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GREENHOUSE DICTIONARY

Figure 1 <Greenhouse dictionary>
PREFACE

This report is the result of our design definition phase of ‘Integral Design Project (IDP)’ 2007-2008. IDP combines the specialized skills and knowledge of three master variants in the Industrial Design Engineering (IDE) faculty at TU Delft. Acting as a design consultancy, the IDP group is carried out in a partnership with a company to offer a design proposal at the end of the project. The main goal of IDP is to translate the interests and goals of the company as well as other stakeholders into a tangible product.

The report is produced for LTO Groeiservice as part of the ‘Integral Design Project (IDP)’ by SINDES design. The problem of pepper growers in the Netherlands is that the speed of harvesting is slowed down due to the fact that pickers have to use two hands. Moreover, the current tools can damage the pepper by leaving a cut in the pepper, and this is a constant complaint from the clients. Therefore, the assignment from LTO Groeiservice was to design a new harvesting tool for peppers that is work saving, improves quality and provides better ergonomic standards.

This report gives the main findings of the last phase of this project. As a result, SINDES produced prototypes for the two concepts, followed by user testing and market introduction.

ACKNOWLEDGEMENTS

We would like to thank Ingrid Kuiper from LTO Groeiservice, Aad van Dijk, and Henk Kuipers from TU Delft for their support, guidance and constant feedback throughout the project.

“MAKING CONNECTIONS, SINDES”

The name SINDES comes from a Greek word ‘sindesi’ which means connection. Our work reflects the connections we have tried to make between many stakeholders, product, user, and the company.

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Delft, January 2008, SINDES Design
SUMMARY OF PREVIOUS PHASES

This Integral Design Project had three phases: a problem definition phase, a conceptualisation phase, and the implementation phase. The summary below gives a short overview of the first two phases in this project.

1. DESIGN DEFINITION PHASE

The main purpose of this phase was to define the design assignment into a specific domain that we can focus on. As the diagram above shows, the current situation within the context of given design assignment was analyzed. The internal situation of the company (in this case, van Dijk as an example company) was analyzed, as well as the external situation of the company which included looking at the existing products, trends and so on. These analyses led to a selection of strategic domains.

Original design description from LTO Groeiservice

- The speed of harvesting pepper is slowed down due to the fact that pickers have to use two hands. If they use one hand, then efficiency of harvesting could be improved by 10 to 20%.
- Current tools can damage the pepper by leaving a cut in the pepper, and this is a constant complaint from the...
New problem definition

- The quality of a box of peppers cannot be assured (because of the unrecognised damaged peppers).
- The quality of the harvesting process for the users is not assured (because of a combination of working conditions, ergonomics and motivation)

Main findings from the Internal & External Analysis

Company

Changes in the efficiency of labour will only give a small saving of the total cost.

In order to save the total cost, it is more strategic to invest in improving the heating system which accounts for 60% of the total expense. If we consider the total R&D projects for the greenhouse, there are other projects on heating system as well as other aspects which focus on improving the efficiency of the current system. What is lacking in this list of investment projects is investment in quality. Therefore, we propose that this project should focus on the quality

Users

Invest in quality of work environment.

The current greenhouse does not ensure ergonomically-friendly work which does not seem to be a serious problem; however it can lead to long absence from the picker (which is already happening most frequently due to harvesting) if they have RSI. Therefore, maintaining a quality work environment for the pickers should be a compulsory investment for red pepper greenhouse.

Interaction

The cutting speed is already fast enough.

It is not strategic to improve the speed of cutting the pepper, because it is already fast enough. It takes most time to throw the pepper away after cutting it. The time for throwing away the pepper is longer than the time that is needed to get to the next pepper.

Product

There is a limited range of products especially designed for harvesting peppers with high standards of technical and ergonomic design

Time span

A short term solution (5-10 year) before the development of full automation

Conclusion

From the analysis, we have concluded that the core of the problem is not about efficiency but quality.
Focusing on efficiency of the harvesting process means that the speed of each step of the harvesting process (cutting the pepper, throwing away the pepper to the container, and reaching for the next pepper). However, increasing the total efficiency of the harvesting process will not solve the real problem. The real problem is that the quality for a box of pepper decreases when even one pepper in the box is damaged. The number of damaged peppers or undetected damaged peppers will still remain the same even if the harvesting process becomes more efficient or faster. Therefore, this project will focus on improving the quality first before efficiency.
Vision

Our design will provide a short-term solution to foremost improve the quality of the work. This means that we aim to provide better ergonomic condition for different kind of workers in a greenhouse to ensure that there is less impact on the workers health. It also means that we aim to create a more steady pepper production for the picker, with the goal of increasing his/hers efficiency.

The whole domain with the vision is shown in the scheme above, which sums up the project.

a. Horizontally
   The two parts of the problem definition will be provided with solutions that will result in improvements for both parts.

b. Vertically
   This is done within the context of all the trends and within the boundaries formed by the design criteria.

To make a start for the next phase, we decided to look further at five main categories of solutions in the conceptualisation phase.

• Make it easier to recognise damaged peppers
• Less damaging of peppers
• Improve working conditions for users
• Improve the ergonomics of the working environment
• Improve motivation of users
2. CONCEPTUALISATION PHASE

The main purpose of this phase was to come up with feasible concepts which fit in the domain we chose in the previous phase.

After we have identified each step of the harvesting process, we generated possible ways to achieve each step (such as, how to find, how to grab, how to separate, etc.) Then, we have made different combinations of ideas from each step to come up with several potential concepts that address all the steps in harvesting process. Combinations refer to selecting one from each row in the morphological map as shown below, and consider something that can fulfill most of the functions selected from the map.
### IDEA GENERATION <MORPHOLOGICAL MAP>

<table>
<thead>
<tr>
<th>Properties</th>
<th>Idea 1</th>
<th>Idea 2</th>
<th>Idea 3</th>
<th>Idea 4</th>
<th>Idea 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
</tr>
</tbody>
</table>

- **Figure 6 <Morphological map>**
Many ideas have been generated (for detail information, refer to report 2). However, some of the ideas were future-oriented, and some were out of our design definition. Since our design goal was to create a short-term product (that can be used before the robots) by the pickers in the greenhouse, we decided that the tool should be handled by man. Therefore, the ease of use as well as the weight of the tool was important criteria in deciding the mechanism. In conclusion, mechanical mechanism was preferred over electrical and we decided to focus on a simple mechanical solution.

Some potential ideas were not selected due to the aforementioned reasons. However, some of the future ideas were developed more into detail and can be found at the end of this report.

Final ideas

![Figure 7](Final ideas)

We have three categories of ideas: transport system, motivation, and separating tool. All of the three are interdependent on each other in order to make the complete system.

For the transport system, a wearable tube idea was selected that can either be worn in front or in the back of the picker. The tube will be attached to the container so the transport system becomes easier than before.

For the motivation system, we had an idea about various motivating gadgets that can be added to the container. Each picker will have his/her own motivating box that they can
add on the container and make his or her preferred environment while working. It will contain exercise tools to relax and ensure the ergonomic quality of the work.

For the knife category, there were three ideas we conceptualized further.

**Brontosaurus**
The first idea was named ‘Brontosaurus' because of its shape resembling the head of a dinosaur. The difference with this knife compared to the other two, is that it is the only tool that cuts the stem from both sides. This could end up in a different kind of cut-surface quality. The tool is longer than the rest, so it would be easy to grab the stem in between the leaves.

**Lizard**
The second one was named ‘Lizard' because of the lizard that grabs the pepper towards the blade which we thought resembles the lizard. This is a simple, ergonomically shaped knife. Its strong points are that it consists of very few parts and can be made really cheap. The biggest disadvantage is that there is still thumb pressure (similar to existing knife). Also because the thumb is used on the front point of the knife, it can sometimes prevent positioning the knife correctly on the stem.

**Ladybug**
The third was named ‘Ladybug' because of its top and bottom cover that has a similar shape of a ladybug. Ladybug is one of the safest solutions because the cutting mechanism is on the inside of the tool. The idea is that the (visible) grabbing tool grabs the stem, and pools it inside to be cut. This automatically will result in less accidentally damaged peppers.

![Figure 8 (Picture early ladybugt)](image-url)
EXECUTIVE SUMMARY

This report is the result of our third phase of ‘Integral Design Project (IDP)’ 2007-2008. The project started in September 2007 and lasted for about 20 weeks.

Improving the quality of pepper and the work
The goal we have set up was to improve the quality of pepper and the quality of work. As a result of the conceptualisation phase, we presented three directions the company should consider. First concept was a knife that can ensure the quality of pepper by ensuring that there is no cut on the pepper). Second one was a wearable tube that connects to the container so that it is easier to throw away the peppers. Finally, we presented a motivation part that can either be implemented into the knife and the wearable tube or created separately.

Knife, wearable tube, and motivation
Three concepts for the knife were presented at the last meeting with LTO Groeiservice and van Dijk, and the ladybug knife concept was chosen to be developed further into a working model.

Working prototype for the ladybug knife concept
In this phase, we have considered many aspects to actualise the concept into a working prototype such as the production method, ergonomic criteria, assembly, material, colour, the cost, and so on. As a result, we have one functional model and an interaction model for the knife concept, and a rough prototype for the wearable tube concept. We have tried to incorporate the concept of motivation as much as possible into the knife and the tube; hence did not develop anything separate on its own.

Market introduction
Finally, the last part of this report concerns the product introduction to the market. We have formulated a marketing plan which LTO Groeiservice can use to convince a manufacturing company that is interested in producing our final concept. This marketing plan only concerns the knife, and not the wearable tube or the motivating part.

Delft, January 2008, SINDES Design
PART 1. INTRODUCTION

1 CONCEPT

The final concept from the previous phase consists of three parts:
- the ladybug knife
- the wearable tube
- a motivating part
The picture on the right summarizes our final idea.
2 METHOD

The idea (1) from the previous phase is further developed into a product. This product development (2) considers production development (3) and market development (4), as far as this contributes to our product. The final product (5) will be tested and is then followed by an advice on market introduction (6). This then will be evaluated (7).
PART 2. FINALISATION

The final idea from the last phase was to develop a ladybug knife, a wearable tube, and a motivating part to create the total solution. However, due to the time constraint of the IDP project we only developed a working prototype for the knife. For the wearable tube and the motivating part, some criteria and guidelines that one should consider in developing them are presented.

Mechanism, materials, assembly, ergonomics and colour are considered in finalising the concept. Based on the finalisation results, cost and weight estimations are presented.

1. LADY BUG

1.1. Mechanism

To finalise the mechanism, it is necessary to have a set of criteria to judge which mechanism fits the best to our product and how to create the mechanism into the dimensions that are optimalized for our use. For this we analysed the cutting force and the hand size.

1.1.1. Cutting force analysis

In appendix 1 and 2, the research we did on the cutting force is further explained. Below you can find the main results.

![Comparison of cutting force using different knives](image-url)
It can be concluded from the graph that a slicing cut needs much less force than the movement that only goes downward. This especially applies for the harvesting and potato knife. For the Stanley knife the effect is less. Still, when designing the final concept, a slicing movement/blade made under an angle would be important.

It is assumed that the cutting force of both harvesting and potato knife are more or less the same because the harvesting knife is already used, while potato knife is new. Also, if the Stanley knife is implemented in the design, it is important that the blade is kept sharp. When blunt, Stanley knife needs even more force than the other ones.

The mechanism was further developed into different possibilities. The mechanism was developed with the vision in mind, guaranteeing the quality of the pepper (no sharp parts or blades sticking out) and guaranteeing the quality of the work for the user (most simple movement; since the movement has to be done 8000 times a day). The basic mechanism had the function of both grabbing and cutting the stem. The grabbing was necessary to facilitate easy cutting.

1.1.2. Evaluation of the mechanism
We have chosen the ladybug concept to develop further. The mechanism of the ladybug was evaluated and then developed into a better mechanism.
The figure below shows how the ladybug mechanism will work in process. As shown, it closes the stem and the body of the product will be pushed backward. Since the blade stays in the same position, pepper will be moved across the blade.

1.1.3. Force calculation

The maximum force needed to cut the stem with an almost blunt blade is 65N (see appendix 1). This force has to be provided by the cutter. To fully cut the stem of the pepper, a horizontal translation distance of 20mm is needed. A maximum stem diameter of 20mm was considered.

We know that a maximal comfortable grabbing force of a person is about 100N (max. 500N). In order to get an output of 65N, a gear ratio of 100N/65N = 1.54 is needed. Because of the overall size restrictions of the product we made a criteria that the biggest gear has to be at most 20mm in diameter. By dividing this diameter by the gear ratio we get the diameter of the small gear and the vertical translation of the button rack. This is 20/1.54 = 13mm.
A spring is added to the construction (part of the lower grabber) to get the button back into its starting position. Because the spring pushes in the opposite direction than the hand force, the user has to compensate this when cutting. The spring force is estimated to be not more than 40N. The force is based on an amount of friction in the mechanism and the possible dirt obstruction (this needs to be compensated by the spring in the opposite direction). The force can be varied by material thickness of the spring (wide/alternative material also possible). So added to the original 100N, eventual hand force of the user will be slightly more:

**Hand force**  
MAX 140N

### Summary

<table>
<thead>
<tr>
<th>Needed gear ratio</th>
<th>1.54</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biggest gear</td>
<td>20mm</td>
</tr>
<tr>
<td>Smallest gear</td>
<td>13mm</td>
</tr>
<tr>
<td>Blade holder trans(---)</td>
<td>20mm</td>
</tr>
<tr>
<td>Button rack trans(↑)</td>
<td>13mm</td>
</tr>
</tbody>
</table>

### Disadvantages of the mechanism

- The space needed for the grabbing part to turn inwards was relatively big, making the size of the knife relatively big.
- The movement that was made by the hand was not in one direction. In figure 9 it is shown the movement is made diagonal.

### Points of improvement

Making an extra sliding shell would make the knife more expensive and made the size of the knife bigger again.  
A positive thing about the ladybug is that it is able to deal with all kinds of stem sizes. When the stem is small, the ladybug would need some space around to perform its action. The stem is actually ‘dragged in’, so the ladybug has to be able to go around the stem.

We have tried to overcome or improve these points by:

- Going back to an earlier version and rethinking it
- Finding a new solution using another kind of rotation
- Finding a new solution using a gear

### 1.1.4. Trials to improve the mechanism

For every trial, a description is given on the next points:

- Minimal size of mechanism
- One or more directions of hand movement
- Taking care of different sizes of pepper stem
We have thought again about the earlier mechanism and evaluated against the three criteria mentioned above. The original mechanisms as well as other mechanisms were considered before we made a final decision on the mechanism.

**Earlier mechanism rethought**
- Minimal size of mechanism: Around 60 mm, same as Ladybug
- One or more directions of hand movement: two
- Taking care of different sizes of pepper stem
- When small sizes are cut, the mechanism has to go around the stem, which is a problem because often there is only little space around the stem.

**New solution (rotating)**
- Minimal size of mechanism: Maybe bigger, this can be improved
- One or more directions of hand movement: only one
- Taking care of different sizes of pepper stem: no

**New solution (gear)**
- Minimal size of mechanism: Smallest possible
- One or more directions of hand movement
- Taking care of different sizes of pepper stem: Yes, although the grabbing part should get attention to this aspect
1.1.5. Mechanism for the first prototype

This is the starting position of the blade. The horizontal rack is in its most right position, and the button is most downward.

The springs of type $a$ are more easy compressible than those of type $b$. Here for, when the user squeezes the button, first the lower, loose, grab will move upwards and after this the vertical rack will grasp the small gear. This small gear is fixed on the same axis as the big gear, which, in turn, drives the horizontal rack that is attached to the blade holder.

Through this, the blade goes forward. It cuts the stem of the pepper, which is secured in the upper grab.

1.2. Ergonomic criteria
According to Peter Vink, $^1$ for the user to hold the tool in a neutral position the grip should be angled at $15^\circ$. Also, the suggested shape of the grip is a four-sided design with a cross-section that increases gradually towards the middle. The corner of the grip should be rounded.

$^1$ Comfort and Design: principles and good practice, CRC Press, Peter Vink, 2005, Florida
It should also be versatile for both right and left-handed users. The best way to achieve this, as recommended by Peter Vink, is to have a symmetrical design in the vertical plane.

Considering the above information, we decided to give a slight angle in between the main body of the tool and the grabbing part.

Bend the tool, not the wrist

unstressed: stressed:

If the entry point of the tool is kept horizontal (see arrow), the wrist is unstressed (at an angle of 15° with the hand/ finger position).
1.3. Production

We have consulted several teachers inside the faculty of Industrial Design at TU Delft to ask for advice on the production method for our design. However, we still need further consultation to decide on the final production method which will impact the choice of material and assembly.

**Injection moulding**
- Too expensive for small series of this kind of product
- Metal sheet will be a cheaper solution than plastic

**Low pressure moulding**
- To have 2 shells and save in assembly costs. The accessibility is much better when applying two shells, instead of one U-form, because there would be only one, instead of multiple, direction-of-assembly needed.
- Thermo forming
- Soft tooling (Using a mould from a softer metal, that can be milled, instead of spark-erosion, or use silicone.)
- Low pressure in combination with aluminium

**Extrusion**
- Extrusion of the u-profile in aluminum (the extrusion of plastics is more expensive)
- Sheet metal: more rounded shapes will be possible
- Location of the spring (at the knife or at the lower rack)

For the production of the moulded parts (housing, button) it is possible to injection mould, which could be profitable if a series of more then 10.000 (estimation anatech.nl) is made.

To make a test series, an expert in production methods suggested silicon moulding. This process is used in first instance as test series for possible injection moulding. Next to this it is used for other kinds of small amounts of small products (productionnavigator.com). Silicon moulding is one of the indirect rapid manufacturing techniques. This means you could use a rapid prototyping technique to produce one ‘master’ of the product that can be adjusted to optimal dimensions. This is then possible to use to make a silicon mould. Together with an epoxy mould to ensure support up to a thousand pieces can be realised with these moulds. (pnh.be) This is more cost effective then producing up to thousand pieces with direct rapid prototyping. It is a RIM method (Reaction injection moulding). More information can be found in the appendix 8

1.4. Materials

The housing can be made of PVC because its strong mechanical specifications (good stiffness and strength). Same goes for the blade holder and the safety button. When stabilized, PVC has optimum resistance to weather conditions (important in glasshouse). The only drawback that has to be taken into account is the lower resistance to temperature (around -5 would become a problem). This temperature is not reached inside the glasshouse. PVC is one of the three most used injection moulding materials. (together with PE and PS).
In general, metal gears are more reliable, but add more weight and costs to the product. We use plastic because it can also handle the force. Also plastic gears can be bought/molded as 1 part (this will be more difficult, so more expensive, which is less standard with metal). Acetal was chosen for the gears because its relatively good against moisture resistance (see appendix 6) and has good mechanical data.

Cold rolled steel easy to shape with cutting and bending. The button rack too. Especially because of the small dimensions and the needed precision.

1.5. Assembly

The button assembly is weak, since it is not fixated in any way. This could be solved by making the lower grabber be fixed to the button (changing the injection moulded button). Then although still the blade holder is not fixated. This could be solved by changing the lower grabber. In this final design it is chosen to keep the parts as simple as possible, but further analysis of assembly could make the changes. An overview of the assembly process as can be used now is shown below.

One aspect we need to consider in order to reduce the total cost is the angle of assembly. If possible, our product should be designed in such a way that it is possible to assemble from one side. Now the subassembly for the button needs different angles to assemble.

1.6. Colour study

In order to choose the colour for the knife, we first looked at the existing tools for cutting, harvesting, as well as for motivating. The cutting tools mainly were in the gray-black colour spectrum, while motivating products had bright colours of red, green, and blue.
The colour of the tool should not be red, green or yellow to distinguish the tool from the colour of the pepper & stem. We also think that it should be a bright colour to add a little bit of motivation. We therefore decided blue as the colour of our knife.

The colour we have used for the prototype was a type of blue called ‘Hammerite donkerblauw’.

According to HACCP, many products that are used inside the greenhouse have to be blue in order to find them easily when they are lost. Therefore, the existing knife they use to cut the pepper is also blue. This regulation from HACCP is another reason why we should choose blue as the main colour for our design.

The above blue is not recommended for the real product. We only chose that colour because of the limited range of paint sold at the shop. We have conducted a questionnaire, and found that many people preferred darker blue. It was interesting to hear that women preferred light blue and the men preferred darker blue. Since most of the pickers are men, we decided to choose darker blue from the questionnaire as the main colour and have yellow as the supplementary colour since many people mentioned yellow as motivating.

However, the sample number is small to make any generalization. Therefore, we suggest more in-depth user research to decide upon a colour for the real product.
1.7. Concept sketches

1.8. Digital model
We first made 3D models to test if our mechanism works, and developed a prototype based on it.

Rough developments
(Technical drawings (perspective and ‘uitslag’) are included in the appendix 3).
First prototype

Figure 14 <Rendering of the prototype>

Figure 27 <Rendering of the prototype>
Figure 29 <Technical drawings (perspective and ‘uitslag’) of the housing>
1.9. Prototype

The finished prototype is shown in the figure above. The mechanism is designed in such a way that when a user grabs the lower part, it will move the gear which pushes the blade forward. As the lower grabber is flexible, the stem can be pushed to enter into the space between the top and the lower grabbers. Then, the blade that is hidden in the housing will cut the stem and prevent the damage on the pepper. The process of how this prototype can be used is shown in steps below.

Find the knot of the pepper, and reach it with the grabber part until the knot is inside the grabber.

Place the desired cutting place exactly with the hallow line in the middle of the grabber (where the blade will come out).

Squeeze the tool, and the blade will come out and cut. At the same time the lower part of the grabber will move up and thus can grab the cut pepper.
Improvements of the new design
- Covered Blade: preventing damage the pepper during harvesting process
- Ergonomically designed: physical discomfort in thumb, hand, and wrist will decrease
- Solves the specific problem of harvesting pepper
- Motivation: Personalized grip & various colour
- Affordable (not a high-tech expensive tool): within € 10/ per tool

2. WEARABLE TUBE

2.1. Ergonomic criteria

According to the ‘arbo wet’ clothing should give sufficient freedom of movement, and it should stay in place during wearing. There should also be:
- no sharp, rough or hard surfaces
- no parts that squeeze the blood circulation
- no irritation by smell, sound or movement restriction.

Of course there is a difference between a product to attach on the body, like the wearable tube we intend, and the regulations on actual clothing.

2.2. Materials

Strong material Material should be strong for wear and tear. It should hold the weight of several peppers before they are put away into the container.

Extendable tube The tube itself should be extendable to connect the picker and the container, but also be kept in a small volume preferably.

2.2.1. Suggested information from ‘arbo wet’

The following two (Dutch) parts from the ‘arbo wet’ are relevant for the wearable tube, summarized after the arrow:

Restricted weight of the fabric to avoid burning “De kleding mag na een kortdurende blootstelling aan vonken of vuur niet catastrofaal gaan branden. Om deze reden is het gebruik van luchtige, open stoffen met een doekgewicht kleiner dan 100 g/m2 niet toegestaan.”

Use specified healthy and hygienic fabrics “De kleding mag alleen stoffen bevatten waarvan is aangetoond dat deze de gezondheid of hygiène van de gebruiker niet schaden.”
2.3. Shape

Backpack shape

The wearable tube should be in the shape of a backpack. Large backpacks offload the largest part (up to about 90%) of their weight onto padded hip belts, leaving the shoulder straps mainly for stabilizing the load. This improves the potential to carry heavy loads, as the hips are stronger than the shoulders, and also increases agility and balance, since the load rides nearer the person's own centre of mass.

External frame pack

The frame of external frame packs has a system of straps and pads to keep the sack and the frame from contacting the body. The open structure has the added benefit of improved ventilation and decreased sweatiness.

2.4. Prototype

We used metal sheets just for the purpose of the prototype, however in reality it should not be used. Materials that are recommended in the previous section should be used. The prototype allowed the user to change the level of the tube according to his/her size.

3. MOTIVATION

Instead of developing another separate product on motivation, we decided to incorporate the motivation aspect as much into the knife and the wearable tube. We had some separate concepts for motivational gadgets, however due to time limit, we have not developed any concepts into full prototypes.
3.1. Incorporated into the knife

**Different grip size**
By providing different sizes for the bottom part of the knife, users will be able to personalize the tool according to their hand size. This will enhance the ergonomic aspect of the tool as well, and provide a much comfortable grip for the user.

**Different colour**
If there is the possibility to provide different coloured products, it can enhance the feeling of owning a product as many mentioned in the questionnaire “having a different tool would make me feel more attached to the product.”

**Different colour grip**
We think that the grip parts will wear out faster than the other parts because it has constant contact, thus friction, with the palm of your hand. Since the main body of the product will not wear out so quickly, we can sell grip parts separately. This will allow pickers to change the grip parts frequently and give them a feeling of “change” once in a while. From our interviews with the pickers, many mentioned that there is nothing changing within the greenhouse. We hope that offering a variety of different colour grip can provide some change and motivation.

3.2. Incorporated into the wearable tube

**Ergonomic standards**
We have tried to give guidelines for an ergonomic design of the tube so that users do not get easily tired by wearing this tube. Ergonomic standards are mentioned in the previous section.

**Adjustable height**
It is important that the tube is positioned near the waist of the user. For users with different height, we made adjustable positions to move the tube to user’s desirable height. However, we have to consider that the container will also be near the waist of the user. Therefore, future investigation of the wearable tube should consider ways to have the tube at a comfortable height, yet do not get in the way of the container. Within the time limit of this project. The time limit prevents further evaluation.

**Motivating gadgets**
Other ideas that are separate ideas of various products that can motivate the users are illustrated below.
(1) An add-on box to the container which includes an individual cup holder, various exercise equipments like a power ball to exercise the wrist during the breaks, or even a beamer that can project anything of user’s choice.
(2) Exercise tool
(3) Coffee cup that is kept inside the box (drawing number 1)
(4) The beamer
3.3. Others

Figure 33 <Other motivational tools>
PART 3. EVALUATION

1. USER TESTING
After we have developed the prototype, we went to the Improvement Centre in Bleiswijk where research and experiments are performed to improve the cultivation processes and techniques.\(^2\) Within this centre, real peppers for user testing could be found (in January, all the greenhouses are finished with pepper harvesting). The knife prototype and a rough model of the wearable tube were tested. In Bleiswijk, not much harvested could be assessed, so this test would focus mainly on the functional aspects of the product. This functional prototype will test the function of ‘assuring the quality of the pepper’. The quality of work is harder to test with this prototype since it does not have the interaction characteristics that we designed. This is therefore tested with a different prototype, focusing on the quality of the work, so the interaction with the product. This is done through a questionnaire (see appendix 4).

![Diagram](image)

Figure 34 <Scheme: desired goal and work process>

Below one can find the criteria that were most important to analyse through the user tests. Results were gathered and points of improvements with the current prototype were made.

\(^2\) [http://www.improvementcentre.com/frameset%201280.htm](http://www.improvementcentre.com/frameset%201280.htm)
1.1. Test criteria

The aspects that were tested were gathered from the vision, goal and the criteria that were not clear in the previous phase. They can be structured through some research questions.

1. What are people doing in actual use of the model, more particular what problems occur in terms of poor usability?

This is based some aspects that were supposed to be important in earlier phases of the design process:
- Force needed to cut
- Sight that it gives on pepper stem
- Easy grabbing the stem
- Different sizes of the stem
- Different positions that the peppers can be in
- Shape of the body
- Size of the whole model
- Damaging the pepper easily
- Weight of the model
- Height of the upper ring in the tube model

2. What role play material and functional product features (whether designed as use cues or not) in the occurrence of usability problems; which problems are the result of missing adequate use cues.

What aspects might be understood incorrectly when it comes to using the model.

3. Has the occurrence of usability problems a relation with the difference in human capacities?

Especially in relation to
- Left-right handed
- Size hand
- Force hand

4. What is role of the time of usage? Could usability problems disappear after a while (getting to know the product) or could different problems come up only after using the product a while?

Incorporating:
- Learning effects
- Everyday usage

5. Does the occurrence of usage problems have a relation with the experience of the users with the cutting method?
Next to this from the vision some keywords should be addressed:

**Knife**
- Comfort
- Impression
- Easy to use
- Confidence
- Motivated

**Ring**
- Easy to use
- Efficient
- Comfort
- Impression

The participants were chosen from various gender, age and nationality, this is also done to find people with various experience (proxy, fifth research question), which could be verified later in the questionnaire.

It was told before to the user that no answer is wrong or right. We tried to make the users feel at ease so the video camera had to be as less distracting as possible. The functional test was done in the actual working area; the interaction test was done in a situation as realistic as possible, with a full grown fake pepper plant.

The questions in the questionnaire about the different aspects were asked after usage, to try to let the questions not influence the usage of the product.

### 1.2. Results functional test

The user testing did not give us all the results and insights we have expected, partly because the prototype had its limitations in easiness of use (due to too much friction in the mechanism) and the blunt blade (due to the lack of real blade in our prototype).

**Blunt knife**

We had contacted a company that sells different kinds of blades and have made an agreement to get just one special blade. However, when we called again to make sure that it is being delivered on time they refused to send us the blade. They have explained that it is impossible to send only one blade. Therefore, we had to make our own blade with the existing metal. Due to the friction it required quite a lot of force to operate this new tool. Because of this limitation of the mechanism the user did not find the tool efficient.

**Too much friction**

Since we have developed the mechanism ourselves, it would be less far less efficient than a real prototype developed by a manufacturer. We think that this problem can be improved when the production is handled by a real manufacturing company. For the test, the friction caused a high force needed to operate the knife.
Because the prototype could not cut the peppers, we were not able to test it with a large sample of users. We mainly received feedback from one person. For the research questions, only the first could be addressed in this test.

1. What are people doing in actual use of the model, more particular what problems occur in terms of poor usability?

**Size of the grabber**
One big surprise at the user test was the position of the stem in the pepper plants. We thought that there was some distance between the stem of the pepper and the main plant, as we have seen at van Dijk (see figure 35). However, the pepper stems were really close to the main plant (see figure 36). Unless the grabbers are really thin, it would be impossible to operate the tool.

**Size of the tool**
The user mentioned that the first impression he got from the tool was that it was bigger than what he expects from a harvesting tool. Since we had to use big-sized gears for this prototype the size of the model got bigger. However, we think this problem can be solved in real production.

**Wearable tube**
Peppers getting jammed in the tube were also tested: the material of the tube for our prototype is made of fiber, which makes it possible for the peppers to get jammed or hang inside the tube. It might take more time for the pickers to get rid of the peppers in the tube during the harvesting process. It must be possible to have an equal distribution of pepper in the container: with only the wearable tube, we cannot guarantee that the harvested peppers will be evenly distributed into the container. Instead, the peppers will more likely be accumulated at the exit of the tube.
1.3. **Conclusions functional test**

Due to several limitations of the knife prototype, it did not cut the pepper as we have hoped for. And since the functional part of the prototype was not working, the user mainly showed negative reactions. However, we think some of the problems recognized during the user test can be improved. And, with several improvements, we think it is possible to develop a harvesting tool that is easier to cut and more ergonomic for the user.
We will improve the current prototype and develop a new model with adjustments. This new model will not be a functional one with working mechanism; however we plan to make a model that will allow the user to feel how it would be in ideal situation (given that it will be developed in a real manufacturing company).

<table>
<thead>
<tr>
<th>Points of improvement knife</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grabbing part has to be thinner</td>
</tr>
<tr>
<td>Ensure that it can really grab</td>
</tr>
<tr>
<td>Different mechanisms can be brainstormed</td>
</tr>
<tr>
<td>▪ ways to grab the pepper without the horizontal movement of the lower grabber</td>
</tr>
<tr>
<td>▪ rotating mechanism instead of directional mechanism</td>
</tr>
<tr>
<td>Lower grabber has to be more flexible</td>
</tr>
<tr>
<td>Size can be reduced because it reality it will use smaller gears</td>
</tr>
</tbody>
</table>

To solve the problem of peppers getting jammed or stuck inside the tube, we think that the use of harder material can prevent the peppers from hanging in the tube. To use stretchable material (structure) that can be stretched on one side while the other side stays, can be an ideal solution. The plastic material will prevent the tube from hanging, and also the stretchable structure will make it possible for the tube to be bent, curved, or extended. Possible examples of such material are shown below.

Container can be changed to solve the problem of uneven distribution of peppers. We thought that it might be possible to place a board and make it a ramp of which one side is attached to the bottom of the container, and the other side will stay higher supported by a rotating canvas mechanism (like a safety belt). At first, the peppers will be put into the container at the higher end, so the peppers will fall into the lower part naturally. As more and more peppers accumulate, the weight of the peppers will make the mechanism stretch, which will make the slope become flat gradually. In this way, the peppers can be possibly equally distributed in the whole container.

![Possible material for the tube](image-url)
We have found out that there is already a similar ramp system that exists and is used by the growers. However, this system is not employed within the pepper greenhouse because the containers open up at the bottom.

With this restriction, we have thought of another way to employ the ramp system for the type of container used inside the pepper greenhouse. It will be the same mechanism, but instead of one board it will have two separate boards that are attached to two conveyor belts. When the container needs to open, the board will be totally horizontal and will open as the container opens.

**Points of improvement tube**

- Different material to prevent stuck peppers
- Make ramp in container
1.4. Interaction user test

The prototype of the improved version did not have a fully working mechanism due to the time limit. Therefore, the model actually will not be able to cut the stem. We will only test the interaction process.

See the prototype of the tree and the prototype of the further developed knife prototype on the pictures below. For each branch that is sticking out in the plant, we put tapes around to make it look like a stem (see figure 39). Also real peppers were put into the tree. Using the improved model (it will have simple springs on the bottom part of the model just to give an impression of how much force would be needed in reality) the participants cut the fake stem. Also the action of throwing away the pepper into the wearable tube was tested.

Six participants could be reached, from who were five men, one woman, five Dutch, one Iranian, 4 right handed (and 2 missing results for left/right handedness). Remarks: one said it did not matter which hand, he was both handed: he used it with his right hand. The
participants differed in age from 19 to over 50. Four people had no experience (except for a brother working with flowers and a father that was in this business). Two did have experience; one worked professionally with peppers, cucumbers and tomatoes, other worked professionally with peppers and now also grew a lot in his ‘volkstuin’ (special private garden not linked to the house).

1.5. Conclusions interaction user test
The results of the user test (for clear results in questionnaire see appendix 5) answer the research questions below, summing up the results from the second user test.

1. What are people doing in actual use of the model, more particular what problems occur in terms of poor usability?

Most important is to mention that the participants thought it was easy to use. From all the tested criteria, this aspect scored best. Some problems occurred due to the weight and shape of the prototype. Two out of the six participants said the body is too big. A longer mouth was mentioned as a solution to make it even easier. A bit lighter would be appropriate for half of the tested participants. The reaching of the peppers was scored positive. Three out of six people were satisfied; the others were neutral about this aspect. For damaging the peppers, almost the same results were gathered. Remarkable is that the experienced participants scored this aspect lower then the inexperienced ones.

For half of the participants, the tube was too height in order to use the tube a long time after each other, it was said to be better to have it on belt level.

2. What role play material and functional product features (whether designed as use cues or not) in the occurrence of usability problems; which problems are the result of missing adequate use cues.

Without explanation everybody knew right away how to hold the tool and which part would be the cutting part, one person in contrary held the knife up side down. This might be due to a lack of adequate use cues. One of the participants referred to the grabbers without explanation as ‘the mouth’. This seems to make the usage clear.

3. Has the occurrence of usability problems a relation with the difference in human capacities?

Left/right handedness did not seem to matter in the results for the other questions, although the only participant that mentioned to use his left

<table>
<thead>
<tr>
<th>Points of improvement interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce big size of knife as much as possible</td>
</tr>
<tr>
<td>Make a larger mouth for the knife</td>
</tr>
<tr>
<td>Reduce the weight of the knife</td>
</tr>
<tr>
<td>Lower the ring of the tube</td>
</tr>
<tr>
<td>Reanalyse place tube (bit to the side?)</td>
</tr>
<tr>
<td>Make it possible to store the knife somewhere</td>
</tr>
<tr>
<td>Adjust colours according to results</td>
</tr>
</tbody>
</table>
hand took the product with his right hand. As expected, the bigger hands scored better on size of the product. Especially the female participants (smaller hands) complained thoroughly on the big grip of the tool.

4. What is role of the time of usage? Could usability problems disappear after a while (getting to know the product) or could different problems come up only after using the product a while?

No results on learning effects could be found. It would need a real test environment (not possible in January) in order to let the users use this product a couple of weeks. Everyday usage was taken into account by all the participants. No special results from this aspect.

The height of the belt was only mentioned because of the implication that it would be used very frequently.

In relation to the painful places mentioned in the research of the existing knife, in this user test far less places were mentioned as painful, even when asked if they would use it a long while.
5. Does the occurrence of usage problems have a relation with the experience of the users with the cutting method?

The only difference assessed was that the experienced people were less optimistic about being sure no pepper was damaged, the rest did not really differ.

Next to this from the vision some the keywords are addressed:

- The first impression of the knife was neutral or satisfied for all participants. As is said, once used, the ease of use was scored best out of all results.
- The safety was also scored very positive (all participants minimal satisfied).
- The speed that people expected was scored very differently.
- The analysis of the video show this is promising, no stronger results can be given.
- One aspect that can influence further the scores is the colour of the product. Everybody was satisfied, although for some it did not matter.

The ring was also easy to use, the participants were all satisfied. For the tube the efficiency was scored highest. Because of the soft sides (as mentioned by participants) the comfort was good. The only aspect that influenced the tube that is not mentioned earlier is the freedom of movement. This is although suggested by a participant that did not want to wear the tube in the test.

Some further recommendations mentioned by the participants:

- Maybe a special sack on your belt that you can store your knife in
- Colour does not matter because it will get dirty and if it falls the colour will scrape off
- You have to make a very big movement
- The tube should be placed somewhat aside of you, under your armpit.
- Yellow was in 3 cases mentioned as a nice, motivating colour.

1.6. Interaction-cycle analysis

We had planned to analyze the video of user test as we did in the first phase, and give special attention for the time for each step of the harvesting process (finding a pepper, cutting a pepper, throwing it into a container). However, since it was not possible to cut the pepper the interaction analysis could not be performed. Estimation can be made on basis of the video, but since the participants did not have a row of plants to cut, this would be a too rough estimation, having nothing to do with the real usage.
2. IMPROVED PROTOTYPE

2.1. Concept drawing

![Concept sketches](Figure 42)

2.2. Design

![Final rendering: front view](Figure 43)
Figure 48: Final rendering: grabber.

Figure 49: Final rendering: exploded view.
Figure 50 <Final rendering: exploded view>

Figure 51 <Final rendering: prototype with different colour>
2.3. Mechanism

This is the starting position of the blade. The horizontal rack is in its most right position, and the button is most downward.

When the user squeezes the button, the curved rack will drive the small gear. This small gear is fixed on the same axis as the big gear, which, in turn, drives the horizontal rack that is attached to the blade holder.

Through this, the blade goes forward -to the left in this picture. It cuts the stem of the pepper, that is secured in the upper grab. The flexible lower grab clamps the stem by a T-junction that is fixed on the blade holder.

Figure 52 <Mechanisme pictures>
When the blade moves forward, this T-junction drives the lower grab in a horizontal position, and keeps it in this place. By this, the pepper will stay clamped after it is cut from the plant, and can be released when moved to the other hand, or above the container.

2.4. Technical drawing
The technical drawings are included in appendix 9.

2.5. Rib position
In order to get the right strength and stiffness of the cutter, several parts have to be provided with ribs. This mainly applies for the big plastic molded parts like the two housing shelves, grip and the button. It is important that the ribs are not dimensioned to thick to prevent sink-forming on outside of the product. Also the ribs need to have a slight angle in the vertical direction so they are easy losable from the mold. It should be regarded that in general, the more ribs are added, the higher the price will be. This is not only caused because of more material but also the mold complexity.

In the housing shelves there are some important areas to focus on. Because most of the force comes in the vertical direction of the product, the constructed ribs (not in the model) should be positioned in a way that they can cover the pressure force of the users hand. Some other areas are marked with a red circle:
1. Placing ribs in vertical direction both on top as bottom of the cover. This to cover the hand pressure.
2. This area needs to be made very rigid because this is the place where the lower grabber strip is guided trough.
3. Mount place of the upper grabber can endure a high force, during cutting or a fall.
4. At the back of the housing a good strength is needed because of the spring that tries to push the plastic button out of the housing.
5. Safety button hole needs to be good reinforced for in case someone tries to force the cutter when it is still in its blocked position.
On the inside of the button ribs can be applied to gain more stiffness. This is after all the part that has to endure the most force. If especially dimensioned, the ribs can also function as fixation for the lower grabber (spring steel strip).

The grip has a bigger overall thickness because it is made of PUR, a more softer material compared to PVC, where the housing and the button are made of. In this part the ribs are mainly added to increase stiffness (see picture). The wider/more ribs there are, the harder the grip will feel like. Because the grip is replaceable, there could be a variation in grips softness, adapted to users preference.
2.6. Name

The name of this product will be PEPPER SNAPPER. The shorter version can be PEP. The name shows the characteristics of the tool and suggests that it is a tool that snaps and cuts the pepper. Moreover, ‘pep’ in Dutch is also used when you encourage or motivate others (op-pep-pen).

Figure 57 <Pepper snapper, the Pep>
2.7. Usage process

Safety button

The button is maybe the smallest part of the whole product, but it is definitely not the least important one. The knife is designed in a way that the blade is not easy accessible, but there is always a chance of getting injured. To diminish this chance and to improve safety, a blocking button is added to the cutter. The button is little molded part with click fingers on both sides. This way it can be easily clicked into the left housing from outside. By sliding it forth into a groove on the backside of the button rack, the mechanism can be blocked. Sliding the button back unlocks the mechanism again.
The position of the button is especially chosen before the gears. This is done because when pressed in a blocked position, there is no unnecessary stress on these parts. The knife is blocked in a ‘cutting’ position, so that the knife is fully extracted. This has several advantages:

- The sharp part of the blade is safely closed in by the grabbers.
- With the button inside the housing, it makes a more compact product, easier to store.
- The blade is better accessible for replacement
- Pepper dirt can easily be removed from the knife and possible moisture can dry in the open air.

A negative effect could be that the spring and the parts connected to it get a constant stress. But this should not be a big problem because more of the existing products are closed in a similar way. This should be regarded in modeling the whole shape (see part about reinforcing ribs).
2.8. Parts list

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Part</th>
<th>Amount</th>
<th>Material</th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Housing (left)</td>
<td>1</td>
<td>PVC</td>
<td>Silicon molding</td>
</tr>
<tr>
<td>2</td>
<td>Housing (right)</td>
<td>1</td>
<td>PVC</td>
<td>Silicon molding</td>
</tr>
<tr>
<td>3</td>
<td>Button</td>
<td>1</td>
<td>PVC</td>
<td>Silicon molding</td>
</tr>
<tr>
<td>4</td>
<td>Grip</td>
<td>1</td>
<td>PUR</td>
<td>Silicon molding</td>
</tr>
<tr>
<td>5</td>
<td>Upper grabber (left*)</td>
<td>1</td>
<td>Cold Rolled Steel (Type C1018)</td>
<td>Cutting, bending</td>
</tr>
<tr>
<td>6</td>
<td>Upper grabber (right*)</td>
<td>1</td>
<td>Cold Rolled Type C1018</td>
<td>Cutting, bending</td>
</tr>
<tr>
<td>7</td>
<td>Lower grabber</td>
<td>1</td>
<td>Spring Steel (SAE 1095)</td>
<td>Cutting, bending</td>
</tr>
<tr>
<td>8</td>
<td>Blade</td>
<td>1</td>
<td>Tool Steel (D2)</td>
<td>Bought in</td>
</tr>
<tr>
<td>9</td>
<td>Blade holder</td>
<td>1</td>
<td>PVC</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Big gear**</td>
<td>1</td>
<td>Plastic (Acetal)</td>
<td>Bought in</td>
</tr>
<tr>
<td>11</td>
<td>Small gear**</td>
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<td>Plastic (Acetal)</td>
<td>Bought in</td>
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<td>12</td>
<td>Button rack</td>
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<td>Cutting</td>
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<td>13</td>
<td>Safety button</td>
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<td>PVC</td>
<td>Injection molding</td>
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<tr>
<td>14</td>
<td>Screw</td>
<td>2</td>
<td>Steel</td>
<td>Bought in</td>
</tr>
</tbody>
</table>

* Upper grabbers are almost identical, only difference is that the two top flaps are bended in a mirrored direction. This is done to gain a gap where the blade holder can slide. Alternatively the upper grabbers can be made identical, with an extra part (metal strip) in between.

**The gears are bought in separately and assembled. Alternatively they can be injection molded together as one piece.
For steel types, plastic gear types and properties see appendix 6.

2.9. Weight estimation

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Part</th>
<th>Volume (mm³)</th>
<th>Density (g/cm³)</th>
<th>Weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Housing (left)</td>
<td>28219</td>
<td>1.02</td>
<td>28.78</td>
</tr>
<tr>
<td>2</td>
<td>Housing (right)</td>
<td>28209</td>
<td>1.02</td>
<td>28.77</td>
</tr>
<tr>
<td>3</td>
<td>Button</td>
<td>14794</td>
<td>1.02</td>
<td>15.09</td>
</tr>
<tr>
<td>4</td>
<td>Grip</td>
<td>19736</td>
<td>1.02</td>
<td>20.13</td>
</tr>
<tr>
<td>5</td>
<td>Upper grabber (left*)</td>
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<td>7.83</td>
<td>20.68</td>
</tr>
<tr>
<td>6</td>
<td>Upper grabber (right*)</td>
<td>2641</td>
<td>7.83</td>
<td>20.68</td>
</tr>
<tr>
<td>7</td>
<td>Lower grabber</td>
<td>6415</td>
<td>7.83</td>
<td>50.23</td>
</tr>
<tr>
<td>8</td>
<td>Blade</td>
<td>382</td>
<td>7.83</td>
<td>2.99</td>
</tr>
<tr>
<td>9</td>
<td>Blade holder</td>
<td>7162</td>
<td>1.02</td>
<td>7.31</td>
</tr>
<tr>
<td>10</td>
<td>Big gear**</td>
<td>1866</td>
<td>1.41</td>
<td>2.63</td>
</tr>
<tr>
<td>11</td>
<td>Small gear**</td>
<td>1351</td>
<td>1.41</td>
<td>1.90</td>
</tr>
<tr>
<td>12</td>
<td>Button rack</td>
<td>2069</td>
<td>7.83</td>
<td>16.20</td>
</tr>
<tr>
<td></td>
<td>Component</td>
<td>Quantity</td>
<td>Weight (g)</td>
<td>Dimensions (mm)</td>
</tr>
<tr>
<td>---</td>
<td>-----------------</td>
<td>----------</td>
<td>------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>13</td>
<td>Safety button</td>
<td>615</td>
<td>1.02</td>
<td>0.63</td>
</tr>
<tr>
<td>14</td>
<td>Screw</td>
<td>417 (x2)</td>
<td>8.03</td>
<td>6.70</td>
</tr>
</tbody>
</table>

**Total Weight:** App. 220 grams
2.10. Production cost estimation

Cost price calculation

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
<th>Weight (g)</th>
<th>Price/kilo (€)</th>
<th>Price/part (€)</th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Housing (left)</td>
<td>PVC</td>
<td>28.78</td>
<td>1.98</td>
<td>0.06</td>
<td>Silicon moulding</td>
</tr>
<tr>
<td>Housing (right)</td>
<td></td>
<td>28.77</td>
<td></td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>Button</td>
<td></td>
<td>15.09</td>
<td></td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>Blade holder</td>
<td></td>
<td>7.31</td>
<td></td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Safety button</td>
<td></td>
<td>0.63</td>
<td></td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Grip</td>
<td>PUR</td>
<td>20.13</td>
<td>4.41</td>
<td>0.09</td>
<td>Silicon moulding</td>
</tr>
<tr>
<td>Upper grabber (left*)</td>
<td>Cold Rolled</td>
<td>20.68</td>
<td>1.48</td>
<td>0.03</td>
<td>Cutting, bending</td>
</tr>
<tr>
<td>(Type C1018)</td>
<td>Steel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper grabber (right*)</td>
<td></td>
<td>20.68</td>
<td></td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>Button rack</td>
<td></td>
<td>16.20</td>
<td></td>
<td>0.02</td>
<td>Cutting</td>
</tr>
<tr>
<td>Lower grabber</td>
<td>Spring Steel</td>
<td>50.23</td>
<td>2.53</td>
<td>0.13</td>
<td>Cutting, bending</td>
</tr>
<tr>
<td>(SAE 1095)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blade</td>
<td>Tool Steel</td>
<td>2.99</td>
<td>-</td>
<td>0.30</td>
<td>Bought in</td>
</tr>
<tr>
<td>(D2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Big gear</td>
<td>Plastic (Acetal)</td>
<td>2.63</td>
<td>3.17</td>
<td>0.80</td>
<td></td>
</tr>
<tr>
<td>Small gear</td>
<td>Plastic (Acetal)</td>
<td>1.90</td>
<td></td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td>Screw (2x)</td>
<td>Steel</td>
<td>6.70</td>
<td>-</td>
<td>0.08</td>
<td></td>
</tr>
</tbody>
</table>

(see appendix 7 for resin prices in January 2008)

Material costs

According to Kals et al. (‘Industriële Productie’), there should be taken a waste percentage into account of approximately 40% when moulding, and 30% when using sheet metal as production method. The figure 63 shows a sheet of metal out of which the grabbers can be cut. Even with a smart positioning there will be material wasted, which can be reused by melting, but must be taken into account.

This gives a total of € 2,25 + 20-40% waste material = € 3,00 on material costs.
**Production costs**

The figure 64 shows the share of the different parts of the cost price, of which the material costs (2) is almost half of the total cost price. But since the costs on the field of designing (1) and selling and overhead (6, 7) are at a minimum in this project, the diagram will be different. Also the use of rapid prototyping would influence the cost price.

![Figure 64: Shares cost price](image)

**Assembly costs**

As told in this report the assembly takes place with two different orientations, which means repositioning the tool while assembling it. The number of orientations should be as low as possible in order to keep the assembly costs as low as possible.

With this taken into account we can give a rough estimation of a cost price of €1,00 per tool.

![Figure 65: Assemble orientations](image)
2.11. Advantages of the new design

The advantage of 'Pepper Snapper' is that it will ensure that the blade does not cut into the pepper, and also provide a more ergonomic hand position for the users.

Existing knife vs. New harvesting tool

<table>
<thead>
<tr>
<th>Quality of pepper</th>
<th>Ergonomic criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>The blade can easily cut into the pepper.</td>
<td>Pain in thumb and finger after long use.</td>
</tr>
<tr>
<td>The blade does not have contact with the pepper.</td>
<td>Less pain by using bigger arm muscles.</td>
</tr>
</tbody>
</table>

When it is compared to the existing knife, we expect that the average amount of harvest pepper will be similar to the current rate. Although pepper snapper might be slow in the beginning, the speed will not decrease so dramatically as in the existing knife because it provides a more comfortable cutting position for the user. Therefore, when two tools are compared in a long period of time, we expect the production rate of pepper to be similar.
However, this has to be tested out with a real prototype over a long period of time to really find out the advantages. This process is very important not only for product testing purpose but also to convince the potential users with clear data to support the advantages of ‘pepper snapper’.

2.12. Adaptations

In these pictures the positioning of the grabber is shown: through the gap between the two upper grabbers, the cutting spot is visible. When pushing the button, the knob of the pepper stem will be secured in this position. In this way the picker can lose his sight on the cutting location, right after he found the spot.

After our experience of the various circumstances between different green houses, we advice to test the reachability of the grabbers at more plants in the different green houses.

The damaging peppers will be avoided by rounding the ends of the grabbers, made of 3 mm thick steel, like shown in figure a. If, after testing, it points out that this is not sufficient, there can be decided to choose for a closed end, like shown in figure b. A closed end can be more rounded.
The grabbers will be strong enough to survive a drop on the floor. This is very important because the grabbers also act as guide for the blade holder, if the grabbers are bended, the blade will not be able to move. Even though, it is good to prevent the Pep from dropping at all. This can be done by a wrist strap, attached on the tool.

2.13. Product life cycle

We expect the life cycle of the tool to be at least more than one year (the body of the tool and the mechanism inside). The product life cycle of the new designed tool mainly depends on the gear system. From our research results of the gear, there are a lot of factors that will affect the life cycle of the gear. Thus, we thought that it is better to take another way around, to determine first the desired life cycle of the gear, and than choose the gear system that can fit the demand. The variety of different materials, teeth, and design of the gear can make the duration of the gear system to be from few months to one year or more. Thus, the gear system can be chosen depending on the product strategy. Another key factor that will affect the product life cycle is the damage of the grabber part. The deformed grabbers can make the tool dysfunctional. To tackle this problem, we designed a wrist strap, as mentioned before, to keep the tool form dropping. As a result, with the correct use of the tool, the product life cycle can last more than one year. However, if the strategy in the future is to make the product life cycle to be more than one year, it can be realized by using a more durable gear system.
PART 4. MARKET INTRODUCTION

This part of the report is our advice on how the finished product (only the knife) can be introduced to the market. We hope that LTO Groeiservice can use this marketing plan as a reference to convince a manufacturing company to develop this idea to production.

Purpose of marketing plan
- intends to serve its customers in the marketplace
- makes money by specifying where it is positioned in the value chain
- which mechanisms will be used to generate revenue and profits
- creates financial value for its shareholders.

Limitation of this marketing plan
Usually marketing plan is written to a company who will approve the idea and manage the manufacturing and production. However, in this case, we do not know who the company will be. Since we do not have the information of the company at this point, it is difficult to give an advice on the financial spending. Therefore, this marketing plan lacks specific financial planning.

1. EXECUTIVE SUMMARY for the MARKETING PLAN

Dutch pepper is famous for its high quality. Thus, quality is one of the most important criteria that need to be insured. There are some problems caused by the existing knife. For example, some of the main problems are the frequent cuts into the pepper by the knife, and the muscle pain in thumbs and fingers for the users. Thus, the Dutch pepper growers intended to find a proper short term solution (5 to 10 years) for these problems.

The new design for the harvesting tool is focused on improving the quality of both the pepper by preventing the damage of pepper while harvesting, and the users by providing an ergonomically shaped tool. This harvesting tool is specially designed for the man power use, in the context of greenhouse.

The core strategy of selling this product is to penetrate through Dutch grower union and making a monopoly agreement (all the Dutch pepper growers to use this product). This strategy can be achieved by communicating the functional benefits the new tool can bring and the financial profits it can yield.

2. CATEGORY ANALYSIS

2.1. Aggregate market factors
a. Category size  
1246 hectares * 3 pickers per ha. = app. 3000 pickers

The target group is the greenhouse pepper growers in the Netherlands. At first, both the open field growers and the greenhouse growers were taken into account. However, in the
statistics of “Holdings with vegetables in the open by size of area and crop”, we did not find the statistic number of pepper in the Netherlands (resource: Centraal Bureau voor de Statistiek). We assumed that either there is no pepper grown in the open field in Holland or too small amount to be counted into statistics. In the statistics “Area vegetables under glass by size of area and crop” we found that in 2005, there is in total 1236 hectares area is used to grow pepper. Besides this number, According to the owner of van Dijk, in high season, in average 3 pickers are needed per ha. As a result, we calculated a number of 3708 workers work at the same time during the high season of harvesting pepper. Thus, this can be seen as the number of the potential needs for the tools (we assume that the harvesting tool is for single use) to harvesting pepper in the Dutch greenhouses.

b. Category growth From 2003 to 2005, the area of bell pepper under glass in the Netherlands grew form 1213 to 1236, around 1.9% growth.

c. Sales cyclicity Estimated life cycle of the blade= max. 3 months
Other tools that are similar such as special scissors for aubergine growers have the product life cycle of 2 to 3 months. Because harvesting inside the greenhouse requires a high number of cutting, the blade or scissor gets rusted quickly. The total Production per year for van Dijk is 5300,000Kg. The average weight per pepper is around 300g. 
→ 5,3 billion/300= 18 million times needed to operate the tool per year. Although it is not possible to estimate at this point how many times the blade can operate before it gets blunt,

d. Seasonality we can assume that the product life cycle of the blade will be at maximum 3 months.
If we suggest that in one product life cycle a tool can operate 20,000 times, it means that a number of 880 tools are needed per year. The harvesting season is from March to November, while the high peak is during May. (In the year 2006, the highest peak is 19th week, the second week of May.)

3. SITUATION ANALYSIS

Based on the analysis from the problem definition phase, we have categorized different factors into internal strengths and weaknesses and external opportunities and threats (SWOT).
3.1. SWOT analysis

Strengths
- Physical discomfort in thumb, hand, wrist will decrease
- Nearly impossible to damage the peppers
- Ergonomically designed
- Solves the specific problem of harvesting pepper
- Affordable (not a high-tech expensive tool)

Weaknesses
- The price of the new tool will be much more expensive than a knife that is about € 0.50.
- Has limitations to be used for other kinds of vegetable
- Initial speed of cutting may be slower

Opportunities
- Within the category of harvesting tool, there is no specific tool for harvesting pepper.
  - Should be a product category competition
  - Emphasize on the functional benefits
- Can be used for another type of vegetable
- Increasing the quality of pepper can increase the selling price, thus more benefit.
- A hortifair for agricultural sector is held annually for companies and growers to come and introduce their work
- No current project to improve the harvesting tool (many focus only on future solutions, not short term)
- Need for high quality of food
- Greenhouses operate in close network with growers’ association and pepper union

Threats
- Growing rivalry from the foreign growers (ie, Spain, Israel)
- Growing of labour cost
- Employers have more responsibility of social security
- The most common appearing causes of health issues in harvesting are short cyclic work, repetitive movements and non ergonomic tools.
- Foreign markets (especially Israel and Spain) are growing: possible competitors of the future
  - regarding their employees
- Providing high quality work place
- Pickers demand higher working standards
3.1.1. SWOT synthesis
We tried to consider the SWOT factors and answer some of the following questions.

- How to maximize the strengths of this tool by benefiting from the opportunities?
- How to fight the threats from the external environment using the strengths of this tool or opportunities?
- How to minimize the weaknesses of this tool by using the opportunities?

**Strengths & Opportunity combination**
- Emphasize that growers can ask for higher selling price per pepper with this tool because it is difficult to damage the pepper because of its shape and form.
- Communicate that this tool will solve the short-term need before the futuristic robots come.
- Promote this new tool in the annual hortifair so that more pepper growers can use it.
- Also, promote this new tool on the websites of the grower’s association and pepper union.
- Benefit from the close network between growers’ association and pepper union and try to make a monopoly agreement among all the pepper growers within the Netherlands to use this tool. This was the case for the specific type of scissors used by aubergine growers in the Netherlands.

**Strengths & Threats combination**
- Growing needs of high quality of workplace can partly be provided by this ergonomic tool.
- Frequent pain in thumb and fingers which can lead to long-term sick-leave of the pickers can improve because of the ergonomic design of this tool.

**Weaknesses & Opportunities combination**
- Communicate clearly its benefits which the current knife cannot bring to justify for the higher price (in comparison to the simple knife).
- Communicate the importance of quality instead of efficiency (or the speed of cutting).

3.2. Competitor analysis
The only used tool in harvesting pepper in the Dutch greenhouse is a simple knife.

**Advantages of the existing knife**
- small & light
- easy to access peppers with different stem positions and sizes
- easy to sharpen
- cheap (under 1 euro)
3.3. Customer analysis
The pepper growers are eager to solve the problems caused by the existing harvesting knife. Our designed tool targets specially to solve these problems, which complete the customers’ aspiration and can thus win the support and be purchased by the growers, our customers.

3.4. Market potential
The market potential represents the maximum sales under a given set of conditions. Several information that you need to calculate the market potential are:

- Maximum number of pepper harvesting workers who work in the greenhouse
- Life cycle of the tool

Since this tool is the only solution in the product category which solves frequent problems many pepper growers are faced with, the market potential can be very high. If all pepper growers in the Netherlands decide to use this tool (as in the aubergine case), there can be a monopoly within this product category.

In such case, the market potential will be:

**Total number of pickers in the Netherlands * life cycle of the product**

(This will be calculated after the life cycle of the product is decided)