Redesign of the reading machine
‘MagniLink Voice’

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Summery

This report describes a thesis assignment which is realised by two students from the Linnaeus University. The students come from the Netherlands but do the last year of their bachelor Mechanical Engineering in Sweden through an exchange project. The assignment is about redesigning a reading machine called Magnilink Voice made by LVI international. This device consists basically of a camera, a mother board, a few buttons, two speakers and a battery. The user can take a picture of the text which is in front of the device and by using software the device will start reading the text. The former model was designed in 2012 and has been selling since then. With the experience of present product and customer feedback the company desires to make a new design.

The problem formulation for this project is; ‘How can the selling amount be increased by making the device more portable and lighter’. This results in the purpose; ‘Develop a new device by a redesign in order to reduce the weight and make it more portable in a cost effective way’. The students wrote a custom made design process and based on this together with the empirical findings the design process has been realised.

The design process is divided into four paragraphs. In the first paragraph product objectives are made using the company’s requirements and customer feedback. After this the product objectives are translated to technical requirements. The product objectives are ranked by importance. The three most important product objectives are:

- Make a product which is easy to use
- Make a product with a reliable result
- Make a product which is appealing for the user

In the second paragraph a morphological chart is used to create different working structures and structure variations. Every time working structures or structure variations are made, they will be ranked and decided which to continue with. In the third paragraph the focus is more on the function of specific parts. Decisions of which components are going to be used in this paragraph as well. In the fourth paragraph specific assemblies as the control panel and camera arm are tested by making a prototype.

The most important change in the new design is that it is much more portable and that it is now possible to scan A3 formats. Also some parts have been changed. The most significant changes are:

- A new 8MP USB 3.0 camera
- A new motherboard (21268hw-hb-pcba)

All the selected components are placed in a squared shaped box of 100x220x250mm. The components are not connected to each other yet but they will fit in the box.
Abstract

A reading machine from LVI which can scan and read a text for visual impaired people needed a redesign to stay competitive. This redesign is done by two students. The students made a specialized method to execute the redesign. They found out that the focus of the redesign should lay on: easy to use, reliable result and appealing for the user. With this taken in consideration the students achieved to design a more competitive reading machine. Prototypes where made for a new camera arm (which goes high enough to scan A3 format) and a new control panel. The students gave a recommendation how to continue with the project from now on.

Keywords: Redesign Reading Machine LVI MagniLink Voice DFX Prototyping
Preface

In this report the whole redesign process of the MagniLink Voice from LVI is presented. The redesign is done because the product needs to be updated to stay competitive on the market. The project is executed by Evert Everts and Mark Ellens as their degree project in the final year a bachelor of Mechanical Engineering. They are studying at Linnaeus University in Växjö through an exchange program with Windesheim University of Applied Science in the Netherlands.

Supervising is done by Henrik Blomdahl for LVI and by Valentina Haralanova for Linnaeus University. Samir Khoshaba will examine the project and be responsible for the educational quality.

The authors would like to thank all the people involved with the project at LVI and especially Henrik Blomdahl for all his time to give advices. His knowledge and positive attitude really helped to finish the project successful. Also great thanks to Valentina Haralanova and Samir Khoshaba for their feedback and support during the project.

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1. Introduction

In this chapter the problem is described in a clear and achievable way. Starting with the background of the problem, where the problem is described in a wide view and shows the context of the problem. After that the problem discussion follows, here is shown which problems are addressed. Than the clear problem formulation and the purpose will be shown. The problem formulation is described in such a way so the main goal is clear. After that the relevance of the project is mentioned. As last the delimitations for this project are shown.

1.1 Background

A company who makes products for visually impaired people started to make a product for extremely visually impaired people and completely blind people in 2013. This product is a reading machine (Figure 1) which can read a paper by taking a picture. The reading machine consists on basically a camera, a mother board, a few buttons and a battery. The strength of this product is that the operation system is very simple to use because of its few buttons.

![Existing reading machine](image1.png)

The company has collected feedback from customers and distributors because the product is already on the market for a couple of years. Customers are complaining about the mobility of the device, this because they think it is too big and too heavy. Customers are also complaining about the handle where the camera is built in. Even though these are the biggest complains, some smaller complains should be treated as well. When these points will be improved by a redesign the probability is high that the device should be sold more. This gives the company more revenues and a better position on the market.

1.2 Problem discussion

If the device would be smaller and lighter customers will be more satisfied with it, this leads to a more competitive product. Important is that the operation of the system stays at least as easy as it is with the old model. By making the device smaller it is easier for customers to put it in a (normal) bag and take it along on travels.

While redesigning it is important to keep in mind that the main goal is to increase the selling amount of the device. To achieve this the device should be made lighter and smaller to make a more competitive product to satisfy the customers.

With a more competitive product the company will sell more units and will have higher revenues. This is a positive direction for the company.

1.3 Problem formulation

How can the selling amount be increased by making the device more portable and lighter.
1.4 Purpose
The purpose of the project is: ‘Develop a new device by re-designing it in order to reduce the weight and make it more portable in a cost effective way’.

To realize this, a method called ‘Design for (X)’ will be used, where X stands for manufacturing, assembly and environment. This method will be combined with other methods to optimize the redesign process. The redesign will be done by using a systematic approach.

1.5 Relevance
Using a systematic approach to do the redesign will have a positive impact on the result (Otto, 1998). By listening to the customers’ feedback, empathy will be gained. When the device will be improved according the customers’ feedback and possibilities of today technology the device will be more competitive. Surveys show that visual impaired people would like to read books and newspapers (Harrison, 2004). So there is a demand for reading machines.

Harrison (2004) proved that a redesign could have a positive impact on a product for visual impaired people. She found out that a redesign on an existing reading machine improved the pleasurability. This makes it more likely that a redesign will have a positive impact on the existing product.

1.6 Delimitations
The project consists of two periods. In the first period the students will also follow a course beside the project. After this is finished, the complete focus will be on the project. Because a limited time is given, it is important to create project boundaries to ensure the main purpose of the project will be fulfilled.

Activities to accomplish
The following activities must be achieved, these activities are realistic according the time frame

- Making a design which is approved by the supervisor from LVI
- Making a prototype from at least the mechanical parts. So that all parts are placed in the prototype, including the electronic parts.

Extra activities
The following activities can be done when there is still time left after the activities mentioned above.

- Making a working prototype

Successful finish of the project
The project is successful finished if the students can show that they reached the goals mentioned above. The rating of this is done by the supervisor from LVI and the supervisor from the Linnaeus University.
2. Method

In this chapter is demonstrated that the designers have the ability of critically and systematically use of knowledge and models. This proves that the reliability and validity of the used theories are sufficient.

There are many different maps, cycles or models of the design process. These models differ in the extensiveness of the explanation. There are for example simple models with just four or five stages or more extensive models like French’s model which build up much more detailed (Cross, 2000). French suggests that:

The analysis of the problem is a small but important part of the overall process.

Many models of the design process are focused on generating a solution concept early in the process. These types of design processes are called heuristic: using previous experience, general guidelines and rules that lead in what the designers hope to be the right direction, but with no absolute guarantee of success.

Other models are more algorithmic. These models are usually systematic procedures to follow, and often regarded as providing a particular design methodology. Often these models describe a lot more about the analytical work which has to be done before generating solution concepts. The intention of this is to try to ensure that the designers totally understand the design problem. This to prevent that excellent solutions are created for the wrong problem. Algorithmic models suggest a basic structure to the design process of analysis-synthesis-evaluation. These three stages where defined by Jones (Cross, 2000). Examples of algorithmic models which uses the basic structure are Archer’s Design Process and the Embodiment steps of Pahl and Beitz (Cross, 2000).

The words ‘a systems approach’ or ‘a systematic approach’ are often used in titles of product development books. The words ‘a systems approach’ means that you need to look at all aspects of the product in the context of its use within a larger system. A system is basically a collection of object in relation to each other (Jackson, 2012). A system is controlled by a structure. The structure sets the boundaries for the transformation of the system (Roozenburg, 1991). A used technique in ‘a systems approach’ is ‘diving and surfacing’. Diving indicates to the detailed view of a system. Surfacing indicates to see the detailed view from a wider angle to a more general view. The difference between system designers and non-system designers is made in the ability to surface (Jackson, 2012).

Designing according a methodology seems sufficient, but simply following the steps in formal logic of a methodology is not sufficient, not by far. This is because designers have to use their own logics and reasoning at the key moments. But all the actions, even in daily life, would get stuck if we stop following standards and methods (Roozenburg, 1991).

A method is the consciously applied structure of an action process. A method could be as vague as possible as long as it: proceeding, rational, universal and recognizable. Methods can be built from a number of rules. Rules can be reliable as well as unreliable. Reliable rules are always based on knowledge. Important is that methods are not based on authority, tradition or intuition. Although it is scientifically proven that design methods work, it requires a sensible approach, especially in situations where the firm has a lake of experience (Roozenburg, 1991).
3. Theory

There are multiple innovative design methods. In this project different methods are combined to get a specialized method. This chapter describes which methods are chosen and why these methods are chosen for this project. Also recent scientific articles are used to have an up-to-date method. The method is divided in four steps. The theoretical explanation is also divided in four phases in this chapter.

The method used for this project is merged from different methods. These methods are chosen based on experience and on applicability on this project. Engineering Design from Pahl (2007) is used because of the clear steps in embodiment design. Getting Design Right from Jackson (2012) is used because of the total systematic product development cycle, where every phase is extensive explained. This makes it easy to pick out some tools and combine it with others. Especially the Optimizing Design Choices part of the book is a great tool to make decisions during product development. Product Design and Development from Ulrich (2012) is used because of the large amount of useful information about Design for Manufacturing and Environment. Also the concept prototyping and testing is very useful for this project. Methodish ontwerpen from Kroonenberg (2004) is used because of the clear steps in morphologic design. Making a morphological chart and creating multiple working structures is explained very good in this book. The Product Life Cycle Management from LVI is used because this is the standard product development line which is used at LVI. The Product Life Cycle Management from LVI is shown in appendix A.

In Table 1 are all the used methods shown. The whole process is divided in four different phases: Initiation & Definition phase, Concept phase, Design & Development phase and Realize & Testing Phase. Tools are chosen from each method. The selected tools are marked in green. These tools will be combined to complete a logical process, which will give the leading line for solving the problem. The process will be explained in details in this chapter.
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3.1 Initiation & Definition

This chapter consists of two main subjects:

1. Opportunities
2. Measure the need and set targets

There must be an idea before the development of a product starts. This idea is called an opportunity. Before spending a lot of effort in the product, the developer has to perceive if the opportunity is promising. After this process, the need of the customer will be discovered and similar products can be explored. Hereby product objectives are made and these product objectives will be translated to technical requirements in the end.

3.1.1 Opportunities

When a product development process is in an embryonic form but there is a rough match between a need and a possible solution, this can be an opportunity. In the beginning of the development when the future is still uncertain, an opportunity can be thought of as a hypothesis about how value might be created.

An opportunity can be formulated on one page where a title, a narrative explaining and a sketch of the product explain the idea.

Though there are many kinds of opportunities, two forms distinguish themselves:

1. The extent to which the team is familiar with the solution likely to be employed
2. The extent to which the team is familiar with the need that the solution addresses

These two forms are illustrated in Figure 2. When the team works on an opportunity which is not well known for the team or the knowledge is poor, the risk of failure increases. The opportunity landscape is illustrated with an “uncertainty horizon” faced by the team:

- **Horizon 1**: No big changes in comparison with the original product (low risk opportunities)
- **Horizon 2**: Less knowledge in the team or on the market (intermediary risk opportunities)
- **Horizon 3**: New solutions for the team or/and the technology (high risk opportunities)

![Figure 2: Types of opportunities (Ulrich, 2012)](image-url)
Effective way of finding opportunities

A good identification process can help to find the right opportunity. Tree basic ways of working are good to keep in mind:

1. Generate large number of opportunities;
   It is more likely that the exceptional opportunity will appear when more opportunities are available.
2. Aim for a high quality;
   Using good methods and sources to generate opportunities will increase the average quality of the final results.
3. Think out of the box;
   Sometimes it can be better to not take the quality too much into consideration in the opportunities phase because it limits the ideas. To come to a very good opportunity wacky ideas and wild thinking can be the very useful at times.

(Ulrich, 2012)

3.1.2 Measure the need and set targets

Products are mostly made to sell to other people. Therefore it is important to know what the customer wants and needs. After knowing what the customer needs, the mostly vague product objectives must be transformed to detailed performance specifications using engineering terms. The needs of a product can also be found by looking to competitive products. The whole process of measure the need and set targets is explained with four main steps:

1. Measure the need
2. Processing data
3. Translate the need into technical requirements
4. Benchmarking

Measure the need

Most people prioritise the things they want. The goal is to specify the customer needs and order them by value. Development schemes can be used to get a structured way of working. If this is done carefully, a clear view of how the design, as well as the competitive designs will meet the customer needs, will be the result. Finding the bottlenecks in the process or product will give the best results. Therefore it is important to see each project as a one-time effort. This could look like wasted effort, but if this is done project after project, the design performance will increase greatly. People working on the project will learn of this as well, so operational techniques will improve. Another motivation is that problems are converted in problems of engineering much easier.

Asking the user questions about the product is the easiest way to gather reliable data. The user can be both the end user as well as the company. The end user is the one who knows the product best because he or she uses the product in daily life. The company can receive this information from the user through distributors. This data can be transformed to a clear overview. This overview is called ‘the voice of the customer’. The next step will explain how the voice of the customer will be used to create ‘product objectives’ (Jackson, 2010).
Processing data
The voice of the customer shows the interests, wishes and needs of the customer. This information can be transformed by using a table to ‘product objectives’. A product objective is a short phrase which explains what the customer wants. Similar customer feedback can be used to form one product objective as shown in Figure 3.

![Figure 3: Defining a product objective](image)

Some features are required to be in every product. These requirements can be separated directly and will be noted as ‘standard requirements’. When the product objectives are formulated, they have to be ranked by importance. There is no regulative way to rank product objectives because this depends on the result which is desired to achieve. This is the moment to set more focus to one product objective and less to another. Mostly the identity of the company is involved in this process.

Translate to technical requirements
Now the product objectives are identified and the importance is recognized, it is convenient to translate them into technical requirements so the problem will be converted to an engineering problem. This means that the requirement must consist of measurable data. The following methods can be used to achieve this:

- Take comparable values as competitors’ products.
- Test the functions and determine the values.
- Search for standardised values in reliable sources.
- Assume by consulting with colleagues or specialists.

First de standard requirements will be formulated into technical requirements, then the requirements which derive from the product objectives. This is also an opportunity to explain the importance which is given to the product objectives.
Benchmarking
Comparing products of competitors is called benchmarking. Having the products in real life is an advantage because of the possibility to really try the products. If the products are not available, benchmarking can be done by searching for product descriptions, product specifications, product reviews etc. These methods can also be used in combination with the real product. The idea is to collect as many advantages and disadvantages as possible. The advantages can be used in the new products as well. The disadvantages can be used to avoid pitfalls. The wanted result is a rating of all products. The product objectives will be rated on each product in a table. It is nice to show the scores of the different products in a graphical way. To show and rank different products a radar chart is a good solution. This chart makes the possibility to show where to improve on a specific product objective.

3.1.3 Summary of the initiation & definition phase
This phase (3.1 Initiation & definition) is the starting phase of the project. It starts with searching for opportunities (3.1.1 Opportunities) and continuous with measuring the need of the customer and defining requirements (3.1.2 Measure the need and set targets).

After completing all the steps which are summarised in Figure 4, the project can continue with the concept phase (3.2 Concept phase).

Figure 4: Steps made in the initiation & definition phase
3.2 Concept phase

In this paragraph ‘Conceptual design’ (Pahl, 2007) and ‘Morfologisch ontwerpen’ (Kroonenberg, 2004) are combined to make one concept generating method. After that ‘Optimize Design Choices’ (Jackson, 2012) and LVI’s Verification and Validation procedures will be combined to make multiply decisions during this phase, which will lead to one concept.

3.2.1 Arguments to use a methodical design process

A design which is designed through older methods and based on solution focused functions is unlikely to be an optimum design. The design will be optimum, or closer to optimum, when new technologies, procedures, materials, and also new scientific discoveries are included in the design process. Every company and especially every designing department is a place where a lot of experience and company standards are leading guidelines. This may reduce the risks but also entail prejudices and conventions which lead to less good economical solutions. Designers should not allow themselves to be influenced by fixed or convention ideas, instead of this, they should search for new and more suitable paths to find the best solutions. Abstraction is a tool which can be used to solve the problem of fixed and conventional ideas. Abstraction is the process of taking away or removing characteristics in order to reduce it to a set of essential characteristics (Rouse, 2014). Abstraction will lead to a properly formulated problem, which opens the way to determine clear functions without prejudicing the choice of a particular solution in any way (Pahl, 2007).

In case of a redesign process the existing design should not limit the functions and solutions of the new design. It can give an inspiration during the redesign process but it should never be leading. And if there are requirements that a certain part or subassembly of the product should stay the same the designer should consider this in the end of the concept phase. So the interim decisions are not influenced by the fixed solution. A methodical approach (Figure 5) will avoid that the designers’ focus lays too much on the solutions instead of the functions and will increase the chance that essential problems are not overlooked (Kroonenberg, 2004).

3.2.2 Establish functions

First the main function should be properly formulated. The main functions can be derived out of different sources. One way is to loot to the difference between ingoing and outgoing conditions. These conditions are based on material, energy and signals flow. Material flow could be processing or editing materials. Energy flow could be force, energy, power, etc. Signal flow could be steering, measuring, and controlling. Examples of this can be (Kroonenberg, 2004):

- Moving of the product from x to y. (m)
- Control the product. (s)
- Delivering energy to the product. (e)
- Giving conformation that the product is starting up. (s)
To clarify the ingoing and outgoing conditions Figure 6 illustrates the flow of material, energy and signals.

Just as a technical system can be divided into subsystems and elements, so can a function be broken down into subfunctions. The reason to do this is to:

- determine subfunctions that facilitate the search for solutions later in the concept phase;
- combine these subfunctions into a simple functions structure (Pahl, 2007);
- discover missing functions (Kroonenberg, 2004).

A tool to find these subfunctions is a Functional Tree (Pugh, 1991). Function trees can be used to divide major systems into sublayers. Functional Trees are even more interesting when ‘the voice of the customer’ (3.1.2 Measure the need and set targets) is known. The subfunctions can be based on the customer feedback but also on the in- and outgoing conditions (Figure 6). A general layout Function Tree layout is shown in Figure 7.

Figure 6: Ingoing and outgoing conditions (Kroonenberg, 2004)

Figure 7: Function Tree (based on Pugh, 1991)
3.2.3 Generate working structures
To solve the main function, it is necessary to generate multiple working structures. A tool to generate these structures is to compose a Morphological overview. The logic behind the Morphological overview is explained in Figure 8.

The task is to combine the subfunctions with the different solutions. According to Kroonenberg (2004) the established functions are placed in a vertical row with the most important one above. Solutions are placed in a horizontal row with the most preferable on the left side (Figure 9). By placing the functions and solutions in order of preference, the total relevant solutions will be decreased significantly.

Figure 8: Logic behind the Morphological overview

Figure 9: Morphological overview
Working structures can be generated through combining different solutions for each function. An orderly way to do this is to draw lines between the different solutions from top to bottom. An example is given in Figure 9. The amount of generated structures depends on the requirements, most common is three or four structures. Solutions are combined based on experience of the designers unless a mathematical method or computer can give a real advantage. The main problem with such combinations is ensuring the physical and geometrical compatibility of the working structures, which in turn ensures the smooth flow of energy, material and signals. To increase the change of generating good working structures, small but clear drawings or pictures are added for each solution. Also each solution should be given a name which describes the principle. A few things to keep in mind while generating the working structure (Pahl, 2007):

- Combine only compatible functions.
- Pursue only solutions which meet the demands of the requirements list.
- Concentrate on promising combinations (left side of the Morphological overview) and establish why these should be preferred above the rest.

### 3.2.4 Choosing alternative from multiple options

Making choices can be easy, but when there are many factors involved it is very difficult. For this reason designers use a method to choose between different alternatives. Jackson (2010) described a decision methods which is applicable to choose between different alternatives. To following steps of this method are used:

- Identify the different alternatives.
- Identify the relevant criteria (product objectives).
- Weight the criteria.
- Score and rank the alternatives.
- Select an alternative and evaluate the result.

After these steps the outcome will be validated by LVI’s procedures.

**Step 1: Identify the different alternatives**

In this step the designers have to list the generated working structures. It is important to give each alternative a distinctive corresponding name. Adding a sketch will make the dissension making a lot clearer. The goal is to select one alternative as the most promising one.

**Step 2: Identify the relevant criteria**

The designers have to list all the criteria which they want to use to compare the different alternatives. The task is to make a table with two columns. In the first column the goals are listed, these can be derived from the list of requirements. In the second column the related criteria are written down. If the designers discover an important way in which the alternatives differ that could be a criteria as well. Only criteria which affects the decision because the alternatives differ in that way are imported to mention. So the other criteria can be eliminated. Also the criteria which are connected to features that are not relevant at this stage of design like decoration or material choice (depends on the design stage) can be eliminated. These features can be added later, irrespective of the particular alternative.
Step 3: Weight the criteria
The task in this step is to weight the criteria. The task is to give every criteria a percentage according to their importance. The sum of all the criteria weights should be 100%, the most important criteria should get the highest percentage. The weights need to be discussed with all the designers involved in the design process. It is important to review the weighting process since as these weights influencing the decision making process in a critical way.

Step 4: Score and rank the alternatives
Now it is time to bring together the criteria weights with the alternative ratings to form the final selection matrix. This matrix approach is a highly effective way to organize the discussion and bring the design team to a consensus. Scores between 1 and 5 can be used to rate the alternatives. If the alternative perfectly meet the criteria the score must be 5, if the alternative does not meet the criteria at all the score must be a 1. To calculate the total score the designers must multiply the criteria rating with the criteria weights. The sum of the weighted scores is the total score. With this total score do designers rank the different alternatives.

Step 5: Select an alternative and evaluate the result
In this step the task is to select one alternative. The alternative with the highest score will be chosen unless the results are equal or close to each other, than the designers must review the data to see if the ranking is in accord with its understanding of the design issues. The discussion must be focused on the matrix instead of the alternatives, through this the team avoids circular discussions. If someone on the designer team wants to argue that another alternative should be chosen to be continued, he or she must:

- argue that its rating in some category should be increased;
- argue that the weights on some criteria should be changed;
- identify a dimension of comparison (a new criteria) that has not been considered.

3.2.5 Verification and validations of a chosen alternative
The verification and validation should not only be down by designers. Although they have the most influence on the process it is important to also take into account the opinion from: sales managers, productions managers, workplace chiefs and the finance department. Therefore LVI’s procedures are to also involve them into the process. After the five steps above (objective judgement) the opinion from employees are asked (subjective judgement).This is done through meetings in different phases of the process. The first time is after choosing a working principle out of the different alternatives. After the Structure and shape variation (3.2.6) this is done again. Who are invited for each meeting must be discussed with the designers and the project leader. A meeting should be prepared by the designers. All invited employees should receive subjective information about the different alternatives well before the date of the meeting. During the meeting the designers show their result (in the first meeting this is the chosen working structure) and explain why they choose this. All the attendees can give comments on the process. When the meeting is over and all attendees agree with the outcome, the alternative is validated and the designers can continue with the designing process. During the second meeting there structure and shape variation is discussed. In this meeting multiple choses can be made so the designers must prepare the meeting so all points are discussed.
3.2.6 Structure and shape variation
The fulfilment of the functions alone does not complete the task of the designers. The working structure is not concrete enough to lead to the adoption of a definite concept. To reach a definite concept the designer must determine the most important properties of the proposed working structure. These properties must be given a much more concrete qualitative, and often also a rough quantitative, definition (Pahl, 2007). Properties like: shape, size, special functions and material must all be defined, or at least approximately. The necessary data to define these properties can be gathered through:
- rough calculations based on simplified assumptions;
- rough sketches or rough scale-drawings;
- market research for the newest technologies or materials.

3.2.7 Summary of the concept phase
To start in this phase the designers have to establish the functions which the product should fulfil (3.2.2 Establish functions). To translate this function structure into working structures the designers have to combine different solutions for the subfunctions (3.2.3 Generate working structures). Then a decision process should be done according section ‘3.2.4 Choosing alternative from multiple options’ and ‘3.2.5 Verification and validations of a chosen alternative’ to choose the best working structure. After that the designers focus on the structure and the shape of the product to create the concept.

When all the steps shown in Figure 10 are completed, the designers can continue with the design and development phase.
3.3 Design & development phase

The concept created in the concept phase will be detailed in this phase. A method based on the steps of ‘Embodiment Design’ (Pahl, 2007) will be explained. General objectives and constraints will be treated, but the focus will lay on production, assembly and environment. That is why ‘Design for Environment’ and ‘Design for Manufacturing’ (Ulrich, 2012) will be combined in the method. When the design is finished, one last check will be done. ‘Validate the Design’ will ensure to build the right product (Jackson, 2012).

3.3.1 Steps in design & development phase

After having created the principle solution (the concept) during the concept phase, the detailed design can now be confirmed. Basically, this phase will proceed from abstract to the concrete, and from rough to detailed designs. Several steps in this phase must be repeated at a high level of information. Although it is difficult to follow a general method for each specific product, it is useful to stay close to the planned steps to be sure nothing will be overlooked. Steps in the design & development phase are:

1. Identify embodiment-determining requirements.
2. Identify embodiment-determining main functions carriers.
3. Develop layouts and form designs for main functions carriers and select the most suitable.
4. Search for solutions for auxiliary functions and select the most suitable.
5. Detailing main and auxiliary carriers and complete primary layout.
6. Validate the design.

3.3.2 Identify embodiment-determining requirements

The first step is to identify the requirements that influence for the embodiment design. The requirements are based on the list of requirements. Requirements that influence the embodiment design are the following:

- Size requirements, could be width, length, height. But also size of connectors, size of wires, size of a certain part.
- Control requirements, could be controls, motion, position, direction of flow.
- Material requirements, could be resistance to wear, weight, machinability.
- Safety requirements, could be standards.
- Ergonomics, could be the characteristics, abilities and the needs of humans. Also the interfaces between humans and technical products.
- Manufacturing requirements, could be possibilities of machines or production time.
- Assembly requirements, could be the time to assembly the product. Or the difficult level of assembling.
- Recycling (environment) requirements, think of the ability to disassemble the product or reducing material use.

All the requirements should be formulated in a SMART way. A smart requirement is:

**Specific:** all requirements should be clear so that there is no discussion possible. Requirements should also be formulated in an appropriate level of detail. Although some requirements may seem specific at first sight, often requirements do not give an obvious description of the objective.

**Measureable:** a requirement is measureable when it is possible, once the product has been constructed, to verify that this requirement has been fulfilled.
Attainable: a requirement is attainable when it is possible to fulfil it under the given conditions. The judgement of this is based on experience of the designers. Ask yourself if: there is a theoretical solution, has it been done before, has a feasibility study been done?

Realisable: attainable and realisable criteria are parallel but not synonymous. A requirement could be possible (attainable) but if there is not enough budget it is impossible to achieve it for the designers.

Time bounded: a requirement must indicate that it must be achieved by a specified time. This could be a date but also a time when a specific event occurs.

Not all the SMART aspects are applicable for each requirement. But if an aspect is applicable for the requirement it must fulfil the above mentioned criteria (Mannion, 1995).

3.3.3 Identify embodiment-determining main functions carriers

The basis for this step is the function structure, described in ‘3.2.2 Establish functions’ and Figure 5. List down for each part/subassembly of the product which functions it carries. Parts/subassemblies can carry more than one function. Main functions carriers are the parts/subassemblies which determine the size, controls or shape of the overall layout.

3.3.4 Develop layouts and form designs for main function carriers and select the most suitable

Now preliminary scale layouts and form designs for the main functions carriers must be developed. This is done through calculations. Preferable are known solutions (repeat parts or standard parts). It may be useful start working on specific areas first, and later combine these into a preliminary layout. A lot information about safety, ergonomics, and especially about manufacturing, assembling and environment, has kept in mind while developing the layout. Relative information about these topics will be treated.

Design for Safety

Safety considerations influence both the reliability of the functions and also the protections of humans and the environment. Safety of a product can be split into three levels: direct safety, indirect safety and warnings. Designers should try to make a product safe by using direct safety. When this is impossible designers should use indirect safety. As least warnings could be used to guarantee safety, since warning alone are not enough for people with bad vision this level of safety is not treated.

Because a high demand for safety can complicate a design extremely which is associated with an uneconomic product. However, in most cases safety and economy go hand-in-hand in the long term. An unsafe product (unreliably functions or danger for humans and environment) will lead to high costs in the long term. Therefore it is advisable to achieve safety by treating direct and indirect safety measures as an integral part of the product (Pahl, 2007).

Direct safety: This is the first level of safety which the designer should try to use to guarantee safety. To ensure and evaluate the safe functioning and durability of components, designers can use two safety principles, the safe-life principle and the fail-safe principle. The safe-life principle conducts that all the parts and their connections should be constructed in such a way that it can impossible for the product to break down or malfunction during the expected life length. This can be ensured by:

- clear specifications of the operating conditions and environment factors;
- calculations based on proven principles;
- multiple inspections during the productions and assembly process;
- determining the limits of safe operation.
Knowledge and deep understanding of all the components and their connections of the product is necessary to achieve a safe-life product. The fail-safe principle does not allow the product to have big consequences when a function fails. This can be ensured by:

- a function must be preserved to prevent dangerous conditions;
- a restricted function must be fulfilled by the failing part;
- the failure must be identifiable;
- the safety of the overall system must stay the acceptable.

**Indirect safety:** A product fulfils the level this safety if it reacts when danger occurs. This reaction should stop the danger and give an indication of the problem (Pahl, 2007).

**Design for Ergonomics**

Characteristics, abilities and the needs of humans are the main points for design for ergonomics. A good design should adapt technical products to humans. The starting point of design for ergonomics is the person who is working with the product. Designer should inspect the body postures and movements. With every movement the designers should considers if the movement is sufficient ergonomic based on:

- how many times the movement occurs;
- how long the movement lasts;
- the body posture during the movement compared with the optimum posture.
Design for Manufacturing (DFM)
The generated concept from ‘3.2 Concept phase’ should be divided into components. For each component the source should be identified. Ordered in preference, sources can be the following (Pahl, 2007):

- Standard parts
- Repeat parts
- In-house made parts/ bought-out parts

It depends on the available machinery if in-house made parts or bought-out parts have the preference.

The design for manufacturing method is shown in Figure 11. Reducing the assembly costs is treated separately from page 22. The rest of the steps are explained in this section.

![Diagram of the design for manufacturing method](image)

*Figure 11: The design for manufacturing method (Ulrich, 2012)*
Estimate the manufacturing costs

Inputs of the manufacturing system determine the manufacturing costs these are listed in the left row. The outputs of the manufacturing system are listed in the right row (Table 2). The manufacturing costs can be calculated by summing up all the inputs and the disposal costs of the waste.

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw materials</td>
<td>Finished goods</td>
</tr>
<tr>
<td>Labour</td>
<td>Waste</td>
</tr>
<tr>
<td>Purchased components</td>
<td></td>
</tr>
<tr>
<td>Energy</td>
<td></td>
</tr>
<tr>
<td>Supplies</td>
<td></td>
</tr>
<tr>
<td>Services</td>
<td></td>
</tr>
<tr>
<td>Equipment</td>
<td></td>
</tr>
<tr>
<td>Information</td>
<td></td>
</tr>
<tr>
<td>Tooling</td>
<td></td>
</tr>
</tbody>
</table>

A clear overview of the elements which determine the manufacturing costs is shown in Figure 12. By decreasing the cost of any element the total manufacturing cost will be lower. One element cost may be easier to decrease than another.

![Figure 12: Elements of the manufacturing cost of a product (Ulrich, 2012)](image)

A Bill of Materials (BOM) is a useful tool to make a clear overview of all the component costs (standard and custom), assembly costs and overhead costs. Each standard part will have a price which is known or which can be assumed according similar standard parts prices. If the component is new for the company the can soliciting price quotes from vendors or suppliers. Prices will be lower if the purchase amount is high. So it is important to estimate the production quantities before contacting vendors or suppliers. Cost of standard components are always variable.

Custom components are component which are especially designed for the product. These can be made in the company or by a supplier. Costs for these custom components can be divided in tooling, raw materials and processing. Cost of custom components can be variable and fixed.
Overhead costs are all the costs which are not directly related to a product. These costs can be company cleaning, facilities, shipping, security guard etc. These costs will not be treated in design for manufacturing because it is not related to the product.

**Reduce the components costs**
During the design it is easy to underestimate the production costs of particular components. For example, designers may give a part a small internal corner radius on a machined part without realizing that physically creating such a feature requires an expansive process (Ulrich, 2012). Often these features are unnecessary for the component’s function. Another example is painting particular parts, which will not be visible to the user. Mistakes like this arise out of lack of knowledge. Designers can avoid these mistakes by communicating with employees who work with the machines and suppliers who deliver the custom products. Components will be lower in production costs without these mistakes.

The best way to reduce component costs is to use as many standardized components instead of custom components. If it is economically better to go for custom components always try to make the components with standardized processes.

**Reduce the productions supporting costs**
Production supporting costs are costs for inventory managers, supervisors, human resource management, engineering support, quality management etc. Productions costs can be reduced by lowering the number of parts, lowering the assembly time, lowering the custom parts etc. Most of the production supporting costs will reduce when reducing the component costs and assembly.

**Consider the impact of DFM decisions on other factors**
Designers should not forget the quality of the product while reducing the manufacturing costs. Before proceeding with the DFM decision, the designers should estimate the impact of the DFM on the product quality. The product quality can be improved by the DFM but is also possible that DFM will have a negative effect on the product quality. Therefore it is advisable for the designers to keep in mind the quality before making DFM decision and evaluate the impact in the end of the process.
Design for Assembly

The design has a big influence on the assembly quality and costs. The cost and quality of the assembly process depends on the type and amount of the operations. These type and amount of operations depends on the design. An assembly process consists of the following operations:

- Storing: the parts which have to be put together have to be stored, if possible in a systematic way.
- Handling: moving parts from storage place to assembly place.
- Positioning: placing the parts in the correct way to assembly (with an automated process this is probably done in the previous operation).
- Joining: connecting parts together on any way.
- Adjusting: adjust the connections to equalise tolerances.
- Securing: test the assembled parts against unwanted movements.

The importance of these operations depends the number of units and the degree of automation. For products made in quantities of less than approximately hundred thousand units per year, assembly is almost always done manually. An exception is the assembly of electronic circuit board, which are almost always assembled automatically (Ulrich, 2012). Also important is to distinguish whether assembly takes place in the company or outside the company. In general, improvements on the assembly process will also simplify the assembly manuals. So when either the assembly process takes place inside or outside the company, it will be easier to inform the employers about the assembly process.

It is useful to already start considering assembly in the early stages of the design process. Easy-to-assemble products can be achieved by a design which is: simplified, standardised, structured and does have as less parts and connections as possible. This will lead to less quality requirements (Pahl, 2007). Standardised parts which can be assembled and dissembled with standard tools will not only make the assembly process easier but also improve the environment factor.

Estimating assembly costs

Manual assembly costs can be estimated by multiplying the time of each assembly operation with a labour rate. Assembly operations mostly require from 4 to 60 seconds each. When a product is produced in high volumes, workers can specialize in a particular set of operations. They can use special fixtures and tools to decrease the assembly time. There are software programs which can estimate the assembly cost continuously according a standard assembly time for each part (Ulrich, 2012).

Reducing assembly costs

Assembly costs can simply be reduced by decreasing the needed time for all the assembly operations or reducing the amount of assembly operations. Consider productions costs and assembly costs together. The production costs should not increase extremely to only make the assembly easier. Also think of transport, safety and quality requirements (Pahl, 2007).

A technique to make sure a product is assembled in a good way is the poka-yoke technique. The poka-yoke technique:

- prevents a mistake or defect;
- makes any mistake or defect obvious at a glance during the assembly.

There is an important difference between a mistake and a defect. Mistakes are made by people, these can occur through bad concentration or bad understanding about the assembly process. Since people
are human it cannot be expected to always be concentrated and always have a good understanding about the assembly process. Due this reason mistakes are not avoidable. Defects, on the other hand, are entirely avoidable. Defects result from allowing a mistake to reach the customer. The goal of the poka-yoke is that the designers must ensure that all the mistakes can be prevented or immediately detected and corrected. Through good poka-yoke designs a quality check can be superfluous since it is possible to achieve a zero-defect assembly process (Fisher, 1999).

**Design for Environment**

Every product has impact on the environment. The aim of design for environment is create a more sustainable product which minimizes the impact to the environment. This can be achieved through the following possibilities:

- Reducing material use;
- Substituting materials for those becoming rare and expensive;
- Recycling materials (Pahl, 2007);
- Easy disassembly possibilities.

A misunderstanding is that Design for Environment (DFE) not always means higher costs. Practitioners of DFE have found that effective DFE can even improve product quality and costs while reducing environmental impacts. The basic of DFE is to look at the life cycle of the product. Starting with the extraction and processing of raw materials from natural resources and ending at the recovery. A simplified product lifecycle is shown in Figure 13.

![Figure 13: Product life cycle (based on Ulrich, 2012)](image)

In each stage of the product life cycle energy and other resources are consumed. The materials in a product must be balanced in a sustainable way. Three thinks which will help to achieve this have to take in mind during the product development phase.

1. Eliminate use of non-renewable natural resources.
2. Eliminate disposal of synthetic and inorganic materials that do not decay quickly.
3. Eliminate creation of toxic wastes that are not part of natural life cycles.
3.3.5 Search for solutions for auxiliary functions and select the most suitable
After the main function carriers are determined the designers have to look to the auxiliary functions. Auxiliary function carriers can be the connections between the main function carriers but also the protection of the main function carriers. Again exploit known solutions (standard parts) where possible. If this is impossible, search for special solutions (Pahl, 2007). Again the design for safety, ergonomics, manufacturing, assembly and environment have to take in consideration during determining the auxiliary functions. Probably this will be less extensive than the main function carries because of the auxiliary functions can be solved through standard parts.

3.3.6 Detailing main and auxiliary carriers and complete primary layout
Now all the solutions for the main and auxiliary carriers must be detailed. A way to do so is to make detailed drawings in a 3D-CAD program. During the detailing process designers have to pay attention to standards, regulations, detailed calculations and experimental findings. If necessary, divide into subassemblies which can be elaborated individually (Pahl, 2007).

3.3.7 Validate the design
‘If you think your design is perfect, it’s only because you haven’t shown it to someone else’ (Harry Hillaker, F-16 architect). This demonstrates that it is important to show your design to relevant people before making decisions on your own. A very valuable technique to validate a design is to conduct design reviews. There are two basic types of reviews. The first one is a customer design review, which is a presentation to a group of individuals who represent the future users or customers of the product. The second type is an internal design review, which acts similar to the first one, but instead the presentation is to a group of subject matter experts within the design organization. A subject matter expert is a person who may be associated indirectly to the project but one who has deep knowledge within his or her area of expertise. The reason for doing the customer design review is to ensure that the product being built will meet the needs of the customers. The reason for doing the internal design review is to ensure that the product can be built and that it matches the standards within the design organization.
3.4 Realise & testing

This chapter explains the finishing touch of the development of a product. The concept is made and will be tested in this chapter. The subjects will be iterated and changed if needed. Finally a prototype can be made.

3.4.1 Iterate the design process

Iteration means ‘repetition’. Iteration can be useful after a design process because it gives a good view of the topics which are treated. ‘Backtracking’ is essential to avoid pitfalls. It can be felt as a waste of time and effort, but the quality of the result will increase. To give a graphic view of a manner of working during projects a ‘continuous improvement cycle’ Figure 14 can be used. (Jackson, 2010)

![Figure 14: Continuous improvement cycle](image)

3.4.2 Design testing

Design testing will be done directly after the concept selection to evaluate if the design meets the customers need and check if the sales potential will be guaranteed. There are some reasons to not apply design testing:

- The time requested is to large in comparison to the product life cycle
- Launching the product is cheaper than testing the design

Overall, the risk respectively the consequences of failure of the product will prevail. To decide when to apply design testing a chart as Figure 15 can help.

![Figure 15: When to apply design testing](image)
Applying design testing
When design testing will be used, a view steps can be followed:

1. Define the purpose
2. Communicate the design and measure customer response

1. Define the purpose
Before starting with the test it is very important to define the desired result and formulate question which have to be answered after the test. Some of these questions could be:

- If there are various designs, which of them should be pursued?
- How can the design be improved to meet the customer needs?
- How many units are likely to be sold?
- Does the development process have to continue?

2. Communicate the design
After defining the purpose people should be surveyed. The next things have to be defined:

- Define the survey population
- Choose a survey format
- Choose a way to communicate the design

The survey population can be defined by an assumption which audience would buy the product. The survey format should fit to this audience. The survey format must be easy to understand and attractive. The concept can be communicated by:

- Face-to-face interaction
- Telephone
- Postal mail
- E-mail
- Internet

The way of communication of the design must be chosen by keeping in mind which survey format will be used. There are various ways to communicate the design:

- Description;
  The design can be explained in words, this can be done both written as verbal.
- Sketch;
  A sketch shows the main shape of the design and can be provided with annotations and key features
- Images;
  Pictures of renderings of the design are an easy way to make a clear explanation
- Storyboard;
  A series of images to explain a function of the design. This is very useful for design which can fold and unfold
- Video;
  A video gives the survey population a view of how the product works and how it can be used for their purposes
- Simulation;
  Simulation is a great way to demonstrate the function or interactive features of the design
- Physical appearance models;
A look alike product made of wood, foam, plastic etc. to show the shape of the design and can contain limited functionalities of the design

- Prototype;
  A working prototype can be very useful during the testing phase. A disadvantage is that the prototype does usually not look that nice as the final product would look like, so the audience might get an incorrect picture of the final product

Not every communication survey can be used by different communication ways as shown in Table 3. The way of communicating the design depends on the amount of people the design should be communicated to, the location of the people, the level of education and culture.

Table 3: Usable survey format for different ways of communication

<table>
<thead>
<tr>
<th>Description</th>
<th>Face to face</th>
<th>Internet</th>
<th>Postal mail</th>
<th>E-mail</th>
<th>Telephone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sketch</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Images</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storyboard</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Video</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simulation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical appearance models</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Prototype</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

After communicating the concept it is good to measure the interest of the audience. Especially the interest of buying the product is interesting (Ulrich, 2012).

3.4.3 Prototyping
A prototype is a look alike model of the final design. The prototype can be used to check if everything fits together, test if it is durable and show the conceptual design to others. Prototypes can be divided in different dimensions which are shown in Figure 16 as well:

- Physical or analytical
- Focused or comprehensive

The dimension physical or analytical shows the type of prototype. Physical prototypes are tangible which are made to approximate the product. The prototype look and feel like the product. Analytical prototypes are non-tangible, mostly in a visual or mathematical form. Interesting aspects of the design are analysed rather than build. The second dimension, focused or comprehensive shows if the focus of the prototype is on a specific part or of the entire design. If the prototype is focused, only a small part of the design is taken into consideration. If the prototype is comprehensive, the whole product is incorporated. Using these two dimensions in a diagram, every prototype can be placed in this diagram as shown in Figure 16:

1. A specific part is tested by dropping it from a certain height
2. A specific part is tested using final element method calculation software
3. A complete product is tested as it would be used
4. A big assembly of the product is simulated and a simulated video is recorded
Principals of prototyping

Making a prototype is often time-consuming and expensive, so there must be some advantages to build a prototype. It is also important to know whether to use a physical or analytical prototype or a focused or comprehensive prototype. The advantage of an analytical prototype is that they are more flexible than physical prototypes in most of the cases. For example; if a simulation is made, it is easier to change parameters or to start the simulation again if the part crashes then if the part would be physically made. On the other hand physical prototypes are desired to detect unanticipated phenomena. Having a physical prototype makes it easier to directly see if the product fulfils the wishes and if no surprises will show up. It can also show the weaknesses of parts even if it does not disturb the main function of the product.

If expensive tools or moulds must be made to produce or assemble the product are going to be used, a prototype can reduce the risk of costly iterations later in the process. If problems or mistakes can be tackled before the product is produced, a large amount of money can be saved. In some cases it will even take less time to complete the design process because the prototype can give a clear view of how something can be made. To decide to make a prototype or not, some aspects must be taken into consideration. The most important aspects are:

1. Technical or market risk
2. Costs (time or money)

Whether the risk of failure increases it becomes more desirable to build a prototype. Especially when the costs of making the prototype is relatively low, a prototype should be made. If the risk of failure or costly consequences is low, often no prototype is desired.

The possibilities to make prototypes are rather advanced nowadays. Tools as 3D printers and simulation programs as SolidWorks and Ansys reduces the time and costs to build prototypes enormous (Ulrich, 2012).
4. Empirical findings

In this chapter the background of the company is shown. After that a benchmarking is done. To achieve a product which meets the requirements of as many people as possible interviews are done a customer feedback is collected. This is also shown in this chapter.

4.1 Background LVI

LVI is recognized as one of the world’s leading manufacturers of equipment for visually impaired people. The head office is located in Växjö, Sweden. The company is going from strength to strength and there are currently 40 people working within the organization. Through our subsidiaries and distributors, we are also well represented worldwide. LVI’s subsidiaries are located in Denmark, Finland, Germany, Norway, Belgium and Switzerland.

All development and manufacturing takes place in the head office in Sweden. It is a great advantage to have everything within the building, from production to finished product as well as sales and service. New products are developed in close co-operation with users and professionals within the low vision rehabilitation industry. The products are sold under the registered trademark MagniLink.

In the year of 2008, LVI celebrated 30 years in the industry. With a wider product range and strength both nationally and internationally, LVI will work towards even more innovative solutions that will make every day easier for people with visual disabilities.

LVI’s philosophy: With the mission to make every day easier for people with visual disabilities, LVI Low Vision International designs and develops products with high standards for reliability, simplicity and serviceability.
4.2 Benchmarking

The benchmarking is done through comparing three different reading machines with each other. The machines are tested with closed eyes. In order to understand who you are designing for, you have to step into their shoes (Gebbia, 2014). The results of the benchmark are shown in section ‘5.1.2 Measure the need and set targets’.

**Optelec ClearReader+ Basic**

**Working:** The Optelec ClearReader is a small but heavy reading machine which is easy to use. The camera is incorporated into a foldable arm. This arm can be folded out by simply pressing on it once, the process is shown in Figure 17 and Figure 18. A LED is mounted in the arm and flashes when making a scan. The reading machine can be turned on through pushing an on/off button on the side of the machine. After turning on, the machine will give confirmation beeps until the machine is started up. A headphone can be connected in the 3.5 jack output. The machine can be carries by a foldable handle.

![Figure 17: Optelec: arm folded](image1)

![Figure 18: Optelec: arm unfolded](image2)
The control panel is placed on the top of the machine, there are 6 buttons with all different functions. The functions of the buttons are described in Figure 19 and Table 4.

![Figure 19: Optelec functions of buttons](image)

Table 4: Optelec: explanation buttons

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Go back a sentence while reading or pause</td>
</tr>
<tr>
<td>2</td>
<td>Play/pause button. Stops reading text when pressed once and continuous when pressed again</td>
</tr>
<tr>
<td>3</td>
<td>Go to the next sentence while reading or pause</td>
</tr>
<tr>
<td>4</td>
<td>Adjust reading speed</td>
</tr>
<tr>
<td>5</td>
<td>Adjust volume</td>
</tr>
<tr>
<td>6</td>
<td>Make a scan and start reading</td>
</tr>
</tbody>
</table>

General information:

- Start-up time: 35 seconds
- Scanning and starting to read a full page: 15 seconds
- Mass: 2.46 kg
- Dimensions: 230 x 240 x 100 mm

Pros and cons (Table 5):

Table 5: Pros and cons Optilec ClearReader

<table>
<thead>
<tr>
<th>Pros (+)</th>
<th>Cons (-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conformation that the machine is starting up through beeping.</td>
<td>Little disturbing noise in the beginning of each function.</td>
</tr>
<tr>
<td>Volume button always available.</td>
<td>No labels on the buttons for people who can see and can help people with bad vision.</td>
</tr>
<tr>
<td>Says when minimum volume is reached.</td>
<td>Handle does not feel strong enough.</td>
</tr>
<tr>
<td>Perfect size.</td>
<td>Arm does not feel strong enough.</td>
</tr>
<tr>
<td>Play/pause button.</td>
<td>Hard to disassemble.</td>
</tr>
<tr>
<td>Overall easy to use.</td>
<td></td>
</tr>
</tbody>
</table>
**ABiSee Eye-Pal Ace**

**Working:** The ABiSee Eye-Pal Ace (Figure 20) is a light reading machine which fits naturally in your hands. This machine has a monitor where you can easily change settings and see zoomed text. The machine uses two built-in cameras so it does not need a camera arm. Next to the cameras are two LED lights mounted, these can be turned on and off while reading. The reading machine can be turned on through pushing an on/off button on the front of the machine. After turning on, the machine will give confirmation beeps until the machine is started up. A headphone can be connected in the 3.5 jack output. The machine can be carried through a foldable handle on the back.

![Figure 20: ABiSee Eye-Pal Ace](image)

![Figure 21: ABiSee: buttons](image)

The ABiSee Eye-Pal Ace has a lot of buttons which are placed on the top and the side of the machine. An explanation of the buttons can be found in Figure 21 and Table 6.

### Table 6: ABiSee: explanation buttons

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Function</th>
<th>Nr.</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>On/off button.</td>
<td>5</td>
<td>Go back to the home screen.</td>
</tr>
<tr>
<td>2</td>
<td>Left roller: scroll to zoom in and out.</td>
<td>6</td>
<td>Volume button.</td>
</tr>
<tr>
<td>3</td>
<td>Back button: Press to bring you back to the previous button. While reading press to turn on the light.</td>
<td>7</td>
<td>Action button: press button to go to selected function.</td>
</tr>
<tr>
<td>4a</td>
<td>Middle: play/pause.</td>
<td>8</td>
<td>Scan button: press button to scan and read a text.</td>
</tr>
<tr>
<td>4b</td>
<td>Left: read the previous word.</td>
<td>9</td>
<td>Right roller: scroll it to go through the menu options or scroll through sentences.</td>
</tr>
<tr>
<td>4c</td>
<td>Right: read the next word.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4d</td>
<td>Down: go to the end of the text.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4e</td>
<td>Up: go to the top of the page.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
General information:

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start-up time</td>
<td>100 seconds</td>
</tr>
<tr>
<td>Scanning and starting to read a full page</td>
<td>20 seconds</td>
</tr>
<tr>
<td>Mass</td>
<td>±1 kg</td>
</tr>
<tr>
<td>Dimensions</td>
<td>300 x 270 x 100 mm</td>
</tr>
</tbody>
</table>

Pros and cons (Table 7):

Table 7: Pros and cons ABiSee Eye-pal Ace

<table>
<thead>
<tr>
<th>Pros (+)</th>
<th>Cons (-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not heavy</td>
<td>Too many buttons.</td>
</tr>
<tr>
<td>Screen</td>
<td>Double camera does not work well.</td>
</tr>
<tr>
<td>Extra functions like; clock, calendar and alarm.</td>
<td>Reading speed adjustment is all the way back in general settings.</td>
</tr>
<tr>
<td>User-friendly software.</td>
<td>Screen is superfluous for blind people.</td>
</tr>
<tr>
<td>No camera arm.</td>
<td>Slow start-up time: 100 seconds</td>
</tr>
<tr>
<td>Confirmation beep when starting up.</td>
<td>Hard to disassemble</td>
</tr>
<tr>
<td></td>
<td>Low quality feeling</td>
</tr>
</tbody>
</table>
LVI MagniLink Voice

Working:

The LVI MagniLink voice (Figure 22) stylish and high quality reading machine. The control panel is placed on the top of the machine. There are just 3 buttons, the buttons are explained in Figure 23 and Figure 24. It is possible to personalise the control panel to make adjustments even easier. The camera is together with the LED light integrated into the handle. The handle is not foldable so the MagniLink is hard to transport.

General information:

- Start-up time: 50 seconds
- Scanning and starting to read a full page: 12 seconds
- Mass: ± 2,9 kg
- Dimensions: 330 x 270 x 250 mm
Pros and cons (Table 8):

Table 8: Pros and cons LVI MagniLink Voice

<table>
<thead>
<tr>
<th>Pros (+)</th>
<th>Cons (-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feels solid.</td>
<td>Missing confirmation beep when starting up.</td>
</tr>
<tr>
<td>Just 3 button on the control panel.</td>
<td>Guiding paper stop does not work good, paper slides under the guiding.</td>
</tr>
<tr>
<td>Advanced setting directly on the device – no external monitor or keyboard needed.</td>
<td>Handle is not in the middle, so it is hard to carry the machine</td>
</tr>
<tr>
<td></td>
<td>Minimum volume is too high</td>
</tr>
<tr>
<td></td>
<td>Pretty heavy</td>
</tr>
<tr>
<td></td>
<td>Missing a button to adjust reading speed while reading</td>
</tr>
</tbody>
</table>

4.3 Interviews

To get some more information from other involved people, two interviews were taken with employees of LVI. The summaries of the interviews are:

Interview with Marcus (assembler of Magnilink Voice)
Date: 26th of February

The assembly of the Magnilink Voice takes about three hours. The assembly consists of three modules:

- Assemble inner part
- Assemble outer part
- Assemble both parts

If the worker has to make ten products the most efficient method is to build the modules first and start with the assembly of the whole product when the modules are finished. The assembly time is increased with about 30 minutes by the textile part. It is a hard job to get the Velcro parts in a proper position.

Some positive characteristics are:

- The wires in the arm are hidden
- The operation is very simple
- White colour is most attractive

Some negative characteristics are:

- Feels big and clumsy
- Not foldable

If something breaks in the panel, almost the whole product has to be dissembled
Interview with Niklas (customer care)
Date: 26th of February

Niklas is the person who the customer will contact if there product is broken. His opinion about the Magnilink Voice is that it is too old fashioned. The design is too clumsy and the used technique is not the technique which should be used nowadays. The machine is very slow compared to nowadays technique. Niklas showed an application on his phone (Samsung Galaxy Alpha) which has OCR and can recognize text. After taking a picture it only takes about one or two seconds and the text appears on the screen. The phone can read the text for you as well.

Some positive characteristics are:
- Electronically good
- The operation is very simple

Some negative characteristics are:
- Slow
- Not so accurate
- Power button is weak (it doesn’t come back some times)

Some other comments which could be taken into consideration are:
- Use your phone and connect the speakers, panel etc. by using Bluetooth
- Raspberry Pi boards
- Samsung exynos board
- Using a traditional scanner is a simple solution
4.4 Customer feedback

Customer feedback is provided by the company. This feedback comes from different dealers all over the world in different languages. In this paragraph all the feedback is translated to English and combined.

Some customer feedback is received after the product has been in the market for a while. The feedback will be distinguished in three different categories:

1. Feedback with some uncomplicated soft- and hardware changes. They can be applied for the upcoming launch.
2. Feedback with more complicated changes. This feedback will be evaluated.
3. Proposals received which will not be applied.

Since the product will be re-designed, the uncomplicated respectively the complicated changes will be applied. Therefore the first two categories will be combined.

1. & 2. Feedback which will be applied
- Give the machine more different voices.
- The on/off button is not reliable. It is not clear if the machine is starting up or not.
- • VolumeView> Lydstyrke
  • Håndtere document -> Behandle document
  • Lys -> Lighting
  • Tillføye tekst -> Legg til tekst
  These words should be corrected
- Scanning button is to stiff. People would like a kind of joystick. LVI will definitely make the button softer/more sensitive.
- Change the menu so the language does not change automatically. The language of both the menu language and the reading language should be changed in the menu.
- The product is unstable when you press the scan button.
- The scan button in not reliable
- Lowest volume is too loud. Start at 10% till 100%. There should be a basic volume so people know that the machine is on.
- Now the machine lets you know every % when it is charging. This is not necessary. So only a notification that warns when the battery goes below a certain level.
- Investigate whether scanning A3 format is possible. (telescopic/foldable arm)
- Clearer sound indication during start-up and on exit.
- Being able to access all functions via external panel.
- Monitor view is desired so people could read the text on a screen together with listening.
- Should be able to structure a larger amount of material, for example, to get the page numbering to seamlessly jump between pages when you create a document by several A4 scans.
  "Walking around in the document." Being able to jump / go forward and backward in the document, for example, line by line, page by page without getting the text read.
- Complicated assemble and high material costs.
- Sell machine standard in super easy mode.
3. Feedback that will not be applied
   - Cracks in the handle. But after several checks the handle would not crack so easy. So probable the crack is the consequence of a rough treatment.
   - Black camera arm is not popular. LVI has chosen not to change it to a brighter colour because LVI thinks the black arm is better in the white variant.
   - Give a bag with the product. When approved the bag can be sold as well when the customer asks for it.
   - Give a pair of good quality headphones to create a greater interest.
5 Applications
This chapter presents all the theory of chapter 3 applied on the case company. This is done according the information from chapter 4 - Empirical Findings.

5.1 Initiation & definition
This chapter consists of two main subjects:

1. Opportunities
2. Measure the need and set targets

There must be an idea before the development of a product. This idea is called an opportunity. Before spending a lot of effort in the product, the developer has to perceive if the opportunity is promising. After this process, the need of the customer will be discovered and similar products can be explored. Hereby product objectives are made and these product objectives will be translated to technical requirements in the end.

5.1.1 Opportunities
After a period of two years of selling a reading machine for visually impaired people, LVI (the company) considered that it is necessary to make a product update. The main reasons to apply a product updates are:

- LVI received enough customer feedback to know what should be changed/improved
- Some parts of the current product are end of life, so they should be replaces anyhow
- The expected sale numbers were not achieved

Since the product is one of the specialities of LVI and there already exists one model it can be concluded that the risk of failure of the project is little. Figure 2 tells that this project belongs between horizon one and two but tends more to horizon one. That means that most of the product is within the companies knowledge but there is a small area with has to be explored.

Finding opportunities
The development of the first product was mainly documented and some groups have already tried to improve the product. But this material is not consulted to not limit the possibilities in the project and have an open view to new options. These documents and reports will be used later to compare the solutions.

5.1.2 Measure the need and set targets
Products are mostly made to sell to other people. Therefore it is important to know what the customer wants and needs. After knowing what the customer needs, the mostly vague product objectives must be transformed to detailed performance specifications using engineering terms. The process is explained with two main steps:

1. Measure the need
2. Processing data
3. Translate the need into technical requirements
4. Benchmarking
Measure the need
The reading machine is a product for a selected group, namely blind and visually impaired people. The product must be focused on this selected group and the people who assist the impaired people. LVI is a specialist in making products for visually impaired people, so the way of working is always focused on this target group. But since the existing model is already sold for two years, LVI has gathered some customer feedback. This, together with interview data and own view of the product will be used to create the product objectives, and the product objectives will be translated to product requirements.

Processing data
The voice of the customer shows the interests, wishes and needs of the customer. This information will be transformed to ‘product objectives’ by using Table 9. A product objective is a short phrase which explains what the customer wants. Similar customer feedback can be used to form one product objective as shown in Figure 3. First some standard requirements will be summed up because they are too obvious to integrate in the table.

Standard requirements:
- The volume must be adjustable
- The reading speed must be adjustable
- There must be a pause/play function
- It must be possible to forward/rewind
- The bass/treble must be adjustable
- There must be USB port(s)
- The must be a connection for an earplug
- There must be a function to read row by row/ word by word/ letter by letter/ instant reading
- There must be a power supply plug
- The product must be safe, so there must not be any sharp edges and the product must fulfil relevant standard and norms of the selling areas

Table 9 shows the wishes of the customers on the left side, and the most leaping out desires which are called product objectives on the right side.

<table>
<thead>
<tr>
<th>The customers wishes:</th>
<th>Product objectives:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latest update of voice software</td>
<td>A product which is easy to use</td>
</tr>
<tr>
<td>People would like a kind of joystick as button</td>
<td></td>
</tr>
<tr>
<td>External control panel</td>
<td></td>
</tr>
<tr>
<td>Menu language should not change automatically</td>
<td></td>
</tr>
<tr>
<td>Scan the document by one button push</td>
<td></td>
</tr>
<tr>
<td>Use one file with more pages and be able to jump between the pages</td>
<td></td>
</tr>
<tr>
<td>Super easy mode (not much functions only speed and volume)</td>
<td></td>
</tr>
<tr>
<td>Result must be accurate</td>
<td></td>
</tr>
<tr>
<td>Exposure button is located wrong. If you push it, the device moves and the result is not that accurate</td>
<td>A product with a reliable result</td>
</tr>
<tr>
<td>Make a product which produces good sound quality</td>
<td></td>
</tr>
<tr>
<td>Make a product which can scan all types of paper quality</td>
<td></td>
</tr>
<tr>
<td>Product must scan documents even if they are out of angle or upside down</td>
<td></td>
</tr>
<tr>
<td>Requirement</td>
<td>Description</td>
</tr>
<tr>
<td>----------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Make the product easier to bring with you</td>
<td>A product which is easy to handle</td>
</tr>
<tr>
<td>Make a low weighted product</td>
<td>Make the product which is easy to handle</td>
</tr>
<tr>
<td>No parts must be sticking out</td>
<td>Make the product which is easy to handle</td>
</tr>
<tr>
<td>Dimensions must not be greater than competitive products</td>
<td>Make a low weighted product</td>
</tr>
<tr>
<td>The product must contain a battery to make it more portable</td>
<td>No parts must be sticking out</td>
</tr>
<tr>
<td>Give a bag with the product</td>
<td>Dimensions must not be greater than competitive products</td>
</tr>
<tr>
<td>Lowest volume is to loud</td>
<td>The product must contain a battery to make it more portable</td>
</tr>
<tr>
<td>The volume should be pleasant for the user</td>
<td>Give a bag with the product</td>
</tr>
<tr>
<td>Switch automatically to other language on the same paper</td>
<td>Lowest volume is to loud</td>
</tr>
<tr>
<td>There should be a basic volume to know the machine is on</td>
<td>The volume should be pleasant for the user</td>
</tr>
<tr>
<td>Access all options via external panel</td>
<td>Switch automatically to other language on the same paper</td>
</tr>
<tr>
<td>Scanning result must be fast</td>
<td>There should be a basic volume to know the machine is on</td>
</tr>
<tr>
<td>Start-up time must be fast</td>
<td>Access all options via external panel</td>
</tr>
<tr>
<td>Start up from standby mode must be fast</td>
<td>Scanning result must be fast</td>
</tr>
<tr>
<td>Microphone to name saved documents</td>
<td>Make the product which is easy to handle</td>
</tr>
<tr>
<td>Bluetooth connection to connect other devices</td>
<td>Make a product which is easy to handle</td>
</tr>
<tr>
<td>Braille display support</td>
<td>Make a product which is easy to handle</td>
</tr>
<tr>
<td>Design must reflect LVI’s core</td>
<td>Make a product which is easy to handle</td>
</tr>
<tr>
<td>Make the external button smarter so it can be used for more functions</td>
<td>Make a product which is easy to handle</td>
</tr>
<tr>
<td>The machine lets you know every % when it is charging which is not necessary</td>
<td>Make the external button smarter so it can be used for more functions</td>
</tr>
<tr>
<td>Only notification that warns when the battery goes below a certain level</td>
<td>The machine lets you know every % when it is charging which is not necessary</td>
</tr>
<tr>
<td>There must be a notification when taking a picture</td>
<td>Only notification that warns when the battery goes below a certain level</td>
</tr>
<tr>
<td>Clear sound indication during start-up and exit</td>
<td>There must be a notification when taking a picture</td>
</tr>
<tr>
<td>Lower material costs</td>
<td>Clear sound indication during start-up and exit</td>
</tr>
<tr>
<td>Easier assembly</td>
<td>Lower material costs</td>
</tr>
<tr>
<td>Make a price competitive product</td>
<td>Easier assembly</td>
</tr>
<tr>
<td>Able to scan A3 format</td>
<td>Make a price competitive product</td>
</tr>
<tr>
<td>Read newspapers</td>
<td>Able to scan A3 format</td>
</tr>
<tr>
<td>Read magazines</td>
<td>Read newspapers</td>
</tr>
<tr>
<td>Monitor view for people who can see a little so they can read the text</td>
<td>Read magazines</td>
</tr>
<tr>
<td>Cracks in the handle (make it more stable)</td>
<td>Monitor view for people who can see a little so they can read the text</td>
</tr>
<tr>
<td>High quality feeling in material and design</td>
<td>Cracks in the handle (make it more stable)</td>
</tr>
<tr>
<td>Start-up button is to sensitive</td>
<td>High quality feeling in material and design</td>
</tr>
<tr>
<td>Scanning button is to stiff</td>
<td>Start-up button is to sensitive</td>
</tr>
<tr>
<td>Control buttons which are identical quality</td>
<td>Scanning button is to stiff</td>
</tr>
</tbody>
</table>

The product objectives are now generated. But some are more important than others. That is why they will be ranked by importance on a scale from 1-5, where 1 represents ‘low importance’ and 5 represents ‘high importance’ in Table 10. They are now organized by highest ranking. The standard requirements and the product objectives will now be translated into technical requirements.
Table 10: Product objectives

<table>
<thead>
<tr>
<th>Product objectives</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Make a product which is easy to use</td>
<td>5</td>
</tr>
<tr>
<td>Make a product with a reliable result</td>
<td>5</td>
</tr>
<tr>
<td>Make a product which is appealing for the user</td>
<td>5</td>
</tr>
<tr>
<td>Make a product which is easy to handle</td>
<td>4</td>
</tr>
<tr>
<td>Make a product with a wide scanning area</td>
<td>4</td>
</tr>
<tr>
<td>Make a product with clear notifications</td>
<td>3</td>
</tr>
<tr>
<td>Make the product useful for both blind and visually impaired people</td>
<td>3</td>
</tr>
<tr>
<td>Make a robust product</td>
<td>3</td>
</tr>
<tr>
<td>Make an economically attractive product</td>
<td>2</td>
</tr>
</tbody>
</table>

*Translate to technical requirements*

To keep a clear overview, the requirements will be organized by subject. Each requirement should be clear and measurable if possible.

*Standard requirements:*

The volume must have a range from 40 dB to 90 dB
The product must have the following functions:
- Pause/play
- Forward/rewind
- Bass/treble (various sound profiles)
- Row by row/ word by word/ letter by letter/ instant reading
The product must have at least three USB ports
The product must have a 3.5 earplug
The product must contain a power supply plug

*Easy to use (5)*

One of the highest priorities is to make the product easy to use because the elderly people are in the majority of the blind and visually impaired people. About 75% of the users are elderly (Harrison, 2004). They are often not that skilled with products like this as younger people. Research has shown that visual impaired people, from an objective point of view, are considerably below what would be required for effective use of electronic devices (Geest, 2014). That is why the product must be very simple to use. Therefore, the following requirements are used:
- The software must be updated. But the most important thing is that the used software is without any bugs.
- The product should contain 4 buttons with the following functions:
  - Power button
  - Capture button
  - Menu button
  - Scrolling button
- An external panel should be optional. The user must be able to control the same functions as with the main panel. The power button is not mandatory on the external panel
- The menu language is set the first time using the product. This can only be changed by changing the settings in the menu
- To scan a document. Only one action is needed, namely pushing the capture button
- A file from a USB storage can contain various pages. There must be an easy way to jump through the pages
• The volume and reading speed must be easy to adjust during reading

**Reliable (5)**

A reliable product is also one of the highest priorities. The product must work without failures and the result must be consistent. The requirements regarding this topic are:

• The device should not move when controlling the buttons. Especially operating the exposure button should not influence the quality of the picture
• A reliable result must be guaranteed. That means that the failure can be max 5%
• The quality of the sound must be good at both low and loud volume. This will be assessed by experience
• The device must scan text on various types of paper, for example glossy, matte and coloured paper
• Documents which are placed up to an angle of 3 degrees must still be scanned. If the position (angle/upside down) is wrong, the device must give a warning

**Appealing (5)**

The last topic with the highest priority number is appealing. The product must be appealing for the user. Besides that the product is useful for the user it must be fun to use it and it should look nice in combination with the furniture. The requirements to realize this are:

• If there is a change in language in the text, the product should recognize it and change to the regarding language
• The volume range should be pleasant with volumes which are describes in the standard requirements. There must be a basic volume so the user knows that the device is still on
• The user must be able to control the same functions with the external panel (accessories) as with the main control panel. The power button is not required
• The time between taking the picture and speaking must be less than 10 sec
• The product must start up in less than 30 sec
• The product must start up from standby mode in less than 5 sec
• The product must contain a microphone to name the files which the user wants to save
• The product must contain a Bluetooth connection to connect other devices like wireless headphones and an external panel
• The product must be expandable with a Braille display
• The design must reflect LVI’s core

**Easy to handle (4)**

An important characteristic of the product is that it should be easy to handle. Though it is not the highest priority, the product must be easy to carry, handle and put away. The requirements to realize this are:

• No parts should stick out more than 20 mm above the main size of the product
• The product dimensions must not be greater than competitive products
• The maximum weight is 2 kg
• The product must contain a battery which lasts for at least five hours of operation
• There must be a possibility to order a customized bag with the product
Wide scanning area (4)

Compared to the competitive products the biggest function to distinguish the product is to make the scanning area bigger. Making it possible to read a newspaper or magazine (A3-format) will make the product much more attractive. The requirement which is needed to accomplish this is:

- The product must be able to scan pages up to A3 format

Clear notifications (3)

For people who cannot see, sound and feeling are useful ways to notify something. Therefore the product must have very clear and understandable notifications. The requirements which will ensure this subject are:

- There must be clear notifications after each action which is taken:
  - Turn the device on and off
  - Taking a picture
  - Scrolling in the menu
  - Selecting an option
  - Turning functions on and off
  - Plugging or unplugging cables
- There must be a notification when the product is busy or starting up
- There must be notifications when the battery is below 20%, 10% and 5%
- When the power cable is plugged or unplugged the device should mention the remaining percentage of the battery
- There must be a notification when the battery is fully loaded
- There must be a light which is lighted up when the device is on

Blind and visually impaired (3)

When people are not completely blind, it might be convenient to read the text on a screen as well. Therefore a screen can be applied in the device. This function has some advantages and disadvantages namely, the cost of the product might increase which is superfluous for blind people. That is why this will not be written as requirement. On the other hand, text and symbols must be applied on the product so it is easier for people around them to understand the product as well.

Robust (3)

The product must both be and feel durable. Therefore the next requirements will be applied:

- High quality feeling in material and design
- Constant quality in the parts
- Control buttons with same pressing force needed
- No crack sounds when moving parts

Economically attractive (2)

There is often a consideration between quality and price when making a product. For this product the focus will be more on the quality. But if the product is made to expensive, they will not be sold or there will be no benefit of it. This requirements should help to make an economically attractive product:

- The product must be mountable in less than one hour
- The design of the parts and the product must be as smart as possible to reduce the machining actions and time
- The price should be the same as competitors’ products. The maximum price is SEK 2500.
Benchmarking

Benchmarking is a way to compare the product with competitive products. The reading machine of LVI is compared with two other competitors. The results are based on the information of Benchmarking in chapter 4. The result is shown in Table 11 and Figure 25. A conclusion is shown under Figure 25.

<table>
<thead>
<tr>
<th></th>
<th>LVI Magnilink Voice</th>
<th>Optilec Clearreader</th>
<th>AbiSee Eye-pal Ace</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easy to use</td>
<td>○ ○ ○ ○ ○</td>
<td>○ ○ ○ ● ○</td>
<td>○ ○ ● ○ ○</td>
</tr>
<tr>
<td>Reliable</td>
<td>○ ● ○ ○ ○</td>
<td>○ ○ ○ ● ○</td>
<td>○ ● ○ ○ ○</td>
</tr>
<tr>
<td>Appealing</td>
<td>○ ○ ● ○ ○</td>
<td>○ ○ ○ ● ○</td>
<td>○ ○ ○ ● ○</td>
</tr>
<tr>
<td>Easy to handle</td>
<td>● ○ ○ ○ ○</td>
<td>○ ○ ○ ● ○</td>
<td>○ ○ ○ ● ○</td>
</tr>
<tr>
<td>Wide scanning area</td>
<td>○ ○ ● ○ ○</td>
<td>○ ○ ● ○ ○</td>
<td>○ ○ ● ○ ○</td>
</tr>
<tr>
<td>Clear notifications</td>
<td>○ ○ ● ○ ○</td>
<td>○ ○ ● ○ ○</td>
<td>○ ○ ● ○ ○</td>
</tr>
<tr>
<td>Blind and visually impaired</td>
<td>○ ○ ● ○ ○</td>
<td>○ ○ ● ○ ○</td>
<td>○ ○ ● ○ ○</td>
</tr>
<tr>
<td>Robust</td>
<td>○ ○ ● ○ ○</td>
<td>○ ● ○ ○ ○</td>
<td>○ ○ ● ○ ○</td>
</tr>
<tr>
<td>Economically attractive</td>
<td>○ ○ ● ○ ○</td>
<td>○ ○ ● ○ ○</td>
<td>○ ○ ● ○ ○</td>
</tr>
</tbody>
</table>

The results of benchmarking are graphically shown in Figure 25. Using this radar chart, it is easy to see where the focus must be to achieve a great improvement on the product. Since the subject reliable and appealing are highly prioritised and the score is not as good as than the competitors, the focus should be on these subjects. On the contrary, the product of LVI scores good at easy to use. So this should not be radically changed. Another leaping subject is easy to handle. So the focus must be mainly on the next subjects:

- Reliable
- Appealing
- Easy to handle
5.2 Concept phase

To generate different concepts Conceptual Design (Pahl, 2007) and Morfologisch ontwerpen (Kroonenberg, 2004) are both used because these two methods have similarities. This makes it possible to combine these two methods easily. The technical requirements and benchmarking from previous paragraph will give inspiration to establish functions and generate solutions for Conceptual Design and Morphological designing. When multiple concepts are generated, Optimize Design Choices (Jackson, 2012) will be used to choose a concept. The criteria to rate the different alternatives are based on the technical requirements from the previews paragraph. The chosen concept will be verified and validated by LVI’s procedures.

5.2.1 Establish functions

In this sections the functions which should be fulfilled by the product are established. First the main function will be determined, this main function will be split up in different subfunctions.

Flow of material, energy and signals

The difference between ingoing and outgoing conditions lead to the flow of material, energy and signals.

Flow of material:

- Paper with text
- Record text
- Paper with text

Flow of energy:

- Electricity
- Transform electricity
- Sound
- Light

Flow of signals:

- Press scan button
- Paper position
- Adjust preferences
- Adjust to signals
- Start scan and read
- Higher/lower volume/
- Adjust reading speed

Figure 26: Flow of material, energy and signals reading machine
Establish main function

To establish the main functions, and later on the subfunctions, the following information is used to give inspiration:

- The voice of the customer (Table 9)
- Product objectives (Table 10)
- Technical requirements (5.1.2 Measure the need and set targets \(\rightarrow\) translate to technical requirements)
- Benchmarking: by looking to the functions of competitive devices (4.2 Benchmarking)
- Flow of material, energy and signals (Figure 26)

Not all this information is useful to establish the main function and subfunctions. Some information will be used to generate concepts or later on in the design & development phase.

The main function for a reading machine can be described as following:

---

Help visual impaired people with reading

---

Establish subfunctions

The subfunctions of the reading machine will established with the information mentioned at ‘Establish main function’. The subfunctions will be shown in a function three (Figure 7). The lowest level functions are the subfunctions for the reading machine. These functions will be used to generate working structures. The function tree for the reading machine is shown in Figure 27.
5.2.2 Generate working structures

For each subfunctions different solutions are invented by the designers. All these solutions are combined in a morphological overview (Table 12). Four working structures are created by combining the solutions. The created working structures are shown in Table 13.

### Table 12: Morphological overview

<table>
<thead>
<tr>
<th>Solutions Subfunctions</th>
<th>Solution 1</th>
<th>Solution 2</th>
<th>Solution 3</th>
<th>Solution 4</th>
<th>Solution 5</th>
<th>Solution 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scan the text</td>
<td>Camera</td>
<td>Scanner</td>
<td>Scan pen</td>
<td>Mobile phone</td>
<td>Retyping</td>
<td></td>
</tr>
<tr>
<td>Present the text</td>
<td>Speakers</td>
<td>Headphones</td>
<td>Screen</td>
<td>Braille</td>
<td>Morse</td>
<td>Vibration</td>
</tr>
<tr>
<td>Lifting/moving</td>
<td>Handle</td>
<td>Edge</td>
<td>Hole</td>
<td>Rope</td>
<td>Grip</td>
<td></td>
</tr>
<tr>
<td>Stabilize</td>
<td>Tripod</td>
<td>Weight in the bottom</td>
<td>Big surface</td>
<td>Guy lines</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lightning</td>
<td>LED</td>
<td>Scanner light</td>
<td>Xenon flash</td>
<td>Fluorescent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>Voice control</td>
<td>Buttons</td>
<td>Touchscreen</td>
<td>Joystick</td>
<td>Handles</td>
<td>Remote control</td>
</tr>
</tbody>
</table>
### Table 13: Created working structures

<table>
<thead>
<tr>
<th>Subfunctions</th>
<th>Working structure</th>
<th>Scan the text</th>
<th>Present the text</th>
<th>Lifting/moving</th>
<th>Stabilize</th>
<th>Lighting</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Camera</td>
<td>Speakers</td>
<td>Handle</td>
<td>Tripod</td>
<td>Xenon flash</td>
<td>Buttons</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Camera</td>
<td>Speakers</td>
<td>Hole</td>
<td>Weight in the bottom</td>
<td>LED</td>
<td>Joystick</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Scanner</td>
<td>Screen</td>
<td>Handle</td>
<td>Big surface</td>
<td>Scanner light</td>
<td>Buttons</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Mobile phone</td>
<td>Speakers</td>
<td>Grip</td>
<td>Tripod</td>
<td>Xenon flash</td>
<td>Voice control</td>
<td></td>
</tr>
</tbody>
</table>

#### 5.2.3 Choosing alternative from multiple options

One concept has to be chosen from the four generated working structures. This choosing process conducted as described in 3.2.4.

**Step 1: Identify the different alternatives**

For each working structure a name, description and a sketch are made to create a clear overview of the different alternatives (Table 14). Extensive working structure descriptions including a SWOT-analyses of each alternative are shown in appendix C.

### Table 14: Identify the different alternatives (working structures)

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Sketch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working structure 1</td>
<td>The device is standing on three supports. The camera arm is foldable. The camera arm will reach to the middle of an A4 and A3 paper. A handle is placed on the top. A Control panel is placed on the right side.</td>
<td><img src="image1.png" alt="Sketch 1" /></td>
</tr>
<tr>
<td>Working structure 2</td>
<td>The device has a box shape. The control panel is placed on the right side. The control panel can be taken out and used as a remote control. The camera can be pulled out, the camera is placed on the left side of the device. The camera can scan both A4 and A3.</td>
<td><img src="image2.png" alt="Sketch 2" /></td>
</tr>
</tbody>
</table>
Working structure 3
Notebook scanner

The device has three layers. The first layer is a scanner. The second layer is a control panel and also the protection sheet for the scanner. The third layer is a screen. The screen presents the text, an option is to put speakers in the device. The device is totally foldable to notebook size.

Working structure 4
Smartphone reader

This product will scan and read the text by using a smartphone. The phone will be mounted in the universal holder. The user can choose to control the phone with either the buttons or voice control. Speakers are integrated in the product and connected to the phone through Bluetooth. Volume and speed adjustments can be made through buttons.

Step 2: Identify the relevant criteria
The criteria used to rate the different alternatives are the requirements which are determined in section 5.2.1. The criteria are listed in Table 15. The alternatives differ for each of these requirements but the requirement ‘clear notifications’ is not suitable for a criteria because this can be ensured during the design & development phase.

Step 3: Weight the criteria
The importance of each criteria is already given in section 5.2.1. These importance numbers from 1 to 5 will be translated into percentages. The percentages are shown in Table 15.

Table 15: Criteria to rate alternatives (working structures)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Importance (1 to 5)</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easy to use</td>
<td>5</td>
<td>16 %</td>
</tr>
<tr>
<td>Reliable</td>
<td>5</td>
<td>16 %</td>
</tr>
<tr>
<td>Appealing</td>
<td>5</td>
<td>16 %</td>
</tr>
<tr>
<td>Easy to handle</td>
<td>4</td>
<td>13 %</td>
</tr>
<tr>
<td>Wide scanning area</td>
<td>4</td>
<td>13 %</td>
</tr>
<tr>
<td>Blind and visually impaired</td>
<td>3</td>
<td>10 %</td>
</tr>
<tr>
<td>Robust</td>
<td>3</td>
<td>10 %</td>
</tr>
<tr>
<td>Economically attractive</td>
<td>2</td>
<td>6 %</td>
</tr>
</tbody>
</table>
Step 4: Score and rank the alternatives

All the alternatives are rated and ranked according to the criteria. This is done by the designers. Later in the decision process all the influenced people are asked for their opinion about the outcome. The score and ranking table is shown in Table 16. An explanation for each score is given:

**Easy to use:**
Working structure 1, 2, and 4 are all easy to use because the user only need to put the paper/book in the front of the machine and press one button. The notebook scanner is a little bit less easy to use because when the user places a paper or book on the scanner he or she has to close the scanner first. And in the case of a book it will not be possible to close the scanner totally and the control panel will be hard to reach.

**Reliable:**
Working structure 1 and 2 uses the same camera on the same height so have the same reliability. The scanner is more reliable because it cannot make faults in the focus. The reliability of the smartphone reader depends on what kind of smartphone the user has but overall this will be a bit less reliable.

**Easy to handle:**
Working structure 2 and 3 are both equally easy to handle. They will fit in standard (notebook) bags. The smartphone ready is even easier to handle because it is smaller. Working structure 1 is bigger and will need a specialized bag, this makes it harder to handle.

**Appealing:**
Working structure 1, 2, and 3 are all equally appealing, this because they all do the same thing. Only the smartphone reader has an extra possibility to use you own phone, this is why it could me more appealing for users.

**Wide scanning area:**
Working structure 1, 2, and 4 are all able to scan up to A3 format. The notebook scanner can only scan up to A4 format.

**Blind and visual impaired people:**
Working structure 1 and 2 are both equally attractive for blind and visually impaired people. The notebook scanner give some additional possibilities to the visual impaired users. The smartphone reader is less attractive for blind people because they more often do not have a smartphone.

**Robust:**
Working structure 1 and 2 are both really robust because they have a solid body. The notebook reader has multiple thin layers so is less robust. The smartphone reader is even less robust because in consists of multiple small parts.

**Economically attractive:**
Working structure 1, 2, and 3 are approximately equally economically attractive. They will all have some expansive parts. The smartphone reader on the other hand, does not have so expansive parts at all. It will be by far the cheapest solution.
Table 16: Score and rank the alternatives (working structures)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Weights</th>
<th>Working principle 1</th>
<th>Working principle 2</th>
<th>Working principle 3</th>
<th>Working principle 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Rating</td>
<td>Weighted score</td>
<td>Rating</td>
<td>Weighted score</td>
</tr>
<tr>
<td>Easy to use</td>
<td>16 %</td>
<td>4</td>
<td>0.64</td>
<td>4</td>
<td>0.64</td>
</tr>
<tr>
<td>Reliable</td>
<td>16 %</td>
<td>4</td>
<td>0.64</td>
<td>4</td>
<td>0.64</td>
</tr>
<tr>
<td>Appealing</td>
<td>16 %</td>
<td>3</td>
<td>0.48</td>
<td>3</td>
<td>0.48</td>
</tr>
<tr>
<td>Easy to handle</td>
<td>13 %</td>
<td>3</td>
<td>0.39</td>
<td>4</td>
<td>0.52</td>
</tr>
<tr>
<td>Wide scanning area</td>
<td>13 %</td>
<td>5</td>
<td>0.65</td>
<td>5</td>
<td>0.65</td>
</tr>
<tr>
<td>Blind and visually impaired</td>
<td>10 %</td>
<td>3</td>
<td>0.30</td>
<td>3</td>
<td>0.30</td>
</tr>
<tr>
<td>Robust</td>
<td>10 %</td>
<td>4</td>
<td>0.40</td>
<td>4</td>
<td>0.40</td>
</tr>
<tr>
<td>Economically attractive</td>
<td>6 %</td>
<td>3</td>
<td>0.18</td>
<td>3</td>
<td>0.18</td>
</tr>
<tr>
<td><strong>Total score</strong></td>
<td></td>
<td></td>
<td></td>
<td>3.68</td>
<td></td>
</tr>
<tr>
<td><strong>Rank</strong></td>
<td></td>
<td>2</td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Continue?</td>
<td></td>
<td>Yes</td>
<td></td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

**Step 5: Select an alternative and evaluate the result**
Working structure 1 and 2 are close to each other in score. Decided is to continue with both of these working structures. Later on in the verification and validation of a chosen alternative, the both working structures will be discussed and the best parts of both will be combined.

5.2.4 Verification and validations of a chosen alternative (working structures)
A meeting was arranged with all influenced people within the project. In this meeting the designers gave an explanation of all the working structures. This was with help from the working structure sheets (appendix C). After that each person gave his or her opinion about the working structures. It turned out that majority thought working structure 2 (box with retractable camera) was the best option. This because they liked that:

- the design is compact;
- the retractable camera arm looks solid;
- the handle is integrated in the model;
- the design looks like an old radio.

There were also points they did not like about the design, this was that:

- the camera does not retract enough;
- the wireless remote control is superfluous.

The working structure 1 (3 supports with foldable camera) had some good points according the attendees. They thought this design:

- has new product look;
- is really stable;
- has a good handle;
- is reliable because of the camera in the middle of the paper.

The good points of the both designs will be combined. This is done in section 5.2.5.

5.2.5 Structure and shape variation

Out 3.2.5 Verification and validations of a chosen alternative is becomes clear that the camera arm and the control panel should be reconsidered. Some ideas about the camera arm and the control panel which can up during the meeting will be taken in consideration during this step. Multiple options will be shown in more detail than with the working structures.

**Camera arm:**
The exact camera position will be used to see if each option is possible. The camera position is determined through a test with the camera which will be used. The different options are shown in Table 17.

**Table 17: Structure variation camera arm**

<table>
<thead>
<tr>
<th>Structure variation camera arm</th>
<th>Transport</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The camera arm is integrated in the machine. It can be pushed up through and a second arm will twist automatically to the middle of the machine.</td>
<td><img src="100x220x250" alt="Transport" /></td>
<td><img src="100x220x250" alt="Use" /></td>
</tr>
<tr>
<td>2. When the machine is in transport mode a handle is available on the top of the machine. When the camera arm is folded out the handle will disappear behind the machine.</td>
<td><img src="100x220x280" alt="Transport" /></td>
<td><img src="100x220x280" alt="Use" /></td>
</tr>
<tr>
<td>3. In transport mode the camera arm is totally integrated in the machine. The arm can fold out and extend.</td>
<td><img src="100x210x220" alt="Transport" /></td>
<td><img src="100x210x220" alt="Use" /></td>
</tr>
</tbody>
</table>
4. The camera arm will fold out when you push on it. When you push another time on the top it will shove out extend.

(100x210x220)

5. The reading machine has a triangular shape. The camera arm only need one movement to reach the needed camera position. The camera arm is foldable.

(188x210x217)

6. The reading machine has a triangular shape. The camera arm only need one movement to reach the needed camera position. The camera arm is extendable.

(210x210x250)

The camera arm is rated according the same criteria as the working structures (see Table 15). Some criteria are deleted because the options do not differ on those criteria. These criteria are: reliable, wide scanning area, blind and visual impaired people, economical attractive. The scoring and ranking is shown in Table 18.

Table 18: Score and rank the alternatives (structure variation camera arm)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Weights</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rating</td>
<td>Rating</td>
<td>Rating</td>
<td>Rating</td>
<td>Rating</td>
<td>Rating</td>
<td>Rating</td>
</tr>
<tr>
<td>Easy to use</td>
<td>16 %</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Appealing</td>
<td>16 %</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Easy to handle</td>
<td>13 %</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Robust</td>
<td>10 %</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total score</strong></td>
<td></td>
<td>2.29</td>
<td>1.78</td>
<td>1.75</td>
<td>2.23</td>
<td>2.01</td>
<td>2.00</td>
</tr>
<tr>
<td><strong>Rank</strong></td>
<td></td>
<td>1</td>
<td>5</td>
<td>6</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td><strong>Continue?</strong></td>
<td></td>
<td>YES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Control panel:
All the control panels consist of one photo button and two adjusting buttons. After pressing the photo button the machine will make a photo and start reading. The adjusting buttons can turn and be pressed. With these buttons you can change settings like, volume, reading speed, voice, equalizer etc. This is the same as the original MagniLink Voice. Customers where happy about this control panel so decided is to keep this the same.

Table 19: Structure variation control panel

<table>
<thead>
<tr>
<th>Structure variation control panel</th>
<th>Sketch</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The control panel is placed on the right side. It is possible to take the control panel out of the machine and lay in on the table. This could go with or without wire</td>
<td><img src="image1.png" alt="Sketch 1" /></td>
</tr>
<tr>
<td>2. Only a photo button will be accessible if the control panel is folded in. When the control panel folds out the adjust buttons will appear. Also a photo button is placed on this side. The control panel is placed on the right side of the machine.</td>
<td><img src="image2.png" alt="Sketch 2" /></td>
</tr>
<tr>
<td>3. All the buttons are place on the top of the machine. The photo button will appear when the camera arm slides up.</td>
<td><img src="image3.png" alt="Sketch 3" /></td>
</tr>
</tbody>
</table>
The control panel is rated according the same criteria as the working structures (see Table 15). Some criteria are deleted because the options do not differ on those criteria. These criteria are: reliable, wide scanning area, blind and visual impaired people, economical attractive. The scoring and ranking is shown in

Table 20: Score and rank the alternatives (structure variation control panel)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Weights</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Rating</td>
<td>Rating</td>
<td>Rating</td>
</tr>
<tr>
<td>Easy to use</td>
<td>16 %</td>
<td>4</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Appealing</td>
<td>16 %</td>
<td>5</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Easy to handle</td>
<td>13 %</td>
<td>4</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Robust</td>
<td>10 %</td>
<td>4</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Total score</td>
<td></td>
<td>2.36</td>
<td>2.42</td>
<td>2.27</td>
</tr>
<tr>
<td>Rank</td>
<td></td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Continue?</td>
<td></td>
<td>YES</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5.3 Design & development phase

In this phase the steps described in section 3.3 are followed and applied on the design & development phase of the reading machine.

5.3.1 Identify embodiment-determining requirements

A list of requirements for the design & development phase already shown in section 5.1.2. These requirements are SMART formulated so can be used in this phase as well.

5.3.2 Identify embodiment-determining main function carriers

The main functions for the reading machine are determined and shown in Table 21.

Table 21: Main function carriers

<table>
<thead>
<tr>
<th>Main function carrier</th>
<th>Standard/specialized</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camera + camera arm + lamp</td>
<td>Standard parts and specialized part</td>
<td>Extend and scan the paper.</td>
</tr>
<tr>
<td>Control panel</td>
<td>Specialized part</td>
<td>Give order to scan the paper and adjust preferences.</td>
</tr>
<tr>
<td>Speakers</td>
<td>Standard part</td>
<td>Present text.</td>
</tr>
<tr>
<td>Mother board</td>
<td>Standard part</td>
<td>Runs Windows XP and LVI software.</td>
</tr>
<tr>
<td>Battery + battery board</td>
<td>Standard parts</td>
<td>Provide the machine of electricity.</td>
</tr>
<tr>
<td>In and output board</td>
<td>Standard part</td>
<td>Connect power cable, 2xUSB, 3.5 Jack.</td>
</tr>
</tbody>
</table>

5.3.3 Develop layout and form design for main function carriers and select most suitable

**Camera + Camera arm + lamp**

The camera which will be used is an 8 MP (Mega Pixel) (8mp E88i059 from E-con systems). This camera is tested on the camera angle and focus. A SolidWorks drawing from the camera view is shown Figure 28. The camera will have a view of 423x310 at a height of 410 (mm). This is enough to scan an A3 paper (420x297mm).The camera needs to be connected with a USB 3.0 cable. This has to take in consideration with choosing a mother board.

![Figure 28: Camera view 8mp E88i059](image-url)
The focus of the 8 MP (right side of Figure 29) camera is good enough to read the text from a height of 410. This instead of the 5 MP camera (left side of Figure 29) which shows a too vague text.

Figure 29: Camera focus 5 MP vs 8 MP

The camera arm will be telescopic. The camera arm will be made of an aluminium tube which is guided in a U-shaped sheet metal covered with plastics. The plastics should be adjustable on the friction against the camera arm. This to prevent that the camera arm falls down when you release it. Two pictures of the camera arm are shown in Figure 30 and Figure 31.

Figure 30: Camera arm
Figure 31: Upper part camera arm
**Control panel**

Ergonomics. In the case of the control panel the following characteristics are important to discuss:

**Number of buttons:** In general, the visually impaired people need more time and training than normal people (Hoang, 2008). Therefore it is extremely important that a control panel should be design easy to understand. The more buttons the more complicated a control panel is. But to less buttons can also be complicated if many functions should be adjustable with a little amount of buttons. Decided is to put four buttons on the control panel. But maximum three buttons are accessible at the same time. This will make it easier for the user to understand the functions.

**Material:** Material used for buttons should be resistant against wear. It must be impossible that somebody can hurt him/herself on the buttons. This is especially important with products for visually impaired people. Be aware that even hand positions where normal looking people never should come must be impossible hurt. Since the control panel is foldable the possibility is that finger get stuck between the control panel and the machine. This movement goes manually so the force will not be high. Nevertheless the edges of the control panel should have a big enough radius. This to prevent that the control box will get a scissor effect.

**Adjustment force:** The adjustment force of the buttons should be low enough for elderly and to avoid that the machine is falling while adjusting functions. Nevertheless the buttons should also not be adjustable with to low force that there is no feeling/confirmation what the button did. In the old MagniLink voice is an extra spring (black square in Figure 32) used to connect the photo button. In the button on the electric circuit board (blue square in Figure 32) is already a spring mounted so the needed force to press the button is now pretty high. In the new control panel only the spring in the button on the electric circuit board will be used.

![Figure 32: Extra spring for the photo button of the old MagniLink voice](image)

**Luminous contrast:** Luminous contrast is the amount of light reflected from one surface component, compared to the amount of light reflected from the background or base surfaces. A 30% difference in luminous is generally the minimum discernible by a person with partial sight. Black and white have a 100% luminous contrast. Grey and black or grey and white have a 50% luminous contrast (Buildings Department, 2008).

To measure the luminous contrast the following equation can be used:

\[
\text{Luminous contrast} = \frac{B_1 - B_2}{B_1} \times 100
\]

B1 = light reflectance value of the lighter area.
B2 = light reflectance value of the darker area.
Decided is to make the base of the control panel black. This because the base of the reading device will be white (since the customers like this colour the most). The control panel will have a good contrast and this makes it easier to see for users which can still see a little bit. If the control panel is flipped out the top surface will be white. The photo button will be orange and the adjustment buttons will be black. These three colours have a good luminous contrast. A luminous calculator tool is used to proof that these colours have a high enough contrast (Figure 33, Figure 34 and Figure 35). This tool uses the same equations as mention above.

![Figure 33: Luminous contrast white and orange](image1)

![Figure 34: Luminous contrast black and white](image2)

![Figure 35: Luminous contrast black and orange](image3)

The control panel must be easy to assembly and all the parts must be easy to manufacture. The body of the control panel can be made out of sheet metal or plastic. Two designs are made to see which is the easiest to manufacture and assemble. A comparison is shown in appendix B. Depending on the expected selling amount a decision can be made. Most likely the control panel with the plastic body will be the best solution. The whole control panel is detailed in SolidWorks. Three pictures are shown in Figure 36, Figure 37 and Figure 38.

![Figure 36: Control panel total](image4)

![Figure 37: Control panel without sticker and cap](image5)

![Figure 38: Control panel open](image6)
Speakers
Two types of speakers are tested. The speakers which are placed in the old MagniLink Voice and PUI Audio speakers. A comparison is show in Table 22. Decided is to use the same speakers as in the old MagniLink Voice. This because the PUI Audio speakers does not fulfil the volume requirement (40-90 dB).

Table 22: Comparison speakers

<table>
<thead>
<tr>
<th>Speaker</th>
<th>Original MagniLink Voice</th>
<th>PUI Audio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sketch</td>
<td><img src="image1.jpg" alt="Image of Original Speaker" /></td>
<td><img src="image2.jpg" alt="Image of PUI Speaker" /></td>
</tr>
<tr>
<td>Volume</td>
<td>91 dB</td>
<td>87 dB (blurry sound from 80 dB)</td>
</tr>
<tr>
<td>Dimensions</td>
<td>64x64x27mm</td>
<td>45x36x20mm</td>
</tr>
<tr>
<td>Mounting</td>
<td>4 screws</td>
<td>2 screws</td>
</tr>
</tbody>
</table>

Mother board
There were two mother boards selected by LVI which could be suitable for the product. Only one of them supports USB 3.0. Since the selected camera needs USB 3.0 the choice of the mother board is easy to make. The mother board which will be used is the 2i268hw-hb-pcba.

Figure 39: Mother board 2i268hw-hb-pcba
**Battery + battery board**

The battery + battery board will stay the same as in the old MagniLink Voice. But the way of connecting the battery into the battery board may change. The left side of Table 23 shows the connection between the battery and the battery board like it is in the old MagniLink Voice. The right side of Table 23 shows the connection how it will be after the redesign. Because the battery is the heaviest part of the machine it will be placed in the bottom to maximize the stability. By placing the battery board perpendicular on the battery the length will be reduced by 58mm.

**Table 23: Battery and battery board connection**

<table>
<thead>
<tr>
<th>Battery and battery board connected in line</th>
<th>Battery and battery board connected perpendicular</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.jpg" alt="Battery and battery board connected in line" /></td>
<td><img src="image2.jpg" alt="Battery and battery board connected perpendicular" /></td>
</tr>
<tr>
<td>Total length = 210mm</td>
<td>Total length = 152mm</td>
</tr>
</tbody>
</table>

5.3.4 Search for auxiliary functions and select most suitable

The auxiliary functions for the reading machine are combining and protecting the parts. Protecting the parts is done in the same way as the old machine. A bended sheet metal plate with a thickness of 1mm will protect the components and be the base to connect all the components. The sheet metal will make the reading machine robust. The squared shaped box will be 100x220x250mm. This will keep the machine easy to handle. All the components fit in the box as shown in Figure 40 till Figure 43. The upper part will be made of plastic. The control panel will be placed on the right side because most people use their right hand to control things. On the left side an on/off button, two USB ports, a 3,5 Jack and the power input are placed. The two speakers are placed high in the machine. The battery is placed in the bottom because this is the most heaviest component.
Figure 40: Redesigned reading machine front

Figure 41: Redesigned reading machine front, folded out

Figure 42: Redesigned reading machine front, inputs

Figure 43: Redesigned reading machine back
5.3.5 Validate the design

Because the design of the reading machine is not worked out as a working prototype the best way to validate the design is to do an internal design review. This is done by showing the design to the technical manager of LVI. He said that the design is better than the old reading machine because the dimensions are reduced significantly. He also agreed that all the components will fit in the box. He mentioned that one board was missing but that was no problem to also fit it into the box. The looks could be improved but this was not the task of this project. An industrial designer should have to improve this. A comparison between the old and the new reading machine is shown in appendix D. Here you can clearly see that the dimensions of the reading machine are reduced and that it makes the machine more appealing. One picture of the comparison is shown in Figure 44.

![Figure 44: Comparison old and new reading machine](image)
5.4 Realise & testing

The design will be examined in this chapter. After taking away as many pitfalls as possible a prototype is made and the design will be communicated to the customer using a prototype. After this the design is iterated to increase the quality.

5.4.1 Design testing

In the design are several components which could cause a problem because a precise assembly and a continuous movement will occur during the use of the product. These parts are:

- The control panel,
- The camera arm.

The other parts in the design are not that critical so there is no need to test them as extensive in this phase of the design process.

Design testing will be applied because of this reasons:

- To know how the products feel and look
- To be sure that the product fits together
- To be sure the product works
- To know how the design can be approved to meet the customers need
- If the assembly is easy
- To check if there are no surprises

After defining these reasons, the design must be communicated. In case of this project the design will be communicated to the company who will produce, assemble and sell the product. Because the company is nearby, the most common way to communicate is face to face. But there is not always a possibility to communicate face to face, so sometimes the communication also goes via telephone or e-mail. Before a meeting, often a description, sketch and images of the concerning part will be communicated by e-mail before so the supervisor or the employees of the company will already have an idea of what will be coming. Regarding the control panel and the camera arm, a physical prototype will be built to simulate the design and the working. This prototype will also be communicated with the customer.

5.4.2 Prototyping

Because the design of the complete product is not ready, there won’t be made a prototype of this. But not every single part of the design requires a prototype. Nevertheless, the control panel and the camera arm are outstanding parts to prototype. Because of the compact and fragile looking design it is good to check if these parts will fulfil their function decently. Therefore two physical prototypes are made which are both focused and a little comprehensive. But during the design process was a continuous check if the parts would fit together. This could easily be done using 3D modelling software. Because there are two different prototypes which are made, they will be explained separately. For 3D printing, a XYZPrinting da Vinci 1.0 AiO is used as shown in Figure 45.
Control panel
Making a prototype for the control panel is convenient because of the many parts in a small area. Because the boards and switches are custom made, they are simulated using the 3D printer (Figure 46). In order to make it easy, the picture button is also simulated by the 3D printer instead of CNC milling. The turning button is made by the students using a conventional turning machine at the company as shown in Figure 47.
After all parts are finished (Figure 48) the parts are assembled (Figure 49) the prototype is ready now. This control panel is not working because of the fake parts. But it gives a feeling about how to operate the product.

Figure 48: Parts of the control panel  
Figure 49: Assembled control panel

**Camera arm**

The camera arm is the second assembly which the students want to prototype because of the relatively big parts in the assembly. The camera is tested in section ‘5.3.3 Develop layout and form design for main function carriers and select most suitable’. But the lamp is not tested together with the camera yet because the students did not have the right equipment at the time the prototype is made. The lamp is already used in other products of the company and it works good. The body of the camera arm was designed in metal, but for the prototype a 3D printed body is used. The cover is designed as plastic and will be printed as well. The connection of the camera arm with the square aluminium tube is also designed as plastic part.

The lamp is mounted on a thin metal plate with double sided tape. This plate is mounted right under the camera. The camera is connected by a USB 3.0 connector. But there was no small USB 3.0 connector available, the connector does not appear in the picture. The cables are guided through the joint, and in the end the cover is mounted. This process is shown in Figure 50 and Figure 51.

Figure 50: Camera arm without cover  
Figure 51: Camera arm complete
5.4.3 Iterate the design process

Iteration is been applied continuously during the design process. The students had frequent meetings with each other, the supervisor from the company and the supervisor from the university. This continuous communication made it possible to reflect on the design after every step which was made. But some failures were still detected after the prototyping process. The basic part of the camera arm was designed to fragile in the beginning. When the parts where mounted, the screw connectors and the locking part broke easily. Therefore a more robust design was made and after that it is strong enough (Figure 52). Another obstacle which was encountered is that the cable of the connector is too stiff. The cable of the camera cannot move smooth into the tube. So before testing the camera together with the light, a smaller connector and more flexible cable must be ordered. When this is tested the rest of the camera arm should also be tested on the movement. The question is if visual impaired people will understand to slide the camera arm up and flip it out. According Ambrose-Zaken (2015), who disagrees that a person who is blindfolded is an appropriate comparison or ‘like group’ to someone who is blind, the camera arm should be tested by visual impaired people.

Figure 52: The camera arm with the more robust base part

The locking part is thicker and is now connected to the screw

The thickness of the screw connecters increased
6 Results

In this chapter the results of the whole project are shown. Each of the four faces in chapter 5 has his own results. Only relevant results will be given.

The need of the customer is determined according the voice of the customer. Project objectives for the reading machine are shown in Table 10. This shows that a product which is easy to use and has a reliable result is the most important. Remarkably the economical attraction of the product is the least important project objective. The benchmarking results are shown in Table 11 and Figure 25. This gives an indication where LVI can focus so that their reading machine will distinguishes itself from the rest. The areas where LVI can gain compared with the other reading machines are reliability, easy to handle and wide scanning area.

The concept phase led to a concept. This concept was selected out of four different working structures. The score and ranking from the different working structures can be found in Table 16. It turned out that the best solution is to have a small squire shaped box with a telescopic camera arm and a foldable control panel. The dimensions from the box are 100x220x250mm. The telescopic arm will reach the height (410mm) which is needed to read an A3 format. The control panel is designed with four buttons. When folded in only the scan and read button will be accessible. When folded out another two buttons to adjust the settings will appear.

The main function carriers are determined and shown in Table 21. Selected is that the camera must be an 8 MP camera. The camera arm is designed to slide up. The upper part of the camera arm will automatically fold to the middle using a spring. The camera arm is made of an aluminium tube which is guided in a U-shaped sheet metal covered with plastics. The control panel is made out of two plastic parts and aluminium buttons. Pictures of the camera arm and control panel are shown in Figure 53 and Figure 54. The speakers will stay the same as in the old MagniLink Voice. New speakers where tested but did not met the requirements. Also the battery will stay the same, but will now be placed perpendicular on the battery board. The mother board will be the 2i268hw-hb-pcba because that is the only suitable one which also supports USB 3.0. USB 3.0 is needed because of the 8MP camera.
A prototype is made of the control panel and the camera arm (Figure 55) to get a feeling with the size and the function. After prototyping there were some things which stood up. The hole for the cables in the control panel seemed too small. This was not noticed in the 3D model. The top of the camera arm was not as stable as expected and also the connector of the 3.0 USB was not able to fit in the top camera arm. For the rest the two prototypes where equal or better than expected. The movement of the camera arm seemed possible and both prototypes where compact.

Figure 55: The prototypes of the control panel and the camera arm

The redesigned reading machine is shown in Figure 56 and Figure 57. This box will be easy to handle when everything is folded in.

Figure 56: Redesigned reading machine
Figure 57: Redesigned reading machine, folded out
7 Conclusion, recommendations and discussion

In this chapter are the results discussed. The designers will give their opinion about the outcome and will give recommendations for what to do in the future.

LVI has to focus more on the areas reliability, easy to handle and wide scanning area for their reading machine ‘MagniLink Voice’. When doing so they will probably distinguish themselves from the competitive products. The best way to achieve a wider scanning area is to use a telescopic camera arm which slides up and flips out to reach the needed height to scan an A3 format. Because of this needed height a higher quality camera than the original one. We recommend to use an 8MP camera. To make the reading machine easier to handle, we recommend is to make the reading machine in a small squared shaped box. All buttons and connections are falling within the box so there are no protruding parts. The capture button is always accessible, and when the user wants to control more functions, the control panel can easily be flipped out. The control panel consists of the three buttons which are used in the current design as well. Controlling the device will just be as easy as it is today. The battery is placed in the bottom of the device to make the device more stable.

We recommend that the camera arm and control panel should get tested by a visual impaired person. This to check if the functions on the machine are easy enough to learn and that the movement of the camera arm is easy enough to understand. We also recommend to make the base part of the camera arm of a stronger material. The dimension of the hole in the hinge of the control panel should be increased so a cable can be passed through. The other task left for the company is to connect all the components in the main frame of 100x220x250.

Overall we think the project is executed in a good way. We started in time and achieved a result which is satisfying. Although, we hoped on a little bit more detailed model in the end. The product is not even close to be ready for production. This also seemed kind of unrealistic as the project proceeded. Maybe we could have be a bit further with the design if we moved a bit faster to the application part instead of totally finishing the theory first. After two weeks focusing on the theory the spirit of designing a reading machine was a bit gone. When started with the application part we were totally motivated again to success the redesign.
8 References


Appendices

Appendix A – LVI Product Life Cycle Management
Appendix B – Comparison control panel
Appendix C – Working structures sheets
Appendix D – Comparison old and new reading machine
<table>
<thead>
<tr>
<th>Body made of</th>
<th>Sheet metal</th>
<th>Plastic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body outside</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td>Exploded view</td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
<tr>
<td>Amount of parts</td>
<td>29</td>
<td>17</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>Mass (excluding electrical board and buttons)</td>
<td>52 gram</td>
<td>44 gram</td>
</tr>
</tbody>
</table>
Concept 1

This concept has a foldable arm. This arm reached to the middle of an A4 paper. A foldable handle is integrated in the top. Speakers are placed inside the box and will give stereo sound straight to the user.

The concept is stable through three spots which touches the table.

A3 and A4 is possible to scan with the camera arm.
### Table C1: SWOT analysis concept 1

<table>
<thead>
<tr>
<th>Helpful</th>
<th>Harmful</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Internal origin</strong></td>
<td><strong>Strengths:</strong></td>
</tr>
<tr>
<td></td>
<td>- A4 and A3</td>
</tr>
<tr>
<td></td>
<td>- Easy to handle</td>
</tr>
<tr>
<td></td>
<td>- Good looking</td>
</tr>
<tr>
<td></td>
<td>- Stable</td>
</tr>
<tr>
<td></td>
<td><strong>Weakness:</strong></td>
</tr>
<tr>
<td></td>
<td>- Too big</td>
</tr>
<tr>
<td></td>
<td>- Camera arm is protruding</td>
</tr>
<tr>
<td></td>
<td>- Hard to transport</td>
</tr>
</tbody>
</table>

| **External origin** | **Opportunities:** |
|  | - Could be used as a radio  |
|  | **Threats:** |
|  | - Standard components could go from the market  |
Concept 2

Concept 2 is based on a simple design. The box has no protruding parts when it is in folded position. This makes the device, easy to move. The device has its control panel on the side so it is easy to control. For even more flexibility, the control box can also be removed so it can be used as wireless remote which can be put next to you up to 10 meters from the main device. The range of the camera is enough to capture pictures up till A3 formats so magazines and newspapers can also be read. The white, black and orange colours reflects LVI’s core and will look nice in combination with other furniture’s!

A4 format and A3 format
<table>
<thead>
<tr>
<th>Helpful</th>
<th>Harmful</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Internal origin</strong></td>
<td><strong>Weakness:</strong></td>
</tr>
<tr>
<td><strong>Strengths:</strong></td>
<td>- Device might move when pushing buttons.</td>
</tr>
<tr>
<td>- Compact</td>
<td>- Camera position might not be good yet.</td>
</tr>
<tr>
<td>- Wide scanning A4 and A3</td>
<td>- The remote control might get lost.</td>
</tr>
<tr>
<td>- Control panel which is easy to access</td>
<td></td>
</tr>
<tr>
<td>- Control panel can be used as remote control</td>
<td></td>
</tr>
<tr>
<td>- Stable design, battery in the bottom</td>
<td></td>
</tr>
<tr>
<td>- People can use the device when they are sitting on a couch or in the kitchen</td>
<td></td>
</tr>
<tr>
<td><strong>External origin</strong></td>
<td><strong>Threats:</strong></td>
</tr>
<tr>
<td><strong>Opportunities:</strong></td>
<td>- Component may become end of life</td>
</tr>
<tr>
<td>- Give a cord to connect the remote control to the device</td>
<td></td>
</tr>
</tbody>
</table>
This concept consists of 3 layers.
1. Scanner
2. Control panel and also the protection sheet for the scanner
3. Screen

This concept is totally foldable just like a notebook. It will fit in regular notebook cases.

The text will be presented on a screen and speakers could be placed behind the scanner.

Only able to scan A4 or smaller formats.
<table>
<thead>
<tr>
<th>Internal origin</th>
<th>Helpful</th>
<th>Harmful</th>
<th>External origin</th>
</tr>
</thead>
</table>
| **Strengths:**  | - Easy to transport  
                 - Screen  
                 - Reliable result  | **Weakness:**  
                  - Only A4 or smaller  
                  - Hard to transport  
                  - Books or other thick things are hard to scan  |
| **Opportunities:**  | - Combinable with a notebook  | **Threats:**  
                  - Standard components could go from the market  |
Concept 4

- Use **OCR software** for phones
- **Cheap** solution
- **Bluetooth** connection

Concept 2 is an device which is used together with a Smartphone. The phone makes an connection with the control panel and the speakers of this reading machine. The software is standard software which can be downloaded from the different stores. The phone will be mounted in the universal holder. The user can choose to control the phone with either the buttons or voice control. The speakers will create a clear sound. The arms are completely foldable and fits perfect between the buttons and the speakers. This way it is very easy to take with you.

Because of the simple design and the small amount of parts this product will be much cheaper than other reading machines.
### Table C 4: SWOT analysis concept 4

<table>
<thead>
<tr>
<th>Internal origin</th>
<th>Helpful</th>
<th>Harmful</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strengths:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Cheap solution</td>
<td></td>
<td>- Each phone might have another range of view.</td>
</tr>
<tr>
<td>- Compact solution</td>
<td></td>
<td>- Blind people might don’t have a phone.</td>
</tr>
<tr>
<td>- Compatible with almost every smartphone</td>
<td></td>
<td>- The persons arm might cover the paper when controlling the buttons.</td>
</tr>
<tr>
<td>- Updates can be realised by the phone</td>
<td></td>
<td>- Making a phone holder in which every phone can be attached securely.</td>
</tr>
<tr>
<td>- Voice control</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td>- Saved documents can be read without de-folding the device</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Read text on the screen of the phone</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Weakness:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Strengths:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Compact solution</td>
<td>W</td>
<td></td>
</tr>
<tr>
<td>- Compatible with almost every smartphone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Updates can be realised by the phone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Voice control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Saved documents can be read without de-folding the device</td>
<td></td>
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<tr>
<td>- Read text on the screen of the phone</td>
<td></td>
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<tr>
<td><strong>External origin</strong></td>
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<tr>
<td><strong>Opportunities:</strong></td>
<td>O</td>
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</tr>
<tr>
<td>- Speakers can be used to play music</td>
<td></td>
<td>- Phone might be designed different in the future.</td>
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<tr>
<td>- Product can be used to scan documents and sent them by email</td>
<td></td>
<td>- App might not get updates</td>
</tr>
<tr>
<td>- If the app is not working, there is nothing to do about it</td>
<td>T</td>
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<tr>
<td><strong>Threats:</strong></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Old design</td>
<td>New design</td>
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<tr>
<td>---------------------</td>
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</tr>
<tr>
<td>Height (folded in) [mm]</td>
<td>320</td>
<td>250</td>
</tr>
<tr>
<td>Width (folded in) [mm]</td>
<td>256</td>
<td>220</td>
</tr>
<tr>
<td>Depth (folded in) [mm]</td>
<td>250</td>
<td>100</td>
</tr>
<tr>
<td>Height (folded out) [mm]</td>
<td>320</td>
<td>443</td>
</tr>
<tr>
<td>Width (folded out) [mm]</td>
<td>256</td>
<td>220</td>
</tr>
<tr>
<td>Depth (folded out) [mm]</td>
<td>250</td>
<td>195</td>
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