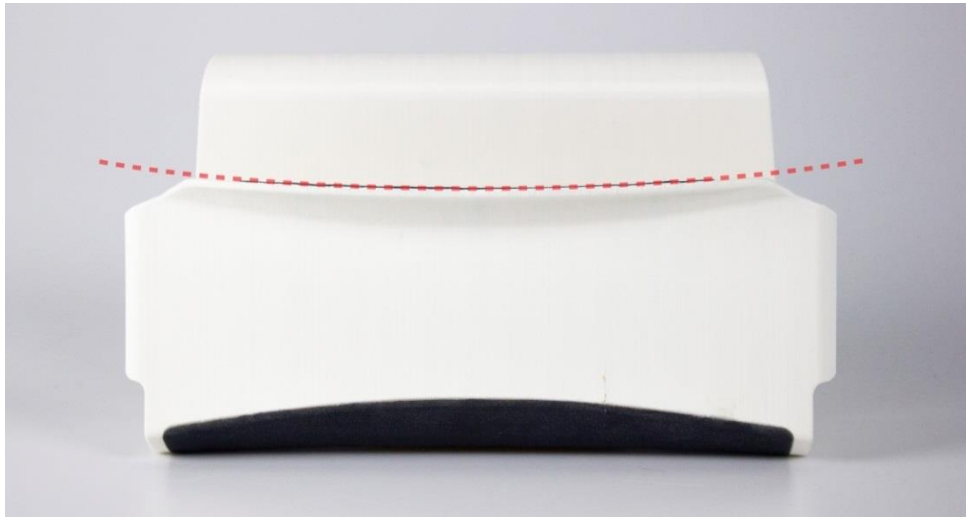
**Figure 10.11** The intended grip

This grip was refined during the iterations of prototyping; in the earliest prototypes of the final concept, no dedicated grip function was provided. In the more detailed and refined prototypes the upper edge of the front wall of the holder was bent out at an angle, which provided an edge for the thumb to press against, as well as a surface for the bottles to slide against when inserting them into the holder enabling the front wall to flex out. (see Section 10.3.3, Fit for Bottles)

In the final prototype, this protruding edge was divided into a flat section where the thumb can rest more comfortably, and an angled section which allows the bottles to flex out the front wall.

The flat section is slightly arched (highlighted in Figure 10.12) to further indicate and invite the use of the thumb against this surface.





**Figure 10.12** Arch of the flat section

Different height dimensions of the front wall were tested during prototyping. Due to the design of the holder, the height of the grip is decided by the height of the front wall. A compromise was found, which resulted in a front wall considered high enough to safely contain bottles and low enough to fit smaller hands.

On the final prototype, two grip surfaces were added. These are intended to be made from a thermoplastic elastomer, injection molded onto the holder body. The first grip surface is placed onto the protruding thumb surface, and the other is placed over the fillet at the bottom part of the holder. The grip surfaces can be seen in Figures 10.13 and 10.14.

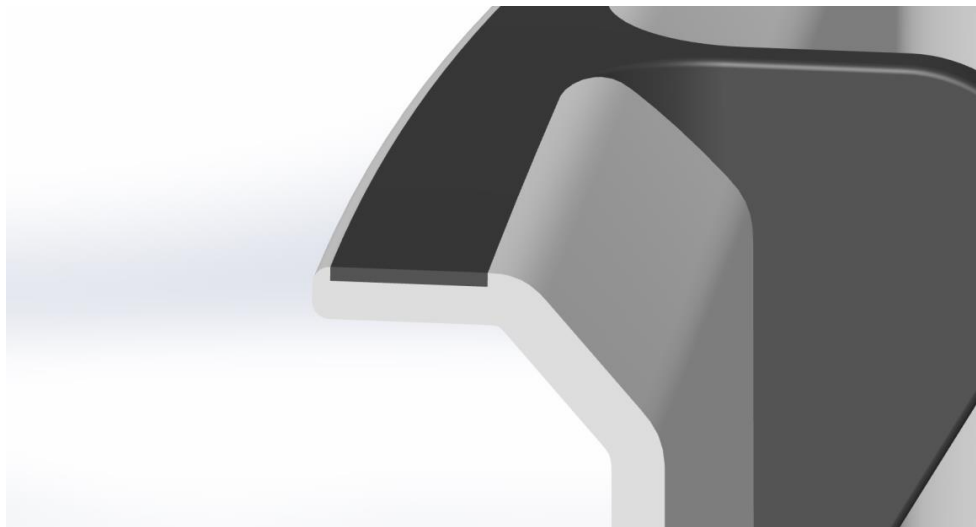


**Figure 10.13** The upper grip surface seen from a slightly elevated side view



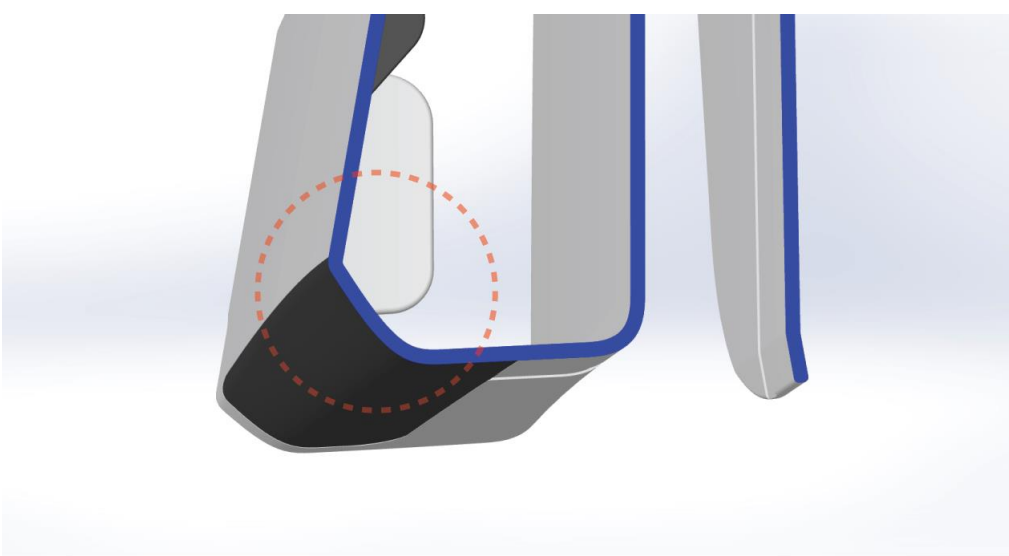
**Figure 10.14** The lower grip surface, seen from a bottom view

These grip surfaces are meant to provide an increased friction and a softer feel to the areas where the hand interact with the holder when holding it. The grip surfaces were also added to indicate the intended grip, and to inform the user that the holder can be held with one hand. The transition between the body of the holder and the grip surfaces are designed to prevent dirt accumulation (see Figure 10.15).



**Figure 10.15** A section view of the CAD model, showing the seamless transition between the grip surfaces and the body of the holder.

The filleted part at the bottom of the holder was added to the final prototype in order to provide a more comfortable grip for the fingers. The meeting of the front wall and the fillet surface is arched in order to further indicate the intended grip of the holder (see Figure 10.16).



**Figure 10.16** The arched filleted surface, indicating the intended grip

#### 10.3.5 Back Attachment Wall

The back of the holder is designed to be able to attach the holder on the Carevo handles. The dimensions of this part were chosen to allow this. The height of the back attachment wall is decided by the holes in the Carevo handles; with a sufficient height, the bottom of the back attachment wall reaches beyond the hole in the Carevo handle when the holder is attached (see Figure 10.17). A sufficient height of this wall also enables the holder to stand upright on a flat surface, as shown in Figure 10.18.

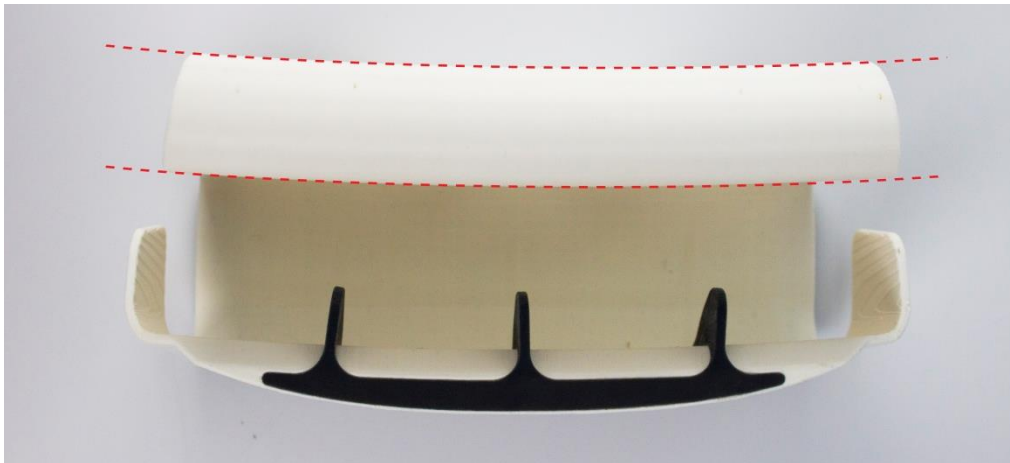


**Figure 10.17** The holder attached to the Carevo, showing the function of the back attachment wall.



**Figure 10.18** The holder standing upright on a flat surface

The final prototype is slightly arched along its length to visually match the curved Carevo handles (see Figure 10.19). The arched form is intended to clarify that the holder can be attached to the Carevo handles, as well as provide a better physical fit between the holder and the handles.



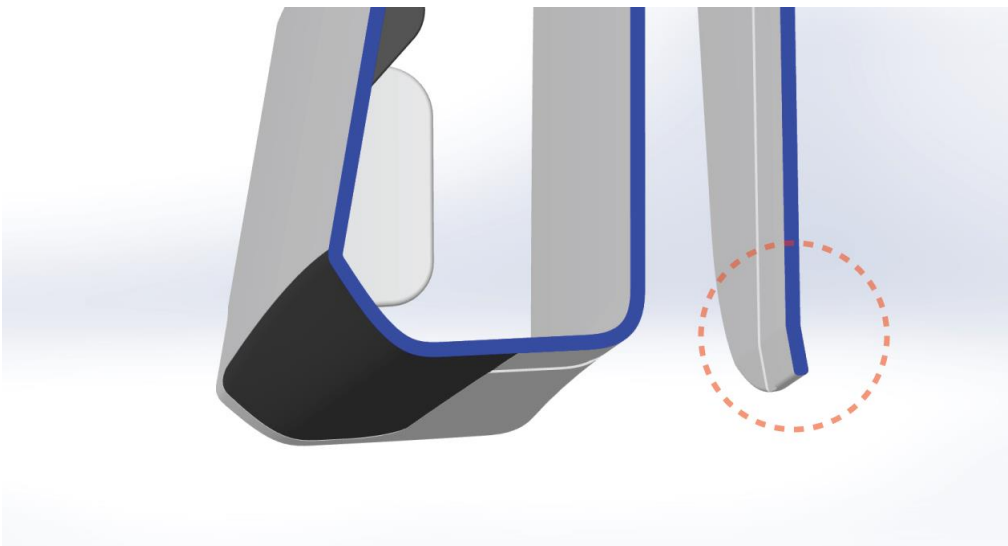
**Figure 10.19** Curvature of the holder seen from above

The shape of the back attachment wall, seen in Figure 10.20, is intended to clarify how the holder is attached to the handles. It is also intended to indicate a downwards motion and associate to the shape of a hook.



**Figure 10.20** A back view of the holder showing the shape of the back wall attachment

A slight protrusion of the lowest part of the back attachment was added to the final prototype in order to further visually indicate that the holder slides onto the Carevo handles (see Figure 10.21).



**Figure 10.21** A section view of the CAD model showing the slight protrusion of the lowest part of the back attachment

During testing of an earlier prototype of the chosen concept, it was noted that the experience of attaching the holder to the Carevo handles was unsatisfactory due to the bare plastic material of the holder sliding against the plastic material of the handles. With the intention to improve this experience, stripes meant to be made of a

thermoplastic elastomer material were added to the concept design at the inside of the back attachment, as seen in Figure 10.22.



**Figure 10.22** A bottom view of the CAD model, showing how thermoplastic elastomer stripes were intended to be placed.

This change was however never implemented in the final prototype due to a dimensional error, see Chapter 11.2.4.

### *10.3.6 Side Walls*

The side walls of the final prototype are included to prevent bottles from falling out of the holder. There are several reasons for the gap between the side walls and the adjacent walls:

- It allows the front wall of the holder to be flexible
- It allows water to flow out of the holder
- It is intended to facilitate cleaning of the holder due to less confined corners and improved access for the hand of the user

The reason for attaching the side walls to the front wall instead of the back wall is to prevent the edge of the side wall to protrude towards the user.

### *10.3.7 Water Outflow*

In order for water to freely flow out of the holder, the short sides of the holder are open. To prevent water from staying in the holder after showers, the bottom of the holder is slightly arched, see Figure 10.23.



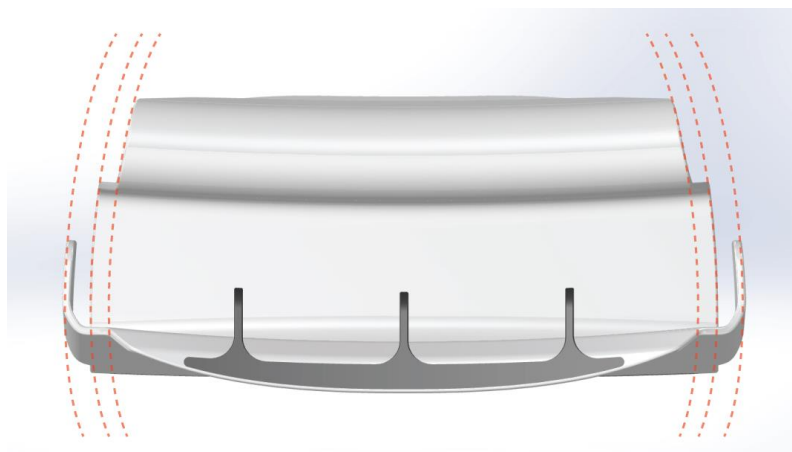
**Figure 10.23** The arched bottom of the holder guides water out through the open sides of the holder

### 10.3.8 Expression and Form

ArjoHuntleigh has established guidelines to be used in development regarding the design and ergonomics aspects of their products. These guidelines are intended to create coherence between developed products, and to make these products instantly recognizable as ArjoHuntleigh products. These guidelines were kept in mind during the detail design process. Additional advice regarding the design was given by the Carevo design and ergonomics team member.

The shape of the final prototype is largely decided by its functions. The room for aesthetic adjustments was limited, much due to the simple and distilled nature of the concept. Some aesthetic details which are not strictly decided by the intended functions of the holder are presented below.

**Arched sides of the holder**, as well as arched side walls (see Figure 10.24).



**Figure 10.24** The arched sides of the holder.

**Prominent curves along the front wall of the holder.** The meeting between the grip surface at the bottom of the holder and the front wall creates an arched curve. At the top of the front wall, the meeting with the protruding section creates two additional curves arched in the opposite direction. These curves are intended to break up the large surface of the front wall in order to give the holder a more characteristic expression (see Figure 10.25). These prominent curves are also meant to associate to the shape of the Carevo handles.



**Figure 10.25** The prominent curves along the front wall of the holder

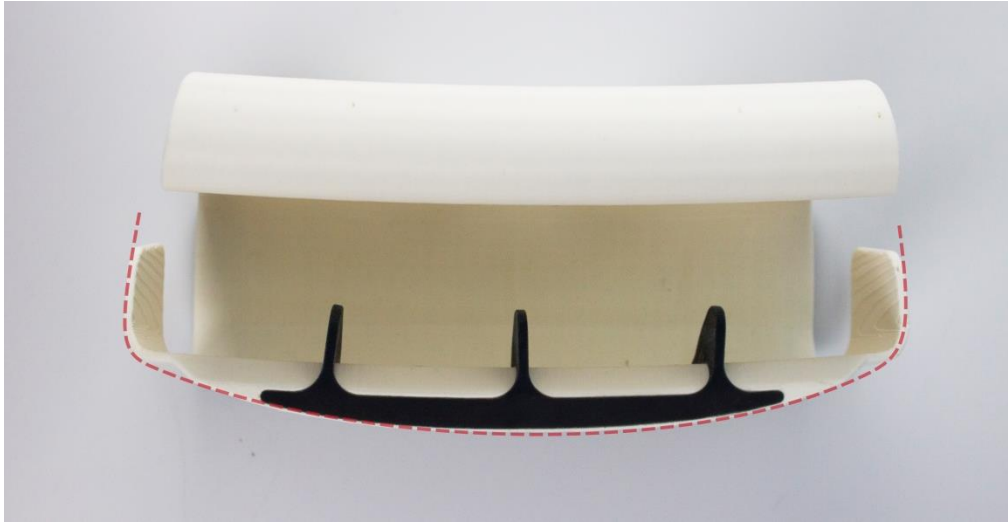
**The transition between the protruding front section and the side walls.** A slanted line, highlighted in Figure 10.26, connects the shape of the side walls to the protruding section and the front wall.



**Figure 10.26** The slanted lines marking the transition between protruding front section and the side walls

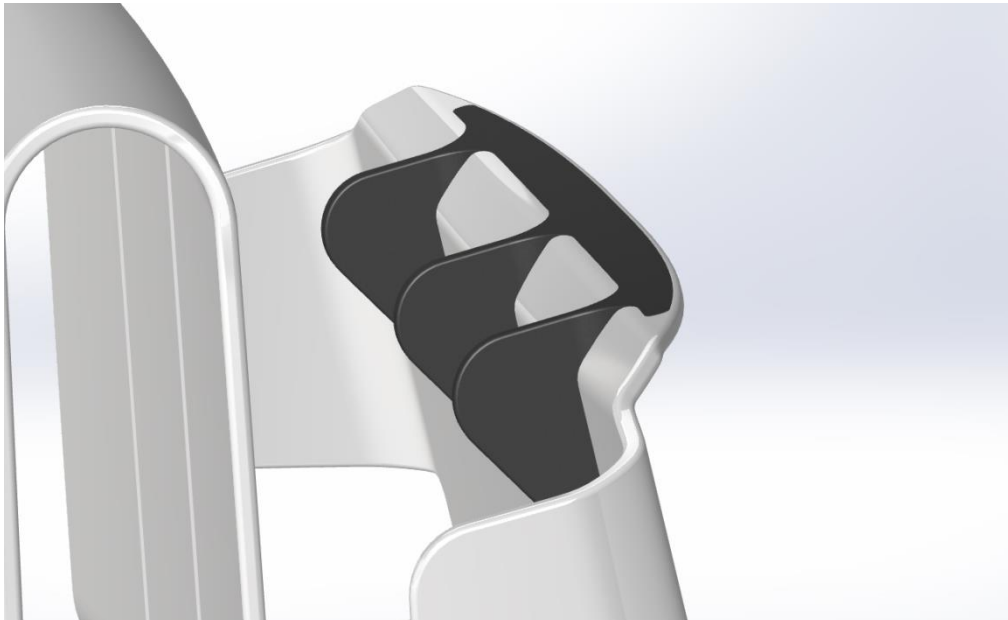


The arched transition of the side walls are meant to connect to the outer curve (highlighted in Figure 10.27) of the protruding grip section, to connect these two elements further.



**Figure 10.27** The arched transition connecting the side walls and the grip section

**The transition between the grip surface and the tabs.** The top surface of the thumb grip follows the top surface of the protruding flat section without any offset. Further in towards the flexible tabs, this surface starts to deviate from the surface of the protruding section, and constitutes the top edges of the tabs as shown in Figure 10.28.



**Figure 10.28** The transition between the grip surface and the separating tabs

The color of the final prototype is a result of the 3D printing method used. Some thoughts regarding the color of the holder was given during this phase of development, but due to the time limitations of the project, a final proposal on the colors was not made.

### 10.4 3D model and FDM Prototype

The final prototype was modeled in the CAD software Solidworks. During this modeling process changes were made along the way, and through iteration different details in the design were tested. When finished, the model was 3D printed into a physical model. The body of the holder was printed in ABS, Acrylonitrile Butadiene Styrene, using fused deposition modeling, and the parts intended to be overmolded in a flexible thermoplastic elastomer were printed in the material DM9885, using the PolyJet printing method. The DM9885 material is an acrylic-based photopolymer material which is used to reproduce the flexibility of thermoplastic elastomers.

### 10.5 Material

Due to time restrictions and prioritization of other areas in development such as detail design, the materials of the final concept was not thoroughly examined and decided. However, regardless of the exact material chosen, the final concept is designed to be made out of a thermoplastic. The main reasons for choosing a thermoplastic material are:

- **Mechanical properties** - The relatively high elasticity of thermoplastics allows the design with a flexible front wall to work properly without reaching plasticity which permanently deforms the holder. The final concept design relies on these properties. Also, the strength-to-weight ratio of the plastic material is desirable since it will make the handling of the holder less cumbersome.
- **Hygiene** - The surface of a plastic material can be manufactured to be smooth. This allows for easy cleaning and disinfection.
- **Manufacturing** - Using injection molding, plastic details can be manufactured relatively inexpensively.

Although no choice of thermoplastic was made, a considered alternative is ABS. This is due to the impact resistance, toughness, and creep resistance properties of the material. The choice of material will however require a more detailed study.

### 10.6 Finite Element Analysis

During the detail design of the final concept, two simple finite element analyses were performed in order to verify that the developed design would perform as intended. The main concern was regarding the flexible front wall of the holder. All finite element calculations were based on the material data of Acrylonitrile butadiene styrene (ABS), since this was the material in which the 3D printed prototype would be made. The finite element analyses were performed using Solidworks Simulation 2012.

### *10.6.1 Establishing desired amount of flexibility*

An earlier prototype of the final concept, made of a heat formed plastic sheet, had a wall thickness of 2 mm. The front wall was considered to be too flexible after testing the prototype. Also, this wall thickness was believed to give the prototype a fragile expression.

In order to decide the desired amount of flexibility provided by the front wall of the holder, rubber bands were attached around the prototype until the desired flexibility was reached. Weights were then hanged on the front wall of the holder while measuring the displacement of this wall. This meant that a desired relation between the force applied and the displacement of the front wall could be determined, which could be compared to the results of the finite element analyses.

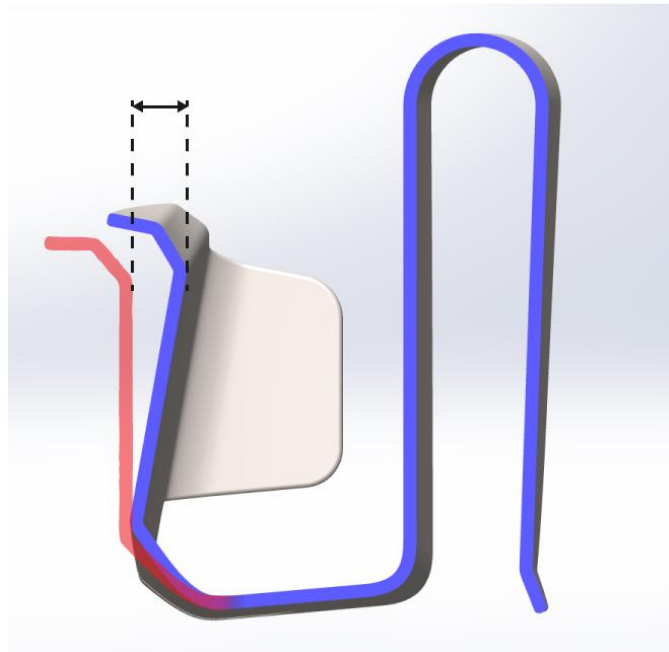
### *10.6.2 First Analysis*

The first analysis was conducted in order to approximate the flexibility of the front wall of the final concept design, and to check whether this flexibility was within tolerable deviation from the desired flexibility. The final design involved drastic changes in geometry compared to the previously mentioned prototype, such as an arched shape and a wall thickness of 3 mm. If the results of the analysis would indicate a severe deviation from the desired flexibility, the design would have to be changed in order for the prototype to be functional.

The model was analyzed when subjected to the same force as tested on the prototype when determining desired flexibility of the front wall. The displacement of the front wall was close to the displacement measured when establishing the desired amount of flexibility, which indicated that this design would allow a 3D printed model to be functional.

### *10.6.3 Second Analysis*

Another important criterion which decides the necessary amount of flexibility of the holder is the fact that it must withstand (i.e. no plastic deformation acceptable) being removed from the tools used in the injection molding process. The negative draft angle of the front wall means that it must be able to flex out 10 mm in order for this to be possible, as shown in Figure 10.29.



**Figure 10.29** The amount of flex needed in order for the holder to be removed from the tool in the molding process

In the second finite element analysis the force applied to the front wall was increased until the displacement of the wall was greater than the distance which would allow the holder to be removed from the manufacturing tools. The analysis indicated that this amount of displacement was possible without any plastic deformation in any part of the model.

#### 10.6.4 Conclusions

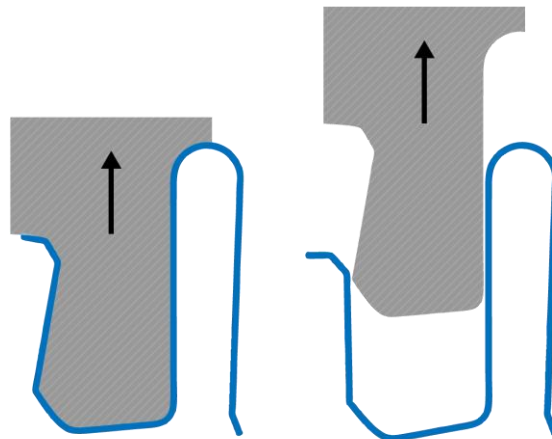
The mechanical properties of a 3D printed geometry will of course differ from that of corresponding injection molded geometry; even if the same plastic material is used, the mechanical properties of a FDM-printed part depend on factors such as layer bonding and layer orientation [15]. The results of these finite method analyses were however considered to be accurate enough in order to provide a coarse approximation of the behavior of the final prototype. Since all results were satisfying, no further structural design changes were considered necessary.

### 10.7 Manufacturing

The final concept was developed with simplicity in mind; it is a distilled version of other concepts stripped down to the bare essential functions required for holding bottles. The manufacturing aspect of the developed concepts had only been briefly considered during the iterations of the concept refinement phase of development. A thermoplastic material was considered for the final concept, and the considered manufacturing method was injection molding. However, the negative draft angle

between the front and “middle” wall of the holder is unsuitable to manufacture without modification. This is due to the fact that the produced part needs to be detached from the molding tool.

Several attempts to address this issue were made, but no solution was found which did not interfere with the functionality of the concept design. The function of this negative angle is to keep bottles in place regardless of their dimensions by using the flexibility of the plastic material. It was however discovered that these kind of negative draft angles, also called undercuts, sometimes are possible, provided that the produced geometry is able to flex over the molding tool (see Figure 10.30)



**Figure 10.30** How the ability to flex allows negative draft angles. The blue figure represents the section of the holder and the grey area represents the tool

The grip sections and the flexible tabs are intended to be injection molded onto the body of the holder, using insert overmolding. This means that the body of the holder is first injection molded in one tool, and then removed and inserted into a second tool. In the second tool the thermoplastic elastomer parts are molded onto the body. This further complicates the issue of removing the holder from the tools.

In order to confirm that the final concept was possible to manufacture, Katarina Elnér Haglund, Assistant Professor at Department of Design Sciences, Faculty of Engineering LTH, was contacted. With the additional advice of an experienced designer and a toolmaker, she could confirm that the concept is possible to make, but requires very advanced tools, and would be relatively expensive to manufacture.

Further investigation and refinement of the concept design is considered necessary before this concept is to be considered for manufacturing. This is further discussed in Chapter 12.



# 11 Final Concept Evaluation

*This chapter describes the process of testing and evaluating the final concept prototype.*

## 11.1 Purpose & Method

The purpose of the Concept Evaluation phase was to determine how well the final concept prototype satisfies the needs of the target users and how well it meets the necessary requirements formulated in the functional analysis in Chapter 7.4. The different functions of the concept prototype were evaluated in order to identify which functions live up to the expected performance and which ones need to be improved, modified or even removed.

First, the basic functions of the concept prototype were tested and evaluated, as well as the material properties and dimensions.

Once the basic features and functions of the prototype were verified to perform in a satisfactory way, the concept prototype was tested by the target users. One of each facility type was visited in order to see how well the concept would work in the different workflows. The results of the interviews were analyzed and used as suggestions for further improvements that can be made to the concept.

## 11.2 First Hand Tests and Evaluation

The first hand tests were conducted in order to evaluate how well the prototype behaved and functioned according to expectations.

### 11.2.1 Ability to Flex and Clamp

An important feature of the concept is the ability of the front wall to flex in order to keep contained bottles in place. The results when testing with bottles of different shapes and sizes were satisfying, as it had no problem to support bottles with a diameter of 60mm and under.

### 11.2.2 Bottle Action

The angled section which connects the front wall and the thumb plateau is intended to guide the bottles which are being placed in the holder. This feature was tested and performed well; the bottles could be placed in and removed from the holder without difficulties.

### 11.2.3 Separating Tabs

Due to the limitations in the assortments of materials that can be 3D printed, it was not possible to make the separating tabs act exactly as desired. The material used for the 3D printed separating tabs was soft and rubbery, but the tabs take a long time to flex back to their original state when bent down. However, the tabs still performed in a satisfactory way and proved to be very efficient in keeping bottles of different sizes in place in the holder simultaneously.

### *11.2.4 Back Attachment Wall*

Due to an error in the CAD-model of the prototype, the distance between the back wall and the back attachment was undersized on the 3D printed prototype. The prototype can still be hanged and placed on the handles of the Carevo, but due to this fit being too tight the results were not satisfying in this aspect, especially when the holder is empty.

Due to this dimensional error, the stripes of elastic material intended to be placed on the inside of the back attachment was not added to the final prototype. The experience when attaching the prototype was hence still considered to be unsatisfactory, as described in Chapter 10.3.5.

### *11.2.5 Attachment Locations on the Carevo*

The prototype was tested on the different intended attachment locations on the Carevo in order to determine how much it blocks other features. On the side supports it is inevitable to attach the holder without blocking a handle, but these supports are seldom used as handles during the actual showering, and three others are still unblocked. It is possible to attach the holder to the side supports without blocking the shower handle holder and the integrated control panels, and still have the holder accessible.

On the head-end, the intended placement blocks the control panel which could be problematic and should be avoided. On the foot-end however, it could be attached without hindering any other functions. When this was tested, the prototype did not perform in a satisfactory way. The attachment did not feel stable since the holder could tilt and glide on the two handles, see Figure 11.1





**Figure 11.1** When attached to the foot or head end, the holder could tilt and glide. The holder was meant to be stable by allowing the lower edge of the back attachment get support from the base of the handles.

In its current state, the back attachment also fits poorly on the handles located on the foot and head-end of the trolley. This is due to the fact that these handles have a different curvature and a slightly thicker shape than the handles located on the long sides of the trolley.

#### *11.2.6 Water Outflow*

The bottom of the prototype is slightly arched in order to lead water out through the open sides and prevent water from staying in the holder, making easier to dry and keep clean. This function was tested by exposing the prototype to water while being attached to different locations on the Carevo. The results of these tests were satisfying, very little water residue was left in the holder and not considered to be a problem.

#### *11.2.7 Grip*

The intended grip worked well when tested, the dimension between the thumb plateau and the bottom of the holder did not feel too big or too small. Using a softer material for the grip made the grip feel safer and more stable.

### **11.3 End-user tests and Evaluation**

The prototype was tested at two of the facilities (Elderly Care and Special Care) visited in the research phase, but with other interview subjects who were not familiar with the project. These two facilities both use an older version of the shower trolley. A hospital in Copenhagen, Denmark was also visited, where the Carevo is used on a daily basis.

During these evaluations the interview subjects were given the holder prototype and asked to simulate how the holder would be used in their current workflow while being

interviewed. Their behavior using the holder was observed and filmed (if possible). The aim of the field evaluations was to evaluate how well the concept works and how well its functions are understood.

### *11.3.1 Special Care Facility*

The interview subject seemed to have no problems understanding the main function of the holder. However, when prompted to show how the holder is thought to interact with the trolley, it was attached by clamping both the mattress and side support, facing inwards. When explained, the intended way to attach the holder was considered a better alternative since the objects are out of reach for the caretakers who might want to grab them, which could be unsafe.

The interview subject stated that the holder would be cleaned in the sink using dish soap and dish brush, to get the areas around the separating tabs as clean as possible. This was not considered a problem.

The holder was considered to be fairly useful in the used workflow and might improve safety in some cases. Since the shower articles are usually stored in the mattress next to the caretaker, caretaker contact is not considered to be a concern. However, it was stated that objects could float out of reach on occasion, due to the water inside the mattress. Also, it was stated that the caretaker could grab the shower articles for amusement purposes.

The interview subject stated that the holder could potentially be personal, if there was a way to mark it with a name tag or a photo. The caretaker could then identify which holder belongs to him/her. The personal holders could be stored in the cabinet together with the other belongings of the caretakers.

### *11.3.2 Elderly Care Facility*

The interview subjects had no problems understanding the functions of the holder and were positive to the concept. The holder was perceived as durable, safe and easy to handle. The intended grip was not understood, the interview subjects used two hands to grip and move the holder around. When asked to use the intended grip, it was considered to be comfortable. The interview subjects had no complaints on the size and capacity of the holder. Most importantly, the interview subject believed usage of the holder could improve safety and ergonomics of their workflow, due to not having to twist and turn away from the caretaker to fetch shower articles.

### *11.3.3 Hospital*

The main function of the holder was understood, however it was perceived to be an aid for the caretaker and not the caregiver. This could be explained by the fact that the ward is a rehabilitation ward, where the caretakers are encouraged to be active and take part of the shower. The intended interaction with the trolley was not understood, the holder was placed on the comfort handle, facing inwards. The holder was perceived as being hard to clean due to the separating tabs. However, it was stated that they would probably not clean it after usage since it was considered to be a basic requirement that the holder would be used as a personal holder.

In terms of perceived safety and durability, there were no complaints. The interview subject used the intended grip correctly, supporting it with the other hand. When asked to use only one hand, the fully loaded holder was stated to be perceived as on the verge of being too heavy.

The holder was not believed to save time or make the workflow safer, and the interview subject stated that there was no particular need for it in the workflow used. The bathroom was very tight and the sink was conveniently placed in a way that the caregiver did not have to break caretaker contact to fetch the shower articles on it. The holder was considered to impair the mobility of the caregiver around the trolley, and was therefore not considered as useful.

## **11.4 Conclusions**

This section summarizes the conclusions drawn from the end-user tests and evaluations.

### *11.4.1 Understanding the Functions and Intended Use*

The Main Function of the holder was clearly understood in all cases. However, the intended way of interacting with the trolley was not clearly understood at all evaluations. The holder was hanged on the mattress facing inwards on several occasions.

### *11.4.2 Understanding the Grip*

The intended grip received mixed responses. Some interview subjects used the intended grip, some not at all, and some in combination with another grip (using both hands). None of the interview subjects used a grip that felt unsafe or unreliable.

When asked to use the holder with the intended grip (one hand only) most of the subjects were positive to the ergonomics of the grip.

### *11.4.3 Ability to Stand on Flat Surface*

All of the interview subjects understood that the holder could be placed on a flat surface when not used on the trolley. This seems to be a useful and desired function since the holder is rather left in the bathroom than attached on one of the short sides of the trolley during transport.

### *11.4.4 Size and Capacity*

Most of the interview subjects were satisfied with the size and capacity of the holder. It was stated that the holder would probably not fit some of the bigger bottles that some of the caretakers owned, which was expected.

### *11.4.5 Separating tabs*

The separating tabs performed well in the field studies, the bottles were kept in place and prevented from tilting or moving around in the holder. As expected, they were

considered to be somewhat of a problem from a hygiene aspect. The function of the separating tabs was clearly understood.

### *11.4.6 Cleaning and Disinfection*

In regards of hygiene, there did not seem to be a consensus between the different interview subjects. The holder was regarded as both easy and difficult to clean, because of the separating tabs. When it comes to how carefully they would clean the holder it is believed that this has more to do with the routines of the respective facilities than the holder itself. Another important factor is if the holder is personal to the caretaker or not, since the need to clean and disinfect a personal holder is not necessarily required.

### *11.4.7 Safety and Durability*

In cases where the caregivers usually have to twist or turn around to fetch shower articles, the holder was more appreciated for its potential to make the workflow safer.

The holder was kept intact during the entire evaluation phase and was never dropped. Most of the interview subjects perceived the holder as safe and robust enough. This was also indicated by the way the interview subjects handled the prototype; the prototype was not handled with care. There were some concerns that smaller objects could fall out through the gaps on the sides of the holder.

### *11.4.8 Placement on the Carevo*

The locations on the trolley where the holder is intended to be placed were not clear. The holder was incorrectly placed on the Carevo/Concerto on several occasions, facing inwards and placed on the mattress and handle/railing simultaneously. Placing the holder on the short sides of the Carevo was not desired in any of the field studies.

### *11.4.9 Side Walls*

The advantages of leaving the sides on the holder open were understood, but there were some concerns that smaller objects could not be stored in the holder since they would fall out through the gaps on the sides. These concerns could indicate that the functionality regarding containment of smaller objects is desired, but also that the current design of the holder clearly indicates its limited support for this functionality. However, since the holder is mainly intended for use with bottles, this is not considered to be a major problem, but it could possibly make the holder to be perceived as less safe.

### *11.4.10 Aesthetics*

The aesthetics of the holder received no complaints, it was considered to be neutral and discrete which the interview subject seemed to consider a good quality. It was also stated that the holder looked durable and safe.

According to the Functional Analysis (see Chapter 7.4), it was stated as necessary that the holder expressed reliability and safety, which was considered to be achieved.

### **11.5 Product Compatibility**

During the final concept evaluation, only one of the three visited facilities used the Carevo shower trolley. During evaluations which were performed earlier in the concept development phase, it was discovered that the smaller holder concept worked satisfactory with the older version of the ArjoHuntleigh shower trolley, Concerto. It was even considered to be better adapted to the Concerto than the Carevo. This backward compatibility was intentionally retained during the concept refinement process, and during the final concept evaluation it was confirmed that the final concept design also worked well with the Concerto.

Compatibility with other ArjoHuntleigh shower related products, which include bathing solutions and shower chairs, were examined throughout the development. The physical restrictions implied by these products were different from those of the Carevo. It was not considered as a requirement for the holder to provide compatibility with these products, partly due to the fact that some of these products already provide a solution for handling of smaller objects. However, if a concept could be modified to allow this compatibility without sacrificing other functionality, it was to be considered. This was not believed to be the case with the final concept.



## 12 Further Development

*In this chapter suggestions for further development of the final concept are given.*

### 12.1 Suggestions for Further Development

Based on the evaluations of the final concept, conclusions were drawn regarding the areas of the concept which are in need of improvement and which functions could be further developed.

#### 12.1.1 Attachment Understanding

Although the holder is arched to match the curvature of the handles of the Carevo when placed outwards, this intended way of attaching the holder to the shower trolley was not always understood during the evaluations. There is room for improvement in the area of communicating how and where the holder is intended to be attached, for instance by modifying the looks of the back attachment. However, as long as the placement of the holder does not imply a risk for the caretaker or the caregiver, this is not seen as a big concern.

#### 12.1.2 Attachment Design

Due to the dimensional error of the back attachment of the prototype, the intended back attachment could not be properly evaluated. The intended dimension must be tested and further evaluated. This also applies to the use of the elastomer stripes intended to be placed at the inside of the back attachment. On the head- and foot-ends, the width of the back attachment should be modified to better fit between the two supports and not tilt. If the lower edge of the back attachment can get support from the basis of the handles, the holder would not be able to tilt.

#### 12.1.3 Manufacturing

The aspect where the final concept needs most improvement is that of producibility. At the moment the holder is very difficult and expensive to manufacture through injection molding, mostly because of the separating tabs. Without the separating tabs the holder would be easier to manufacture in spite of the negative draft angle, but it would result in a holder that feels less stable due to bottles moving around and falling over when moving the holder around. This could be resolved by a redesign of the tabs or using another method of manufacturing. A cost analysis should be made in order to determine the most viable alternative.

### *12.1.4 Personal Holder*

The idea of having a personal holder for each caretaker is advantageous for both the company, since more holders would be sold, and the buyers, since this would save time by reducing preparations when showering caretakers. By modifying the design of the holder this could be further encouraged. For instance, the holder could have a slot for name tags or pictures that is waterproof, an idea which received a positive response when suggested at the special care facility visited during the concept evaluation. However, this feature would be redundant for some target facilities and probably perceived as a negative quality.

### *12.1.5 Supported Objects*

The final concept is designed to assist with the handling of shampoo bottles. If functionality which enables the holder to support other objects used during the shower process can be added without compromising the existing functions, this would be desirable. However, a lot of effort was put into the development of such functionality without finding a viable solution. This would perhaps require a broader redesign.

The final concept does not assist in the handling of clothes, but this does not exclude the possibility of developing a separate product providing this functionality, as discussed in chapter 9.3.1. If such a solution is developed, it is important that the two holders are compatible with each other. Further research at elderly care facilities with central bathrooms and special care facilities would be recommended since no facility visited during the research in this project had the specific need for this functionality.

### *12.1.6 Supported Bottle Size*

The method used when choosing the supported bottle size of the developed holder was a result of limited time resources. A more thorough investigation of the sizes of the bottles used within different care facilities would provide more motivation for this choice.

### *12.1.7 Cleanability*

The transitions between the parts made of elastomer materials and the body of the holder are intended to be seamless (see Figure 10.15) in order to prevent dirt from accumulating. This must be tested and verified. When choosing the specific elastomer material to be used, the friction properties and the tendency to collect dirt of the material must be taken into account.

### *12.1.8 Aesthetics*

Even though the colors to be used in the design of the holder were never determined, there are some suggestions regarding this matter. The holder should consist of two colors, one basic neutral color for the base of the holder and one accent color for the elastomer parts (grip surfaces and separating tabs). The colors should be taken from the ArjoHuntleigh predefined color palette.



### *12.1.9 Grip*

The height of the grip was based on estimations regarding hand sizes. None of the interview subjects during the evaluation had any complaints about the grip being oversized. However, the height of the grip should be reviewed against relevant ergonomic data, in order to make sure that the grip is adapted for the Carevo user population.



## 13 Discussion

*In this chapter, the project methodology and the results of the project are discussed and reflected upon.*

### 13.1 Target Specifications

It can be argued that a more sophisticated system for handling requirements of the product should have been used. In the methodology described in *Product Design and Development* [9], all requirements and functions are translated into detailed target specifications which are clearly defined and measurable. The development process used by ArjoHuntleigh also includes this step, and describes these specifications in the used Traceability Matrix (see Chapter 7.3) These specifications are useful when evaluating the developed concepts; instead of having to interpret ambiguously described requirements or desired functions, the clear and measurable target specifications are evaluated with a predefined method.

It was decided that such target specifications would not be used in this project since they were believed to depend largely on how the developed concept would look like and function; the product developed in this project was not based on an earlier product solution, and restrictions considered unnecessary were consciously avoided. Also, these detailed target specifications were believed to overshadow some of the more subtle functions and requirements which are harder to quantify.

The inclusion of detailed target specifications might have been useful during certain areas of development. As an example, the requirements relating to the cleanability and hygiene of the developed concept caused for many discussions and some uncertainty. If clearly defined specifications would have been set regarding these requirements, either at the beginning of development or at a later stage, the evaluation of the concepts would perhaps have been more conclusive.

### 13.2 Research

The field research that was conducted in this project was a significant part of the project both regarding time and effort. While the research provided many insights, some factors have likely affected the quality and usefulness of the results:

**Experience** - The resulting conclusions from the research data is likely different from the conclusions which would have been made from more experienced ethnographic researchers.

**Observer influence** - The presence of the observers/interviewers were likely to influence the behavior of the observed/interview subjects. This is believed to have affected the results of the observation to a higher degree than the contextual interviews.

**No Carevo** - Other shower trolleys than the Carevo were used in the visited care facilities. While not considered as a cause for relevant differences in behavior and workflow, some valuable information specific to Carevo usage might have been overlooked.

**No central bathrooms** - None of the visited elderly care facilities used central bathrooms for showering caretakers. All information gathered regarding the behavior and used workflow at elderly care facilities with central bathrooms was provided by the brief telephone interviews conducted. When analyzing the needs and workflows of these facilities, many assumptions were made. This lack of research evidence served as motivation for excluding the development of a holder which assisted with handling and transportation of clothes, since the need for this functionality was mainly associated with central bathrooms within elderly care and special care.

The research phase was more time consuming than originally expected. The problem statement describes a very specific problem in the healthcare environment. Given that the authors had no relevant experience from these healthcare environments prior to the project, the extra amount of time spent on the research is still considered as valuable. This allowed for a greater understanding of the specific problem and the surrounding factors which has been useful during the whole development process.

### **13.3 Delimitations in development**

Decisions about delimitations in the concept generation and refinement phases were made relatively late in the project. A lot of time was spent on trying to generate good concepts in all three concept categories mentioned in Chapter 8.5. This had a direct impact on the last phases of the project, since both the research phase and the concept generation and refinement phases were more time consuming than originally planned for.

In order to distribute the time more evenly, delimitations could have been done as early as in the concept generation phase. Most of the research data was gathered from Sweden, where the need for clothing storage and/or transportation was not common. Therefore it would have been reasonable to make the delimitation to focus development on the “holder for easy access” from the beginning of the concept generation phase. More time could then have been spent on detail design, concept evaluation, material choice, cost analysis and manufacturing aspects.

### **13.4 Concept Evaluation**

Only one facility visited during the final concept evaluation was using the Carevo shower trolley. This makes the results of the evaluation less conclusive; one thing that has been seen at care facilities during this project is that their workflow and needs look very different. Further evaluation at care facilities which use the Carevo would

lead to more insight regarding the performance and quality of the final concept design.

### **13.5 Caretaker Dignity**

Throughout the development of the Carevo accessory, the intention was to develop a product which both assist caregivers in their daily work and provide a more dignified care for caretakers. However, this is a big responsibility for a small accessory. The main way in which the accessory is intended to improve the dignity of the caretakers is by reducing the distractions which the use of unorganized object might cause, thus providing a better contact between the caretaker and caregiver. During an interview it was stated that worried caretakers could be calmed by physical contact; the caregiver laid a hand on the caretaker in order to convey calmness and security. It is the hope of the authors that the developed holder could mean the difference between that hand being free or occupied.



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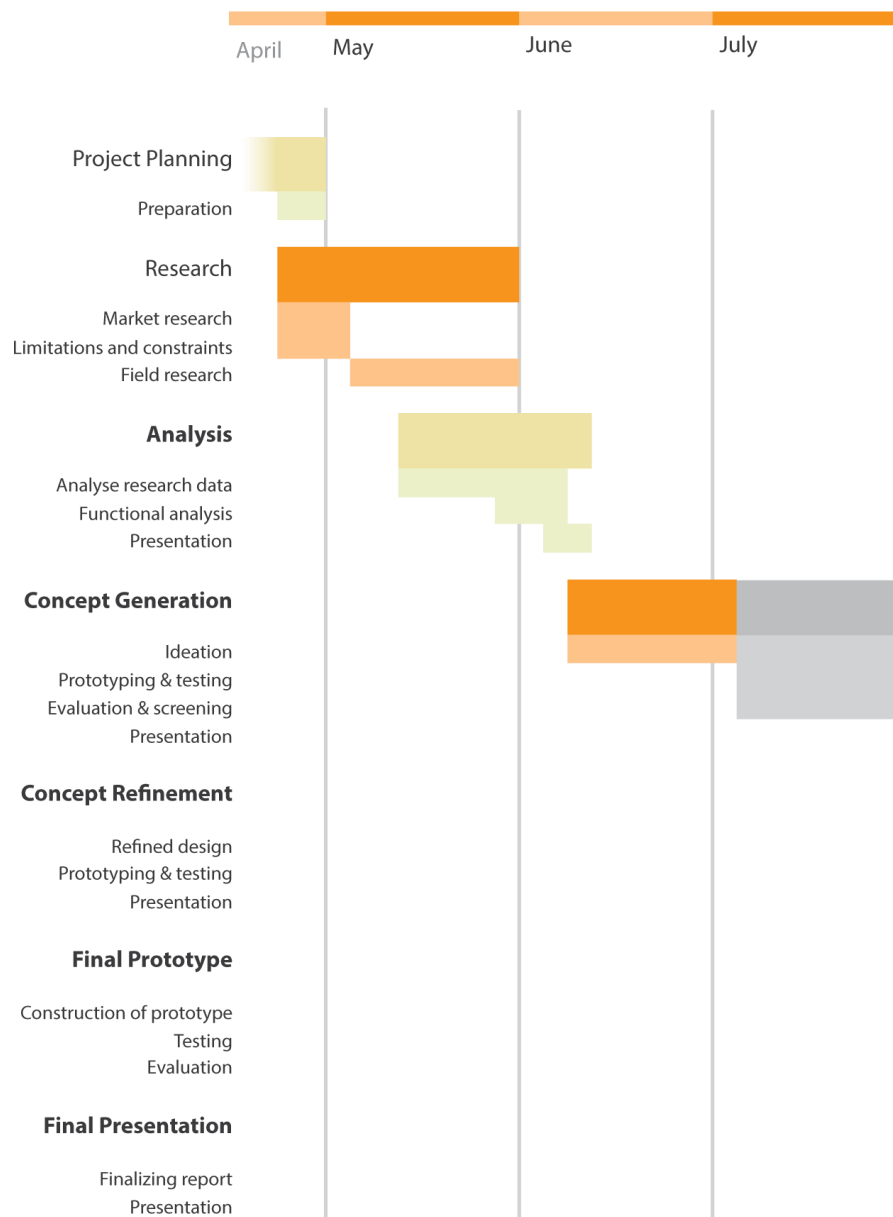
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## Appendix A: GANTT-schedule of Project Plan

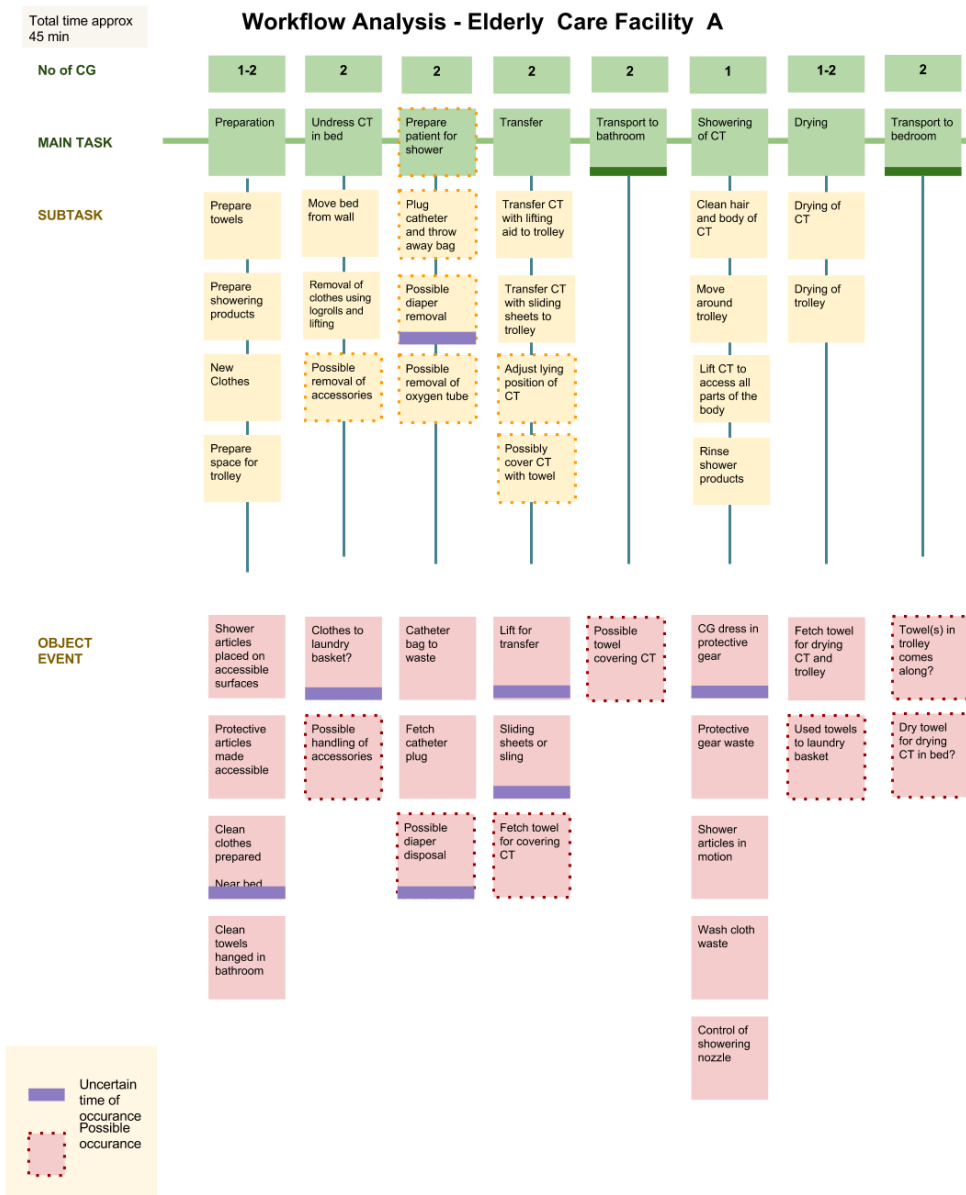


Appendix A: GANTT-schedule of Project Plan

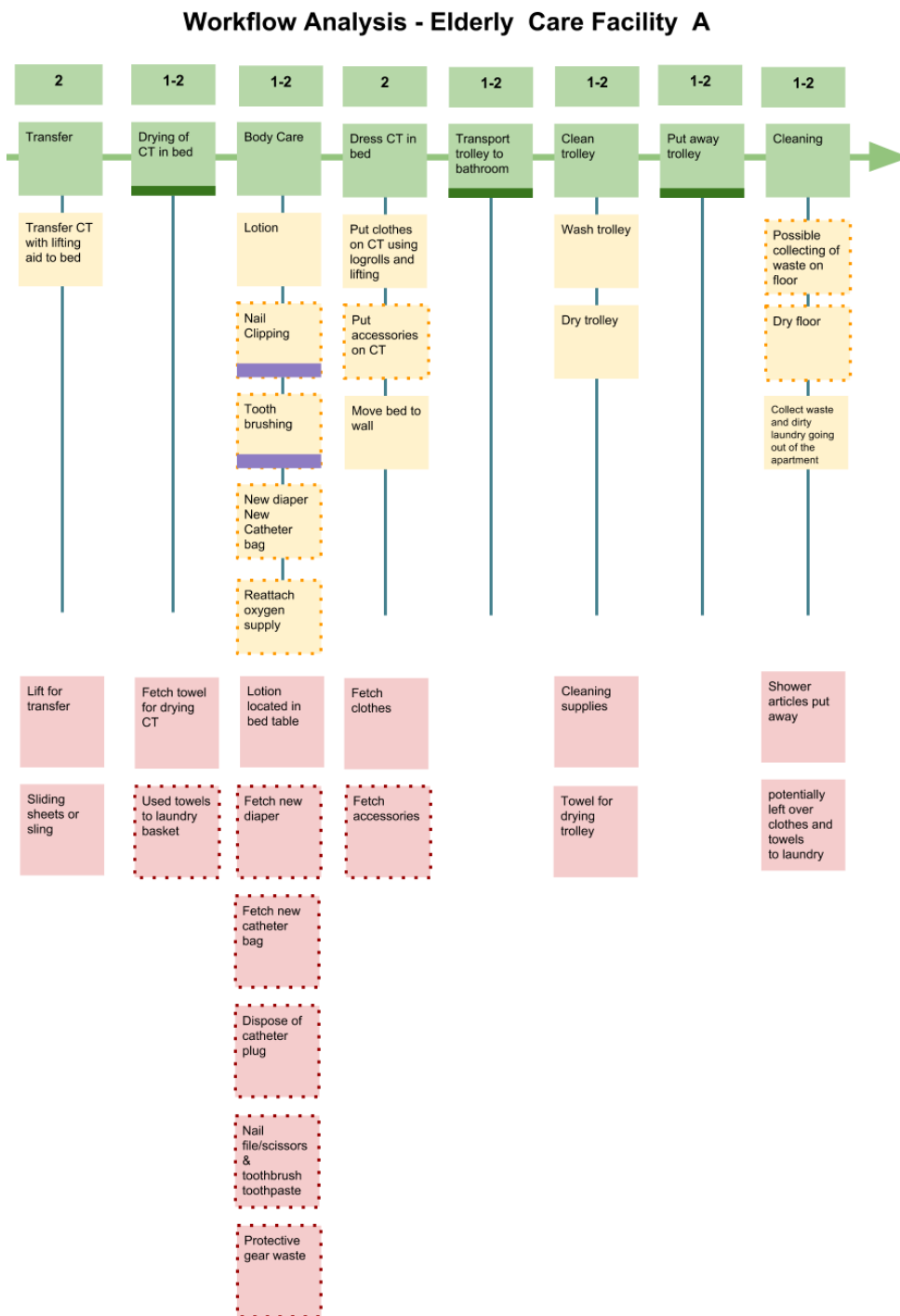
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# Appendix B: Example of Workflow Flowchart



Appendix B: Example of Workflow Flowchart



## Appendix C: Functional Analysis

<b>MAIN FUNCTION</b>		
Facilitate handling of shower articles	MF	
<b>CARETAKER CONTACT</b>		
Improve CT contact	D	
Reduce occurrences where CG leave the trolley	D	
Minimize risk of dropping objects	D	
Facilitate physical contact with patient	D	
Minimize risk of distractions	D	
<b>WORKFLOW</b>		
<b>Allow easy cleaning and disinfection</b>	<b>N</b>	
Simplify workflow	D	
Personal HFB	D	
Enable more effective work flow	D	
Reduce steps of preparation required before shower	D	
Collect and organize objects	D	
Organize clothes	D	
Organize personal (shower-related) belongings	D	
Encourage use of trolley	D	
& SAF.	Minimize water on floor	D
<b>ASSISTANCE</b>		
<b>Assist CG when showering patient alone</b>	<b>N</b>	
Assist during shower with multiple caregivers	D	
Assist with handling of protective gear	D	
Assist in handling and transportation of clothes	D	
Assist in handling of critical medical equipment	D	
Assist in handling of oxygen tank	D	
Assist in handling of soaked towels	D	
Assist in handling of towels	D	
Assist with dirty laundry	D	
Assist with handling of diapers	D	
Assist with handling of sliding sheets	D	
Assist with waste handling	D	
Assist during "trapped" working positions	D	
Assist when trolley is used as nursing table	D/U	

## Appendix C: Functional Analysis

---

Facilitate dressing/undressing of patient in trolley	D
Facilitate use of critical medical equipment during shower	D

### **FLEXIBILITY**

---

<b>Be flexible</b>	<b>N</b>
<b>Allow usage by multiple caregivers</b>	<b>N</b>
Be compatible with various workflows	D
Enable to adjust working position	D/N
Practical storage (of product itself)	D/N
Facilitate handling of injured/sensitive body parts	D
Be compatible with various shower articles	D
Be compatible with various environments	D
Be compatible with all caregivers	D
Be compatible with all patients	D
<b>Able to be used without trolley</b>	<b>D</b>

### **SAFETY**

---

Allow single CG to keep patient contact during shower	D
Prevent harm to patient	D
Allow safer workflow	D
Reduce risk of infection	D
Minimize water on floor	D
Keep certain objects out of reach for patient	D

### **CARETAKER EXPERIENCE**

---

Add value to shower for patient	D
Allow freedom of choice for patient	D
Allow patient to feel clean and hygienic	D
Preserve patient integrity	D
Reduce fear	D
Add to patient's feeling of independence	D
Add to patient's feeling of safety	D
Reduce patient discomfort	D
Reduce patient's feeling of being exposed	D
Encourage CT involvement	D
Prevent patient from feeling cold	D
Keep certain objects out of sight for patient	D
Prevent handling of items near CT's head	D

& CG	Reduce stress	D
& SAF.	Allow single CG to keep patient contact during shower	D
& SAF.	Prevent harm to patient	D
& CG	Improve social atmosphere	D

### CAREGIVER EXPERIENCE

---

Reduce stress	D
Improve social atmosphere	D

### CAREGIVER ERGONOMY

---

Enable ergonomical access to objects	N
Save CG from exhaustion	D
Enable ergonomical workflow	D

### EXPRESSION

---

<b>Express feeling of reliability</b>	<b>N</b>
<b>Express and convey feeling of safety</b>	<b>N</b>
Express cleanliness	D
Express durability	D
Express functions clearly	D
(If used as furniture) Be aesthetically pleasing in context	D

### OBJECT ACCESS

---

	Allow access to objects with one hand	N
	Provide necessary items within reach	N
	Enable easy access to objects	D
	Enable easy access to towels	D
	Assist in finding objects	D
	Provide necessary items within reach for all CG's	D
& WF	Collect and organize objects	D
	Facilitate use of multiple objects simultaneously	D/N
	Offer working surface	D
	Assist during bodycare in trolley	D
	Assist during drying of patient	D

## Appendix C: Functional Analysis

---

Assist in dressing/undressing patient D

### **OBJECT STORAGE**

---

Offer storage space for miscellaneous objects D  
Practical storage of catheter during shower D  
Temporarily store towels D  
Keep stored objects clean D  
Keep toothbrush hygienic D  
Keep towels clean D  
Able to store bodycare products D  
  
Allow storage and organization of hygienic/bodycare items at all times D  
Serve as temporary laundry basket D  
Temporarily store clothes D  
Temporarily store medical equipment D  
Allow storage of individual (shower-related) belongings D  
Allow storage of cleaning and disinfection products D  
Temporary storage of waste D  
Provide temporarily storage of CG's belongings D/U  
  
Enable transportation of medical equipment with trolley D  
Enable transportation of oxygen tank with trolley D  
Enable transportation of towels with trolley D  
Allow transportation of catheter with trolley D  
Enable handling and transportation of objects which are in need of disinfection D/U  
  
Enable hanging of objects D

### **WATER**

---

Protect clothes from moist/water D  
Protect relevant objects from water D  
Protect stored objects from moist/water D  
Protect critical medical equipment from moist/water D  
Enable control over water D  
Able to dry by itself D  
Keep water within bathroom D