UNIVERSITEIT TWENTE.

# SMART ENVIRONMENTS PROJECT

# DOCUMENTATION REPORT

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# Chapter 0: Introduction

The problem we decided to tackle is the endangerment of many bee species. All over the world, numbers of bees are plummeting. This is an even more prominent problem in places that have high levels of urban development. As bees are part of the main pollinators for local flora, it is important to keep the bee population steady and healthy. For bees, the biggest problems are parasites, pesticides, radio waves from telephones and the disappearing of its habitat.
To counteract the extinction of bees, we came up with a smart beehive for people to have at home. With sensors we will monitor the hive from the inside and furthermore count the number of bees that currently live in the smart hive. Next to the beehive we will provide flower seeds to ensure that the bees do not only have the necessary habitat but also enough food close by to sustain the colony. We want to make the beehive for private use to teach people more about bees and their needs. This way we hope that more people will grow aware of the importance of bees and their endangerment.

We are a determined and diverse team, ready to face this problem and solve it. Our team consists of:

Ben Ligthart (team leader)
Ilse de Haan (innovator)
Wouter Bleker (analyst)
Nikki Warries (innovator)
Alex Bosch (driver)
Tristan van Marle (analyst)

Together, we are Hivey.

# Chapter 1: Literature Review

In this chapter we will discuss certain publications we found regarding disasters.

**Climate change**
*Source:* https://www.cbd.int/doc/press/2020/pr-2020-09-15-gbo5-en.pdf
In this document there is stated that due to the disaster of climate change the world is changing and that we will need to do 8 things to come close to save our planet. These 8 things could help us finally save the world if we want to give the future of humanity a chance of survival.

**Power outages**
*Source:* http://eprints.lincoln.ac.uk/id/eprint/12908/2/Blackouts4ZR%2BDP.pdf
In this paper the consequences of the power outage of Venezuela in 2019 are stated. Furthermore there is spoken about what might have caused it. These power outages have heavy consequences on economic as well as medical field.

**Overpopulation**
*Source:* http://www.scielo.org.za/pdf/samj/v98n3/01.pdf
In this document is stated that overpopulation of our planet is a problem and accelerates the demise of the earth. Since more and more people get born and people get older every day, the population of earth will continue growing. It will not take long before a food shortage or something alike will occur due to this.

**Stock markets getting hacked**
*Source:* https://247wallst.com/economy/2020/08/28/after-new-zealand-global-stock-exchanges-face-reminder-of-cyberattack-risks/
In this article there is spoken about the disaster of the new Zealand's stock market getting hacked. This could result in a serious problem for their economic market. Values of companies could drop heavily or the value of their valuta. This will then develop a greater spread of economic problems across the world.

**Flooding**
*Source:* https://interestingengineering.com/7inventions-and-ideas-to-stop-flooding-and-mitigate-its-effects
Several ways to solve the flooding problems around the world. Because of the changes in nature due to climate change more and more floods are occurring each day. Especially in 3rd world countries they are not capable of defending against them and neither in rebuilding their cities and villages after one.

**Earthquakes**
*Source:* ttps://today.tamu.edu/2020/10/29/bridgeswith-limb-inspired-architecture-could-withstand-earthquakes-cut-repair-costs/
Article about a hydraulic kind of pillar for bridges that make bridges earthquake-proof. The heavy incident in Genoa still dwells in our minds. We have seen more of these incidents

happen more and more regularly. To stop people dying from the collapse of bridges due to earthquakes we need to come with a solution.

**Avalanches**
*Source:* ttps://gearjunkie.com/bcatracker-s-avalanche-beacon-review
Review for an avalanche tracker. Mostly used by people that go hiking in the mountains or go skiing. When people are buried under snow after an avalanche it is very hard to search for them, this tracker could help with that.

**Fire outbreaks**
*Source:* https://abc7news.com/home-insurance-fire-fair-plan-risk-score/7167949/
An article on how American communities try to prevent a fire outbreak in their local area. These fires and wildfires happen more and more often and have great consequences.

**Disappearance of bees**

*Source:* https://www.onegreenplanet.org/animalsandnature/the-disappearing-bees-and-what-you-can-do-to-help/
An article on the disappearance of bees. Mainly discussed are the reasons why bees are disappearing and what we can do to solve this problem. The disappearance of the bees has a direct influence on the agricultural sector and our food circle. If left unsolved it could result in a food shortage.

**Grasshopper plagues**
*Source:*https://www.bbc.com/future/article/20200806-the-biblical-east-african-locust-plagues-of-2020
An article on the 2020 grasshopper plague in South Africa. How did the South African population try to solve this problem and what were the consequences of these 'solutions'? These grasshopper plagues have great consequences on the affected countries and most of the time result in food shortage.

**Floating homes – flooding**
*Source:* https://theconversation.com/how-our-floating-homes-will-help-people-in-flood-prone-countries-118064
A few inventors came up with an idea for floating homes. People who live in areas where flooding is common can keep on living at their home after a flooding. Flooding has been a big problem for quite some time, with this solution the rebuilding after a flood would be made easier.

**Impact of disasters on children**
*Source:* https://www.tandfonline.com/doi/full/10.1080/20008198.2018.1500823
An article on how children are affected mentally by natural disasters and the consequences of them. Most children who have been in a natural disaster get traumatised and will fall astray of the right path of life. They become criminals instead of getting the help to deal with

their feelings.

**Emotional and physiological well-being after disasters**
*Source:* https://doi.org/10.1016/j.janxdis.2020.102297
About the impact on the emotional and physiological well-being of the people that are directly or indirectly impacted by natural disasters. Lots of people have a hard time dealing with natural disasters after experiencing this. For many it becomes a life changing experience but not for the best. Losing their job or mental stability are examples of the consequences.

**Weather disasters**
https://www.nature.com/articles/nature16467
On how extreme weather disasters can ruin regional crop production. This has great influence on the economic parts of countries, and on their food circulation. If left unhandled it could result in food shortages.

**Elevator accidents**
*Source: https://prideandservice.wordpress.com/2013/04/17/5-ways-to-avoid-elevator-accidents/*
Although the chances of being killed by an elevator are really small (approximately 1 in 10 million) there is still a chance that an elevator can get you hurt or killed. Elevator accidents mostly happen because of falls ( elevator slams people into walls or people step into an empty shaft) and mostly occur with people who are repairing or installing an elevator. Even though taking the elevator is safer than taking the stairs, people could still be trapped inside an elevator which to some might be a huge disaster. Ways to avoid elevator accidents are for example keeping the equipment clean and dust-free, report if an elevator is mis-leveling, be patient when you get trapped inside an elevator and not entering an elevator when the doors are already closing.

**Explosions**
*Source:* https://www.cdc.gov/masstrauma/preparedness/primer.pdf
Explosions can cause rare injuries to people and also severe trauma. The most common fatal injury are lung injuries. If an explosion takes place in a confined space like a building it is most likely to be fatal. So, even though people survive the blast power itself or the flying rubble, their lungs will probably not be able to handle it and decease because of it.

**Nuclear accidents**
*Source:* https://thebulletin.org/2011/05/five-steps-to-prevent-another-fukushima/
A couple of things which the government can do to help prevent nuclear accidents are; stabilizing the supply system for electricity, storing fuel in a safer place, installing filtered vent systems, preventing sabotage at nuclear facilities and military attacks.

**Cultural disasters**
*Source:* **https://www.bulletin.nzsee.org.nz/index.php/bnzsee/article/view/463/442**
When natural disasters happen, a lot of pieces of culture get lost. These lost pieces of culture damage people's way of living and could result in a lot of emotional unstable people leading astray. This then has impact on society as a whole and should not be left unhandled.

**Firework safety**
*Source:* http://henkvoogd.nl/pdf/refereed12.pdf
Right now, there are a lot of fireworks that can't be sold this year and need to be put away safely. This piece talks about the firework disaster in Enschede. Because the government wants to ban the selling of fireworks this year the unsold fireworks are left untouched but are not allowed to be stored normally. To prevent another firework disaster a new way of storing has to be thought of.

**Fire safety in high buildings**
*Source:* https://link.springer.com/article/10.1186/2193-0414-2-7
In case of a fire it's more difficult to evacuate from a high building. Especially since people start to behave differently in case of an emergency. When it is impossible to flee down or up a lot of people get into distress and die by making bad choices because of this. To be able to rescue these people a solution has to be thought of. This piece talks, among other things, about that.

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# Chapter 2: Identification of General Problems and Challenges

This chapter is a continuation of chapter 1. We have identified eight of the problems discussed in chapter one and elaborated our findings.

1. Overpopulation

   Due to overpopulation on our planet, there are less and less resources around. If we do not handle this problem, the end of humanity might not take a long time. After looking at the reproduction rate in different countries we have concluded that especially in 3rd-world countries across Africa the reproduction rate is high. Therefore, it seems that overpopulation could be solved by handling poverty.

2. The disappearance of bees

   The disappearance of the bees is a problem that is problematic for our future, research states that a third of your general meal is there because of the influence of bees. If the bees disappear the agricultural sector would suffer heavily, and a food shortage will occur.

3. Disasters with firework (like the one in Enschede)

   On the 13th of May 2000 a fireworks disaster occurred in Enschede because of an exploded fireworks storage. Now that this year the government wants to ban fireworks because of covid-19 a lot of fireworks entrepreneurs have large amounts of fireworks which they have to store. However, they are not allowed to store them because of the firework disaster that happened in Enschede. There is a need for a solution on since this problem should be solved fast.

4. Psychological consequences of disasters regarding children

   When a disaster occurs it is never a nice thing to most people. But especially children have hard times coping with these thing they cannot understand yet. This results in traumatised children which would need care to get them back on track. Most of the time there is no time or place for these children to get the help they need. This results into children going off track and most of the time results in more criminals. By making it possible for these children to get the necessary help we could lower crime rate.

5. Influence of the weather on the cultivation of plants

   Due to the warming of the earth the weather has changed and continues to change every day. This has a great influence on the cultivation of plants and the whole agricultural sector. Lands which were at first capable of harvesting crops become dry and other lands become flooded by water. This has influence on the food circulation and could result in a food shortage if left unsolved.

6. Grasshopper plague

   Especially in Africa and neighbouring countries the grasshopper plague has had great impact. These countries mostly live of their agricultural sector. Due to this grasshopper plague a lot of people had no food and therefore had to starve. If we want to prevent these countries who were trying to get up on their feet from becoming 3rd world countries, we need to get a solution for this grasshopper plague.

7. Wildfires

   More and more wildfires are occurring nowadays. This is partly due to people not correctly putting out their campfires which could cause the fire to spread. However, the wildfires are mostly due to the warming of the earth and the drought that is occurring because of it. Because of this drought large forests burn away which impacts our oxygen values and decrease the biodiversity of our world.

8. Power outages

   Power outages are a disaster that nowadays could have a great impact. Not only on economic scale but also on medical field. Think of all the hospitals or self-care homes. If a large, long-duration power outage would occur the people in need will not be able to get the help they need.

# Chapter 3: Identification of Relevant Problems

For this assignment we used five of the problems we already described in the first and second chapter. We did this so that our range of subjects wouldn't get broader but more narrow. We specifically thought about the questions "what is this problem about?" and "what are ways to solve this problem?".

## Problem 1: overpopulation

Since overpopulation is a very broad problem, we wanted to narrow it down. For the ultimate result we tried to look at overpopulation and its consequences from different angels. We specifically researched overpopulation in Africa since the fertility rate in African countries are by far the highest in the world.

First, we looked at the cause of this problem. While in the Netherlands the fertility rate (children born per woman) is 1.77, a country in Africa like Congo has a fertility rate of 5.77. This huge difference between these two countries is a result of several factors. The main factor is the wealth gap between the countries. Where having children in the Netherlands is a luxury, in African countries it's most of the time a way of survival. We therefore mostly looked at solutions to increase the wealth in African countries:

1. Improving the educational system in Africa. An educated population will in long-term have a positive effect on the countries' wealth. Since the assignment is to make a smart environment we were thinking about making some sort of educational robot which could teach not just in schools but in for example town halls or community centers.
2. Automize/robotize big and small-scale farming. Big companies are already busy with automizing their businesses. However, small-scaled farmers don't have the resources to purchases such machines. Therefore, their children must help maintaining the field. Our idea was to help these farmers with automizing their small businesses by creating a smart environment which can be used for small-scaled farming and still be accessible for African farmers.
3. Education about birth control. By spreading awareness about birth control we can prevent unwanted pregnancies which will help in decreasing overpopulation. Our idea for this was quite similar to the first problem: create some kind of educational robot or program which introduces birth control to African citizens.

## Problem 2: the disappearance of bees

This disaster really affects our future since a third of your meal is there because of the work bees do for us. If bees would completely disappear it would have a great impact on the world. After research we found the two main reasons for this disaster:

1. The use of pesticides on farmers' fields. While these pesticides are not intended to target bees they still are one of the two main causes bees are killed. While this is a serious problem we did not go into depth on this part of the problem since this is more of a political issue. Illegalizing these pesticides or compensate farmers who do not use these sort of pesticides are some solutions we came up with.
2. The disappearance of the bees' habitats. These habitats are for example wildflower meadows with enough different kinds of flowers and safe nesting places. Due to for instance large-scale farming and urban development these habitats have rapidly vanished. To solve this problem our plan was to make some sort of smart bee habitat, which can monitor how many bees are attracted to the habitat and inform people on the importance of restoring the bees' homes. This habitat could take the form of a bee house or a patch of wildflowers.

### Problem 3: Unexploded ordnance

This problem was derived of a problem from chapter 1: explosions and the consequences. We tried to specify this problem to the following problem: explosions (think of landmines, grenades etc.) which have not exploded yet but are still buried somewhere. When these explosives are accidentally triggered it could have fatal consequences. Therefore, we brainstormed about how we could prevent these accidents from happening and smart robots which could defuse the explosives. Finally, we came up with a chip that could detect certain elements of explosives. If these were detected you would get a notification on your phone and the information would be passed towards a general database. By using all the data gathered the program can detect and locate potential unexploded ordnance. Next to that smart vehicles could be used which are programmed to defuse a kind of explosive.

### Problem 4: Grasshopper plague

The grasshopper plague is a very recent disaster. Last year Africa was hit by a huge grasshopper plague. Huge swarms of grasshoppers swarmed over farmers' fields and ate all the vegetation they could get to. For the African farmers this was a huge disaster since, as we already have discussed in problem 1 'overpopulation', they do not have the wealth we have. Current solutions are not satisfactory and can even be traumatizing. Children who had to run across their parents' fields screaming and slamming on jerrycans to scare the grasshoppers away cannot even sleep properly because of the constant drumming. Next to that they do not have the time to go to school since they need to help their parents.
As a solution we thought of smart fields which could detect incoming grasshopper swarms by using sensors and turn on its defenses. For example shielding the crops or electrocuting the grasshoppers that come too close.

## Problem 5: Wildfires

Wildfires are a huge and recent disaster in a lot of parts of the world. We have all heard about the Australian wildfires and the wildfires in Florida. As a solution we tried to think about a way to prevent these wildfires from happening so that we do not have to find a way to extinguish these fires. This is because in our opinion prevention is better than curing.

Wildfires have the ability to spread because of the fact that trees usually stand very close to each other, which means that fire can easily jump from one tree to another. A solution for this problem could be dividing forests in squares. Since the borders of the squares would not be filled with trees wildfires would be limited to just one square and would be way easier to extinguish. To illustrate this we thought of a smart environment which explains this phenomenon in small size. Its use would be to inform people of the disastrous consequences of one small fire and how to solve this problem. We could for instance make two prototypes: one where the forest is not divided into squares and one which is.

# Chapter 4: Problem Selection and Motivation

After brainstorming about our five favorite ideas it did not take us long to make a decision: we wanted to make a smart environment for the bees. This decision was made because of several reasons. While quite a few of our ideas were about problems far away from the Netherlands this was a worldwide problem. Therefore, we felt more connected to the problem and had more motivation to investigate it. Next to that it was a disaster that was not as broad as for example overpopulation. We could investigate this problem and detect the causes quite easily, which made brainstorming about making a smart environment way easier. Lastly, a lot of us were really motivated about solving this problem which is of course very important when starting a project.

## The general problem

### The disappearance of bees

Over the last couple of decennia, the bee population has been declining. This is a big problem because bees pollenate a lot of flowers and fruits. They are key to the growth of a lot of crops. Without them, natural food resources will decline a lot. They are disappearing because of three major problems.
The first of these is parasites. The parasite that causes a lot of trouble is the Varroa Destructor. This parasite feeds of the fat of the bees. The parasite sits tight just under the skin of the bee and then “steals” the fat from the bee.

*Fig 4.1: Cross section of a Varroa mite nestled between the abdominal plates of the honeybee.*

The fat body, an organ in a bee’s body, is damaged by this. This organ is responsible for breaking down pesticides, which brings us to the next problem. Human-made pesticides. The living area for bees has been greatly reduced because of the use of pesticides. Bees cannot operate on plants that have been sprayed with this toxin. Besides that, people have also been destroying the living area for bees by making human living areas, building cities.
The last problem is the signal coming from telephones. Bees cannot handle the signal coming from these electronic devices and research points out that bees are often unable to find their colony because of this. This will eventually result in the bee not coming home and often dying.

# Chapter 5: Potential Solutions

After having found our problem, it was time to come up with solutions. In this chapter we will discuss seven possible solutions in detail.

## Tracking Bees

Working against the extinction of bees

Tracking bees has its many upsides. One could use the information to for example monitor foraging sites for bees, gather more detailed information about the landscape the bees reside in and of course track the bees themselves, all the way back to the nest. Tracking the location or general information on where bees are located is useful for conserving their existence. Tracking bees has been done before, but not on a very large scale. Bees have been fitted with GPS “backpacks” and radar has been used more as a proof of concept.
One way to track bees could be through radar. Bees are obviously quite small and difficult to track over large distances using the naked eye or a camera. With the use of radar we could create a system that detects bees and their movement by algorithmically differentiating it between the bee and its environment. By placing small radar stations around a certain area we can discover more about their foes and allies. One radar technology that is well equipped and has proven effective in the past is the harmonic radar, which can accurately depict small flying insects over a non-flat surface. The radars would remain in the same spot for several hours, creating a mesh or map of the area depicting the precise locations and general movements of the bees. This information can then be used to further research the optimal living conditions for bees and what difficulties they experience.

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## Tiny drones

We also looked at the possibility that there was no option to save the bees. What would happen then? The most important thing that the bee does is transferring pollen from one flower to another. If the bee would go extinct and we did not have something to replace them with, this would have a big impact on the plants and therefore our food sources. What could we possibly replace the bee with? A couple of things why bees are the best at transferring pollen; they have sticky and long hairs on their legs, they are small and they can fly. So, if something were to replace the bees it must have these same qualities. That is how we came up with a tiny drone, which can easily fly from one flower to another. The outside of the drone has a sticky and long hairlike coat which is slightly positive charged (electrostatic) so it attracts negative charged pollen. It is programmed to look for plants and it flies from one plant to the other.

How would we realize this? For this project we would need a small drone (or parts in order to make one) with a camera to scan for plants. We would also need to program the drone, most drones are programmed with C++ and/or python. If we want to make the drone even more high tech we would need sensors to track how much plants are at a certain location (GPS). Then the drone would need to send that information to a computer so that the information which it collects will be stored. With this information the drones know better where what types of plants are growing and where it has to go to spread pollen.

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*How Wild Bees Carry Pollen*. (n.d.). Retrieved from sharp-eatman nature photography: https://www.sharpeatmanguides.com/how-bees-carry-pollen

## Smart sprinkler system

For this solution we tried to replace the harmful pesticides farmers use to protect their crops from insects. The purpose of these pesticides is to keep the insects away, therefore we decided to think of a solution that could do exactly that.
Our idea was to make a smart sprinkler system that could detect certain insects that would be harmful for the farmer's crops. When the sensors would detect the harmful insect, the sprinklers in that area would automatically turn on to scare the insect away. This could be done with normal water or ecological insect repellent spray which is already on the market. The advantage of this problem is that harmless insects, like bees, would not be the victim of pesticides. Even the insects who in fact were trying to eat the crops are not killed but repelled. It is therefore way better for the environment. Next to that, when using water to repel the insects the plants would get their water at the same time: a win-win situation.
However, this solution has some downsides. First, it would be an expensive solution. Especially for farmers who have huge fields with crops. They would have to place sensors and sprinklers all over their fields which is no cheap operation. The sprinkles should be on stand-by all day long. Next to that, we discovered that there were already products like this idea on the market for small-scale detection like gardens.
We can conclude that this solution would be great for the environment. No insects are harmed because of the deadly pesticides sprayed on crops. However, we must consider that this solution will cost a lot of money and is already on the market for small-scale detection.

## Commercial beehives

One of the ideas for preventing the decline of bees is to commercialize the solution. This means that the solution should be compact and fun to have. One of the ideas that we came up with during our brainstorm sessions was an interactive beehive. This means that people can see what is going on in their beehive.
To build a beehive for the masses, you first need to know what satisfies the bees, what they need to have nearby to stay alive. We need the bees to function like they would do in a natural beehive, so we need to emulate their original living environment as good as possible. That gives us the question: What do bees need to live a normal life?
First up is enough nature. They need flowers to suck the nectar out of and take pollen back to the nest to feed the bee family. This can easily be dealt with by planting flowers nearby. They should not be sprayed on with pesticides though. These pesticides are one of the

causes of the very disappearance of bees. So, we can just deliver a bee “bed” along with the product.
The next thing to think of is that they need water. This should not be completely clear water though. Bees seem to prefer water that is a bit dirty, because of the minerals that are inside. Having water near the hive will prevent the bees from making tiring flights for a few drops of it. However, the bees should not get too much water. They need dryness. This means that the hive should be protected from water. Because of this, the moisture level of the hive should be monitored.
The hive should not be completely isolated though. They need fresh air to keep the nest healthy. Bees can do this themselves by flapping their little wings at the entrance of the hive and by waving air away at the other side. They also should not be in areas where wind is too strong. Because of their extremely low weight (around 1 gramme) they can have a tough time flying through gusts of wind.
In winter, beehives should be protected from being cloaked in snow. Keeping the nest snow-free is not necessary but keeping the temperature at the sufficient level is key to get the bees through the winter. Of course, bees can handle this themselves, but they need the room for it. Otherwise they cannot preserve the heat correctly.
As you can see, there are a lot of factors to consider when designing a safe home for these little flying pollenating machines. If we get the conditions right though, we can make the world a lot more bee friendly and thus better the flower population as well.

### Interactive beehive

People like to care of animals. If it’s a dog that like to be with you all the time, a cat that only comes home for food or a fish that probably does not even know that you exist, people like to take care of it. That is, for a big part, because they can look at what the animals do and thus, they are a kind of entertainment. So, the question now is, how would people be motivated to take care of bees.
As said before, people interest themselves in animals if they see what the animals do. Ways to activate people to take care of bees would be to let them see how many bees are in their beehive. This can easily be achieved by a sensor at the entrance of the hive. Measuring things as humidity and temperature would also be nice, just so that people feel like they should watch out for the well-being of the bees. Be(e)sides that, it would also be informative for people to see how it looks from the inside so maybe we can put a camera in an angle so that the nest is visible. If people know more about the bees living environment, they will become more like pets and thus people will care more about the wellbeing of the animal.

Since bee’s are essential to our environment, we should create the perfect environment for them as well. This means creating bee houses/hives with regulated temperature, humidity and population growth. This can all be done by using certain sensors to generate data and using that data in devices which manipulate these variables. To make the decrease of the bee population disappear we need to let the bee population grow again. This should be done with control so that we do not get an overpopulation of bees which will then result in a plague. Luckily these two problems can be solved in one and the same way. This is by using the action of the bees when they are without a queen.

A bee queen normally produces a certain chemical signal which stops the other female bees from being able to lay eggs. But when a bee hive no longer has a queen the female worker bees notice the absence of the chemical signal and start laying eggs. But how can this be used to generate an exponential growth? For that we had to look into where the bees lay their eggs. Bees always lay their eggs in a certain spot in their hive. By making this part of the hive moveable one could transport new eggs or larvae from one hive to another. If we were to move female and male workers to a new hive without a queen but with the eggs or larvae from their old hive an interesting phenomenon would occur. When there is a lack of the chemical signal of a queen the worker bees create special vertical hanging “queen-cells”. They can then move the earlier moved eggs and larvae into these special queen cells and feed them royal jelly. This is a secretion that is made by the nursing bees. This royal jelly triggers the development of queen morphology. And with this a new queen will emerge after about 2 weeks. This queen will then start mating and laying new eggs. These eggs and the new eggs from the old hive could then be used to generate two extra (so four in total) hives. This way we could stimulate an exponential bee growth, and save the bees from disappearing.

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## Spreading of flower seeds by drones

Drones are a great way to get to places that aren’t easily accessible for us humans. That is partly why there are drones being made and tested to re-plant forests. The other reasons are that it is quicker and cheaper to do it with a drone than by hand.
Drones are also used to intercrop on corn fields. Since drones do not touch the ground, they won’t destroy the corn crops while planting other seeds on the same field. There are other options: a tractor for example. The problem there is that although they can avoid the corn crops, it takes more time.
Like you see in the previous two examples drones have a big set of advantages over other ways of planting. Therefore, it is a great plan to plant flowers seeds with drones. Open fields, verges, but also gras strokes in cities can be filled with flowers without completely destroying them. This way the bees have an easier access to pollen.
To choose the right seeds you have to look at the flowers that attract bees the most. It is also important that the plants are easy to grow and don’t need attention since they won’t get any. According to https://www.westcoastseeds.com these plants are great for our purpose:

Licorice Mint – A plat that grows great in full sun or partial shade. This plant comes back every year
Bishop's Flower – An easy to grow plant that besides bees also attracts predatory insects. This will help to eliminate a lot garden pests.
Buckwheat – Again an easy to grow flower. It grows fast but will eliminate other plants in the area so this one should not be mixed with other plants in the same space.

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### Bee reservoir

One way how we could save the bees is by creating bee reservoirs, which would be big domes with a lot of different plants and trees since bees like to live in woodlands, meadows, gardens, orchards and other areas where there are a lot of flowering plants. These reservoirs would also have the best conditions for the type of bees they are housing. For the conditions you need to think about temperature, humidity and the natural terrain. In these domes one or multiple colonies of wild or domesticated bees could live. The reservoirs should be maintained regularly by a group of beekeepers and gardeners, to keep the bees and plants healthy. These caretakers would be able to enter the reservoir by entering multiple doors after each other, to make sure the bees would stay inside the dome. For the safety of the bees, the reservoir would not be open to the public.

This is not a very realistic solution as bees can fly up to 5 kilometers away from there hives so you would need to build a dome with at least a diameter of 10 kilometers. There may still be bees, but these bees do not live in the wild and cannot help the plants outside the reservoir. If there are multiple bee colonies living in the reservoir, one of them could always be moved out of it, but then you have the question if these bees will be able to survive outside of the reservoir. They would have lived their whole lives in these perfect conditions, suddenly they would have to live in a rougher environment impacted by different weather conditions. In conclusion, this solution would not help with the pollination of plants outside the reservoir.

# Chapter 6: Solution Selection

## Commercial beehives

A lot of our potential solutions were not realistic for us to make. Tracking bees is a little too ambitious and a sprinkler system or a bee reservoir are not practical smart solutions. This left us with the beehives or the drones. Because we decided we wanted to go for the scenario where we can help the bees instead of replacing them, we chose for the beehives. The goal of this plan was to make a smart beehive which could sense the temperature, humidity and the number of bees currently in the hive. This data would be transferred to an interface/app which gives the owner valuable data to maintain the strength of the hive. The smart beehives seemed the best solution to us because it is an idea which is realistic for us to make and we could make a real product out of this idea.

## Task dividing

Ben: Contact beekeepers for bees, maintaining overview, implementing feedback, gathering video footage for promo video, final presentation with Wouter
Tristan: Programming app for Arduino, editing the promo video.
Ilse: Design of commercial beehive, managing Instagram page
Wouter: What sensors do we need, and how will we implement these into our environment/app. Final presentation with Ben.
Alex: gathering materials and looking how and what we need to implement. Look at economic values as well.
Nikki: Researching about appropriate conditions in a beehive. Merging the design side and the material side, creating the beehive with Ilse and Alex.

# Chapter 7: Methodology

You can divide our project into three branches we will be working on: building/finding a suitable beehive, applying the sensors and developing an app for the received sensor data.

## The beehive

For the beehive we have two options: building one ourselves or buying one. We have investigated both options which you can find below.

### Constructing a beehive

Constructing a real beehive is a complicated task. Beehives contain many components which are not advised to build yourself. Constructing a beehive therefore means within our project: simulating the idea of a beehive with building a box out of wood and using this as a prototype. For this we have investigated the materials needed and next to that a little research about flowers the owner of the hive could plant for supporting the swarm.

#### *Material list*

##### Body

Wood is a good material to build the beehive from, as it is easy to get and easy to build with. Some good options are:

- *Pine*, it is one of the cheapest woods and it is easy to work with. One thing to note is that pine in not very durable to the weather element, so you have to use an outdoor paint or varnish. There are different grades of pine wood, two good ones are:
    - *Knotty or standard pine*, it's the cheapest, but it has knot and other cometic imperfections. It is still good to build with, but your hive will have a more rustic look. You also may need a little more material, as the knots can get in the way.
    - *Clear or premium pine*, it will cost you more, but it does not have any knots and usually the grain is tighter and straighter.
- *Cypress*, the tree produces sap that helps preserve the wood and repel insects and mold. It will cost you more than pine.
- *Cedar*, the natural oils of this tree make the wood less prone to warping, less susceptible to bug infiltration and less likely to rot. It a durable wood so you do not have to paint it. It is more expansive than pine.
- You can also use wood that looks good like *cherry or black oak*, this will cost you way more but the results will look beautiful.
- You could also use *synthetic wood* which is made of recycled plastics and sometimes wood fibbers. It is completely weatherproof, verry durable and environmentally friendly. The downside of it is that it is heavier and more expensive than normal wood.
- Instead of wood you could also use *metal*. As it is not insulating it will make the temperature in the beehive change more. So it is not the best option.

### Frames

Some good woods to use for the frame are *spruce and fir*, as these are stud lumber. Both spruce and fir are quite the same, so it does not really matter which one you use.

### Flowers

It is important for bees that there is biodiversity in the garden, so you need a mixture of different flowers and plants. These are some good options:

- *Agastache (Licorice Mint)*, it is easy to grow in full sun or partial shade and it will come back every year.
- *Ammi (False Queen Anna's Lace)* an easy annual pant that is attractive for predatory insects.
- *Asclepais (Butterfly Bush)*, the flowers have a lot of nectar which attracts the bees. But it is challenging to grow from a seed, as it needs an early start indoors.
- *Bergamot***,** it blooms in late summer after most flowers have finished.
- *Calendula,* it is easy to grow and attracts bees and other beneficial insects.
- *Centaurea (Cornflowers)*, easy to grow and attractive to pollinators. Needs to be planted every year.
- *Cosmos*, they can bloom all summer and are easy to grow. But they can get high, up to 2m and they need to be planted every year.
- *Echinacea (Purple Coneflower)*, they have long lasting blooms. They look their best after three years.
- *Phacelia (Purple Tansy)*, an annual plant with nectar rich flowers, that has flower opening up over multiple weeks.
- *Sunflowers*, the face of a sunflower is actually a landscape of tiny, tightly packed together flowers, which open op weeks. These small flowers are nectar rich.

Blackiston, H. (2016, 26 March). *How to choose lumber for your beehive*. dummies. https://www.dummies.com/home-garden/hobby-farming/beekeeping/how-to-choose-lumber-for-your-beehive/
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### Purchasing our own beehive

Purchasing a beehive would save a lot of time and effort, which we could put in applying the sensors and making the app. However, it is only a reasonable option if we decide to continue with this project after Module 2, if that is not the case it would be a waste of materials and money.

### Final conclusion

After researching the construction of beehives, we concluded that making a beehive ourselves was not advised. A beehive consists of a lot of parts. We did not have the time nor

the resources to replicate those parts. Purchasing a beehive will make sure we can exactly simulate a bee environment, opposed to working with a wooden box. Therefore, we decided to buy our own beehive and adjust this hive to our liking.

## Applying sensors

### Measuring the environment

An artificial beehive should have the same circumstances as a real nest. This means that the same humidity and temperature should be achieved. Under normal circumstances the bees regulate the temperature and humidity to their liking. However, when the hive is too weak to do this it could have huge consequences. We therefore decided to implement a temperature and humidity sensor into our hive. With this information the owner will know when there is something off and can jump to action at once. When the temperature and/or humidity is way off the owner of the hive will receive a warning to make sure the hive is checked upon.

Sensing temperature and humidity are most of the time entwined: you only need to use a sole sensor to measure both. For this project we will be using the SHT15 or DHT11 to achieve this.

### Measuring the bees

A significant detail of our product is that we want the consumer to be able to track their bees. They need to be able to see how many there are. A good question of course is: How can this be achieved for insects? Luckily, there are already several techniques for this.
One such technique is produced by *Insignia*. This company sells a product that measures how many bees fly in, and how many fly out (https://www.insignia-bee.eu/counting-beesthanks-to-beecounters/). This, however, is already a product of its own and should thus not be incorporated into our prototype build. There also is a relatively simple way to make such a device yourself. On hackaday.com, they talk about using reflective sensors to track the amount of bees foraging. They were talking about Using a Teensy+ board. If a bee would pass this board, they would trigger the sensor and thus be recorder into the system as leaving or entering.
The distinction between those two could be determined by putting two sensors close to each other and calculating the velocity of the bees this way. If this velocity is negative, the bee could for instance be leaving and with a positive value the opposite would be occurring. This could be a great in and out system.
Knowing how much the bees move in and out is just one part. The other part is to know how many are just lazily being inside the hive and are not leaving. This could of course be monitored by knowing the approximate start value of the number of bees. Thereby, there is a certain reproduction number that bees have. This could also be incorporated into the estimate of how many bees are inside the nest. I think that it is not likely that we can give pure accuracy on how many bees are inhabiting the commercial hive, but we can give the

owner an estimate. The owner will be satisfied with the approximate number and manually counting would be impossible and this way the illusion will not be broken.

$$B = (Startnumber + f) * r$$

Here, B is number of bees, 'Startnumber' is the number of bees at purchase, f is the number of bees that are foraging and r is a reproduction value that should change per season. In winter it should be negative and in summer it should be positive.
Another way to know how many are inside is to weigh the hive. The thing is that could differ every second because of the produces honey. This, however, could work nicely in combination with the in and out system that was mentioned before. A bee approximately weighs 280 mg. This could make the calculation a lot easier.
A formula that could work for calculating the number of bees this way may look like this:

$$B = \left(\frac{Mass - Mass\ hive}{0{,}00028kg}\right) + f$$

Here, B is the number of bees. Mass is the total mass of the object. Mass hive is the mass that the hive without any bee weighs and f is amount of foraging bees.

After researching multiple methods for tracking bees we decided to use infrared sensors, in particular the HY-S301. It is a strip of eight infrared sensors which we could place at the entrance and exit of the hive (since we have bought two of these sensor strips).

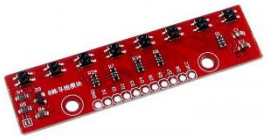

*Fig 7.1: Infrared tracking module*

### Validating the data

Before we apply the sensors to the beehive itself we want to run several tests to ensure the sensors are functioning as they should. Since we do not have a bee swarm at our disposal we will test the infrared sensors by simulating a bee flying in front of the sensor. This can be done with multiple objects, as long as the object resembles a bee in both size and infrared radiation.
The best way to validate our data after this is to deploy our smart beehive for some time and check on the data we receive. However, this will sadly not be possible within this module. This is partly because it is winter right now; at this moment most of the bees are huddled up very close to each other to ensure the queen bee will not die, which means they do not leave their hive. To remove a whole swarm from one hive to another is definitely not advised. Next to that we need to ensure the hive is one hundred percent safe for the bees to use which we cannot guarantee in such a short time span. We work with living creatures after all.

Instead of deploying our beehive we want to validate our idea by giving a presentation to an expert. We are currently in contact with a beekeeper experienced in the well-being of bees. The goal of this presentation is not to validate the sensor's data but to validate the importance of our project and to have the approval of an expert regarding our idea.

## App development

For our smart beehive we wanted to make an app on which you could check a couple of things: the number of bees in your beehive, the temperature in your beehive, the humidity of your beehive (the last 2 combined to form the percentage of an ideal condition for the bees), a camera view of the beehive.
These things are the most important for our beehive. A couple of extra's could be: a feature for making pictures from your cam view, settings to change the humidity and temperature, statistics on the amount of bees and how well the ideal condition has progressed.

Below there is a sketch on our view for the app:

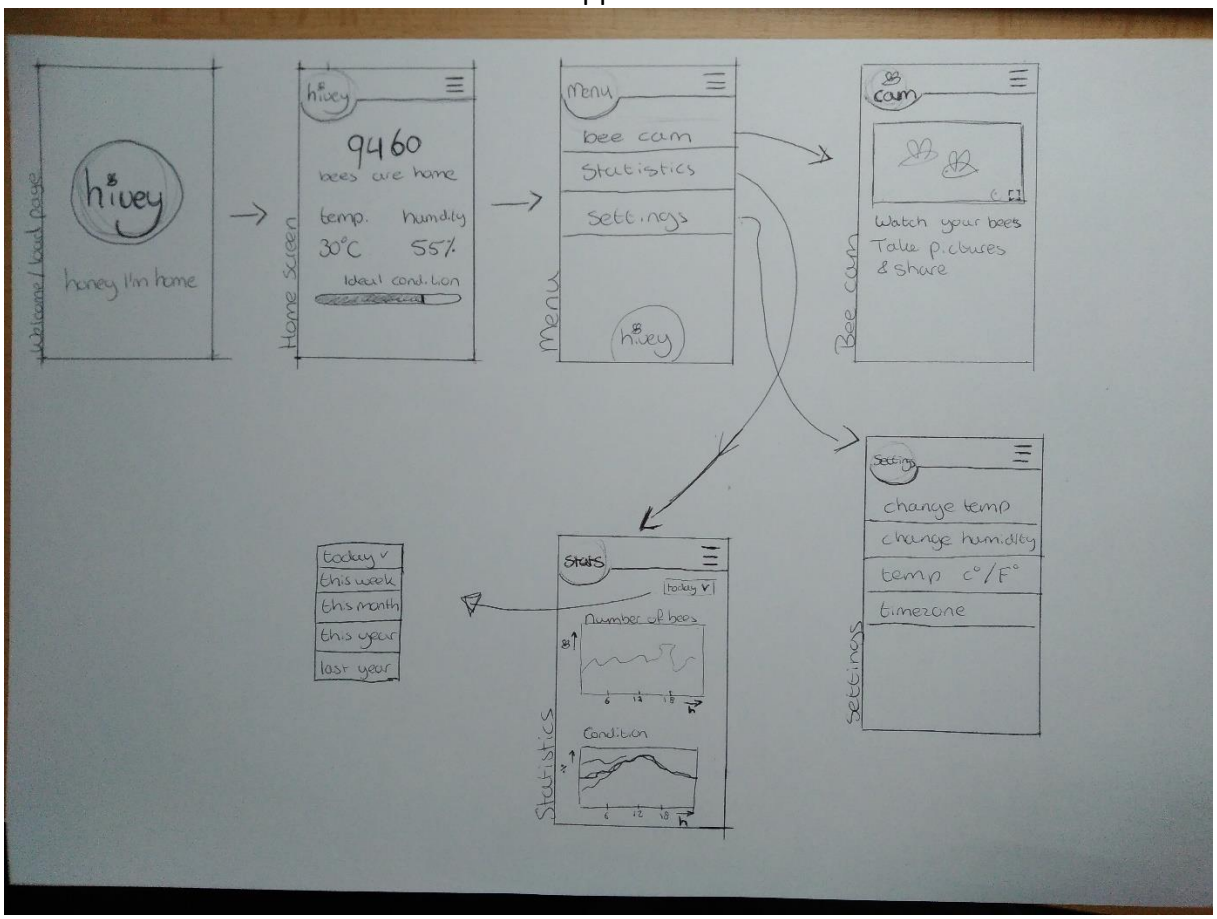


*Fig 7.2: sketch of app interface.*

This app will most likely be a web app created through processing. But we will conduct some research on Android studio as well.

After some research most likely Android Studio will be used for that an online course will be followed: Android Development for Beginners - Full Course . In here a full understanding of Android studio will be taught.


The app could be launched in the play store by a one-time-fee of $25. This is not too much money so creating an app for our beehive and launching it officially is possible.

# Chapter 8: Results and Conclusion

In this final chapter we will discuss our results, findings and the conclusions regarding our project. We decided to go for the basic approach including one aspect of the ambitious approach: making an app to monitor the data.

## App development

After researching it was found that it was best to create the app in Android studio. This was due to the access to an easy emulator and the online course that could be followed online. The app development has had some challenges. There has been a lot of debugging and extra research on certain functions and usages. The plans have also changed a bit from the initial sketch that had been proposed:

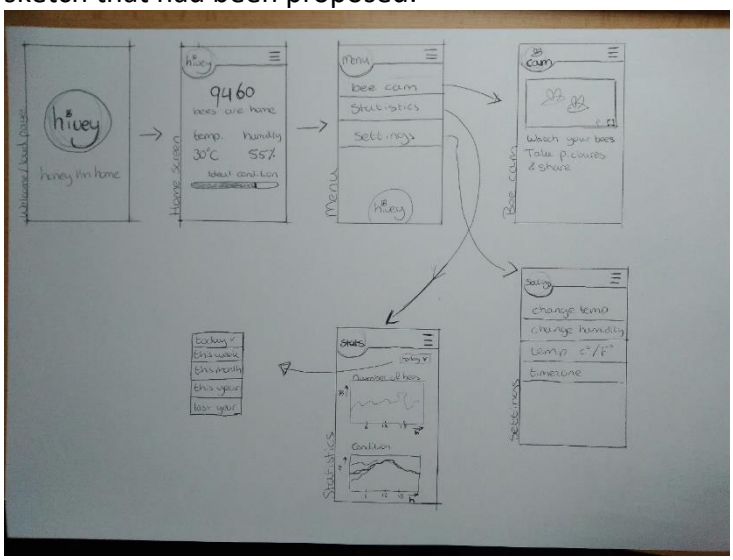


*Fig 8.1: sketch of the app interface*

Here we see multiple screens with access to for instance a camera view and the ability to change the temperature and humidity. These functions were part of our ambitious plan and were left out in the end. This is because we did not have a camera to put in for the basic function and we decided to stick to measuring first instead of being able to actually change the humidity and temperature in the beehive. So, the app will have 2 screens. A home screen with basic data view as seen in the 2nd screen in the sketch above. As well as a screen with graph-based data view called statistics. Furthermore, it will be possible to move through the app using a vertical navigation panel.
The essentials of the app would look like this:

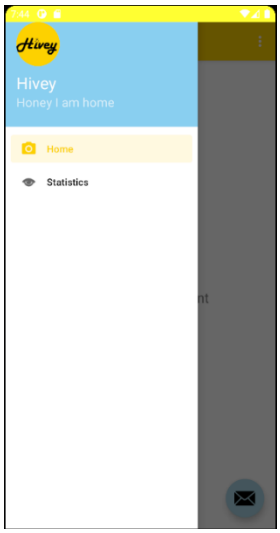


*Fig 8.2: The main structure of the app.*

The data from the beehive collected by Arduino will be send over to the phone by Bluetooth.

## Market research

There are already a few smart beehives, but they are all different from each other and so is our hive also different from the already existing ones. A few of the already existing ones are the following:

The BEEP base is a system you need to put under your beehive and has some sensors you need to insert into the hive itself, these measure the temperature and take audio fragments and the base weighs the beehive. These values will be measured every fifteen minutes and sent to the app.
https://beep.nl/

Gobuzzr is a smart beehive which tracks the temperature and humidity, at the entrance and in the hive itself. It also keeps track of the weight of the beehive for keeping track of the honey production. What it does not do is keep track of the bees leaving and entering the beehive, which our beehive will be able to do.
https://www.gobuzzr.com/

Pollenity makes the Beebot which is a system you hang on one of the frames in the beehive, this monitors the temperature, humidity and the buzzing of the bees. This company also sell a scale for your beehive called the HiveBase.
https://pollenity.com/

Osbeehives have the BuzzBox witch is a little box you install on the back of your beehive and comes with a solar panel to power it. It uses an app to keep track of the indoor and outdoor temperature and humidity, pressure and local weather. It also records sound from inside the beehive. You could also use the app without the BuzzBox to record and analyse the sound of your beehive and keep a logbook of your hives activity.

https://eu.osbeehives.com/

What distinguishes our hive from the other smart beehive products is that we keep track how many bees are approximately in the hive, through infra-red sensors in the entrance of the hive. This is something none of the other hives are able to do, but gives the owner of the hive a better inside of the colony of bees they own. Another plus point for our hive is that ours is a complete hive and the consumer will not have to install any component in the hive themselves. This is not the case with most of the other smart beehives on the market, where you have to get the hive separately from the sensors.

## Our prototype

Our goal was to create a beehive for the consumer where the consumer has a form of interaction with the bees. If the consumer feels more connected to the bees, they are more likely to buy a beehive. This way the population of the bees does not only rely on wild bees and beekeepers but also on the average human. Therefore, we want to create a beehive where you can watch your bees and which tracks how many bees are in the hive, the temperature and the humidity inside the hive and connect this to an app which shows you all this data.
For our prototype we decided to order a beehive and install multiple sensors in it. The sensors include a temperature and humidity sensor, infrared sensors and a Bluetooth sensor. The schematics can be found in the picture below.

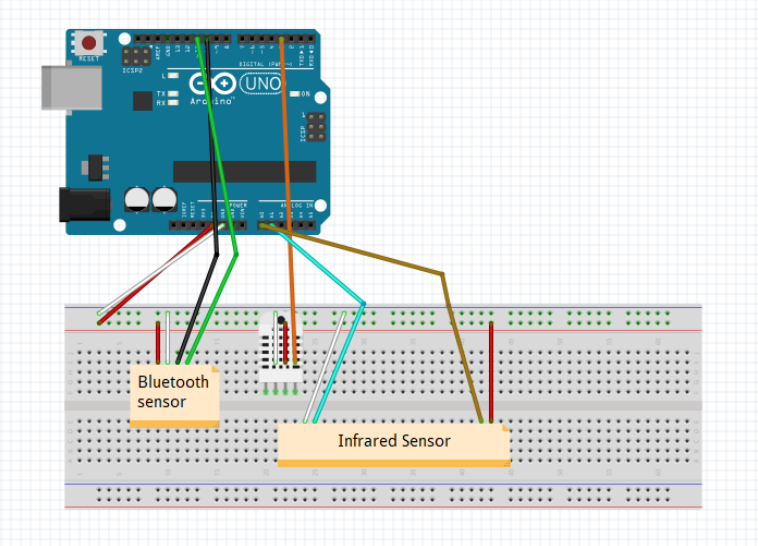


*Fig 8.3: schematics of Arduino setup.*

We ordered a beehive because it was not possible for us to make a complete beehive within the time that we had, and we did not have the right equipment to construct a beehive ourselves. It is also not recommended to make a beehive completely by yourself because there are some components which are too complicated to make if you do not have experience with beehives. So, an advantage of ordering the beehive is that we have all the components which we need. We chose for a beehive which is often used for starting a bee colony, because this type of hive is the size we wanted to use, and it also fitted within our

budget since we did not want to spend too much money on our prototype. Our other option was to put the sensors in a wooden box without all the specific components of a hive to simulate the idea of a smart beehive, but then we would not be able to test our prototype with real bees. Since we are planning on testing the beehive with help of a beekeeper somewhere in the future, we decided it would be the best thing to order a functional beehive. This way we can get all the data and information we need before we start building on our own design.
The temperature and humidity sensor are placed in the chamber where the honey is made (in the middle of the hive). We placed it there because it is important to know the climate on the inside of the hive, because it helps estimate how many bees survive the winter. It can also help prevent a lot of deaths of bees when you understand what is happening in the hive. The beekeeper which we spoke to told us that it is a real issue for beekeepers that they cannot see or notice what is going on in the inside of the hive. Therefore, this feature would be a great addition to not only hives for commercial purposes but also for hives of beekeepers.
Another thing what would help with the issue of the beekeepers is knowing how many bees are approximately in the hive. Not only is this useful for the beekeeper but also for the consumer because it helps them feeling connected to their bees. The infrared sensors are placed at the entrance, this is the little slit in front of the beehive. These sensors will track movement and can estimate how many bees are in the hive. By using multiple sensors and comparing them to each other you will get a + or – speed which indicates whether a bee is flying in or out of the hive. We chose these sensors because there is not much space at the entrance to put sensors in while still maintaining enough space for the bees to enter or exit and since these are small sensors, they will be able to fit. We did think about using the weight of the hive to estimate the number of bees inside, but we didn't think this would be a good solution because we want to keep the hive compact and adding a scale to it would make it too large.
The Bluetooth sensor is for the connection with the app and is placed closely to the other sensors. This sensor will send the data of the other sensors to the app. We chose for a Bluetooth sensor because this is the easiest way to connect the app to the beehive.

### Feedback from beekeeper

The beekeeper strongly believes that our concept could uncover something. Furthermore, he believes that our hive could bring clarity about the increasing death rate. They do not know the exact causes right now, but they believe that it is because of a combination of pesticides and the varroa mite. To get the data to research the causes the bees have to get moved to Wageningen. With our beehive data could potentially be collected locally so the process of research will be a lot faster. This might help to find a solution to the increasing death rate of bees.
The beekeepers told us one thing that could become a problem for us. Sometimes bees just disappear, they fly out of the hive and do not come back. The cause of this has been found yet. But a lot of beekeepers believe that bees are not capable of finding their way back. They think that their orientation worsens due to radio waves or frequency caused by electronical equipment. Even though this has not been proven, it is something that should be kept in mind.

He also had a few more ideas and input. Firstly, the beekeepers normally work with plastic beehives while ours is made of wood. This is because when they are travelling having plastic beehives makes the transport a lot lighter because wooden beehives are quite heavy. Secondly and lastly, he has seen a project where they chipped bees and he himself has seen some of them working. He knows that those chips are not expensive and easy to implement onto the bees. He might be able to get his hands om some of these chips if we would want them for data collection. So this could be an option if we might need them later on.
But his end assessment is that our project is something that comes at the right time because it is urgently needed. He believes we could make a difference and that this is something that is new and offers a new and fresh perspective on how to solve the increasing bee death rate. He has already reserved a bee colony for us to use in the spring to collect even more data and create an even better prototype. Furthermore, he will inform the Dutch Bee Association of our idea and try to help us in any way possible because he believes that we could bring the change that is needed.

### Counting System

Our counting system is quite accurate. It works by sensing the movement of the bee with infrared sensors. It for instance senses if the value of sensor 1 drops at least 50 lower then sensor 2 so that would mean that the bee is leaving the beehive so the count goes -1. If done the other way around, if the value of sensor 2 would be at least 50 lower than sensor 1, the bee will be entering the beehive so the count goes +1. We have added a delay because otherwise we would get the problem that the count would always be 0 because it would sense the bee who leaves as going out so -1 and as going in so +1. This fixed the problem for now but it will not work if multiple bees will be entering and leaving at the same time. A solution for this will be made in the future while we continue this project outside of the module.

### Future expectation

As we mentioned before, we have the intend to continue this project after the set deadline in this module. We believe our project has monetary and environmental potential and thus it would be a waste to stop after our final presentation. If we want to continue however, we could use a restructure of our project management. This means that we will redefine team roles according to how everyone performed in the last module.

### The team's restructure

To operate more efficiently and work towards releasing the product onto the market, we must restructure our team roles. We have the vision that we should operate more like a start-up company than a university project. There are a few simple ways to do this. First, we will split up the team in a few categories. This means that everyone is equal on the surface but in each category, someone is the leading figure. The first category will be physical development. This team will work on the building of the final product. They will craft it the way that we will finally deliver it to the consumers. This team will consist of 3 persons (keep in mind that the team consists of 6 persons in total). Next up is the research team. This team will consist of 2 persons and research how we can cut the cost of the product as low as possible while retaining the quality. This team will work very closely together with the

person that is put on marketing. He or she will work on putting the project out there and thus making the Hivey name stronger. If possible, we would like to keep close contact with the project leader so that he could help us with making this step.

### *Scrum planning*

While working on this project, we will keep utilizing the scrum planning method. This method is ideal for week-to-week planning and keeping track of everyone's activity in the project. Down below you can see an online Scrumboard. Everyone gets tasks that must be completed in the next week. On a global planning board, we will put the long-term goals. The weekly task will be a division of the global task. If, for instance, the global task is making a wooden box, the weekly tasks will be order wood, saw the wood, put the wood together. This way, the tasks are not too big to complete.

*Fig 8.4: online Scrumboard*

When we completed our final product, we want to test the product at Harry, our expert when it comes to beekeeping. He has offered us to work on the project together in spring when the bees are getting active again. This way we can validate our expectations about the effectivity of the product. We are going to plot our results and compare them to the results from actual beekeeper's hives.
The final step in our project is to link the product to the phone and thus to make it smart. We are, yet, not sure how to link the product to a mobile device from the consumer but that will get researched in a further stadium. After that is up and running, we are going to bring the product onto the market with help of experts. We are probably not capable enough to bring a product on the market ourselves and that is why we should ask for help in this field.

## Market value of the product

We believe this product will be very feasible. We will be able to target two groups: 'ordinary' people who want to have bees in their garden (amateurs) and the experienced beekeepers who want to monitor their hives and bee colonies.
However, when we continue with this project, we will have to find a way to reduce the costs of our product. Perhaps we will offer a product with just the hardware and software since beekeepers would like to keep their own hives. This would mean we have two separate products: one including a hive and one without.

Next to that, once we become an actual company we will be able to buy parts in large amounts which will reduce the costs.

## Conclusion: could this be the solution?

Our answer to this is: yes. This product can definitely be a part of the solution to stop the decline of the bee population. It is an idea that can be used both by professional beekeepers and ordinary people. Therefore, we will spread awareness about the problem while actively solving it. The more Hivey will grow, the more people will know about the huge problem we are facing and how they could be a part of the solution. Meanwhile, the beekeepers will have a clear overview on their colonies and can take action when something is wrong before it is too late.

Before this product could actually be released on the market it needs, of course, some improvements. We, team Hivey, are dedicated to this project and are looking forward to turning this University project into an actual product.