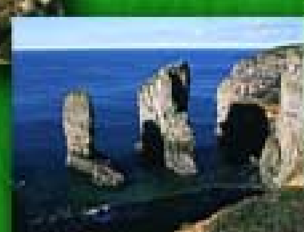
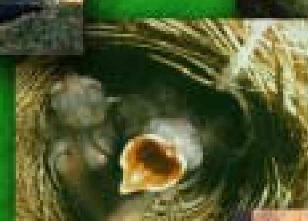
care the nature, but keep moving



Student:
Rimke Holtkamp, S021412

Title of Project:
Care the nature, but keep moving

Unit & Coach:
TU/e Industrial Design, mobility, prof dr
G.W.M. Rauterberg

Committee members:
dr. D. Aliakseyeu
M. Fransen

Expert/s:
dr. D. Aliakseyeu
Employees of 't Mannetje in Haarlem

Project Dates:
01-09-2004 – 12-04-2005

Client:
Stichting Natuur en Milieu, B. de Jong

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Chapter 1

Project introduction and objective

1.1 Introduction

We are all moving. Moving things, and moving us. When we wake up, we move our eyelids open, so that we can see. We move our arm to the alarm clock. We move the button down. Then we move ourselves out of the bed, and move us to the toilet or to the kitchen. It seems that everything only exists of moving. Maybe we see a truth in that when we look to a smaller scale: all the molecules around us are constantly moving. Also when we look to a larger scale: the earth is constantly moving and turning around the sun and around itself.
Without moving, we won't reach anything. More than that, if important organs in our body stopped moving, we soon would be nothing any more.
Another property of humans is that they always want to reach more. And if we assumed that we always have to move for reaching something, we would have to move more, for reaching more. Very practically, this is exactly something that happens the last decades and centuries. We move things and ourselves more and more across increasing distances, with increasing speed, day by day.
This evolution went so fast the last century, that there hád to go wrong something. Exactly: the pollution of our environment. But we want to reach more, so we don't want to move a step backwards. Maybe there is a combination of these things possible: moving forward, ánd reduce the environment pollution.

Maybe this analysis is a bit imaginative, but fact is that we are polluting our planet. What I want to do with this project, is designing something that could help us to keep moving but in a friendlier way for the environment.

I'm interested in both environmental pollution and mobility. Personally I support measures against environmental pollution, but I also want to be free in moving. And that is conflicting. That is not only conflicting for me, but surely also for decision makers who concern these matters. For me it is a challenge to design something that doesn't disturb us too much in our freedom, or is even better for our freedom, and at the same time something friendly or friendlier for the environment.

1.2 Objective

Project

This project is concerning the design of a concept of a product or service, or a combination of both, that fits to my normative mission statement.

My normative mission statement is:

A world in which the products and systems that serve us, serve us on a healthy way for human, animal and plant.

The issue of the project will be directed to the mobility sector. The goal is:

Designing a concept which indicates how the transport of people / goods can happen in a more environmental friendly way

It doesn't have to be something that is lucrative for a manufacturer, but it shows a new opportunity of a durable element in our society. This value is usable for the project client.

Client

The project client is *Bas de Jong* from *Stichting Natuur en Milieu* (organization nature and environment). This is an independent organization which stands up for the nature and the environment. Like they say, the organization tries to reach their goals by the following procedures:
Stimulating discussions and debates by researching and publication actions. Mobilizing the public opinion and influencing key figures in the nature and environment policy, so that durability is going to be anchored in laws and in the policy.
They work on European, national and regional level.

Project goal

So the goal of the project is designing a concept which indicates how the transport of people / goods can happen in a more environmental friendly way. This may be a product, system or services, or a combination of these. For this goal I chose for a research-looking approach. *Figure 1.1* shows the steps of the required process.

Figure 1.1 the steps of the process

Explanation of the steps

Research

After formulating the goal, it is needed to know what factors must be reduced so that transport or traffic will happen in a more environmentally friendly way. With the outcomes I set up a list of *normative goals.*

Idea

With the normative requirements as input, brainstorms will deliver an idea to go further with. A list of *concept requirements* shows what the concept has to come up to, to reduce the environment polluting factors from the normative requirements.

User check

For fulfilling the project goal, (designing a concept which indicates how the transport of people / goods can happen in a more environmental friendly way) it is needed to check whether the new idea should be accepted by users or not. For when it becomes clear for example that the concept idea is not going to be used, the idea won't be a possibility of how transport/traffic can happen in a more environmental friendly way, because the idea won't be used at all. So in that case it should be invalid for the project goal.

Techniques

The concept can also only work for the environment when it is technically feasible. In this step I consider technical possibilities to show how the concept is feasible. When there are more technical options, I research in how far those are the best for the environment. So here the normative requirements are going to be quoted.

Implementation

A part of the concept will be implemented.

Final concept

In this step the principle idea is will be dressed by the best technical possibilities that are researched. Images show how the whole is possibly should look.

Chapter 2

Research environment

2.1 Introduction

Before the industrial revolution, environmental pollution had never existed. But after the introduction of the steam machine, two centuries ago, this has changed. The production by old trades disappeared, and a profit focused mass production toke place, even as the relating advertising to sell the produced mass to the consumer. Everything has to be produced as fast and as cheap as possible. Since then our way of living changed, even as our friendliness for the nature.
Not only more and more factories, but also trains, cars, airplanes came. This has @#$ led finally to unacceptable environmental pollutions.

In this chapter I research the most important environmental polluters that have to do with traffic and transport. I research where the pollution comes from, what effects the polluters have on the nature, and how far they have to be reduced.

The goal of the research is to understand the environmental problems of the transport ways that we use now, to minimize these effects in the design of a concept that has to help decreasing the pollution due to traffic or transport.

I divide the polluter issues into 4 categories. First we have the harmful emissions caused by combustion engines from cars, busses, trucks. The second group contain the harmful factors caused by the used infrastructure: roads, highways, railways, and the elements that belongs to those networks. Thirdly there are the raw materials that are used for making the vehicles in which, and on which, transportation takes place. And fourth there is the electromagnetic radiation which harms the environment. This last one is not specifically a polluter from traffic, but a polluter which you see rising in a lot of areas, so also here it has to be taken in account.

2.2 Harmful effect from use of combustion engines on fossil fuel

2.2.1 CO_2 emission: the greenhouse effect

CO2 gas is one of the gases that cause the greenhouse effect. The greenhouse effect means that the temperature of the earth increases due to certain gasses in the atmosphere. These gases are carbon dioxide, water vapor, nitrous oxide and methane. They are called greenhouse gasses [1]. In *figure 2.1*, the working of the gasses is explained. In the upper situation there is no atmosphere with greenhouse gasses: the heat from the sun reflects back into space. On the situation below, there is an atmosphere with greenhouse gasses, which reflexes a part of the heat back to earth.

The greenhouse effect is important: without the greenhouse effect, the earth should not be warm enough for humans to live on. It should be 16 degrees centigrade colder in that case. But when the greenhouse effect becomes too strong, when more greenhouse gasses come into the atmosphere, it could make the earth warmer than normal. Even a little extra warming can cause problems for humans, plants and animals. Normally this should not happen, because the natural cycle maintains the amount of gasses.

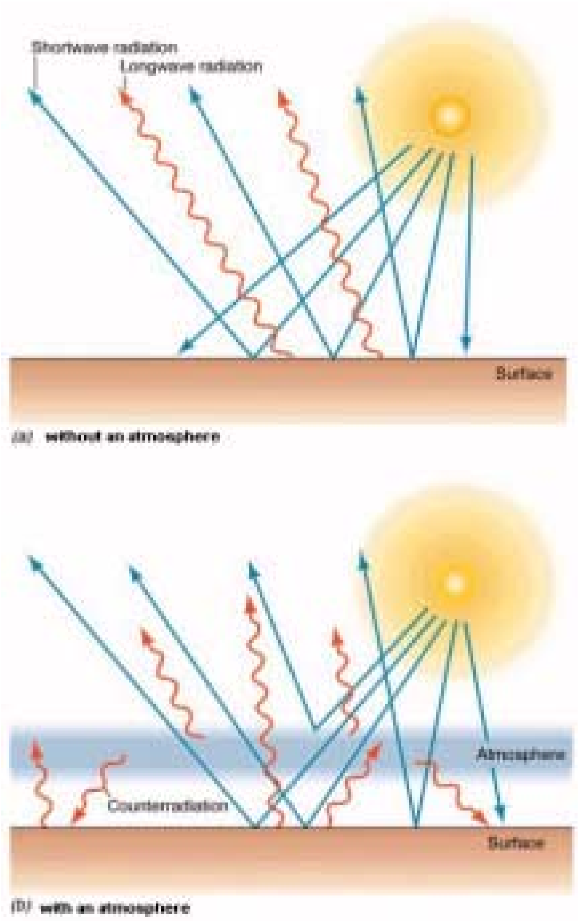


Figure 2.1, *the function of the greenhouse effect*

The effects

And that is exactly happening now, particularly by the over-emission of carbon dioxide. During the past 100 years, the temperature of the surface of earth has increased approximately a half degree centigrade. The chance that this is a natural process is low. According to scientists, the temperature is going to increase one to four degrees centigrade during the rest of this century. [2]
This will have all sorts of effects on the climate and subsequently all sorts of adverse effects on us. The Centre for Earth observing and Space Research, Virginia, sketches an image of what will happen. These are the effects in short, cited from an article of them: [2]

"Water Resources: The quality and quantity of drinking water, water availability for irrigation, industrial use, and electricity generation, and the health of fisheries may be significantly affected by changes in precipitation and increased evaporation. Increased rainfall may cause more frequent flooding. Climate change would likely add stress to major river basins worldwide.

Coastal Resources: A estimated 50 cm rise in sea level by the year 2100, could inundate more than 5,000 square miles of dry land and an additional 4000 square miles of wetlands in the U.S.

Health: Heat-stress mortality could increase due to higher temperatures over longer periods. Changing patterns of precipitation and temperature may produce new breeding sites for pests, shifting the range of infectious diseases.

Agriculture: Impacts of Climate change in developing countries could be significant.
Forests: Higher temperatures and precipitation changes could increase forest susceptibility to fire, disease, and insect damage.

Energy and Transportation: Warmer temperatures increase cooling demand but decrease heating requirements. Fewer disruptions of winter transportation may occur, but water transport may be affected by increased flooding or lowered river levels."

It is obvious that a change in our habits, concerning the emission of CO2, can not be as worse as experiencing the above mentioned consequences. But what can we do?

What has to be changed?

Of course trees can convert CO_2, but that is not enough. For example, if we compensated the CO_2 emission of one car that drives 12000 km each year by planting trees, we should need 200 fully-grown trees, which means 1 to 4 hectare of woods. So preventing the emission of carbon dioxide is necessary to solve this problem. [3]
According to the International Panel on Climate Change, IPCC, the emission of the greenhouse gasses worldwide have to be reduced by 60 to 80 percent. In the Netherlands, 20 percent of the greenhouse gasses are caused by the traffic. So a change in this sector is really needed for solving this problem. [3]

A mean against the emission of greenhouse gasses is the Kyoto agreement. Although it is a step in the right direction, it is just a very small step. According to the agreement, the gas emission has to be reduced with 5.2 percent within 18 to 20 years, in the industry countries, except for the United States. [4] If that limit should be reached and we should go on with that reduce factor, it would take 2 to 3 centuries before the emission reduces will be enough, not counting the hindrance of the US.

Next to CO2, there are several other harmful emissions due to combustion engines. In the next paragraph I describe the most important ones.

2.2.2 NOx gas emission

There is a complex nitrogen / nitrogen-oxide cycle on earth. Also here, there wouldn't be a problem if there were no human interventions. But by the use of a lot of fossil fuel, and a too intensive cattle breeding, too much nitrogen oxide escapes. The traffic causes 33 percent of this problem. The result is acidification and unfruitfulness, which brings on a decrease in nature. An effect is that rare sorts of plants die out. [5]
Several studies indicate a relation between too much NO2 in the air and lung problems. The lung function diminishes and there is a stronger reaction on allergens. [6]

2.2.3 Sulfur emission

There is also a sulfur cycle. This one is also disturbed by our unnatural processes and habits, like factories, transport and intensive cattle breeding.
Also sulfur oxide causes acid rain. That will be fatal for organisms that are highly sensitive for the air quality.
On this area already a lot of things have changed into the right direction. The sulfur in diesel has been reduced, and is going to be reduced further in the future. The sulfur emission from factories has also been reduced a lot. This has prevented the die out of several lichens. [5]

2.2.5 Fine matters

An issue of the last years is “fine matters”. These are very small emitted parts that can penetrate far into the lungs. Your nose, mouth and pharynx have natural “refuse catchers”, but these parts are too small for them: they can easily penetrate deeply into your bronchial tube. Once there, they cause asthma and lung cancer. [7]
These little parts are a collection of under more the very harmful matters like PAC’s (little terry parts), nitrate, dioxin, lead. Fine matters are caused by burning refuse (especially things like PVC), incomplete combustion of under more fossil fuels (so also cars), wearing tires, wearing asphalt and from the building trade. On the area of traffic, cars driven by diesel engines give an important contribution to the emission of fine matters. [7]
The EU takes as limit 30 mg / m^3. But this limit is not acceptable enough: the EU wants to bring this limit back to 20 mg / m^3 in 2010. On *figure 2.2* you can see that almost everyone in the Netherlands lives with far too much harmful gas around him/her. [7]
A step forward concerning the lead part of the fine matters was the removing of lead from patrol and the introduction of the catalytic converter, but still there is a lot of lead in the verges of the roads. [5] (in paragraph 3.2.4 more about the danger of heavy metals in the environment.)

This paragraph forms the first normative goal: minimizing the harmfull gas emissions.

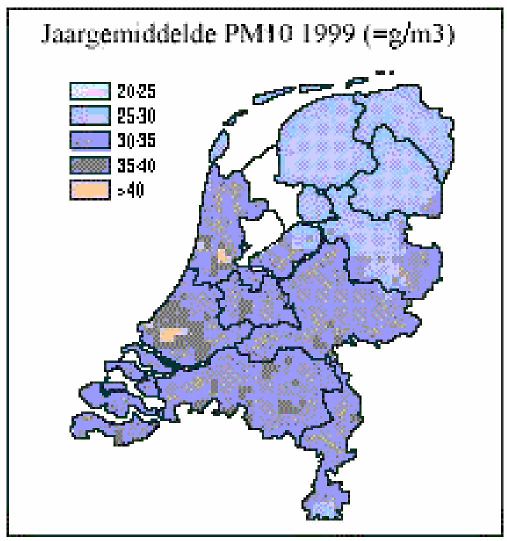


Figure 2.2, the average amount of fine matters in the Netherlands

N1 minimize harmful gas emissions

2.3 Harmful factors due to infrastructural elements

2.3.1 Fragmentation of the landscape

Especially in the Netherlands, there is a high concentration of highways and railways. 5 percent of the Netherlands' surface is used by infrastructure, including parking places [8]. The 133 thousand km roads [43] in the Netherlands take the largest part for their account. The surface of woods in the Netherlands is just 2,4 times as large as the surface used by the infrastructure. [43][44]
This has a negative effect on a lot of animals that use to live here. Animals need a living area of a certain size. But when highways and railways cut across their areas, these needed areas cannot maintain. For example the otter needs 100 square km for its living, while nowadays you can just find an area of this size in the north of the country. For most of the birds it's not a problem. It is mainly a problem for little animals that have to move across the ground. [9]
Also migration routes for animals are cut across by highways and railways. For example the natural migration route of the hedgehog is disappeared. There are ecoducts for animals, see for example *figure 2.3*, but not all kinds of animals can use them. [9]
The crossing ways also have a fragmenting and isolating effect on some plants. These are the plants whose seeds are not spread through the air. [10]
The aim is to give the room what the specific animals and plants, which are used to live on a certain place, need, without being disturbed.
This part forms the second normative requirement: keeping room for the nature.

N2 keep room for the nature

Figure 2.3, an ecoduct

2.3.2 Light and sound emission


Figure 2.4, a cloud of light above a town in the distance

Also light is an environment polluter. Every night a cloud of light hangs over each town and city and above the areas with greenhouses. This effect is visible on *figure 2.4* We send 30 times more light upwards then 70 years ago. [6]
This is harmful for nature areas. Due to the presence of light, days seem to be longer for animals. This has affects the biological clock of animals, which has all sorts of effects on they behavior. For example birds begin to sing earlier in the morning, witch causes fatigue symptoms, which on his turn leads to a shift of their nesting periods. Also the period of moving southward changes. [11]

These are things which we can note evidently, but there will be much more affects on animals than we can note.
Further also the light sources themselves cause disturbing in the living surroundings of animals. Animals are attracted or revolted by street lights. In that way, lighted streets lead to fragmentation of the living surrounding of animals.
A big part of the upward light is coming from street light and traffic. Within our current way of transporting, reducing this light should conflict with the safety of transporting. But it can be considered by designing new transport ways.
Light emission leads to the third normative goal: minimizing of light emission.

N3 minimize light emission

Also sound emission is a polluter. Especially around highways and airports, is has an evidently effect on brood birds. [9] Also here we don't now what the consequences for the rest of the nature are, but it is very probable that there are problems for plants and other animals.
This has almost only to do with traffic. Of course cars become more and more silent, but as long as the highway network keeps extending and the use of cars keep increasing, this makes no sense. This rule goes also for air traffic.
Because the effects are hard to measure, it is not evidently to say how much the sound and light emission has to decrease in order not to disturb the nature. Of course the best way is reducing it until you reach the natural margins, although this is hardly to realize. But keeping these pollutions in mind by making design choices might help the development in the right direction. [9]
Sound emission leads to the fourth normative goal: minimizing of the sound emission.

N4 minimize sound emission

2.3.3 Accidents

Approximately one percent of the people who die each year in the Netherlands, die due to a traffic accident [45]. Each year there are 70 000 people with acute injury, and 152 000 with prevalent injury [46][47].
The deadly accidents occur mostly due to car accidents. In 2003, 1088 people died in the Netherlands due to traffic accidents. From this number, 557 due to car accidents, 219 due to bicycle accidents, 107 pedestrians and 99 moped riders are killed [48].

Traffic accidents don't only harm people, but also a lot of animals. You can seriously not underestimate how much animals become victims of our way of replacing. According to *de toekomst reis*, approximately 8 million vertebra animals ("werveldieren" in Dutch) die each year due to our traffic, including 2 million birds. Particularly a big part of the the barn owls, the heath frogs and the badgers die each year by chiefly car accidents. *Figure 2.5* shows a badger knocked down by traffic. The high accident numbers under the animals cause that on certain places these animals die out. These accidents have to be reduced to keep the animals on the places where they belong. [9]

Besides this, traffic accidents cause a lot of material waste, paragraph 2.4 shows more about this.

The minimizing of accidents is the fifth normative goal, minimizing accidents.

Figure 2.5, a badger knocked down)

N5 minimize accidents

2.3.4 Cupper from overhead wires

In paragraph 3.1.5 I already told about lead from gas emission that ends up the nature. But due to the infrastructure which we know, also another heavy metal spreads in the nature: cupper.
Due to the overhead wires of railroads, a large amount of cupper ends up in the ground. Also leaked bread fluid contains cupper which comes into the nature. This gets into the food chain via worms. It doesn't only harm plants, but also animals and people, because these materials enter the food chain so that they finally also appear in our food. [?]
It is really a threat for our health when these substances get more and more into the nature. According to *de organische gezondheidsleer*, it has a significant negative effect on our health once we get them in our body. [12]

2.4 materials

2.4.1 Introduction

There are a lot of harmful materials. You find them in all areas: plastics, detergents, pesticides, synthetic rubber etc. They can be either harmful during the manufacturing process or at the removal of the products. In this chapter I'm not researching all these things, but there will be a focus on 2 issues which are quite underestimated and which might be from importance for the project. Those are concerning the ending up of heavy metals in the environment, and the extraction of metals.
The use of these harmful materials is going to be minimized according to the sixth normative goal: minimize use of harmful materials.

2.4.2 Ending up of heavy metals

In paragraph 2.3.4 it is explained why cupper that comes in the nature is harmful. But there are more metals which harm the nature in that way. Also lead, cadmium, nickel and mercury appear in our food finally and cause metal accumulation in the body [49]. These are basis parts of batteries. So it is very important that those things don't end up in the nature. But this always happen due to very subtle processes which you can barely influence, like wearing and leaking. Finally alternatives for batteries should be welcome considering this process.

2.4.3 Extracting metals

But not only the removal of several metals is harmful, but also the extracting of it. For example for the extracting of each kilogram of cupper, 100 kilogram toxic waste comes free. [50]
During the extraction, the ore is processed with chemicals and is being contacted with the air, with the result that the small innocent ore changes into dangerous waste with strong acids and heavy metals. This mine refuse is stored in basins, or it is dumped in a river or sea. These problems are with all ways of metal extracting. [51]
Not only toxic waste harms the eco system, but also the digging up of the landscape, which is needed for the mining for metals. The surroundings dry out due to the extraction of water, and the whole extraction costs a lot of energy: the extracting of metals costs 10 percent of the world energy use. [52]
For the nature it is essential that in the future the extracting of metals is going to happen in a nature friendly way. There are possibilities for that, but those are economical inefficient, which is particularly a problem in the poorer countries.
For transport and traffic vehicles, there is a lot of metal needed. So these sectors are co-responsible for this pollution.

N6 minimize use of harmful materials

2.5 Electromagnetic radiation

With the come of power pylons, radio, radars, GSM networks and the UMTS networks that are applied nowadays, the emission of electromagnetic radiation, also called radio frequency radiation or “electro smog”, is grown enormously the last century, and especially the last decade. This radiation seems to be very unhealthy. This fact is not very well known at the moment, so the outcomes of researches are used to find out whether it is dangerous or not.
There are a lot of (scientific) indications which say that EM fields are harmful. In this paragraph I show them in short, even as the consequences of the radiation.

2.5.1 No reliable legislation

The only official recognized harmfulness of electromagnetic radiation is that it can heat the body. This is the “micro wave effect”. This effect only takes place when a very high dose of radiation hits the body. The legislation concerning the maximum amount of EM radiation is only tuned to this danger. But radio frequent radiation seems to have more dangerous effects. These effects do also exist even when the electro smog density is by far within the margins of the current legislations. [13]

2.5.2 Radiation from outside

Already in 1979, a relation between high voltage cables and cancer with children who live near them was discovered. [14] In 2000, A Swedish research confirms that living within a range of 50 meter near a power transmission line leads to a 100% increase of chance for leukemia for children. [15].

Then the mobile phone industry came up. Soon GSM masts were planted all over the country. *Figure 2.6* in an example of a GSM mast. According to several studies, the electromagnetic fields that are used for this means of communication are also harmful. An Israeli and Germen research conclude that near GSM send masts, the risk for cancer 2-4 times higher is. [16] In another German research, the Naila Study, a factor of 3 came out. [17]
But the radiation from GSM masts doesn’t only cause cancer, but also other complaints. A research from TNO shows that UMTS radiation, the GSM network that is build on this moment, causes sickness to stomach, sparkling, loss of memory and loss of alertness at the moment that people are exposed to the radiation. [18]
A French research from Pathol Diol under 500 people who live near GSM masts, discovered that at 300 m distance from the masts, they cause tiredness, at 200 m distance, headache, sleep disturbance and discomfort is added, and within a range of 100 meter it causes even irritability, depression, loss of memory, dizziness and libido decrease. [19]

Fig. 2.6, The GSM mast, one of the largests distributors of electromagnetic radiation

2.5.3 Radiation sources around us

So it is clear that radiofrequency radiation is harmful. But high-voltage cables and GSM masts are not the only radiators. Next to these ones and the other long distances radiators like radio, radar and navigation, EM fields come also from smaller components, often in our direct environment. These components are under more: wireless phone installation at home (in fact a small GSM antenna in your direct environment), television, electric engines and transformers, which are applied in a lot of domestic equipment, from radio alarm clock to halogen lamp and from computer to electric bed. These sources might emit EM radiation on a smaller scale, but they can be dangerous since the source can be very near to us in domestic situations.
Simon Best observed several researches concerning the effects of electromagnetic radiation that is emitted by televisions on people. His concludes that it causes painful eyes, feeling of discomfort and tiredness. [20]
H. Hemelrijk includes on basis of a lot of books and articles also the electric engine and the transformers to the electro stress causers. According to his research, these are the complaints that have to do with EM radiation: Pain in the neck, shoulders and below back, RSI, complaints like tennis elbow, hernia and tendonitis, universal feel of discomfort, without obvious reason nervous, irritable, aggressive and depressive, (chronic) tiredness, eczema, allergy and hay fever, cancer, leukemia and tumors, stomach and intestine complaints, miscarriages and malformation of fetus, rheumatism and arthritis, disturbances in the blood flow and high blood pressure, headache and migraine, hyperventilation, short of breath feeling and heart palpitation, dizziness and swollen feeling in the head, bad nights, restless legs and cramp (mostly in calf and feed). [21]
I assume that next to the harmfulness for people, electromagnetic radiation is also be harmful for other organisms, as long as the opposite is not proven.

2.5.4 Conclusion

There are enough indications to accept that electromagnetic radiation is harmful some or how.
It is clear that for a well-considered sustainable design, it is not enough to listen only to the maximum limits for radiation that is prescribed by the law; since those margins doesn't consider the facts that I have shown above. For the design, the choice for wireless options should be well considered, and eventually harmless methods should be used. Transformers, electric engines etc. should be used conscious, considering the need for it, the place (in relation to the user) and if possible, protection around the source.

The last normative requirement in concerning this aspect: minimizing the electromagnetic radiation.

N7 minimize electromagnetic radiation

2.6 Conclusion

The pollution of the environment, which creates unhealthy circumstances for human, animal and plant, has to be taken very seriously. Some things move in the right direction, but most of the things not. The traffic takes a large part of the pollutions for his account. I think that when we keep going on with just changing little things, and meanwhile the use of car, airplane and others increases, it is going to be hard to succeed in restoring the nature completely.

The goal for this chapter was researching what polluting factors exist, where they come from and what they cause. Then it is known which factors have to be reduced to make transport or traffic occur in a more environmentally friendly way. A list of normative goals is set up with the outcomes.

For the project I have to consider that combustion engines are bad concerning the environment: it is bad for the greenhouse effect, it is bad for the emission of toxic gasses, and causes fine matter. Also electric engines should need energy, what is often made of fossil fuel. So enlarging of the use of nature energy and / or reducing the needed energy is required.
Also tires that make friction with the asphalt cause fine matter, and break fluid and overhead wires lead to pollution with little metal parts. Too much routes on the ground fragment the landscape, and cause collisions with animals. At night there must be not too much light shining upwards, and transporting should be in a silent way.
Eventual used transformers, electric engines and other devices that cause electromagnetic radiation should be placed on a strategic position, so that users won't be too close by them. The choice for wireless options should be well considered, and eventually harmless methods should be used. Transformers, electric engines etc. should be used conscious, considering the need for it, the place (in relation to the user) and if possible, protection around the source.

N1 minimize harmful gas emissions
N2 keep room for the nature
N3 minimize light emission
N4 minimize sound emission
N5 minimize accidents
N6 minimize use of harmful materials
N7 minimize electromagnetic radiation

Chapter 3

Idea

3.1 Introduction

In this chapter an idea will be thought up.
After this introduction, in the second paragraph, an issue for the starting point will be chosen. This will be the frame in which I'm going further.
Then after some brainstorming, a problem is will be defined, and an idea for the concept will be launched. These things will be the issue of the next paragraph.
In the fourth paragraph, after researching some aspects of the idea, the requirements of the concept will be explained. In this description also the relation between the idea and the normative goals of the project will be explained concretely.

3.2 Starting point: bicycle

According to *DTO sleutel verplaatsen,* p19, [39] it takes 50 years between the introduction of a new transport mean and the moment that it is accepted and used by the people. Viewing the research of the last chapter, what indicates that the environmental stress has to be reduced as soon as possible, it is not a good option to design a whole new transport mean, what will take 50 years before general usage. So I take an existing transport mean as point of departure.

I chose to take the direction of the bicycle. I find this an interesting direction, because bicycles are very clean and healthy.
They are also already accepted in the society. Over 13 million people in the Netherlands own a bicycle [40]. Each day, all Dutch inhabitants ride averagely 2,45 km on a bicycle [22]. I want to design something what makes it more attractive to take the bicycle in the future, instead of the car. Reducing the use of the car already helps most of the normative requirements.

Another positive point about the bicycle is that it is also accepted by the authorities as the transport mean that has to be stimulated for reducing the use of the car. A research of *Fietsbalans* [41] indicates that two third of the Dutch local authorities stimulate the use of the bicycle. A research of *Fietsersbond* tells that stimulating the bicycle by means of improving the bicycle's facilities is effective for the use of the bicycle, until 10% growth [42]. This means that the use of the bicycle will probable even increase in the future. So developing something that stimulates taking the bicycle is something that fits to a long term trend. That makes the chance of success larger.

Also in the client vision about traffic in the future, the bicycle plays an important role. In their book, *de toekomst reis*, ("the future journey"), they propose in what way bicycles can be used in the future. The illustrations on this page are copied from this book.

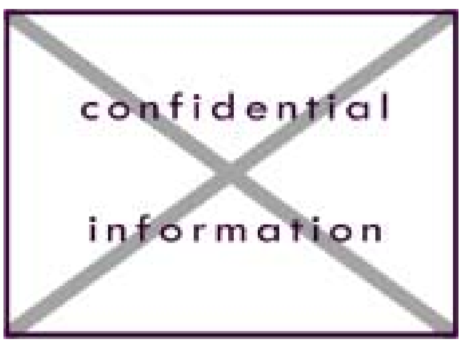


*Figure 3.1, Transporting children by bicycle**

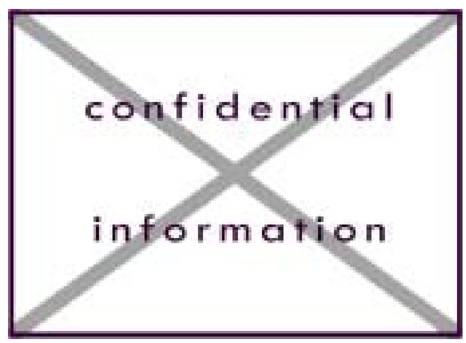


*figure 3.2, longer distances, nature forces**

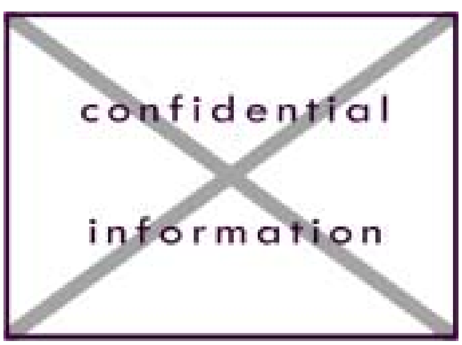


*Figure 3.3, with colleagues to the workplace**

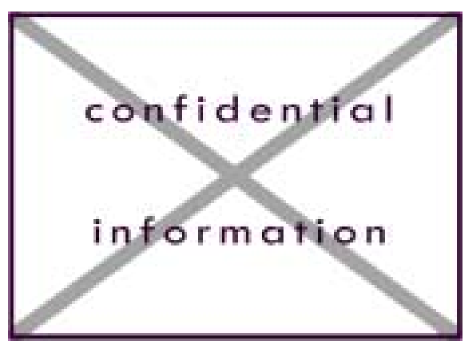


*figure 3.4, cycling with hands and feet**

*Figure 3.5, Borrowing bicycles from an automate and bicycle highways. **

* Copied with permission from "de toekomstreis", by *Stichting Natuur en Milieu*

They propose that cycling can be used for transporting children. On *figure 3.1* you see a kind of carrier tricycle with children in it. And in *figure 3.4* a child is placed in a little trailer. For riding longer distances, a wind sail can be used for the drive, see *figure 3.2*. Further they indicate that in the future extra long tandem bicycles can be functional for longer distances, carrying more people, see *figure 3.3*. There are also ideas of using hands power for the drive, next to feed power, see *figure 3.4*. They further indicate that luxury, as for example a covering, makes riding the bicycle more attractive. Finally they propose the possibility for borrowing bicycles from automates and special bicycle highways between towns, see *figure 3.5*.

3.3 Idea direction

3.3.1 The problem

The function of the bicycle is limited. Concerning the room for taking things with you on the bicycle or taking passengers with you, the bicycle has enormous disadvantages regarding to the car. Taking one passenger with you means a very uncomfortable ride for the one at the back, and a heavy ride for the peddling one. Taking two children with you is possible, see *figure 3.6* but the room is small. The maximum amount of luggage is two full saddlebags and a full basket in front of the steer.

Figure 3.6, taking two children on the bicycle is just possible

Here also counts: the more you take with you, the heavier the bicycle. But the room of the saddlebags and the basket is far too little viewing an average shop in the supermarket. You can hardly drop the contents of a half filled shopping trolley in it.
So it is not strange that people keep using the car a lot while bringing people to school and pick them up again, and for visiting the supermarket. Or when you pick someone up somewhere or bring him/her somewhere. Taking the bicycle is uncomfortable in the last case, and when the person also has a heavy bag, taking the bicycle is far from comfortable.

Not only about taking things with you, but also about the distance, the bicycle is much more limited. While in city-rides the car is not very faster than the bicycle, for a distance further than 2,5 km people find taking the car much more attractive than taking the bicycle[25] [26].
Those two aspects have to do with the idea that I have for the concept.

3.3.2 The idea

I want to tackle the problem by designing a bicycle which provides the possibility to take more stuff along, and to ride longer trips. Taking more stuff and driving further asks more paddle effort from the user. I want to compensate this with a helping force, which is feed by nature energy. This is shown schematically in *figure 3.7*

Extra luggage
When the user can take more luggages along on the bicycle, the bicycle takes over one of the benefits of the car. While the advantages of the bicycle remain the same: no traffic-block, easy to park, no tax or fuel. The help engine will make sure that the driver doesn't have to deliver more muscle power than on a normal bicycle, even less, while he is driving on the same speed. So the engine has to be controlled in a special way, which makes driving on this bicycle comfortable because it makes the extra stuff that is taken unremarkable for the driver concerning his stepping effort. .

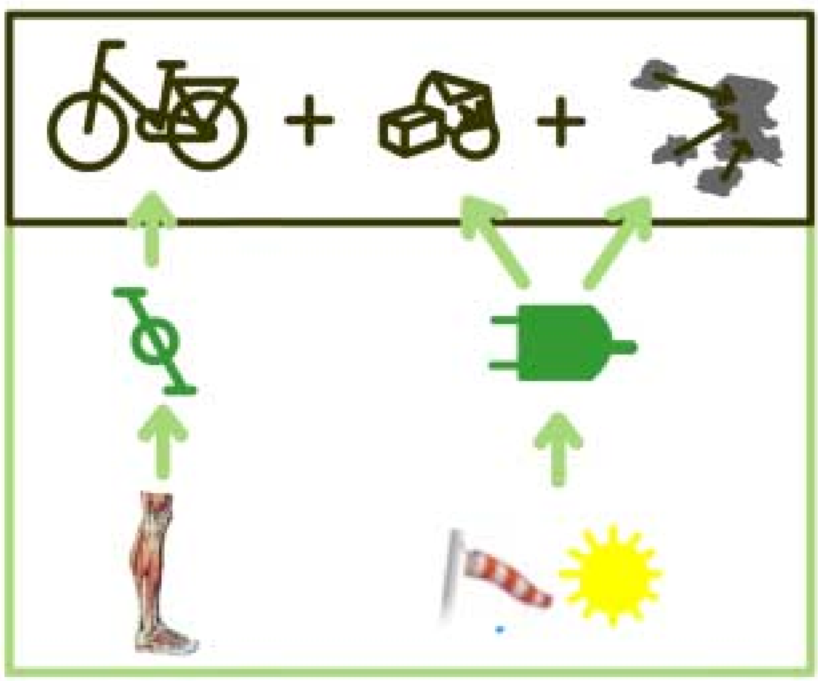


Figure 3.7.The cyclist's effort remains the same, and the nature energy provides the possibility for extra luggage and further trips.

Further trips
The further the trip, the sooner the user takes the car. Maybe this margin can be shifted in the prospect of the bicycle, by making cycling a longer trip more easily. Than the help engine can relieve the user's effort, so that he will sustain a further drive. I will search this out in the next paragraph.

3.4 Concept requirements

I researched some aspects of the idea that is described in the previous paragraph. With help of that, I set up a list of requirements. In 3.4.1 these concept requirements are shown with an explanation of the requirements. In paragraph 3.4.2 the effects of the concept and the concept requirements on the normative goals is explained.

3.4.1 Short research and setting up of requirements

	extra room
CR1	has to be able to carry at least the contents of one shopping trolley (120 L; 75 kg)
CR2	room for one adult passenger or 2 child passengers
CR3	may be max 75 cm wide
CR4	possibility to lock the luggage room
	help engine
CR5	helping engine supports driving
CR6	range 50km
	nature energy
CR7	used energy won from nature sources
CR8	closed circuit between energy provider and bicycle
	behavior help engine
CR9	without pedaling no driving help
CR10	speed controlled by the stepping power
CR11	help engine compensate all extra force needed for luggage, extra passenger(s), hills, head winds etc + 30 % of force needed on normal bicycle
CR12	driving help applied until 24 km/h, if bicycler wants faster, he/she has to reach that by own power
	electromagnetic radiation
CR13	no wireless equipment

Extra room

The first point of the concept is the extra room on the bicycle. The idea is that people can take the contents of one shopping trolley with them on the bicycle. According to Mr Swevers from Wanzl, a shopping trolly company, the possible contents of an empty shopping trolly is 136 L, and the average weight of the contents of a filled shopping trolly is round 40 kg. Though 40 kg is an average value, I enlarged it royally to 75 kg. So the bicycle has to be able to carry shoppings or other stuff with a volume of 136 liter and a weight of 75 kg. This is the first requirement, RC1.
The idea is also that one passenger can be taken with in a comfortable way. So that people don't have to take the car once they want to bring someone somewhere or picking someone up. So that means that there has to be enough room for a passenger. The place for the passenger has to be large enough to provide a comfortable passenger ride. Another terrain that this bicycle has to conquer from the car is the bringing and picking up children to and from school. So in stead of one passenger, there must be room for 2 little children. This room might not be the same room as those of the luggage. For children also have to take their schoolbags with them, and people often take their little children with them when they go to the supermarket. CR 2 indicates this purpose. After a quick search, I found that there do exist bicycle and tricycles which can carry those things, but never on the same time.

Another requirement here is that the maximum width is 75 cm. This is the width of what the bicycle tracks are made for. Crossing this limit means that the bicycle becomes inappropriate for several tracks which may cause uncomfortable situations. See CR3.
A thing that the bicycles and tricycles which I crossed in the search also didn't have is a lockable luggage room. When someone goes shopping, he or she doesn't always want to take everything with him/her. An advantage of the car is that you can lock things away. Once this bicycle is also able to do that, it will be more functional and compete better with the car. CR4 is about this requirement.

Help engine

The heavier the bicycle is loaded, the heavier the stepping is. That is something that will discourage people to make optimal use of the concept. The idea is of a help engine what compensates the extra force is needed for the extra luggage options. So a help engine should be needed. By giving even more force than just compensating, it can make the ride less heavy which may lead to the possibility for longer rides. CR5 is used for this. How the energy has to behave is explained in the description of the last requirements.
CR 6 tells that there has to be a driving range of 50 km. According to the CBS, the central office of statistics, bicycle rides are not longer than 20 km. 50 km is enough for going back and forth, and than there is still 10 km left as reserve. Thanks to this requirement people won't get out of helping force, so there is no barrier of fear about being left alone by the help engine and carrying all the stuff with your own force.

Nature energy

So now we must provide energy for bicycles, namely for the help engines. While we know bicycles as very clean transport means. Using normal energy of course is also better than a car, but as we saw in the environmental research, there has to happen really a lot concerning the polluting factors. So to prevent that the bicycle becomes a polluter itself, the energy that is will be used for the help engine has to be nature energy. See CR7.
CR8 tells that the circuit between the energy provider and the bicycle has to be closed. This prevents the "walk over" of green and gray energy. I learned this from possible users. While talking to some of them, I remarked that they were unhappy about the current situation of grey and green current in their houses. There is confusion about whether they really get nature energy once they choose for that, or not. With this requirement it has to be prevented that people become negative about the product because they expect the same to happen.

Behavior help engine

The help engine should behave in a certain way to get a right compensation and the right stimulation with regard to the long drives, while preventing energy waste and dangerous situations. Here is explained what this means for its control.
Firstly, the help engine may only work when the user gives pedal force. This is needed to prevent dangerous situations. This point is mentioned in CR9. In that way the controlling of the bicycle remains in the stepping behavior of the user. This has to happen at all speeds, see CR10. The help engine always has to react on the stepping behavior of the user. These things keep the bicycle a bicycle, and prevent dangerous situation.
As told above, the help engine has to compensate the extra weight that is taken on the bicycle. Further it has to help with a certain percentage for stimulating longer rides. But there are some problems with that. As I found after some search, the bicycles / tricycles that do exist with help engine, do not give their power really as a certain part of the pedal power. The user can put it on a certain stand, for example 10%, 30% 50% etc, but for the ones I tried I have my doubts about whether they really give that part of the energy that you put in with your stepping force. I didn't try all the systems, so maybe there is someone that can give the power. So the help percentage is something that has to be correct, for stimulating correctly the longer drives.

There is also a problem with the stand-switch. Namely, according to the idea, everything that makes cycling heavier, the luggage, the extra person(s), hills, etc, have to be compensated. This is needed to guarantee a comfortable ride to the users. In a bad situation, it can happen that the help engine should give 200%, or even more, of the stepping force. That means that a stand on the switch has to be 200%. So people can always use 200% help engine force when they want, also in a light, almost empty, situation. That will make the bicycle almost a moped. To prevent energy waste in this way, the correct help force has to be calculated automatically. So it always has to compensate exactly the extra weight that is taken with, the hill, head winds etc. This is mentioned in the first part of CR11. The second part of the phrase is concerning the help percentage that you always have regarding to a normal bicycle. This is stated on 30%. This number is a good percentage on which the user keeps doing something, but can sustain a longer drive. I talked to several physiotherapists to specify this percentage. It seemed to be a point from what you can make a whole new project, so to avoid getting off the track too much, I satisfied with an assumption of a physiotherapist. Physiotherapist Jochem van der Klei told that 30% should be a good number. It agrees with a good tail wind.
The last thing is that the bicycle may not drive too fast. With a help engine, you are able to drive faster than normally. That may also cause dangerous situations, especially when you drive with a heavy bicycle (big impact in a crash). So the requirement is that the help engine works until a certain speed, and if the cyclist wants faster, he/she has to do that by own power. This maximum speed is 24 km/h, a speed that is advised by Patrick Rugebregt from SWOV. CR12 is about this requirement.
In the environmental pollution chapter it is shown that wireless communication causes harmful electromagnetic radiation. In the concept this is avoided by preventing wireless equipement in the bicycle itself. CR13 shows this.

3.4.2 The concept requirements in relation to the normative goals.

In this part I explain the relation between the concept requirements and the normative goals. So it will be clear to what extend the concept will help reduce the environmental polluting factors. *Figure 3.8* shows an overview of the relation between the concept requirements and the normative goals.

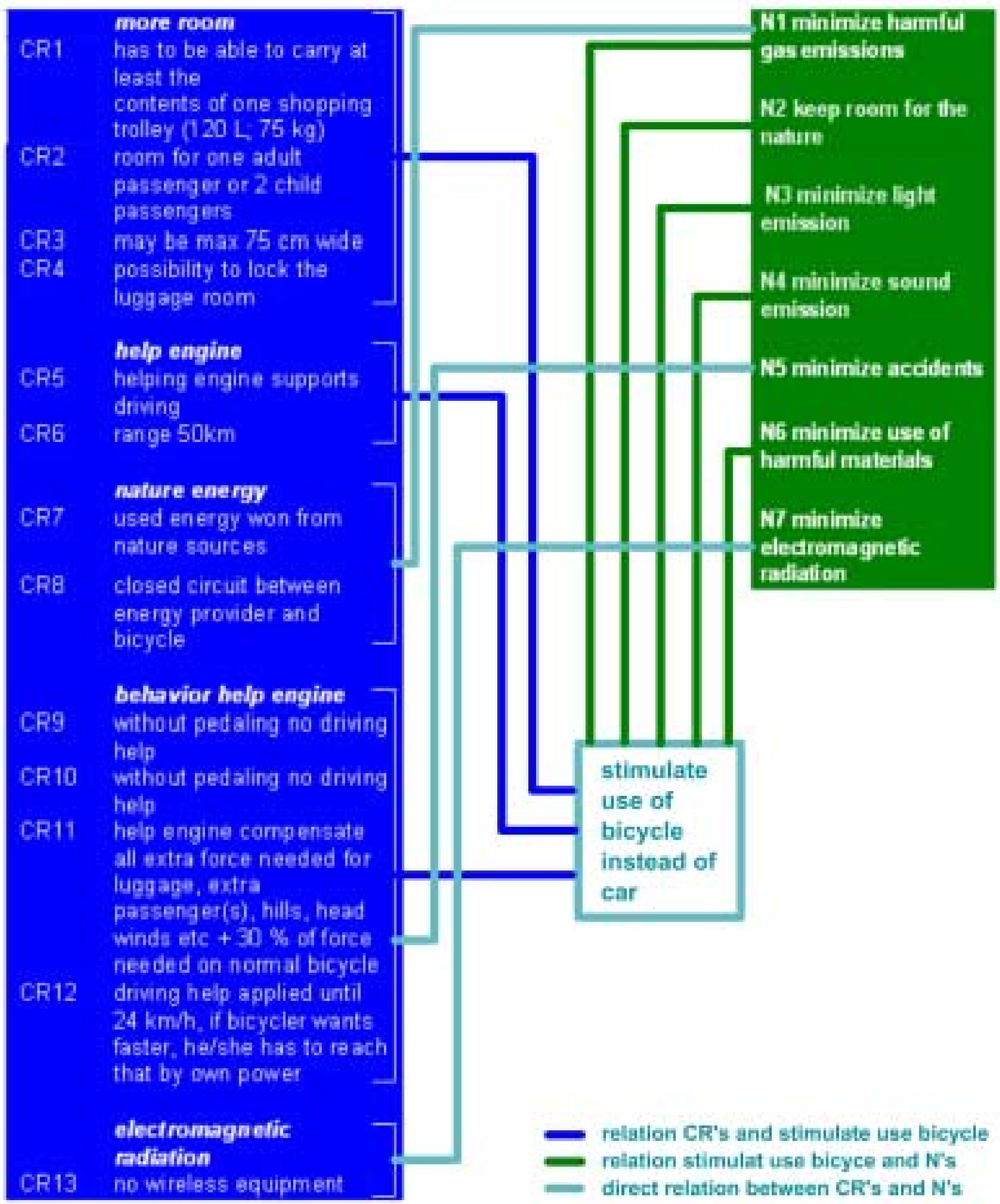


Figure 3.8 Relation between the concept requirements and the normative goals

Stimulating the use of the bicycle in stead of the car serves N1,N2,N3,N4,N6

A large part of the profit for the normative goals is due to the fact that this concept makes the bicycle more attractive to use regarding to the car. This stimulation takes place by the extra room, and the fact that everything that they take with them as extra is automatically compensated by the help engine, including hills, head winds, bad roads. In this way the bicycle can be used for more practical situation than first.
The fact that due to the help engine and his control the needed force and energy for the bicycle is always just 70% from that of a normal bicycle is an extra stimulation that makes longer rides easier. So this also saves car rides finally.

More bicycle and less car use has an effect on almost all normative goals. Firstly of course the gas emissions will be reduced. Secondly less room is needed for traffic: less extra roads are needed and less parking places. Further cars deliver a lot of light and sound emission. So those factors will also decrease once the car is used less. At last harmful material use will be reduced. Cars need for example much more metals, rubber and cupper cables than a bicycle.

Help engine on nature energy serves N1

The fact that the help engine is fed by nature energy is also an advantage for the first normative goal. If normal energy was used, some fuel would have to be burned to obtain that energy. This process, in which the emission of harmful gasses is necessary, is not needed once using nature energy.

Safety serves N5

In the research it is shown that the amount of road victims with deadly end due to the car, is 2,5 times higher than due to the bicycle. But if you also consider that people ride more in a car than on a bicycle, which has a factor of 9,5 (according to a calculation on basis of information from the CBS (C*entral Office for Statistics*) [22][53][54], you remark that you have 3,8 times as much chance on a deadly accident on the bicycle than in the car. This suggests that the transferring from the car to the bicycle will mean more (deadly) accidents.
But there is also another side: in a lot of bicycle accidents cars are involved. So if there were fewer cars, there would also be fewer bicycle accidents. According to Fietsbalans (*bycicle balance*) [55], the growth of bicycle use in cities cause a lower accident rate under cyclists.
So it is hard to say weather the stimulation of bicycle regarding to the car will lead to more or to less accidents. An evident positive effect will be the collisions with animals. Those will be reduced one the car is less used.

For the normative goal “minimize accidents”, some concept requirements from the fourth group, the behavior of the help engine, have effect. Firstly the requirements CR9 and CR10 which tell that the bicycle has to be fully controlled by the steps. So the action of the help engine always takes the stepping behavior into account. Further the maximum speed until where the help engine operates is limited. When someone drives faster than 24 km/h, he or she has to do that by own power. In that way it is not made easier by help engine to drive faster than you can do on a normal bicycle.

No wireless communication serves N7

To avoid harmful electromagnetic radiation, wireless communication in the equipment of the bicycle is not allowed.

Chapter 4

User check

4.1 Introductions

The goal of the project, designing a concept which indicates how the transport of people / goods can happen in a more environmental friendly way, can only be fulfilled when the concept is will be accepted by the users. When nobody is going to use the concept, nothing is will change for the environment at all. This chapter consists of research that tries to find an answer on this question.

With this concept, I try to get people out of the car on the bicycle. I focus mainly on people who ride short car rides (<7,5 km) with the car. In this chapter I study in how far people are willing to take this bicycle in stead of the car.
In the first part I look theoretically in how far the bicycle from the concept could conquer terrain of the car. In the second part of this chapter, paragraph 5.2, I do a research in which I check in how far people are also willing to do that.
So the main goal of this chapter is researching whether this concept has a change to get used, if it depends on the people. That means that it is not a research that has to deliver input for the development of the concept. It is also not a research that will show how much bicycles will be sold. An image has to be obtained of how people react on the idea, how much people find the concept practically, whether they should use it in stead of the car and what they would use it for.

4.1 To what extent could the concept be used, statistics research

4.1.1 Short distances

According to a research from *Kennisplatform Verkeer en Vervoer* [23] (“knowledge platform traffic and transport”) there are 3,0 billion short car rides (until 7,5 km) each year in the Netherlands. In 2003 there were 6.879.000 registered cars in the Netherlands [24]. That means that averagely, every car is used for 1,2 short rides per day. So the short car rides are not something that happens so now and than, but are really a social habit. Below I estimate by the use of core numbers in how far the car user might get stimulated to take the concept bicycle in stead of the car.

More luggages

By giving the possibility to the user to take more luggages with him/her, I try to make the bicycle more practical to several situations. Here I look theoretically to what extends this extra function might help. According to the research of *Kennisplatform Verkeer en Vervoer* [23], the most important goals of the short car rides are the ones called below. The numbers are in short car rides (until 7,5 km far) each year in the Netherlands:

- 900 million: shopping
- 400 million: bringing children and pick them up again
- 400 million: visiting someone
- 300 million: commuter traffic
- 1000 million: other

So the biggest group is shopping. A reason for taking the car for shopping could be the extra room for luggage that a car provides in comparison to a standard bicycle. In this respect the concept could help. Also taking children to school, sport clubs, school of music or the like, and pick them up again, can be easier with the bicycle on which taking little children with you or one bigger one is no problem. Schoolbag, sport bag or music instrument don’t have to be bound on the back, but can be put in the luggage room of the bicycle. So also for this group of rides, the concept might help concerning the extra room. Visiting and commuter traffic have no clear direct prospect by the extra luggage room.

So there is a chance that the extra luggage room can get people from the car to the bicycle. But are people willing to take the bicycle in stead of the car? Therefore I do a survey with people who take the car now. See *paragraph 5.2 user survey*.

Further

In the last paragraph I talked about the extra luggage. But the distance also plays a role. A short car ride namely, is averagely longer than the average distance of a bicycle ride. So to get people from the car on the bicycle, it could also help to make the bicycle more attractive for a longer ride.
As told in paragraph 3.4.1 I try this by decreasing the stepping force that people have to give during a cycling ride. That makes the ride less heavy for the neurovascular system in the body. According to Jochem van der Klei, a physiotherapist, 30 % release in pedal force should be an appropriate reduce. So the bicycle will always ask 70 % of the power that should be needed for a normal bicycle, unesteemed the extra heaviness of the load. In that way the longer rides are tried to stimulate.
But how is the car / bicycle use relation now on several distances? And where lay the biggest chances for the bicycle to take it over from the car?

With use of data from *Centraal Bureau voor de Statistiek* (central office for statistics) [25][26], I made the diagram below.

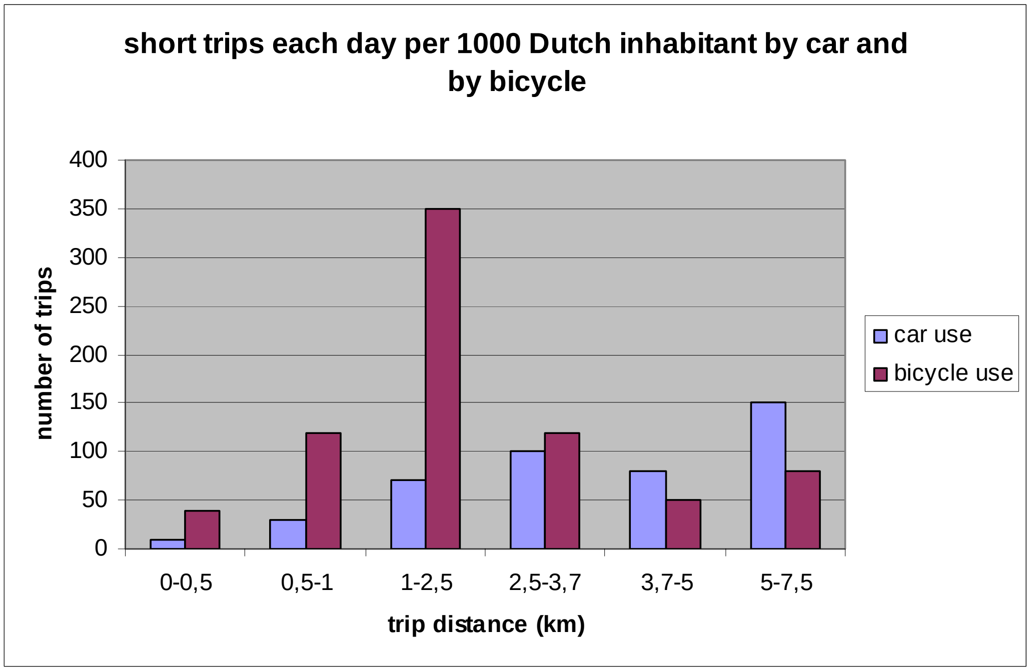


Figure 4.1, the short trips each day per 1000 Dutch inhabitant by car and by bicycle

The chart in *figure 4.1* shows that under the 2,5 km, the bicycle is approximately 4 times as popular as the car. But from 2,5 km, this changes evidently. The car passes the bicycle, and between 5 and 7,5 km it is twice as popular as the bicycle. So if this 2,5 km bound became higher, there should be a lot of car terrain that can be won by the bicycle. For example, if the 2,5 – 3,7 distance had the same popularity as the 1-2,5 km, and the rest had the same value, the amount of car kilometers during the short rides would be 10% less than now. (Going from the situation that a 1 car is replaced by 1 bicycle)
But of course there is also still a lot to win below the 2,5 km.

As told above, a survey will find out weather people are willing to take such a bicycle in stead of the car. With this, I test their reaction to the extra luggage room. This is something practically. The participants of the survey can consider whether they will be able to step over to the bicycle or not, looking to the extra practical possibilities. But in the case of the longer rides, I don't expect useful information from the survey. Because I believe that it is hard to see for them what the effect of lighter stepping is going to be. For their imagination, a bicycle ride of e.g. 5 km will sound long at all for doing it with either the normal bicycle or the bicycle of the concept which steps lighter. That is something that the user will remark slowly when he uses the bicycle. If it is effective, the user slowly gets used to driving further rides. So the effectiveness about the longer rides are not going to be researched in the survey of the paragraph 4.2.

4.1.2 Further distances

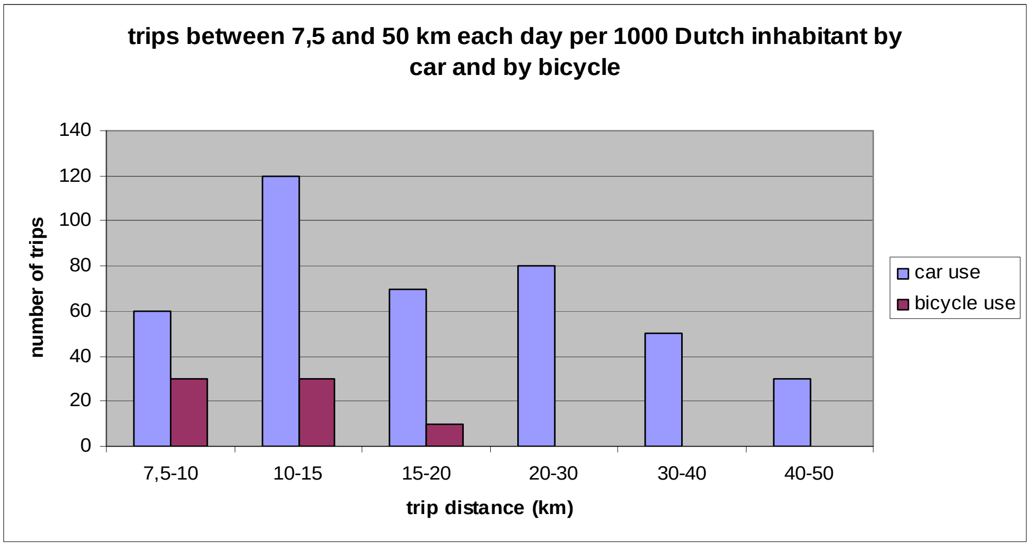


Figure 4.2, trips from 7,5 to 50 km each day per 1000 Dutch inhabitant by car and by bicycle

As mentioned before, with this concept I focus on the short car rides. (<7,5 km). But of course it should be nice if the bicycle should replace the car also on further rides in the future. By partially relieving the cardiovascular system the longer bicycle rides are stimulated.
How is the bahviour now concerning longer drives on a bicycle? In *figure 4.2*, the same kind of table as the one in paragraph is 5.1.1 is shown, but now about rides which are further than 7,5 kilometer. This one is also made with use of data from *Centraal Bureau voor de Statistiek* (central office for statistics) [25][26]. As you can see, until 15 km far, taking the bicycle is not really strange. Further than 15 km is very rare. So until 15 km less habit changes will be needed than above 15 kilometers.
But it is very hard to say something about this, without doing a thorough research about it. There are a lot of factors that have influences on it. Factors like the development of costs for car driving, the building of fast bicycle tracks with windbreaks outside the cities, how social cultural trends concerning people's wish for comfort and people's care for their health will proceed, the silting up of the road network etc.

4.1.3 More user groups

As mentioned, the user groups on which I focus the most are the people that drive short rides with their car. But the concept can also be interested for other groups. Here I suggest very short some possible users.
A possible group contain the people who use the standard bicycle with combustion help engine, in Holland called the "Spartamet". For them the concept bicycle is a cleaner and silencer alternative.
Another group, or an overlap of the just-mentioned group, can be the people who don't have a car, but lean it from others at the moment that they need it. The reasons that they don't have a car can be for example the costs, the room that it needs or the harmfulness for the environment. In those situations the concept bicycle can be a solution.
Or people without a driving license. Maybe they are too young for driving a car, or they are older but don't have it for another reason. For those of them who need more luggage room they have to do it with a normal bicycle or a moped, and possibly they are depended on someone else with a car and driving license. But with the concept they can transport more things themselves.

4.2 To what extent are people willing to use the concept, survey research

4.2.1 Investigation goals

I want to have a feedback on the idea from people that might use the concept. This is needed to understand whether the concept will have a chance to be accepted in the future or not.

What I want to know is in how far people are willing to use the concept bicycle. For what type of rides should they use it, and what factors make that choice for them?
What I also want to know is weather they should abolish the eventual second car, if they could use such a bicycle.

I do a survey for researching these things. Again it is just about the willing of the people to use the concept, not weather they should buy it or not. So I filtered out the purchase factor. I did this by let them propose that they had the concept bicycle.

When I do a survey, I am also going to ask some other meanings concerning the concept which I want to know. I want to know whether they mind if the added energy for the bicycle comes out of the nature or not, and whether they should agree with a little wind turbine on the roof or balcony (in case of flat) of their home.

4.2.2 Survey

I made a survey. See appendix A.
With this I approached car users. Only people who uses the car for short rides (<7,5 km) were appropriate for the survey. The people didn't have to fill in the questions themselves, but I asked them and noted the answers. I did the survey on a parking place of a supermarket. That suggests that I won't get a representative part of the short car ride drivers. In paragraph 4.2.6 I check this Representativeness.

For the survey, I used 14 participants, 50% man and 50% women. In stead of over the 60 years, they are spread in age. I had already filtered out the eldest group, from 60 years and older, because it seems for me too dangerous for them to let them ride on a loaded bicycle. They are all people who use the car for short rides (<7,5 km). Besides this, they might also use it for further rides. In the following paragraph I give the outcomes of the survey.

4.2.3 Outcomes concerning the will to use it

The will to use it
From this group, 10 people (71%) indicated that they should make use of the concept. 9 of them should use it in stead of certain car rides they make normally, and 1 won't use it for replacing the car on a certain moment, but should use it for something he doesn't do now, so a new possibility. In 4.2.6 I explain in how far this is reliable.
The extension of possibilities of the bicycle from the concept, e.g. the extra luggage room, causes that people are able to use this bicycle, in stead of the car. But of course they can also still take the car. The reasons most mentioned for taking the concept bicycle in stead of the car on certain trips, are the facts that cycling is better for the environment, and healthier for them selves. The most mentioned reasons for not choosing for the bicycle are distance, comfort and the weather. These reasons are also for long trips, for which taking the bicycle should not be very appropriate. See the tables of appendix B.

Sex and age
The difference in answers from men and women is striking. Namely, 3 of the 7 men indicated to make use of it, and from the women, they all indicated to make use of it. While the goals, distance and frequency of the car use on the short rides doesn't significantly differ from each

other concerning the sex (see the tables of appendix B). Overall, I remarked that women were more enthusiastic about the concept than men. So the group that I'm designing for exists for the biggest part of women.
Concerning the age, I didn't find any relations of how they react on the bicycle of the concept. See the tables of appendix B. As told in paragraph 4.2.2, I had already filtered out the eldest group, form 60 years and older.

4.2.4 Outcomes concerning will for abolishing second car

From the 14 polled people, 6 have 1 car in their family household, and 8 have 2 cars. From those eight, 7 indicate to make use of the bicycle from the concept. From those 7, two persons would replace all the rides that he or she indicated by the bicycle. 2 people said that they should abolish the second car using such a bicycle. One of them from the group that would just use the bicycle, and one that will use the bicycle for all his main rides. Also 2 people said that they should consider abolishing one of the cars. Those are from the group that would use the bicycle, but not for all rides. This is illustrated in figure 4.3.
Here rides longer than 7,5 km do also count. These outcomes belong to a family situation, and not to an individual.
These conclusions are too specific for a poll on such a small scale, but it indicates that I little part of the possible users might abolish one of the cars, which is quite positive. With respect to the accuracy of the survey, I assume that between 1/5 and 1/10 indicates to abolish the car.

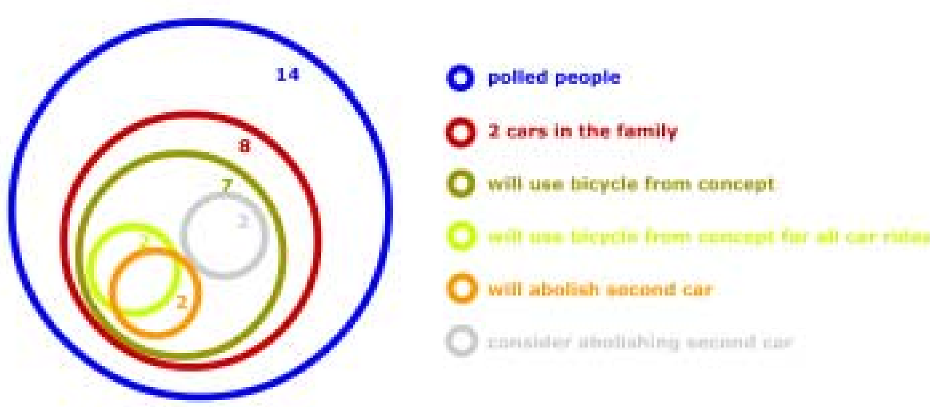


Figure 4.3, diagram of survey outcomes concerning the will to abolish the second car once they use the bicycle of the concept.

4.2.5 Outcome concerning meanings about nature energy and wind turbine on the roof

10 of the 14 polled people indicated that they do mind weather the added energy for the help engine of the bicycle is nature energy or not. Also here, the four people who don't mind are men. They are not the same persons as those who won't use the bicycle of the concept. The most important reason why people support the green energy is that it is better for the environment. But also answers like "stimulates progression concerning the development of nature energy winning", "saves fissile fuel" and "nature energy belongs to a bicycle" are mentioned. The people who don't mind weather it uses nature energy or not, give as reason that it's not important for them, or that it won't help on such a small scale.
Except one, all the participants should allow a little wind turbine on the roof or balcony of there home. On the why question, about half of them answered that they won't have trouble with it. Other answers lay in the direction of "good for environment", "should like it", and "that's the future". The man, who doesn't want it, finds it ugly. See the tables of appendix B. This outcome is very valuable for the concept choice later on.

4.2.6 Representativeness of the polled people

I have already mentioned that the number of participants is too low to make accurate measurements. I have taken that in account by the outcomes.
But there is something else that I should be aware of. Besides the size of the group, in the most ideal situation for the survey, the group that I polled should represent the group of people that make together the in chapter 3 mentioned 3 billion short car rides each year in the Netherlands. So another significant disturbing factor of the representativeness of this survey could be a difference in function of the rides. Since for example the functions “shopping” and “bringing and picking up children” might be earlier won from the car by the concept than for example visiting, because the added value of the concept bicycle is for the biggest part the extra transport room for luggage and children, which are needed for these functions.
So the more the functions of the rides are in the right balance, the more representative this survey is.
This can be tested by comparing the proportions of the functions of the rides that are indicated by the polled persons, to the proportions of the functions of short rides in the Netherlands, researched by *Kennisplatform Verkeer en Vervoer*. [23]. This research is already mentioned in paragraphe 4.1.1. In the table below, I repeat this in the second column. In the third column are the rides that are made in a year by the group that I have polled, calculated from the coming outs of the survey. See the tables of appendix B. The last two columns tell how much percent the rides are in comparison to the total rides, respectively for the outcomes of the research from *Kennisplatform Verkeer en Vervoer* and the outcomes of the survey. For this, I have not included the category “other” in the calculation. This because in the survey the participants was only asked to mention their most used rides, so the outcome of the survey has no data here.

Category	Number[1] * million	Number[2]	Percentage [1] %	Percentage[2] %
shopping	900	1092	45 %	48 %
bringing children and pick them up	400	468	20 %	20 %
Visiting someone	400	312	20 %	14 %
commuter traffic	300	416	15 %	18 %
other	1000	104		

[1] short car rides (<7,5 km) each year in the Netherlands according to *Kennisplatform Verkeer en Vervoer*. [23]
[2] short car rides each year by polled people during survey, outcome per week multiplied by 52, not rounded off

The conclusion here is that the polled group is rather representative concerning the type of rides that they make. In the two groups where the luggage room and the room for the children is important, the two first categories, the percentages deviate minimal. So assuming that there are not other significant representativeness deviations, the outcome that 10 of the 14 people who drive short rides with the car, are willing to use the concept bicycle for one or more of the type of these rides, will lay in the right direction. Regarding the exactness of the poll, I conclude that this number is between two third and three quarter of the possible users.
Again, it are just indications from the persons that they might use it, unconsidered the purchase etc. For this project it says enough about the change that the bicycle part of the concept will be accepted by the people.

5.3 Conclusion

The people who make short car rides, is a large group. A large part of this group uses the car under more for rides which they cannot do without car, but what mostly can be done by the concept bicycle.
Between 2/3 and ¾ of the group indicates that he or she should use the bicycle if he or she had the dispose of it. This means that bicycle has a chance to catch on in the future. More women will use the bicycle than man, so the women form a bigger user group than the man. This is also a group that cares about the environment, which is appropriate for the concept. A small part, between 1/5 and 1/10, indicates to abolish the second car if they had the dispose of the concept bicycle.
Next to this main user group, there could also be other users like people that don't have a car or driving license, but can use a transport vehicle like the concept with possibilities for carrying luggage. This is not researched further.

Chapter 5

Techniques

5.1 Introduction

For the project goal, designing a concept which indicates how the transport of people / goods can happen in a more environmental friendly way, it is needed to research how the realization of the concept may be possible. For without these possibilities, the concepts won't work, and in that case the concept could not make traffic or transport happen in a more environmental friendly way.
So regarding the idea's possibility to succeed in the future concerning the users, which came out of the user check, the technical possibilities for the idea can be researched.
The technical research is documented in this chapter. The chapter exists of several units, which agree with the parts on the list of requirements. Here an overview of the chapter is given.

	extra room
CR1	has to be able to carry at least the contents of one shopping trolley (120 L; 75 kg)
CR2	room for one adult passenger or 2 child passengers
CR3	may be max 75 cm wide
CR4	possibility to lock the luggage room

Room CR1 – CR4
The idea requires a bicycle which can stransport the rider, an extra rider or two children, ánd 120 L / 75 kg of luggage, which has to be able to be closed off. The possibility for this is going to be researched in the next paragraph, paragraph 5.2.

Mathematical model
For the further mentioned research parts I created a mathematical model what helped me doing the research. Paragraph 5.3 explains the use of this model.

	help engine
CR5	helping engine supports driving
CR6	range 50km

Help engine, CR5 - CR6
Than the rider has to be helped by a help engine. This engine needs also energy storage for during the ride. The options for these things will be researched in the second part of this chapter.

	nature energy
CR7	used energy won from nature sources
CR8	closed circuit between energy provider and bicycle

Nature energy, CR7 - CR8
According to the concept requirements, the energy for the help engine of the bicycle has to be won from the nature. The technical possibilities for this will be researched in 6.3.

	behavior help engine
CR9	without pedaling no driving help
CR10	speed controlled by the stepping power
CR11	help engine compensate all extra force needed for luggage, extra passenger(s), hills, head winds etc + 30 % of force needed on normal bicycle
CR12	Driving help applied until 24 km/h, if bicycler wants faster, he/she has to reach that by own power

Behaviour help engine, CR9 – CR12
After all the help engine should behave according to a certain regulation. This is something that I will design in the implantation phase. The implementation phase will be explained in the next chapter of the report, chapter 6.

	electromagnetic radiation
CR13	no wireless equipment

Electromagnet radiation CR13
For this requirement there is no research needed for the concept, it just has to be taken into account.

5.2 Room

5.2.1 Introduction

A bicycle with as many room as the CR's require, is not on the market on the moment. The goal of this paragraph is to find a way in which this room on a bicycle is feasible within the requirements.
Several existing bicycle / tricycles, that come near to the CR's about the room, are tested in the paragraphs 5.5.2 to 5.5.4. A solution is going to be found to let the most appropriate one fit to the concept requirements in 5.5.5.
The models which I tried are product from 't Mannetje, in Haarlem. This company is a producer and seller of carrier bicycles, tricycles and 4-wheel bikes.
In 5.5.6 an idea is created for the shape and the functions of the luggage room.
And in 5.5.7 the bicycle is shown with the room for the passenger(s) on the rear side of the bicycle.

5.2.2 The carrier tricycle

An old one is the carrier tricycle. But there do also exist new versions of. See *figure 5.1*.
A very big advantage of this principle is that they can carry a lot of stuff, or 4-9 children, see *figure 5.3*. Also a covering is possible, see *figure 5.2*.

But there are also some disadvantages. In most of the models, the box turns with the steer wheel. I remarked that this can be uncomfortable. And in a sharp bend that goes downward, you can even fall with it, according to *'t mannetjes*. The turning circle of the steer is also big, so that you have to stretch both arms extremely to the left or to the right to make sharps bends. Personally I didn't like driving faster than about 10 km/h with it, which doesn't really fit in the idea of the concept.

Figure 5.1, the "Filibak" from 't Mannetje

But there do also exist types of the carrier tricycle with a box that doesn't turn with the steer wheel. But in that case the box is much smaller, because there is room needed for the turning wheels. If you made the front wheels smaller so that they take less room, the tricycle would becomes too jumpy, and if you placed the box higher, above the wheels, the sight would be worse and the centre of gravity would lay too high for driving comfortable.
Another disadvantage is that the models are too wide for the standard bicycle tracks. The one I tested is 91 cm. That's not narrow enough to fit on the Dutch bicycle tracks, which are made for 75 cm wide vehicles. According to *'t Mannetje* in Haarlem, the user sometimes has to take the roadway, which may cause dangerous situations. This doesn't fit to the 3rd requirement from the list of requirements.

Figure 5.2, the "Filibak" from 't Mannetje with covering

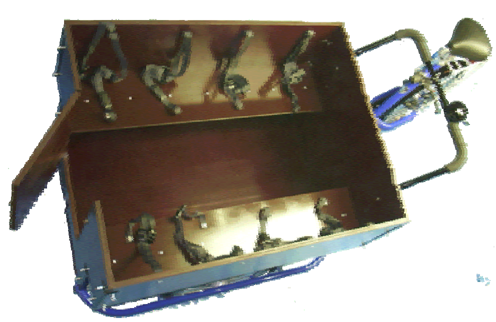


Figure 5.3, "Filibak" from 't Mannetje with eight child seats

+

A lot of room for children and luggage

-

Uncomfortable
Too wide
No room for adult passenger

5.2.3 Carrier bicycle

The carrier bicycle is in fact a normal bicycle but longer. Because it has no extra wheel, the width is appropriate for existing bicycle tracks. There are models with the box above the wheel level, see *figure 5.4*, and with the box lower, see *figure 5.5*. Due to the lower centre of gravity, the second one should have to drive more comfortable. But the version with the box higher rides better: this construction is more stabile. Even loaded with 80 kg in the box and 60 kilo at the rear, the bicycle didn't make any unexpected movements.

My expectation was that the bicycles should steer quite indirectly, because you don't directly steer the wheel, but there is an extra steering stick between the steer and the steering wheel. But by testing it I didn't find any problems at all with that: the bicycle did exactly what I wanted.

A disadvantage of this type is that if you should use the place on the front of the bicycle for transporting little children, there would not be enough room for luggage left. So that doesn't fit to the list of requirements, because the requirements say that there must be transported one passenger or two little children, and at the same time the luggage.

I expected that it should be hard to keep a loaded one straight on a moment that you are standing still. But that was better then I though. Even with the loaded situation as described above, it was for me easy to keep it straight. It is comparable to standing still on a heavy motorbike. Although I expect that some people might have difficulty with it, for example old people.

Figure 5.4 the Filibus from 't Mannetje

Figure 5.5, the Cargobike from 't Mannetje

+
comfortable

-
Not luggage and children at the same time

5.2.4 Three and four wheel reclining bicycle

The 3rd category that seems attractive for the concept are the 3 and 4 wheel reclining bicycles. The 3 wheel versions have 2 wheels at the back and one at the front, see *figure 5.7*. See *figure 5.6* for the 4 wheel version that I tried. Both versions drive comfortable: you don't have to make strange moves or tries to keep it in balance. From the 4 wheel you should expect that it would behave strange on irregular roads, for with a four wheel construction, one wheel can break free from the road surface. But on the type that I tried this didn't happen, due to a flexible frame.
For them who are not used to driving reclining bicycles, they have to become used to the lay position and the steering. Not only because the steer handles are placed next to your legs, but you also have to get used how the steer wheel reacts on your steering commando, for you have to make another movement than on standard bicycle. But finally I find them very comfortable driving, and appropriate for longer distances and higher speeds.

A disadvantage of this type is that there is no place for a passenger. On the 4 wheel there is a lot of room for luggage, on the tricycle there is not enough room for transporting luggage ánd two children at the same time.

Another disadvantage is that also these types are too wide for the standard bicycle tracks. The 3 wheel is 82 cm wide and the 4 wheel 93.

Figure 5.7, the Lepus from 't Mannetje

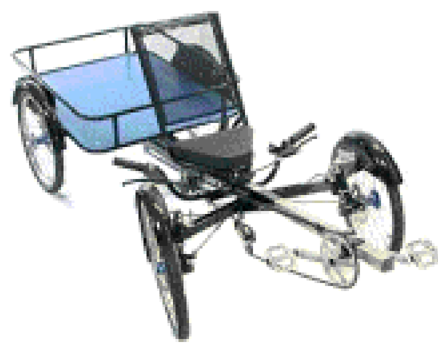


Figure 5.6 the Brox from 't Mannetje

+

Comfortable
Lot of room 4-wheel

-

No room for other passenger
3-wheel not enough room for children and luggage at the same time
Too wide

5.5.5 Choice for concept

Concerning the comfort, the carrier tricycle should drop out. This one is not appropriate for the way of driving what this concept is meant for.
The 3 and 4 wheel reclining bicycles don't have enough room for an extra passenger, and are not narrow enough for the standard bicycle tracks. But according to 't mannetje, the width is already at his minimum, to maintain the stability of the vehicles.

For the carrier bicycle there is a solution: the type with the high box can be combined with a bicycle that has a longer rear side. In that case the negative point – not enough room for 2 children ánd luggage at the same time – is canceled. They have made a version like this some times before. They ensure me that the bicycle which arises than, will behave just like the carrier bicycle which I have tested. The result is shown in *figure 5.8.*

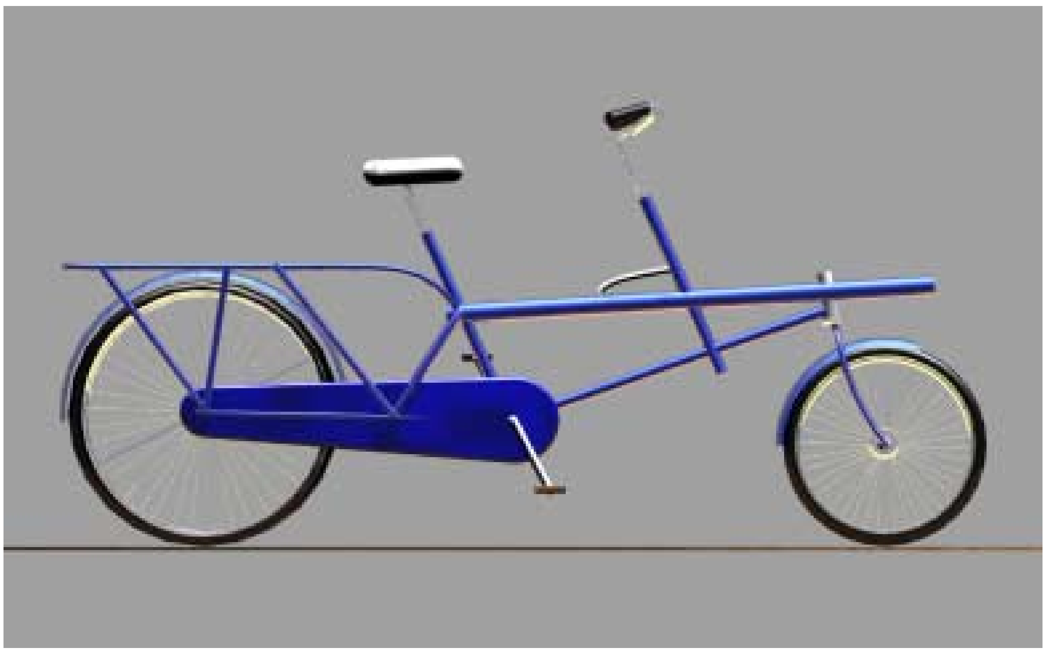


Figure 5.8, the basic construction for the concept, agreed with manufacturer 't Mannetje

The total length is 2280 mm, as *figure 5.9* shows. Length of the room on the rear side is 800 mm and on the front site is 600mm, though at the front side the room for the luggage may hold out.

Figure 5.9 the CAD model with the basis dimensions in millimeters

5.5.6 Luggage storage

So this construction can handle 80 kg on the front side. According to the requirements, the luggage should be locked away. So an open basked or box is not sufficient. There should be closed room for the takings. Figure 5.10 shows the luggage room.

Figure 5.10 the closed box for the luggage

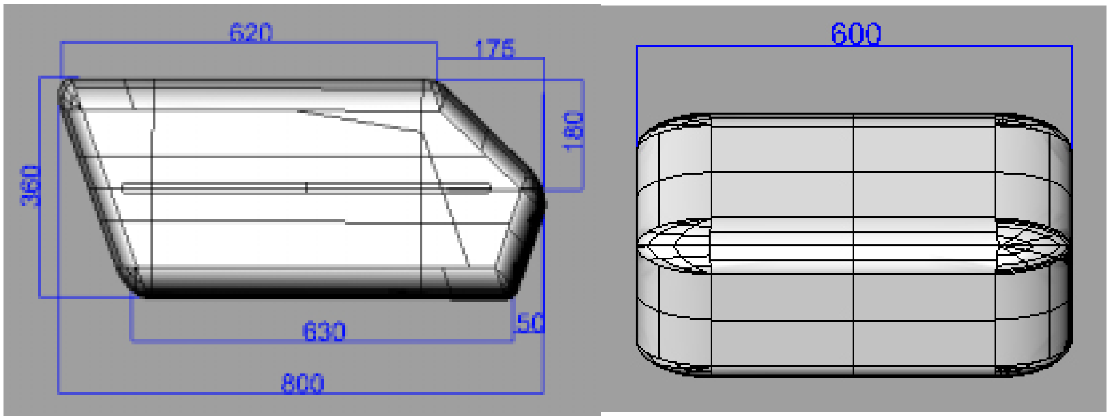


Figure 5.11, (left) the dimensions of this box from the side shown in millimeters

Figure 5.12, (right) the dimension of the with of the box shown in millimeters

The box must be high enough, to place shopping bags and other stuff with a certain height in it. But once the box becomes higher, the sight of the cyclist on the road decreases. The compromise is 350 mm (outside 360). For the length, the total room on the front side of the bicycle is used. That comes on 800 mm. In that way the box doesn't become too wide while the 136 liter volume is reached. The box may be 750 mm wide according to the CR's, but more narrow will give a better balance and more passing possibilities. The with is 600 mm. See the dimensions in the *figures 5.11* and *5.12*.

Compartments

The box is divided into two compartments. See *figure 5.13*. The function of both compartments is explained on the next page.
As requires, the room will be locked off. In that way people can leave their bicycle without being obliged to take their takings with them. So on the places where the box can be opened, a key lock will prevent the use for others. See *figure 5.14*.

Figure 5.13 the room is divided into two parts.

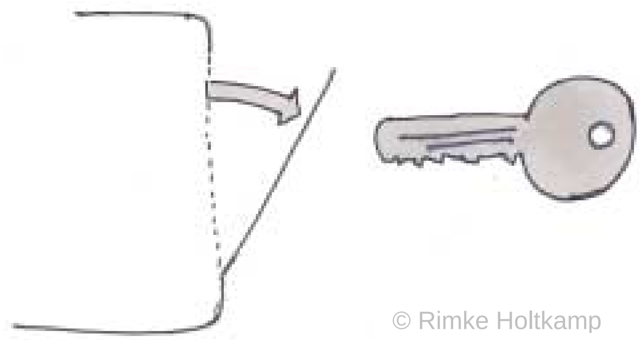


Figure 5.14 the compartments are locked away behind a key lock.

Main room

In the main luggage room, the red colored place on *figure 5.13*, the main luggage can be placed. It can be shifted in and out by opening the side. In that way people don't have to lift (heavy) stuff too high. See *figure 5.15.*

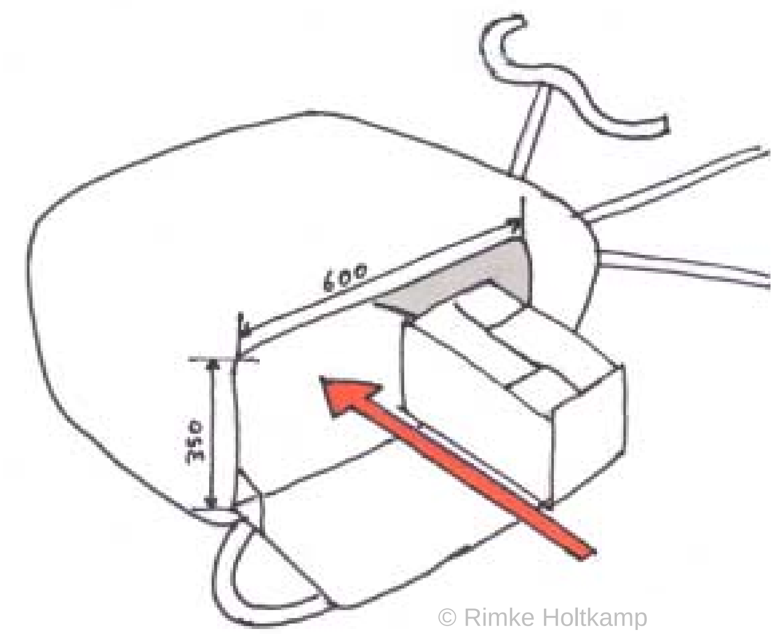


Figure 5.15 placing the takings through the side of the box

But for finding something that you need in the box, or for filling it economically, an opening at the upper side of the box is needed. See *figure 5.16*.

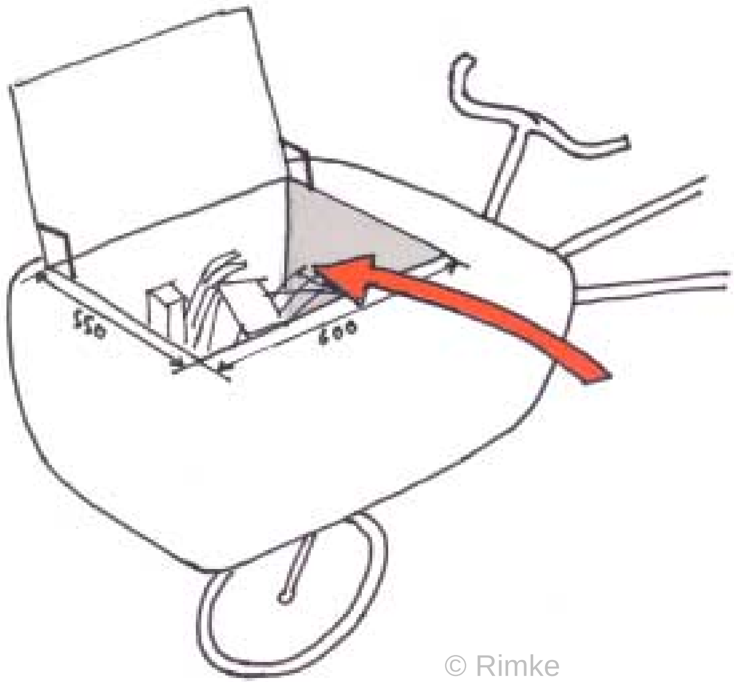


Figure 5.16 the box is also reachable trough a hatch on the top of the box.

The hand-luggage room

As *figure 5.13* shows with the blue place, there is also a smaller room. This one is right in front of the cyclists place. Here the user can place his handbag, some food for along, and other stuff. From the cycling position this room is easy to reach. *See figure 5.17.* Once closed, this area of the box can be used for a kind of table / dasboard that serves the cyclist. *See figure 5.18.* On this place a roadmap can be placed, or a holder of gsm, pda, bidon etc. On the steer, a little computer shows the speed and the achievable range of the energy storage on board.

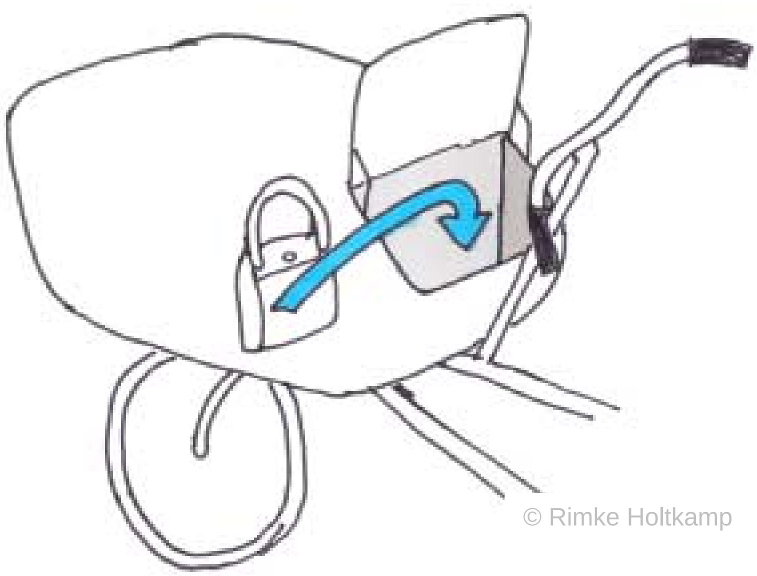


Figure 5.17 room for hand-luggage in the reach of the cyclist

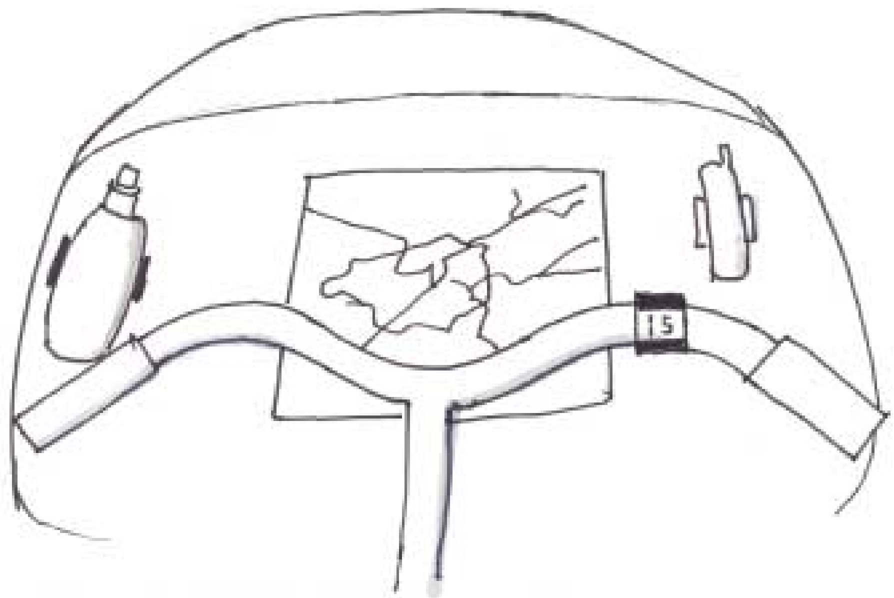


Figure 5.18 the rear side of the box serves the rider during his ride. A little computer that indicates the speed and the range that still can be reached by the energy on board

5.5.7 Room for passenger(s)

The requirements are that two little children can be taken on the bicycle, or in stead of that one passenger in a comfortable way. As seen in paragraph 5.5.5, the rear side of the bicycle is 800 millimeters long. This is enough space for the needed attributes: two child seats or one comfortable saddle. *Figure 5.19* shows how 2 child seats look on the bicycle, and figure 5.20 shows a comfortable room with a large saddle for the passenger.

Figure 5.19 the bicycle can be used with two child seats

Figure 5.20 or the bicycle is used with a large saddle for a second (adult) passenger

5.2 Mathematical Model

5.2.1 Method

For the other technical parts of this chapter a mathematical model is made. This tool helps calculating when a lot of variables are included. During the research to possible technologies for the concepts, like help engines, hydrogen fuel cell technology, solar technology, you can orderly place all new data in it, to see what the effect is on the concept what you want to reach. This saves a lot of time on calculating and recalculating, and the information remains well-organized.

I use the method that is taught by Cees van Overveld, staff member of Industrial Design. This model exists of 4 categories. See *figure 5.21.*

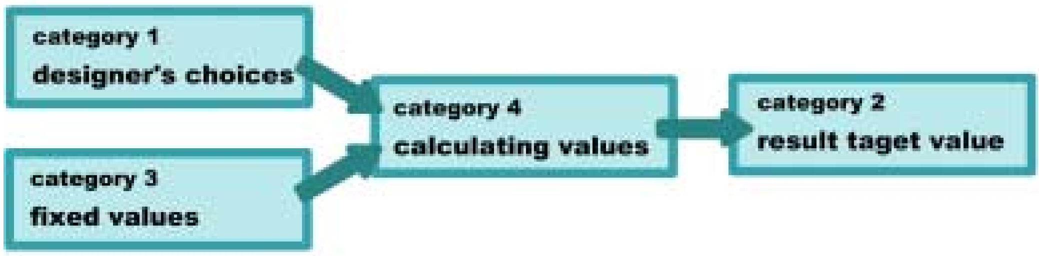


Figure 5.21 the categories of the model

Each category forms a number of rows in the excel sheet. Each row has a function and a value.

Category 1

In category 1 the designer can make choices. For example whether solar panels are used, and how much.

Category 2

Category 2 contains the values that make the stakeholder happy. When you want to optimize one value by changing the designers choices, this value can be placed in this category. But in this technology research there is not one value that should be optimized, so category two will stay empty or will be temporary filled.

Category 3

Category 3 includes the values which the designer cannot choose, but which are fixed. For example how much energy is gained by a solar panel in the month April, or how much a battery with a certain storage weights. Also constants belong to this group.

Category 4

In category 4 all the functions are placed. The values in category 1 and 3 are combined here, and the things that are from importance are calculated. For example how far you can come with a battery from a certain type and size. When you want to optimize one outcome value of this group, by changing the designers choices, you can place this one in category 2.

Use of the model

The model that I made for the concept is based on this principle. As told, the function of the model for the project is to have a calculationtool that makes it easier to consider and compare several technical situations.
By changing designing factors like the size, weight of luggage, frontal area of the bicycle or others, you see constantly what that means for the technical part of the design. For example when the bicycle of the concept becomes 10 kg heavier due to for example an better stand, a fuel tank should be larger, or an extra battery should be needed, due to that, the weight will rise again and than there's also a more powerful helping engine needed, and so on. The model calculates constantly these values that you need for the design, depending on your design choices.

5.2.2 Basis model

But before adding specifications from technologies, there should be a basis. This basis is about the bicycle itself. It is needed to bring the technological specifications in contact with the properties of a bicycle and a bicycle ride. The basis model can calculate how much power is needed for a riding bicycle, as well as during acceleration and on speed. It also calculates how much energy is needed for a certain kind of trip. The variables that are from influence on these performances, which are regulated by the designer, so the category 1 variables, are values like weight of the bicycle, the presence of a passenger or not, and the frontal area of the bicycle. To calculate the needed power and energy, you can set a trip time, with a certain amount of stops, the wished speed, the acceleration etc. See appendix C for the basis model for the bicycle. These are the sources that I made use of [59][60].

Acceleration

One part of the basis model could not be calculated with just formulas, but should be modeled itself. This is the acceleration of the bicycle. How fast the bicycle should accelerate with a certain power, how long an acceleration will last, etc. It has to be modeled in time steps: the acceleration model exists of 600 time steps. The acceleration happens during these steps. See appendix D. This model is in fact a part of the basis model, but is placed on another sheet. It constantly interacts with the basis model. The input for the acceleration model comes straight out of the sheet of the basis model, and the output of the acceleration is directly sent back to the basis model. The input values for the acceleration model are the given force, the weight, the wished speed, the frontal area of the bicycle and some constants. The output values of the acceleration model are the acceleration time and the average speed during the acceleration. So functionally the modeling of the acceleration is a part of category 4.

5.2.3 Extension of basis model

In the next paragraphs I research possibilities for technical components for the bicycle concerning the drive, energy storage and energy yield from nature. These values are put into the model to see what is appropriate for what design-choice situation. So this is an extension of the basis model.
After adding these values in the next paragraphs, the basis model + extensions looks like appendix E.

5.3 help engine and energy storage

5.3.1 Introduction

In this paragraph, the second part of the list of requirements is central. Namely the requirements CR 5 – CR 6, under the header “help engine”. The possibility for a help engine will be researched in the next part of this paragraph, 5.3.2, and the range of 50 km, which is acquired by CR6, will be handled in paragraph 5.5.3.

5.3.3 Electric engines

A patrol or diesel combustion engine is not clean enough for this project, according to the first normative goal: minimize harmful gas emissions. But also N4, minimize sound emission, recommends that a combustion engine should be appropriate, for combustion engines create noise. An electric engine is silence, and produces no emission gasses. Also the energy efficiency of an electric engine is higher: 75-85%, while a combustion engine an efficiency has of 20 – 30 %.

N1 minimize harmful gas emissions
N4 minimize sound emission

There is a lot of choice concerning electric engines. The last years, also electric engines in bicycle wheels have been developed. *Figure 4.22* is a picture of the Sparta Ion, an electric bicycle, which makes use of an electric engine inside the wheel. An inwheel engine doesn’t need a lot of room and it saves energy loss because there is almost no transmission. I tested this one. It performs comfortable: the extra force is given smoothly, besides the lighter pedaling you don’t feel that there is an engine involved. I also checked whether you have resistance from the engine on the moments that you don’t use the help engine. But I didn’t recognize any resistance at all, compared to a bicycle without engine. But that is just by my own feeling.

There is a manufacturer, Heinzmann, who produces in wheel engines for bicycles from a lot of sorts. [28] *‘t Mannetje,* in Haarlem*,* Netherlands, uses engines from this manufacturer, and they are very satisfied with them.
For each wheel size another engine is needed. The size of the Heinzmann wheels with engine varies between 16” to 28”.
The engines are also in different power levels available. The usable types are the
200 W (400 W peak)
250 W (400 W peak)
500 W (750 W peak)
900 W (2 kW peak)
I have put these data in the mathematical model. Depending on the power needed from the help engine, the model indicates which type is most appropriate. The strongest version will be the most appropriate. In that case a heavy loaded bicycle can even compensate hills up to 12,5 % increase.
For each type there are more speed versions. These differ concerning the relation speed and torque. The speed version has to be chosen depending on the wished cruise speed until where

Figure 5.22 Inwheel engine in Sparta Ion

the help engine has to operate. *Figure 5.23* shows how the engine will be placed on the bicycle.

Figure 5.23 the electric help engine in the rear wheel of the concept bicycle.

5.3.3 Range 50 km

In this part the possibility for feeding the electric engine for at least 50 km without any refueling is going to be researched.
For feeding an electric engine, batteries are appropriate, although they are not perfect for the environment. As told in paragraph 2.4.2, batteries contain metals that are harmful.

N6 minimize use of harmful materials

But in the last years there is also a development of hydrogen fuel cells. In this paragraph I research whether it is really an option to replace the batteries with fuel cells, concerning the weight and the volume of the packs that will be needed. 5.3.3.1 Shows the possibilities with batteries and than in paragraph 5.3.3.2 it is going to be researched whether fuel cells in combination with the electric engine are a realistic alternative.

5.3.3.1 Batteries

Lead acid

Using an electric engine, batteries are the most standard solution for the transport of the needed energy. This combination is already used in some carrier bicycles and tricycles, and

in bicycles with help engine. I have to know the specifications of the regular used batteries before comparing it with newer technologies.
The batteries which *'t mannetje* uses in the carrier tricycles and bicycles with help engine, are lead-acid batteries. Those are gel battery versions, which are maintenance free and don't have to be kept with the underside below. For the project it is important what the capacity of the batteries is in relation with their size and weight. This to consider the lightest and less place taken equipment for on board. They make use of two types:
Type one: 12 Ah, 150 * 95 * 95 mm, 5 kg, 24 V
Type two: 20 Ah, 180 * 180* 75 mm, 9 kg, 24 V
This means that using this sort of batteries, every mJ of energy that has to be stored, needs 1,4 L volume and will add 5,3 kg to the weight of the bicycle.

Newer batteries

But there are new developments concerning batteries. For example, Sparta uses mickel-metal-hydride batteries for their electric bicycle. For each mJ of energy, you should need a volume of 1,3 L and 4,8 kg of batteries. After more internet research, I conclude that the lithium ion battery is the best type. For 1 MJ of energy, 0,95 L volume is needed, with a weight of 1,6 kg. I calculated this on basis of specifications from the site of a company that sells them. [29] This seems the best battery, so I use this one in the model.

From the model I conclude that the new lithium ion batteries can provide enough energy without becoming extraordinary large and heavy. In one of the worst situations for the bicycle, like a high weight of the bicycle and the luggage, lot's of traffic lights, minimal pedal power of the driver or something else, even for driving 50 km you just need a battery from 1,15 kg which takes a volume of 0,65 L.

5.3.3.2 Combination of fuel cells, hydrogen storage tank and electric engine

How does it work

The battery part can be replaced by one or more hydrogen cells and a hydrogen tank. The energy is stored in the hydrogen gas: hydrogen and oxide in a critical proportion. This situation is created by splitting water. This reaction costs electric energy, the same energy that comes free by using the hydrogen gas later on in a fuel cell: the fuel cell converts the chemical energy back into electric energy. So hydrogen gas is the transporter of energy, and a fuel cell is needed to get the energy out of it.
A fuel cell has a maximum power. So the needed power of the bicycle defines the size or the amount of fuel cells needed. And as a matter of course, the size of the hydrogen tank is prescribed by the need of energy that has to be stored. For calculating how much room fuel cells will need and how heavy they will be, the model needs to know the values that are important for the fuel cells and the hydrogen tank.

Specifications

There are several manufacturers of fuel cells. The Power-X fuel cells of Anuvu Fuel Cell Products [30], have, in comparison to other fuel cell types that are described on the internet, a relative high power in comparison to their weight and size. These values are for this type 213 W normal power and 319 W peak power for each liter of fuel cells, and respectively 147 and 221 W per kilogram.
After inserting this in the model, and setting the model on a heavy situation for the bicycle concerning weight of load, cyclist and passenger, a fuel pack of one and a halve liter with a weight of 2 kg is needed.

Hydrogen fuel tanks

To calculate the amount of hydrogen gas that is needed on board, I considered the molar mass of hydrogen gas, the potential energy per mol hydrogen [31] and the efficiency of fuel cells. [31] The conclusion of the calculation is that for each kg of hydrogen gas, 13MJ electric energy comes free.
After further calculation, this means that under normal pressure, 1 liter hydrogen gas contains 11 kJ of energy. But gas tanks can contain gas on certain pressure, which means that more fuel can be stored in the same volume. According to the company TeleflexGFI in Gorichum [32], it practically possible to store hydrogen under a pressure of 350 BAR in a save way. This means that one liter on this pressure provides 3,7 MJ of electric energy.
According to the calculation of the model, this means that just 50 gram of Hydrogen fuel gas is needed On a heavy trip of 50 km with the bicycle. This takes a romm of 0,2 Liter. The combination of fuel cells and hydrogen tanks will weight 2,1 kg and take 1,8 liter. But for this calculation, the wall of the fuel tank and some other needed components are not considered yet. On this moment I assume that this has a weight of approximately 1 kg and a volume of 0,5 L. This leads to a package of 3.1 kg with a size of 2.3 L.

Refueling

There do already exist several hydrogen fuel stations around the world. Under more in Amsterdam, Chino (US), Sweden en Berlin. There are two opportunities: tanking the hydrogen fuel liquid or tanking it under high pressure. Both techniques exist. Tanking in the second way, under pressure. is quite normal: it looks a bit like tanking LPG, see *figure 2.24* [58][59][60]

Figure 2.24 the way of refuelling lpg is an example of how hydrogen can be refueled

The refueling of the hydrogen storage can happen inside the home of the user or in the infrastructure, depending on the place where the energy for the bicycle is yield. At home, it can happen in the shed or entrance when there is no shed, by means of connecting the hydrogen gas, which is won at home, with the bicycle. *See figure 5.25*

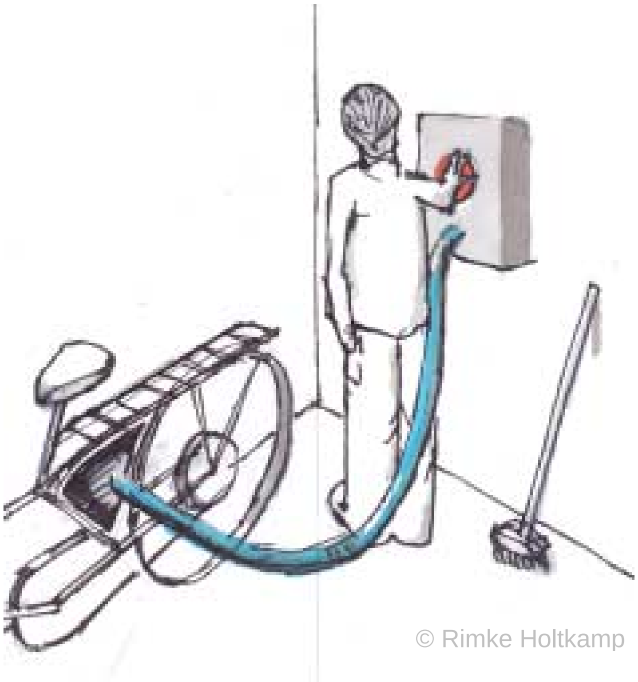


Figure 5.25 refueling at home

When the energy is yield in the environment of the bicycle, refueling will happen on public places. The energy in the form of hydrogen gas will be gained on the places where the users can refuel their bicycle. *Figure 5.26* shows an example of how this is might look.

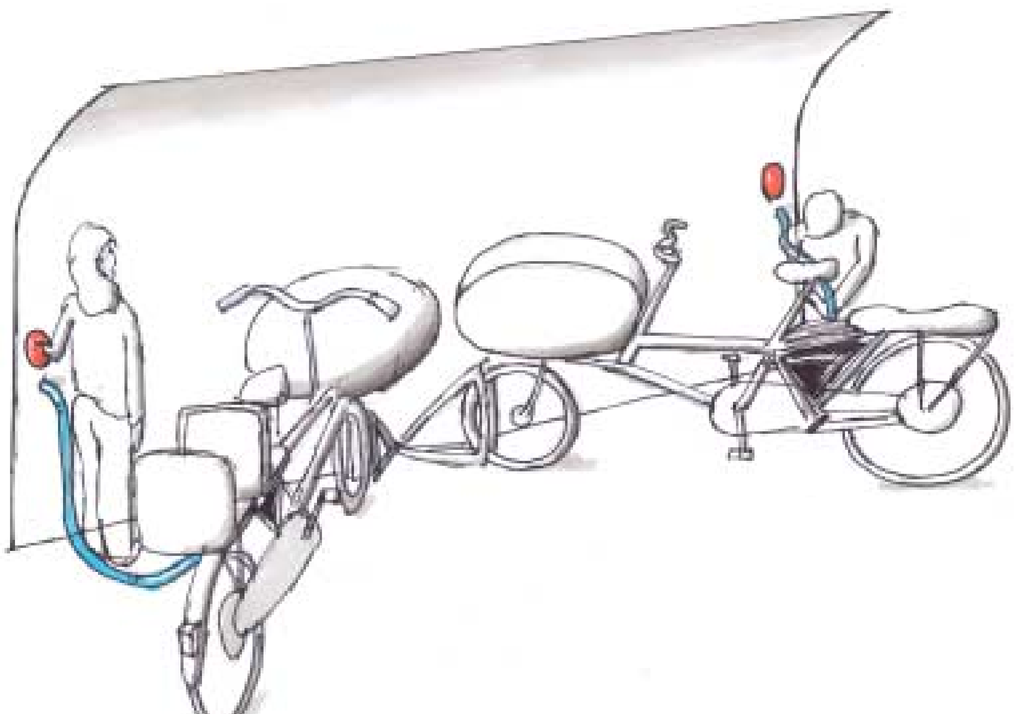


Figure 5.26 refueling on public spaces

comparing battery with fuel cells

The question was in how far fuel cell technology an option is for the concept, compared to batteries.
Although batteries are lighter and smaller, hydrogen is certainly possible. I expect that in the future, fuel cells will become lighter and smaller, but the battery technique development also shouldn't stand still. I can conclude that fuel cells are a serious option for the concept.

The only disadvantage that we still have for the fuel cell option is that when the energy for the help engine is being yield on the bicycle itself, the conversion of the electrical energy into the potential energy of the hydrogen gas, the process which is called electrolyze, should occur in the bicycle itself. The equipment for that must have almost the size of the fuel cell, which means that the package becomes larger. In that case batteries will be better, until the moment that fuel cells exist much smaller.

In *figure 5.27* it is shown where the package of the fuel cell + storage or the battery, including some other needed components, can be placed inside the bicycle. Here is room enough for the needed components, either full cell technology or just batteries. On the box there is a little tube. This is the connection for eventual hydrogen refueling. As explained above, it will work on the same principle as refueling LPG.

Figure 5.27 place in the concept bicycle for energy storage and controlling

5.4 Nature energy

In this paragraph I consider the use of solar cells and wind turbines for gaining nature energy for the helping engine of the concept bicycle. Several technical opportunities and promising technologies are compared.

5.4.1 Solar panels

By day, the sun hits the earth surface with approximately 1 kW of light radiation power per square meter. (Of course the exact value depends also on the place, weather, time etc). [33] Already a long time, a method is used for the process of gaining electrical energy out of this radiation energy. In 5.4.1.1 the pro's and con's of this system are shown. Then, in the next part, a new rising technology is viewed. In 5.4.1.3, the appropriateness of these systems for the concept is researched.

5.4.1.1 Original solar panels

Figure 5.28 solar panels

By using photovoltaic (PV) panels, it is possible to convert approximately 25% of the light radiation energy into electric energy. [34]
For this process, PV panels are needed. They are displayed in *figure 5.28*. They exist of PV cells. These cells are made of 2 slices of silicon. The upper slice does also contain phosphorous, and the other boron. The slices create an electric field. An electric current appears when the photon parts of the sunlight hits the surface of the cell. [33]
According to the company Beldezon, the price of a PV panel is approximately 800 euro per square meter, including several needed components. Each square meter will provide 100 kWh each year. They also say that the panels don't need a routine maintenance; just the surface has to be kept clean. [35] [36] [37]
Solar panels have an approximate thickness of 35 mm. The weight of a panel is about 13 kg per square meter. When a panel has to be large, the thickness and weight will increase due to the need for strengthening. [65]

5.4.1.2 Nanosolar technology

As told above, the traditional solar cells make use of silicon as semiconductor. Silicon causes the problem of high costs and inflexibility. There is a new technology which is not based on silicon any more. [63]
The companies Nanosolar, Konarka and Nanosys are working separately from each other on a new technology for gaining solar energy. The new type is made by use of nanotechnology materials which should be printed on a thin metal foil. See figure 5.29. This foil is flexible.

Nanosolar expects that the price is going to be 5 to 6 times lower than the price of the solar cells of today. [63]
The photovoltaic layers will be just 3 three micrometers thick. In stead of silicon, the semiconductor exists of CIGS: a compound of cupper, indium, gallium and selenium. The yield will be around 10 to 15 percent, against 25 of the traditional solar cells. [64]

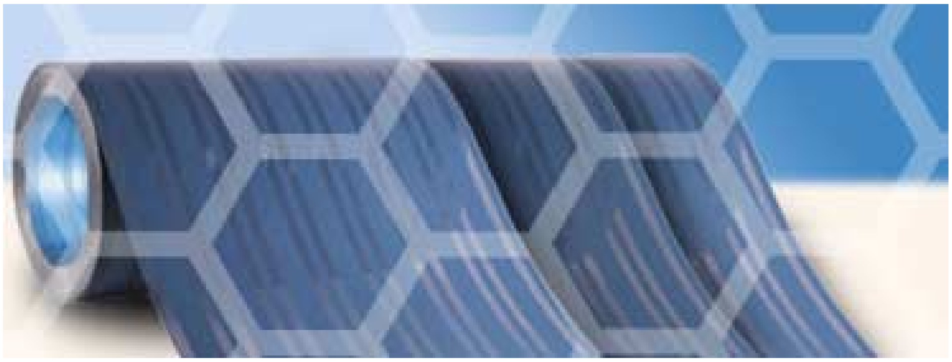


Figure 5.29, Nanosolar foil

5.4.1.3 Use for concept

Seasons
A big disadvantage of solar energy for this concept is the bad spreading of the energy yield over the year. This is visible in the chart of figure 5.30. This chart is made with information of a user of solar panels who tested the yield during the year 2004 [65]. The yield varies between one and 14 kWh per month. The concept want to stimulate riding a bicycle all over the year, so there must always be enough energy. After putting the data in the mathematical model, the conclusion can be drawn that for one bicycle trip of 50 km, the number of square meters of solar panels should vary between 4,6 in the worse month in the winter and 0,3 in the best month.
There is no information yet about the monthly yield of nanosolar, it is plausible that the proportions will be about the same. But since the yield of the nano-technology will be twice as low as yield of the original solar panels, in each month the yield will be about the half of those of the normal solar panels.

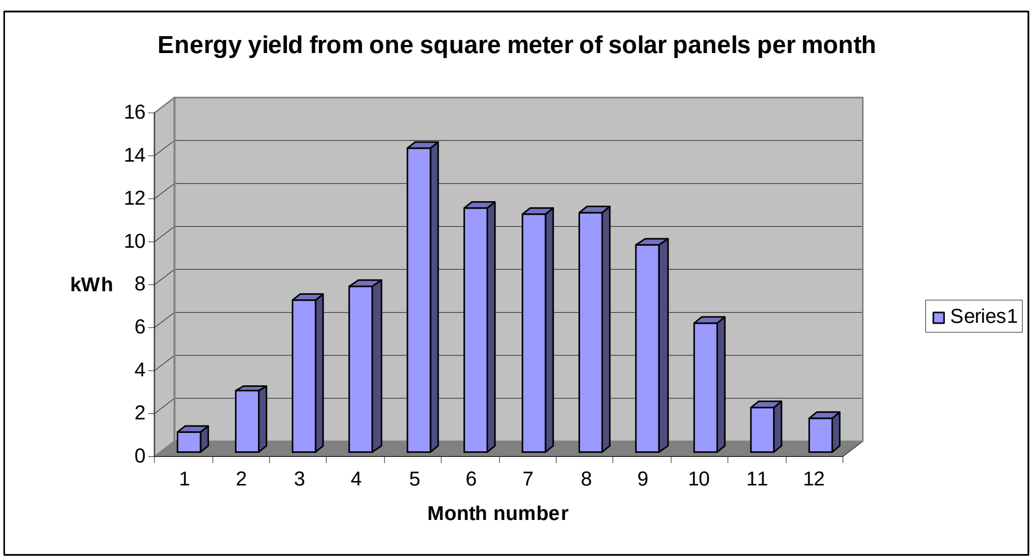


Figure 5.30 the energy yield of solar panels varies a lot during the year, this is an example of 2004

On the bicycle and in the bicycles environment
In the concept, solar panels could be used on the bicycle itself, but also in his environment. See the *figures 5.31 and 5.32*. The first image shows a solar panel on the bicycle itself and the second one solar panels on special bicycle windbreaks outside the city. Those windbreaks are proposed since some years to stimulate interregional cycling. They don't exist yet, but there is a change that they will come in the future. Putting them on the roof of the bicycles' home is also possible for gaining the energy outside the bicycle.

For the first option, solar panels on the bicycle itself, 0,45 square meter on the luggage box is needed for being covered by solar panels. But only in the sunny months this will deliver enough energy for a trip: just 5 months a year the bicycle can be used with the 50 km trip. During another 3 months, the bicycle will have a range of at least 30 km. Enlarging the room for solar panels on the bicycle doesn't help enough: even when 1 square meter can be placed, there are still 4 moths in which the range is lower than 50 km, from which 3 months with a range of under the 30 km.
Another disadvantage for the concept is that the bicycle should always be placed outside for catching the sunlight by day.
It should also be considered that during the measurements, where the used data for *figure 5.30* come from, were done, the solar panels were placed in a certain angle to the sun. This is not reached on the bicycle, so the yield will be lower probably.

For the external solar energy possibility, like for example on the wind breaks (*figure 31),* 4,6 square meters of solar panels should be needed to let one bicycle refuel once a day, in the worst time of the year. This is very expensive.
For the solar panels of the nanosolar technology, about twice the surface is going to be needed. That seems even less appropriate, but viewing the fact that these cells are very thin and flexible, they can be used on much more places in the environment of the bicycle, and they are promised to be become cheaper than the normal cells.

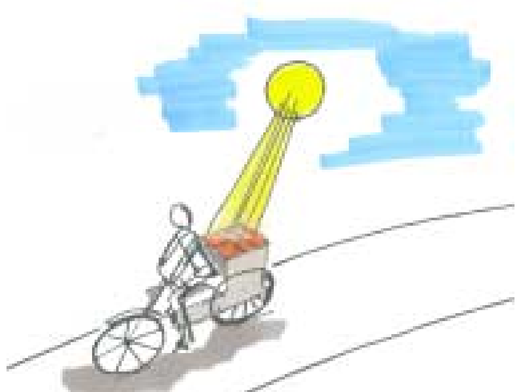


Figure 5.31, solar panel on the bicycle, no refueling needed. (Here the shape of the bicycle is not yet what it became.)

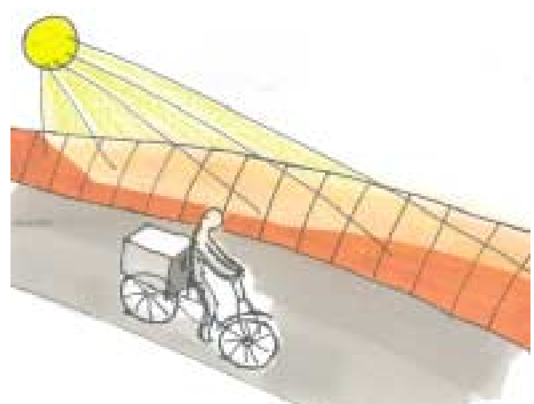


Figure 5.32, solar panel on the on windbreaks for bicycle tracks, which may exist in the Future. (Here the shape of the bicycle is not yet what it became.)

5.4.2 Wind energy

5.4.2.1 Introduction

Focus on small wind turbines

Figure 5.33 a normal wind turbine

Wind energy is also a form of nature energy. It is already used on a large scale, won by the well-known wind turbine. See *figure 5.33*. The use of wind turbines is subsidized by the Dutch governments. One wind turbine delivers enough energy to deliver almost every second a new trip (50 km) for the concept bicycle, calculated on basis of information from *Deltawind* [56]
But the purchase costs are very high, as well as the costs for maintenance. The wind turbines also make quite a noise. This is against N4. Regarding N4, minimize sound emission, an eventually used wind turbine for the concept should be silence. Otherwise there will be a noise added to our environment, 24 hours each day.
Another important point is that all the energy is created at one place. And that is a disadvantage when using this in the project. That is important for the project because energy should be won near the place where it will be used. If all bicycles in a city were feed by for example one source, a lot of energy transport would be needed. The disadvantages of that are explained below.
But next to the large wind turbines, there are also other possibilities in progress. So the focus will be on smaller wind turbines.

N4 minimize sound emission

Disadvantages of energy transport

Energy transport costs energy. Namely in the case of transporting energy in the form of electrical energy, energy lost will occur in the high voltage cables and in the transformers. Also when the energy is transformed in hydrogen form: there has to be a pressure, there is always wearing. So while transporting energy, there will always be a lost. This energy loss causes unneeded *material waste*, when talking about wind energy. For more turbines are needed, to compensate the energy loss.
But also the high voltage cables and transformers costs materials. Or hydrogen pipes and compressors in the case of hydrogen fuel.

N6 minimize use of harmful materials

Next to material waste, in the case of transporting energy in the form of electrical energy, also electromagnetic radiation is will be emitted. While that also has to be minimized, see N7: minimize electromagnetic radiation.

N7 minimize electromagnetic radiation

5.4.2.2 Different technologies compared

I have researched the possibilities for small wind turbines. In this paragraph, three small wind turbines with difference technologies are introduced and compared. They are all silence. An important factor is the energy yield in relation to the amount of raw material that is needed. The large wind turbine that we use now mostly, delivers per 1 kg metal, about 18 kWh each year. For each technology this value will be calculated. [56]

Small wind turbine

There exist small wind turbines based on the same working as the regular wind turbine. For example the Tulipo, from Tulipower, see *figure 5.34*.
It is a silence little brother of the regular one. This type is 15 meter high and weights 860 kg. The diameter of the blades is 5 meter. The yield is 5MWh each year. This means that the average energy that is generated each day is about 50 MJ. This is 50 times as much as one square meter with solar panels. That results to 100 times of refilling the concept bicycle. When you calculate the energy yield / material ratio, you come on about 6 kWh/year for each kilogram of needed raw-material, while this was 18 for the normal one. So the same construction as the regular wind turbine but than for a smaller type, costs a lot of yield.

Figure 5.34 Tulipo wind turbines

Small wind turbines with vertical axis

The Technical University of Delft, Netherlands, started a project about wind turbines that are small and that can use winds that come from all directions, the Darreius. *See figure 5.35*. This ended in the Turby, produced by Turby BV in Lochem, Netherlands. [38] See *figure 5.36*. This wind turbine is two and a half meter high and weights 200 kg. The producer indicates that the turbine will provide 5000 kWh each year. That is the same yield as the previous one, mentioned above. While the Turby is much lighter and smaller. The energy yield / material ratio from this one is with 25 kWh per year, for each kilogram material, higher than the 18 of the regular wind turbine and the 6 of the regular wind turbine in small. This one also can deliver during a day the energy for 100 times a heavy 50 km trip with the concept bicycle.

Figure 5.35 the Darreius wind turbine)

Figure 5.36, the Turby

Small wind turbines with horizontal axis

Aerolift Patent BV, in Beek en Donk, Netherlands, is working on a small wind turbine with long horizontale axis. It is called the Venturi Wind Turbine. See *figure 5.37*. The axis is 110 cm wide. According to the producer, this wind turbine will provide 500 kWh each year. Here the energy / material ratio comes out on 20 kWh each year per kg material, near the 25 of the turby and above the regular technology with propeller blades.

Figure 5.37 the Venturi wind turbine

5.4.2.3 Usage for concept

So the Turby and the Venturi are the most appropriate types. They can for example be placed on the roof of high buildings in the cities, see *figure 5.38*. The gained energy (either electrical al hydrogen) will be lead to leading points for the bicycles.

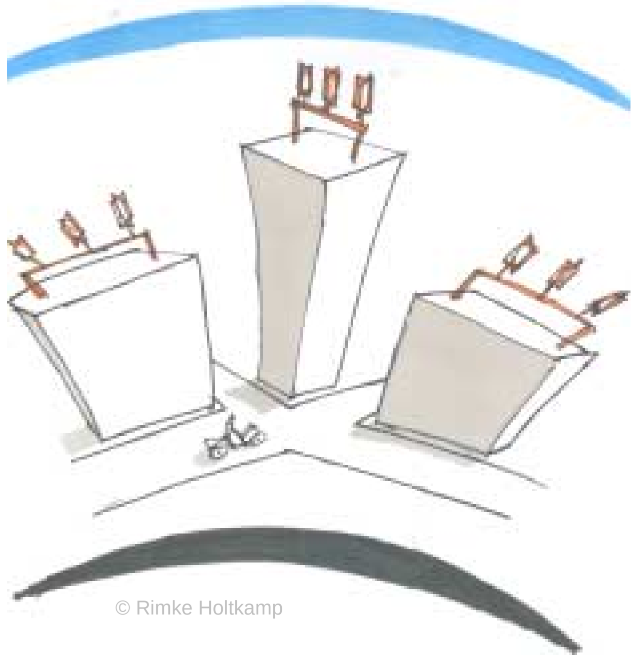


Figure 5.38, small wind turbines on the roofs of high buildings

Smaller design

But if a smaller design was possible, it could be placed even more close to the energy user, the bicycle itself. But at this moment, the Turby and Venturi don't exist yet in a smaller size, although Aerolift Patent BV, the producer of the Venturi, is planning to design a smaller version.
I've contacted the expert who has worked on several projects concerning the Darreius and the Turby at the TU Delft, Sander Mertens, to get an assumption of what the yield of the Turby will be when it is scaled down. He confirms that I can use the next formula: when the scale decreases with factor x, the yield will decrease with factor x^3. This means for example that as a Turby has to provide the energy for one heavy 50 km trip for the concept bicycle, so 100 times less than the normal Turby, it must have the size of 54 cm high and 43 cm wide, while the normal Turby is 2,5 meter high and 2 meter wide.
Applying this formula to the venture, the size of the wind turbine for one trip each day will be 51 cm in all direction.

So a wind turbine with approximately half a meter is height, width and depth should be able to create enough energy for refilling the bicycle for a new trip.

The wind turbines on places like *figure 5.39. 5.40 and 5.41* are showing, have the yield of one heavy bicycle ride each day.
They can be placed for example in the traffic infrastructure - on street lights, traffic lights, see *figure 5.39* - or on the future's windbreak next to the bicycle tracks outside the cities, see *figure 5.40*. It is also possible to place them on the roof of the bicycle owners' home, or on the balcony of a flat apartment. See *figure 5.41.*

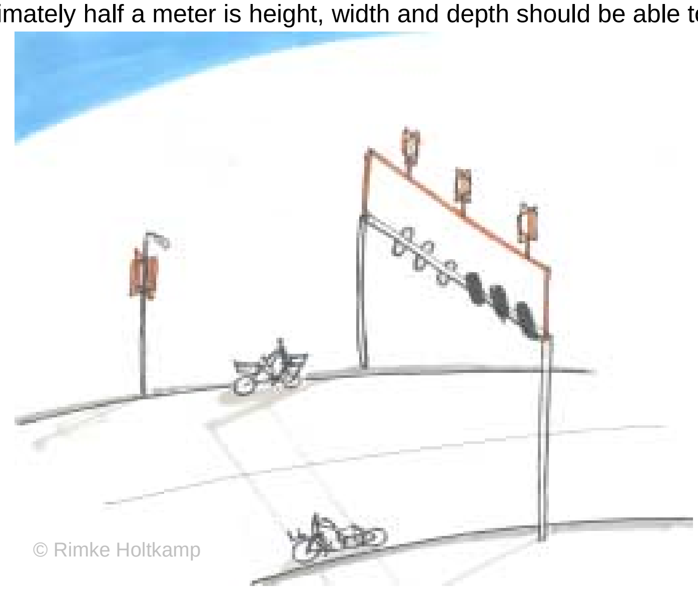


Figure 5.39, little wind turbines in the traffic environment

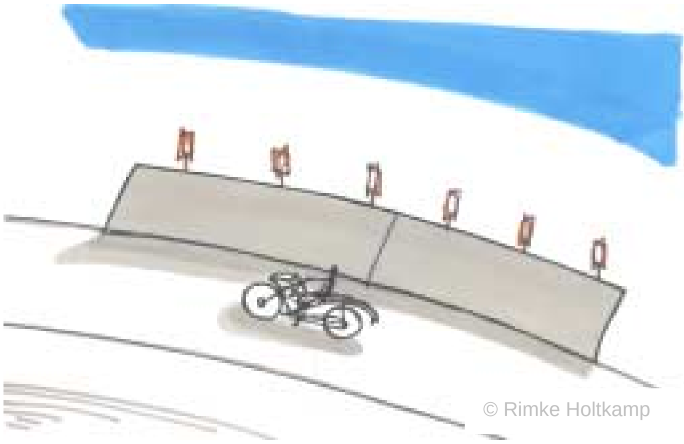


Figure 5.40, little wind turbines on the on windbreaks that may exist in the future. (Here the shape of the bicycle is not yet the official one.)

Figure 5.41, a small wind turbine on the user's house

Chapter 6

Implementation

6.1 Introduction

	behavior help engine
CR9	without pedaling no driving help
CR10	speed controlled by the stepping power
CR11	help engine compensate all extra force needed for luggage, extra passenger(s), hills, head winds etc + 30 % of force needed on normal bicycle
CR12	Driving help applied until 24 km/h, if bicycler wants faster, he/she has to reach

According to CR9 – CR12, a certain behavior of the help engine is required. In this chapter it will be shown how this is realizable.
A necessary element for the concept will be a control unit. It has to regulate constantly the added power of the help engine. It will be the link between on the one hand the speed and the force that the cyclist gives, and on the other hand the added power from the engine.
As far as a research concludes, such a unit doesn't exist yet. In paragraph 6.2 the wished behavior of the help engine is explained further. In paragraph 6.3 the formula is found to realize this behavior. In the last paragraph, a simulation about the help engine behavior is made by means of software on the pc and by means of a little system that doesn't need a pc for making the calculation.

6.2 behavior of the electric help engine

6.3.1 The help engine behavior 0 < V < 24 km/h

Firstly the control unit has to make sure that just 70% of the force will be needed to ride on the bicycle. This 30% reduce is for stimulating the further rides.
This is shown in *figure 6.1.* The total power what's needed to ride on a certain speed is divided into pedal power and help engine power, with a relation of 7:3.

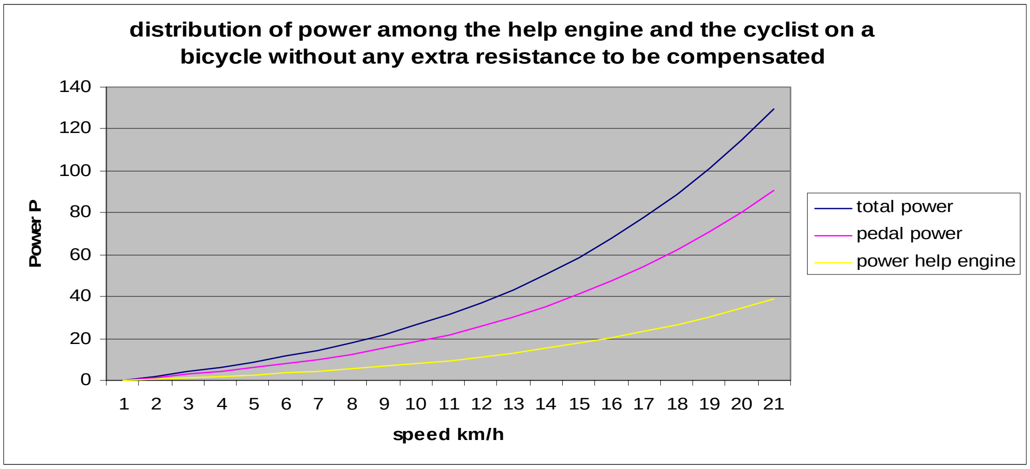


Figure 6.1, *how the needed force will be divided over the help engine and the cyclist without extra resistance to be compensated*

Than the help engine should reduce everything that makes it heavier to ride on the bicycle. Those are extra weight from luggage and/or passenger(s), hills, head wind. In a way that that users of the concept bicycle finally always need to give 70% of the power that they should need to ride on a normal bicycle in normal circumstances. This is illustrated in *figure 6.2.* The blue curve, indicating the total power needed, lays higher than in the previous chart. The pedal power remains the same, so the power of the help engine rises to fill the gap that is created.

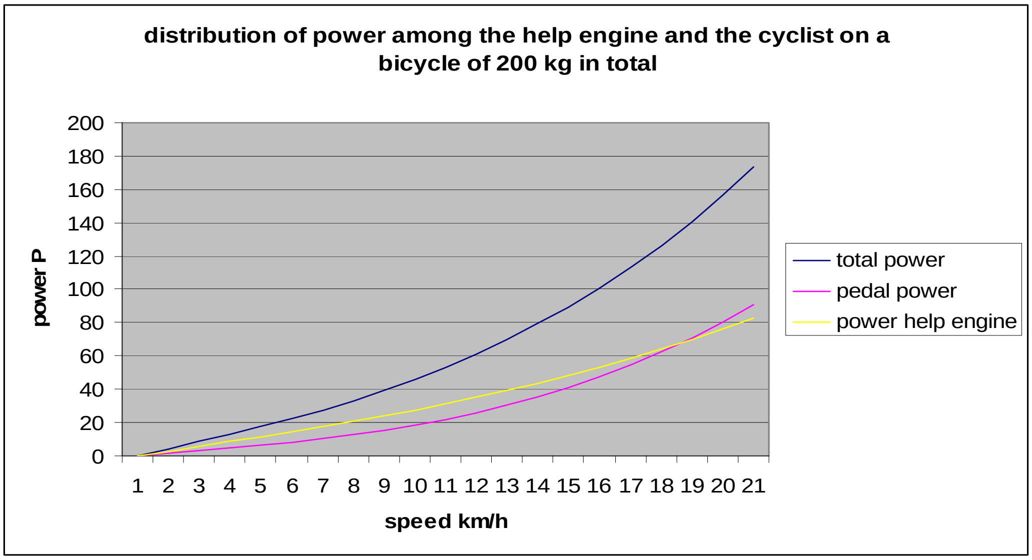


Figure 6.2 how the needed force will be divided over the help engine and the cyclist with extra resistance to be compensated: total mass of bicycle is 200 kg

6.3.2 The help engine behavior >= 24 km/h

But that is not all. The help engine helps until a certain speed, 24 km/h.
When the cyclist wants to ride faster, he gives more force. The control system has to remark this and react on this, by reducing its power. The effect has to be that the bicycle won't drive faster. Just at the moment that the rider adds more force than the help engine should add on this speed, the cyclist can drive faster. On that moment the help engine doesn't do anything, so the higher speed is reached by the cyclists own power. When the cyclist is slowing down, the engine has to work again under the limit of 24 km/h. the chart of *figure 6.3* shows how the power dividing will be in this case. After 24 km/h, the help engine power is zero and the pedal power is the same as the total power that is needed, for the cyclist has to do this by his own power.

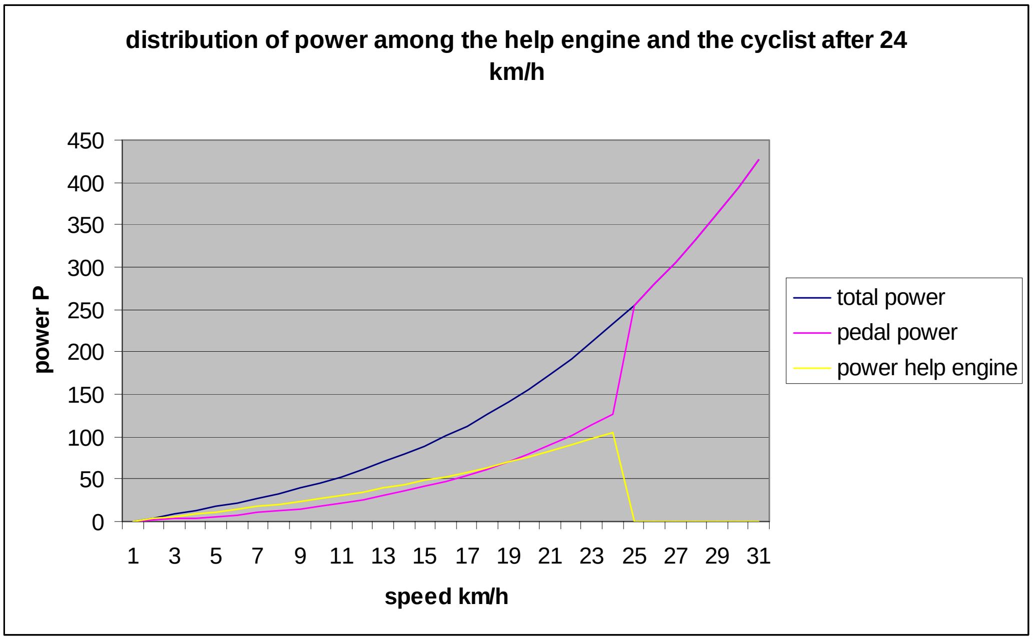


Figure 6.3, how the needed force will be divided among the help engine and the cyclist on speeds over 24 km/h

6.3 The method

So a certain unit is needed to control this behavior. This unit has to know at least constantly the speed of the bicycle and the stepping force given by the rider. The output has to be information about how much power the help engine has to give. 2 possible options are considered to calculate constantly the needed help power.

6.3.1 Option 1

According to option 1, all the information which is needed to calculate the needed extra power is given. These are fixed values and variable values. The fixed values are air resistance coefficient, roll resistance coefficient, and other constants. Those can simply be preprogrammed. When the help engine should really compensate everything that works against during a ride, the variable values are not only the speed and the force form the cyclist, but also the weight of the loaded bicycle, the accent of the road and the head / front wind. *See figure 6.4.*

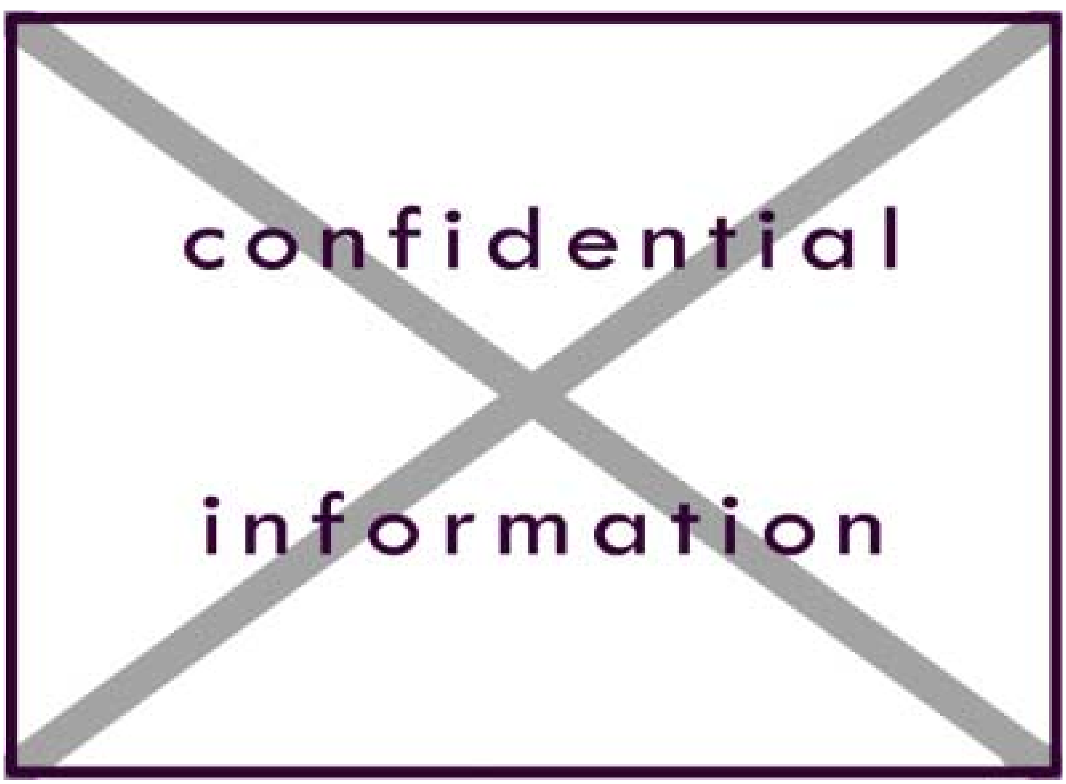
Figure 6.4 the function of the control unit according to option 1

It is very hard to measure all these values constantly, so an easier solution is going to be found.

6.3.2 Option 2

6.3.3 The function

This is the functions for controlling the power for the help engine:

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6.4 Simulations

Simulation on pc

First a simulation on the computer is made to show the working of the formulas created in the previous phase. This simulation has also been useful for optimizing the method.
The simulation is made in Java. The ride of a bicycle is simulated, in which you can set and reset the values of pedal force, weight and hill. Meanwhile the effect on the power of the help engine and the effect on the speed is visible. *Figure 6.6* shows how the simulation looks.
With use of this simulation a more flowing behavior of the help engine is created. This is done by adding more steps to the steps that are explained in paragraph 6.3.3. Appendix G shows the part of the code with the formulas and variables for the simulation.

Figure 6.6 simulation of the control in java

Simulation on controller

Another output is a simulation on a controller.
First this is tried on the PIC16F877 microcontroller, see *figure 6.7*. But that didn't work out: the used programming language for this type is not appropriate for making calculations with floating points, times and quotients.
On the Lego Mindstorm RCX, see *figure 6.8*, these problems do not exist. With this one a simulation is created which shows the working of the control unit without the use of a pc. The pc is just used needed to upload the program.

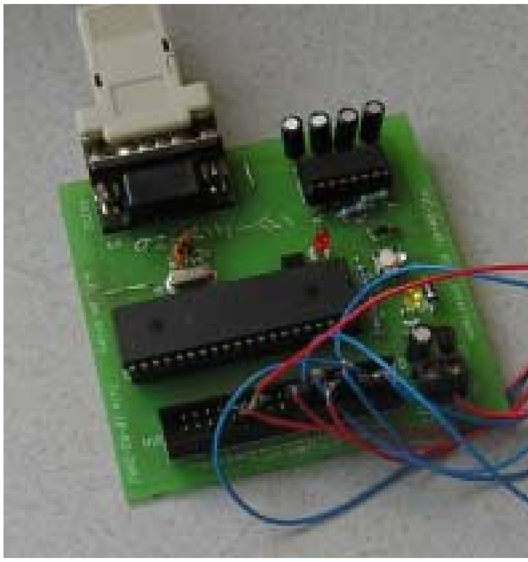


Figure 6.7 the microcontroller *figure 6.8 the Lego Mindstorm controller*

Figure 6.9 simulation of the help engine power control without the use of a pc

Figure 6.9 shows how the simulation on the Lego Mindstorm controller looks. You can simulate a ride on the bicycle with it. In the left unit, you can regulate the force that the cyclist gives. On the same unit you can change the hill. On the right unit a display shows your speed and the power that the help engines provides.

Chapter 7

Final concept

7.1 Introduction

At this stage all the aspects of the concept are researched. Some of these aspects are already fixed, and about some aspects there are more possibilities. In this chapter, the best combination from these possibilities is will be made.
In paragraph 7.2 the choices which are still open and the fixed ones are explained. In 7.3 two combinations are chosen, which form concept A and concept B. In the last paragraph, visualizations of the concepts are shown.

7.2 Conclusion of technique research for concept

First the conclusions of the several technical aspects for the concept are are mentioned. The list of requirement is the guideline.

	extra room
CR1	has to be able to carry at least the contents of one shopping trolley (120 L; 75 kg)
CR2	room for one adult passenger or 2 child passengers
CR3	may be max 75 cm wide
CR4	possibility to lock the luggage room

For the room what is needed on the bicycle according to the concept requirement, a solution is found. There is no structural choice here any more, so this part is fixed.

	help engine
CR5	helping engine supports driving
CR6	range 50km

For the help engine the choice is also obvious: an electrical engine in the wheel. So CR5 is also fixed.
The range of 50 km can be assured by either batteries or fuel cells. Fuel cells are better for the environment than batteries, but they still need a little development. Fuel cells are quicker to charge; batteries have a slow charge or have to be changed in its entirety. This last option is contrary to CR8, because the energy circuit will be open then. So here a choice is still open, see the third row of *figure 7.1*.

	nature energy
CR7	used energy won from nature sources
CR8	closed circuit between energy provider and bicycle

Here the choice is also still open. It is between the use of solar panels, solar cells on foil, and small wild turbines. Solar energy yield differs a lot during the year, which means a big disadvantage. Solar panels do already exist, nanosolar, the solar cells on foil, is still in progress. Regarding to solar panels, nanosolar does almost weight nothing, is cheaper and is appropriate on more places due to his flexibility, but the yield is the half of normal solar panels. Wind turbines on the scale in which they can feed one trip each day are also still in progress. The yield of wind energy is spread all over the year.
These technologies can be used on several places. The general aim is to create the energy as near as the place where it will be used. So the first possibility is on the bicycle itself. For solar energy that means that the bicycle has to stand in the daylight the whole day, and wind turbines don't work on a bicycle. Other places for these technologies are at the home of the user or in the traffic environment.
The choices from this part are shown in row 4 and 5 *of figure 7.1*.

	behavior help engine
CR9	without pedaling no driving help
CR10	speed controlled by the stepping power
CR11	help engine compensate all extra force needed for luggage, extra passenger(s), hills, head winds etc + 30 % of force needed on normal bicycle
CR12	Driving help applied until 24 km/h, if bicycler wants faster, he/she has to reach that by own power

These requirements are met by the control unit which is shown in *chapter 6 implementation*. There are no open options here, so this part is also fixed.

Construction for needed room	Fixed		
Help engine	Fixed		
Energy storage	Battery	Hydrogen	
Way of gaining energy	Solar panels	nanosolar	wind turbines
Place for gaining energy	On-board	Around traffic	At home
Behavior help engine	Fixed		

Figure 7.1 overview of technology possibilities for the concept

7.3 concepts

Than these conclusions are combined so that the best combination(s) for the final concepts can be found. There are two final concept: concept A and concept B. Concept B could be build nowadays, so with technology what is already useable. Concept A is better, but can be realized after a few years.

Concept B

For concept B, the choice for the way of gaining energy is solar panels because the other technologies are still in progress. Hydrogen technology still needs some development, so batteries will be used in this case. The place for the solar panels in the traffic won't be a solution for a concept that should be able to be realized and taken in use directly, because then an infrastructure on the public places around the traffic should be boiled. The place can be at home or at the bicycle itself. The advantage of at home is that the panels can be larger so that the bicycle can also be used in colder months. But there do already exist attractive contracts with energy providers for solar panel on the roof and for a solar panel in front of the home permission is needed. So a solar penal on the bicycle itself is the best option.

Construction for needed room	Fixed		
Help engine	Fixed		
Energy storage	Battery	Hydrogen	
Way of gaining energy	Solar panels	nanosolar	wind turbines
Place for gaining energy	On-board	Around traffic	At home
Behavior help engine	Fixed		

Figure 7.2 the choices for concept B

The only concept requirement which is not met in this combination is CR6, range of 50 km. 0,45 square meter of solar panels can be placed on the bicycle, which as consequence that 7 months a year, the bicycle will not reach a range of 50 km. Three of this seven have still a range between 30 and 50 km, and the coldest month is below 15 km range. The other requirements are met. The normative goals can be fulfilled better, for example batteries are still harmful materials. But this is the concept that should be able to introduce right away.

Concept A

Concept A is not realistic now, but within some years. By that time, small wind turbines will be working, so the irregularity of the energy yield from the sun will not be needed any more. So the choice for the way of energy gaining is wind turbines. The wind turbines cannot be placed on the bicycle itself. So the place for gaining energy can be at the home of the users or in the traffic environment. The first option is more realistic for then it will be a private operation for user once he purchases the bicycle. To reach gaining energy on public spaces, more effort has to be done and more parties are concerned. People indicated in the user survey that they won't have trouble with a little silence wind turbine on their roof. The energy will be stored in hydrogen gas. See *figure 7.3* for these choices.
In the home, the energy from the wind turbine converts water into hydrogen gas. This is going to be stored in a hydrogen fuel storage at home. The bicycle can be connected to this storage, to pump over the hydrogen to the hydrogen storage inside the bicycle. During the ride, the fuel cell converts the hydrogen back into water, and the energy that comes free will be used for the help engine.

Construction for needed room	Fixed		
Help engine	Fixed		
Energy storage	Battery		Hydrogen
Way of gaining energy	Solar panels	nanosolar	wind turbines
Place for gaining energy	On-board	Around traffic	At home
Behavior help engine	Fixed		

Figure 7.3 the choices for concept A

This concept agrees to all concept requirements, and fulfills better to the normative goals than concept B.

Concepts in relation to each other

As explained in the previous paragraph, concept A is better option than concept B according the normative goals, but concept B is realizable at this time while concept A should take several years. In figure 7.4 the points in which they differ are shown.

Concept A	**Concept B**
Realistic within some years	Realistic now
Bicycle can be used whole year	Some months the range is not reached
Fuel cells cleaner for environment	Batteries more harmful for environment
Doesn't have to stand in daylight whole day	Has to stand in day light whole day
Energy for trip during whole year	Energy for trip not during whole year.
Refueling needed	No refueling needed
Energy infrastructure needed outside bicycle	No energy infrastructure needed
No heavy energy provider on board	Heavy energy provider on board: less efficient
Place for rider's equipment on rear side box	No place for rider's equipment on rear side box

Figure 7.4 comparison of both concepts

7.4 visualizations

In this paragraph visualizations are shown from both concepts.
Figure 7.4, 7.5 and 7.5 are renderings of the 3D model of the bicycle itself, so the concept but than without the energy source. So those can be both concept A and B.
Figures 7.7 and *7.8* are hand drawings from respectively concept A and B. They show the bicycle in combination with the nature energy source that belongs to the concepts.

Figure 7.4 3D rendering of bicycle part of concept

Figure 7.5 3D rendering of bicycle part of concept

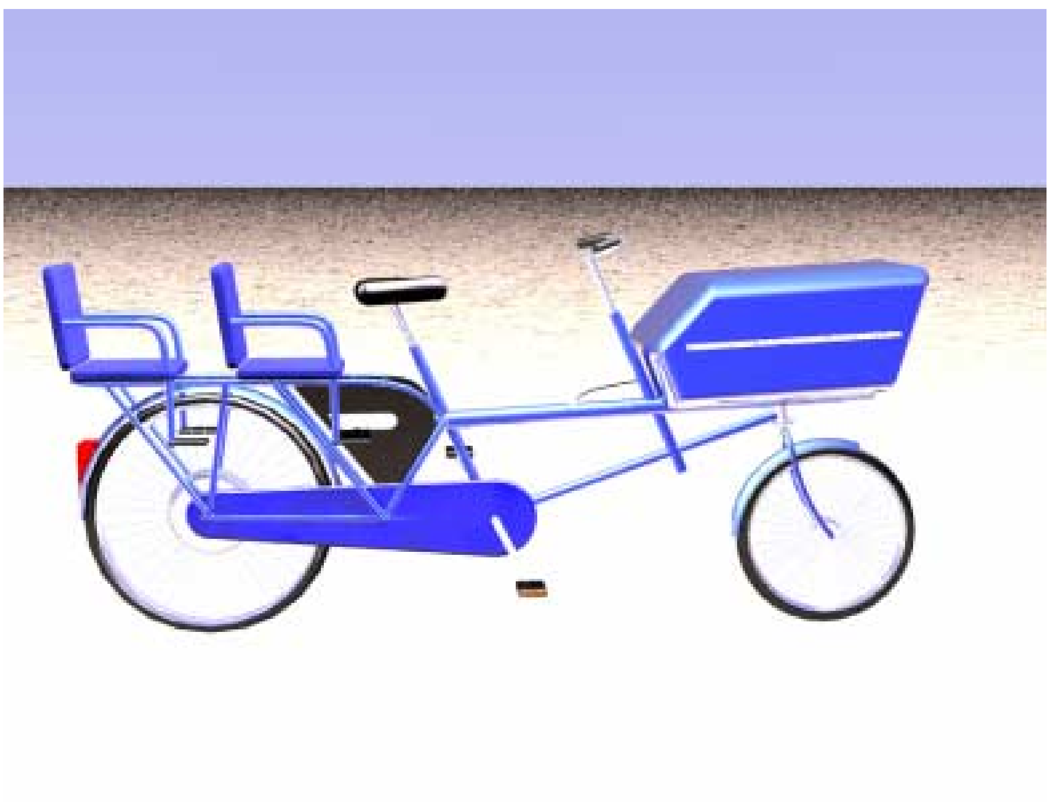


Figure 7.6 3D rendering of bicycle part of concept

Figure 7.7 concept A: the bicycle in combination with a small wind turbine on the home's roof

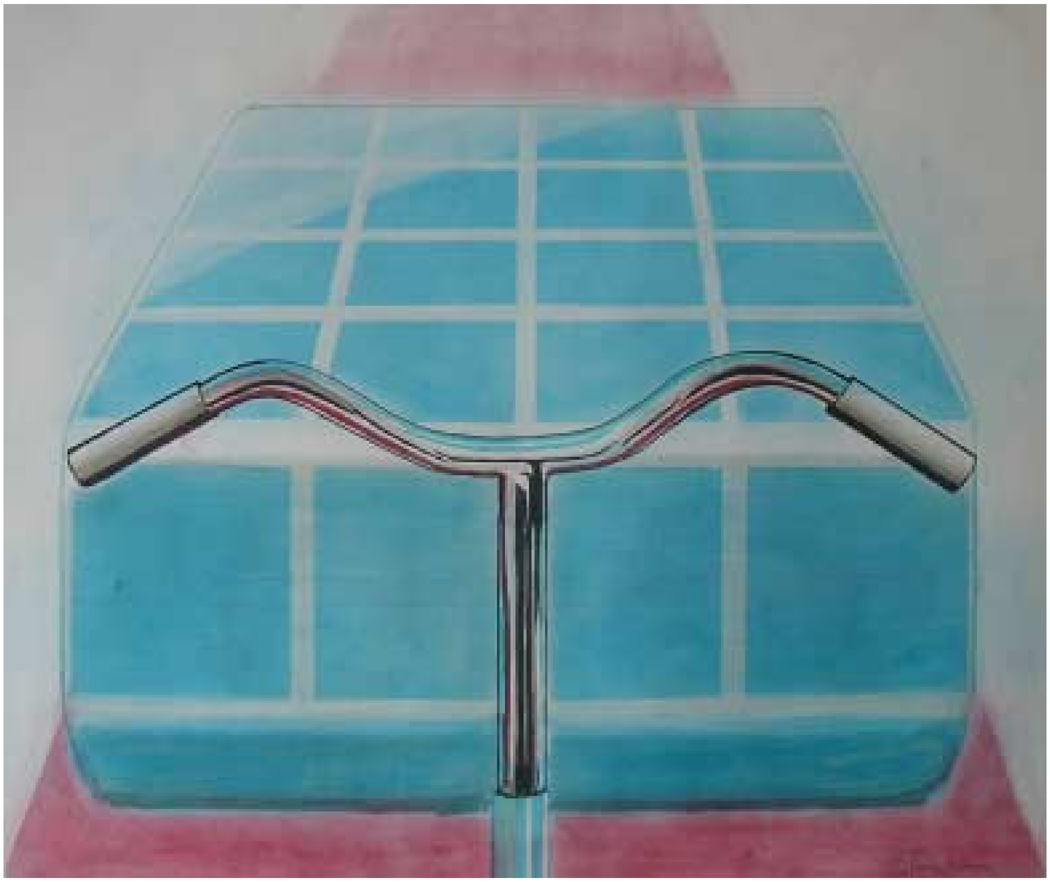


Figure 7.8 concept B: the bicycle with solar panels on the luggage box

Appendix A

User survey

Own administrations

- ✓ Place of interview
- ✓ Sex of person
- ✓ Estimation of age
- ✓ Alone or with others on the moment of interviewing

Questions

1. Do you use a car?
2. How many cars do you and your family have got?
3. How often do you use it?
4. For what kind of rides do you use the car? (goal, estimated distance per trip, frequency)
5. Do you also use a bicycle?
6. How often do you ride on it? (average, not specific in winter)
7. For what kind of rides do you use the bicycle? (goal, estimated distance per trip, frequency)
8. What decides you to take the car either the bicycle?

Please propose you had a bicycle, which complies with the following:

- *You can could take the contents of a whole shopping trolley easily with you in your bicycle*
- *You can take 2 little children or a passenger with you*
- *It should not be heavier to step, but it will even be lighter to step, than a normal bicycle.*

9. Should use this bicycle?
10. In which situations that you indicated before, for what you use the car now, should you use this bicycle?
11. In which situations that you indicated before, should you keep using the car?
12. Which factors stimulate driving this bicycle, in stead of the car?
13. Which factors stimulate to keep taking the car, in stead of the bicycle (concept)?
14. If question1 = “2” & question 9 = “yes”: should you abolish one of the cars?
15. Why yes / no?
16. Do you mind whether the energy that the bicycle uses, is nature energy (in this case defined as energy that comes right out the nature) of not?
17. Why yes / no?
18. Should you mind when for example a little wind turbine should be placed on the roof of your home? This one will provide energy for the bicycle’s help engine.
19. Why yes / no?

Appendix B

Outcome user check survey persons 1 - 7

subject *(number)*	1	2	3	4	5	6	7
sex *(man / women)*	man	man	man	man	man	man	man
estimated age *(years)*	22	23	35	50	50	50	55
will use concept *(yes/no)*	no	no	no	no	yes	yes	yes
car ride 1: fuction *(1-10, refers to list A)*	1	1	1	2	1	1	2
car ride 1: distance *(km)*	35	30	14	1	22	4	2-3
car ride 1: frequentie (times a week)	5	5	5	2	5	5	2
car ride 1: taken over by c. bicycle? *(yes/no)*	no	no	no	no	no	yes	yes
car ride 2: function *(1-10, refers to list A)*	3	3	2	1	2	6	2
car ride 2: distance *(km)*	3	80	5-6	65	2,5	7	>100
car ride 2: frequentie *(times a week)*	6	0,5	5	2,5	1	1	,25
car ride 2 taken over by c. bicycle? *(yes/no)*	no	no	no	no	no	no	no
car ride 3: function *(1-10, refers to list A)*	n/a	2	n/a	n/a	n/a	2	n/a
car ride 3: distance *(km)*	n/a	7	n/a	n/a	n/a	1	n/a
car ride 3: frequentie *(times a week)*	n/a	2	n/a	n/a	n/a	1	n/a
car ride 3: taken over by c. bicycle? *(yes/no)*	n/a	no	n/a	n/a	n/a	yes	n/a
bicycle ride 1: goal *(1-10, refers to list A)*	7	3	4	9	2	2	1
bicycle ride 1: distance *(km)*	1,5	3	10-15	3,5	2	2	3
bicycle ride 1: frequency *(times a week)*	1	2	0,5	2,5	1	1	5
bicycle ride 2: goal *(1-10, refers to list A)*	8	n/a	n/a	10	n/a	n/a	n/a
bicycle ride 2: distance *(km)*	3	n/a	n/a	1	n/a	n/a	n/a
bicycle ride 2: frequency *(times a week)*	1	n/a	n/a	2,5	n/a	n/a	n/a
bicycle ride 3: goal *(1-10, refers to list A)*	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bicycle ride 3: distance *(km)*	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bicycle ride 3: frequency *(times a week)*	n/a	n/a	n/a	n/a	n/a	n/a	n/a
stimulating factors for using c. bycicle for rides instead of car *(1-10, refers to list B)*	n/a	n/a	n/a	n/a	5	4, 1	3
stimulating factors for keep using car for rides *(1-8, refers to list C)*	7,1,3	1, 4	4, 5	1, 6	1,3,4	1	1
second car in the living situation? *(yes/no)*	no	yes	no	no	yes	yes	no
abolish one of the cars? *(yes / evt (eventually) / no)*	n/a	no	n/a	n/a	yes	evt	n/a
reason for previous answer *(1-7, refers to list D)*	n/a	2	n/a	n/a	1, 6	5	n/a
rather nature energy? *(yes/no)*	yes	no	no	yes	yes	no	no
reason for previous answer *(1-6, refers to list E)*	1	2	2	1	4	3	3
wind turbine on roof / balcony okay? *(yes / no)*	yes	no	yes	yes	yes	yes	yes
reason for previous answer *(1-6, refers to list F)*	4	2	1	3	5	1	1

list A
1. to work
2. shopping
3. visiting firiends / family / churchyard
4. recreation with children
5. bringing and picking up children
6. to sport / therapy
7. to school/college
8. to club
9. to the train station
10. from station to work

list B
1. better for environment
2. no traffic stocks
3. likes cycling
4. healthy
5. extra rides due to more opportunities
6. lighter stepping than normal bike
7. saves energy
8. a good example to children or others
9. less parking problems
10. being outside

list C
1.distance
2. trip endurance
3. weather
4. comfort
5. no parking problems for him / her
6. rides are with partner who don't like bicycles
7. no traffic stocks for him/her
8. darkness

list D
1. car is expensive
2. 2 cars remain needed
3. car is not very expensive
4. for when it might be needed ever
5. difficult choice
6. better for environment
7. second car superfluous

list E
1. better for environment
2. not important enough for him/her
3. won't have much effect for environment e
4. stimulates progression about nature energy
5. saves fossile fuel
6. belongs to bicycle

list F
1. no trouble with
2. awkward
3. that's what the future will look like
4. should like it
5. good for environment
6. supports use of nature energy

Outcome user check survey persons 7 - 14

subject *(number)*	8	9	10	11	12	13	14
sex *(man / wom. (women))*	wom.	wom.	wom.	wom.	wom.	wom.	wom.
estimated age *(years)*	30	30	35	40	45	50	55
will use concept *(yes/no)*	yes	yes	yes	yes	yes	yes	yes
car ride 1: fuction *(1-10, refers to list A)*	5	2	5	5	2	2	1
car ride 1: distance *(km)*	6	1	3	8	3	2	10
car ride 1: frequentie (times a week)	1	3	8	10	1	1	5
car ride 1: taken over by c. bicycle? *(yes/no)*	yes	yes	yes	no	yes	yes	no
car ride 2: function *(1-10, refers to list A)*	2	3	3	2	n/a	6	2
car ride 2: distance *(km)*	2	50	15	2	n/a	3	3-4
car ride 2: frequentie *(times a week)*	2	1	2	1	n/a	1	3
car ride 2 taken over by c. bicycle? *(yes/no)*	yes	no	no	yes	n/a	yes	yes
car ride 3: function *(1-10, refers to list A)*	n/a	n/a	2	n/a	n/a	3	3
car ride 3: distance *(km)*	n/a	n/a	2	n/a	n/a	40	12
car ride 3: frequentie *(times a week)*	n/a	n/a	2	n/a	n/a	0,06	2
car ride 3: taken over by c. bicycle? *(yes/no)*	n/a	n/a	yes	n/a	n/a	no	yes
bicycle ride 1: goal *(1-10, refers to list A)*	2	1	5	2	2	2	2
bicycle ride 1: distance *(km)*	1,5	3	3	2	3-4	2	3-4
bicycle ride 1: frequency *(times a week)*	3	5	2	5	2	1	1
bicycle ride 2: goal *(1-10, refers to list A)*	6	n/a	n/a	n/a	6	1	6
bicycle ride 2: distance *(km)*	2,5	n/a	n/a	n/a	3-4	1,5	5
bicycle ride 2: frequency *(times a week)*	2	n/a	n/a	n/a	3	4	1
bicycle ride 3: goal *(1-10, refers to list A)*	n/a	n/a	n/a	n/a	n/a	n/a	3
bicycle ride 3: distance *(km)*	n/a	n/a	n/a	n/a	n/a	n/a	5
bicycle ride 3: frequency *(times a week)*	n/a	n/a	n/a	n/a	n/a	n/a	1
stimulating factors for using c. bycicle for rides instead of car *(1-10, refers to list B)*	1, 4, 7, 8	2, 9	9, 4, 8	1	3, 1, 4	1, 6	4, 10
stimulating factors for keep using car for rides *(1-8, refers to list C)*	n/a	1, 4	1, 3	2, 3	n/a	1, 3	2, 3, 8
second car in the living situation? *(yes/no)*	yes	no	yes	yes	yes	yes	no
abolish one of the cars? *(yes / evt (eventually) / no)*	yes	n/a	no	no	no	evt	n/a
reason for previous answer *(1-7, refers to list D)*	7	n/a	2	2	3, 4	4, 6, 2	n/a
rather nature energy? *(yes/no)*	yes	yes	yes	yes	yes	yes	yes
reason for previous answer *(1-6, refers to list E)*	5	6	1	1	1	1	1
wind turbine on roof / balcony okay? *(yes / no)*	yes	yes	yes	yes	yes	yes	yes
reason for previous answer *(1-6, refers to list F)*	1	1, 5	1	1	1	6	1

list A
1. to work
2. shopping
3. visiting firiends / family / churchyard
4. recreation with children
5. bringing and picking up children
6. to sport / therapy
7. to school/college
8. to club
9. to the train station
10. from station to work

list B
1. better for environment
2. no traffic stocks
3. likes cycling
4. healthy
5. extra rides due to more opportunities
6. lighter stepping than normal bike
7. saves energy
8. a good example to children or others
9. less parking problems
10. being outside

list C
1.distance
2. trip endurance
3. weather
4. comfort
5. no parking problems for him / her
6. rides are with partner who don't like bicycles
7. no traffic stocks for him/her
8. darkness

list D
1. car is expensive
2. 2 cars remain needed
3. car is not very expensive
4. for when it might be needed ever
5. difficult choice
6. better for environment
7. second car superfluous

list E
1. better for environment
2. not important enough for him/her
3. won't have much effect for environment e
4. stimulates progression about nature energy
5. saves fossile fuel
6. belongs to bicycle

list F
1. no trouble with
2. awkward
3. that's what the future will look like
4. should like it
5. good for environment
6. supports use of nature energy

Appendix C

Basis model

I

weight of empty bicycle	kg	50
passenger	yes / no	yes
frontal area of the bicycle	m^2	0,8
speed	km/h	20
force for acceleration from help engine	N	150
force for acceleration from cycler	N	65
power on speed from from cycler	W	75
range	km	100

III

weight luggage	kg	75
weight cyclist	kg	50
weight of passenger	kg	75
acent in degrees	degrees	0
air resistance coefficient	1	1
roll resistance coefficient	1	0,003
amount of stops each 5 km	stops / 5 km	20
waste factor by irragular driving	%	30
needed acceleration force 0-20km/h on normal bicycle	W	100
rho	kg/m^3	1,3
gravity	m/s^2	9,81
average breaking deceleration	m/s^2	3

IV

power needed		
weight person(s)	kg	125
total weight	kg	250
wished speed in m/s	m/s	5,555555556
roll resistance on speed	N	7,3575
air resistance on speed	N	16,04938272
acent resistance on speed	N	0
mechanical resistance	N	1,4
needed force on speed	N	24,80688272
needed power on speed	W	137,8160151
needed power on speed from engine	W	62,81601509
force of cyclist on speed	N	13,5
acceleration time	s	6,9
acent in radians	radians	0
total force for acceleration	F	215
average speed during acceleration	m/s	2,787638942
total power for acceleration	W	599,3423726
cyclist power for acceleration	W	181,1965313
help engine power for acceleration	W	418,1458414
highest power needed for engine	W	418,1458414
factor between power acceleration / speed	1	4,348858674
energy needed		
drive time if only driving on speed	s	18000
distanca during accelerating	m	19,2347087

distance during deceleration	m	8,333333333
total distance for acceleration and deceleration 5 km	m	551,3608407
total distance for acceleration and deceleration during trip	m	11027,21681
total distance on speed during trip	km	88,97278319
total time driving on speed during trip	s	16015,10097
total time driving on speed during trip in minutes	min	266,9183496
total time acceleration and deceleration on trip	min	66
total time driving trip in minutes	min	332,9183496
needed energy for driving on speed during trip	kJ	1006,004824
needed energy for a stop and go	kJ	2,885206305
needed energy for all stops during trip	kJ	400
total added energy needed for trip	kJ	1406,004824

<u>legend</u>

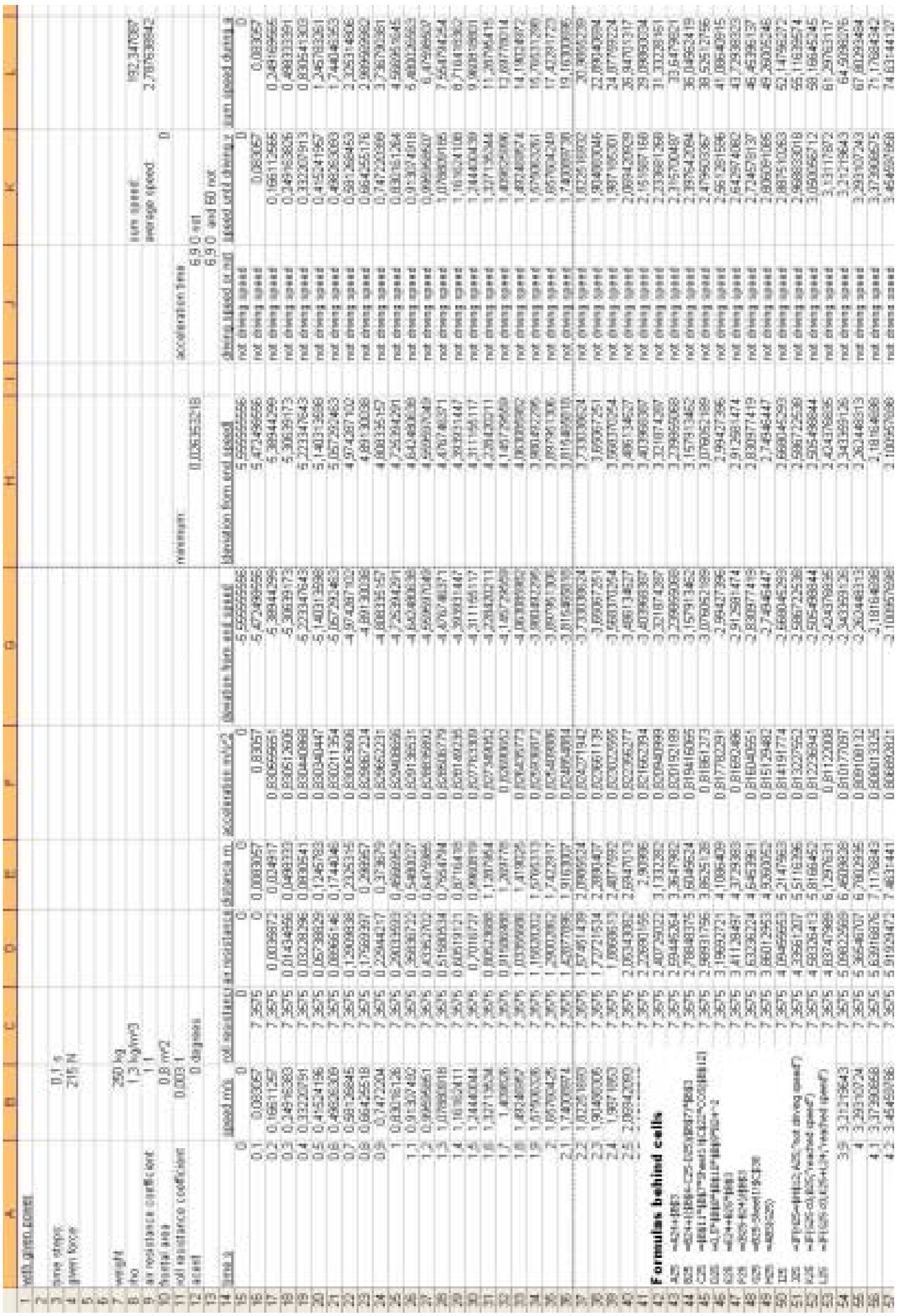
m	meter
km	kilometer
s	second
min	minute
h	hour
N	newton
W	watt
kWh	kilowatthour
J	joul
kJ	kilojoul

Formulas behind group IV of basis model

C28	125	=IF(C3="yes";C13+C14;IF(C3="no";C13;"no indication for the presence of a passenger"))
C29	250	=C28+C2+C12
C30	5,555555556	=C5/3,6
C31	7,3575	=COS(C40)*C17*C22*C29
C32	16,04938272	=0,5*C4*C16*C21*C30^2
C33	0	=C22*C29*SIN(C15)
C34	1,4	=28*0,05
C35	24,80688272	=C31+C32+C33+C34
C36	137,8160151	=C35*C30
C37	62,81601509	=IF(C36-C8<=0;0;C36-C8)
C38	13,5	=C8/C30
C39	6,9	=Sheet2!J13
C40	0	=RADIANS(C15)
C41	215	=C6+C7
C42	2,787638942	=Sheet2!L9
C43	599,3423726	=IF(C42="not enough power for accelerating to normal speed in 60 s";"not enough power for accelerating to normal speed in 60 s";C41*C42)
C44	181,1965313	=IF(C42="not enough power for accelerating to normal speed in 60 s";"not enough power for accelerating to normal speed in 60 s";C7*C42)
C45	418,1458414	=IF(C42="not enough power for accelerating to normal speed in 60 s";"not enough power for accelerating to normal speed in 60 s";C6*C42)
C46	418,1458414	=IF(C42="not enough power for accelerating to normal speed in 60 s";"not enough power for accelerating to normal speed in 60 s";MAX(C45;C37))
C47	4,348858674	=C43/C36
C48		
C49	18000	=C9*1000/C30
C50	19,2347087	=Sheet1!C42*Sheet1!C39
C51	8,333333333	=0,5*C30*C23
C52	551,3608407	=(C50+C51)*C18
C53	11027,21681	=C52/5*C9
C54	88,97278319	=C9-(C53/1000)
C55	16015,10097	=C54*1000/C30
C56	266,9183496	=C55/60
C57	66	=C58-C56
C58	332,9183496	=(C55+(C39+C23)*C18/5*C9)/60
C59	1006,004824	=C55*C37/1000
C60	2,885206305	=IF(C42="not enough power for accelerating to normal speed in 60 s";"not enough power for accelerating to normal speed in 60 s";C45*C39/1000)
C61	400	=C18*C9/5
C62	1406,004824	=C59+C61

Appendix D

Acceleration part of basis model (beginning showed)



Appendix E

Basis model + technology additions

I		
weight of empty bicycle	kg	30
passenger	yes / no	no
frontal area of the bicycle	m^2	1,1
speed	km/h	19
force for acceleration from help engine	N	70
force for acceleration from cycler	N	50
power on speed from from cycler	W	133
range	km	50
use of lithium-ion battery	yes / no	yes
how much use of solar panels	m^2	3
amount of turbies	1	5
pressure in hydrogen tank	BAR	350
certain area of solar panels	m^2	0,45
III		
weight luggage	kg	75
weight cyclist	kg	77
weight of passenger	kg	80
acent in degrees	degrees	0
air resistance coefficient	1	1
roll resistance coefficient	1	0,007
amount of stops each 5 km	stops / 5 km	10
energy / kg of lithium ion battery	J/kg	619327,4336
energy / L of lithium ion battery	J/L	1055486,012
waste factor by irragular driving	%	40
needed acceleration force 0-20km/h on normal bicycle	W	100
rho	kg/m^3	1,3
gravity	m/s^2	9,81
average breaking deceleration	m/s^2	3
peak power electric engine 1	W	400
average power electric engine 1	W	200
peak power electric engine 2	W	400
average power electric engine 2	W	250
peak power electric engine 3	W	750
average power electric engine 3	W	500
peak power electric engine 4	W	2000
average power electric engine 4	W	900
energy profit of 1 m^2 solar panel worst sunlight month	kWh / month	0,94
energy profit of 1 m^2 solar panel best sunlight month	kWh / month	14
energy profit of 1 m^2 solar panel in January	kWh / month	0,94
energy profit of 1 m^2 solar panel in February	kWh / month	2,8
energy profit of 1 m^2 solar panel in March	kWh / month	7,1
energy profit of 1 m^2 solar panel in April	kWh / month	7,7
energy profit of 1 m^2 solar panel in May	kWh / month	14
energy profit of 1 m^2 solar panel in June	kWh / month	11
energy profit of 1 m^2 solar panel in July	kWh / month	11
energy profit of 1 m^2 solar panel in August	kWh / month	11

energy profit of 1 m^2 solar panel in September	kWh / month	9,6
energy profit of 1 m^2 solar panel in October	kWh / month	6
energy profit of 1 m^2 solar panel in November	kWh / month	2,1
energy profit of 1 m^2 solar panel in December	kWh / month	1,6
normal power / L H2 fuel cell	W	213
normal pewer / kg H2 fuel cell	W	147
peak power / L H2 fuel cell	W	319
peak power / kg H2 fuel cell	W	221
chemical energy of H2	J	286000
efficiency fuel cells	%	83
molar mass of H2 + O gas	g/mol	18,016
volume of 1 mol gas (p=p0)	L/mol	22,4
possible presure in hydrogen tank	BAR	350
energy profit form standard wind turbine	kWh / year	3608333
energy profit form stulipo wind turbine	kWh / year	5000
energy profit from turby wind turbine	kWh / year	5000
energy profit from venturi wind turbine	kWh / year	500
axis width turby	cm	250
diameter rotation turby	cm	200
axis lenth venturi	cm	110
diameter rotation venturi	cm	110
IV		
power needed		
weight person(s)	kg	77
weight of empty bicycle including batteries	kg	
total weight	kg	182
wished speed in m/s	m/s	5,277777778
roll resistance on speed	N	12,49794
air resistance on speed	N	19,91628086
acent resistance on speed	N	0
mechanical resistance	N	1,4
needed force on speed	N	33,81422086
needed power on speed	W	178,4639434
needed power on speed from engine	W	45,46394345
force of cyclist on speed	N	25,2
acceleration time	s	9,5
acent in radians	radians	0
total force for acceleration	F	120
average speed during acceleration	m/s	2,742330527
total power for acceleration	W	329,0796632
cyclist power for acceleration	W	137,1165263
help engine power for acceleration	W	191,9631369
highest power needed for engine (nog helling bij)	W	191,9631369
factor between power acceleration / speed	1	1,843956022
energy needed		
drive time if only driving on speed	s	9473,684211
distanca during accelerating	m	26,05214001
distance during deceleration	m	7,916666667
total distance for acceleration and deseleration 5 km	m	339,6880667
total distance for acceleration and deseleration during trip	m	3396,880667
total distance on speed during trip	km	46,60311933
total time driving on speed during trip	s	8830,064716
total time driving on speed during trip in minutes	min	147,1677453
total time acceleration and deseleration on trip	min	20,83333333

total time driving trip in minutes	min	168,0010786
needed energy for driving on speed during trip	kJ	401,4495629
needed energy for a stop and go	kJ	1,8236498
needed energy for all stops during trip	kJ	100
total added energy needed for trip	kJ	501,4495629
battery needed		
energy needed from battery	J	501449,5629
battery volume	L	0,475088781
battery weight	Kg	0,809667933
electric engine needed		
type 1 needed	yes/no	yes
type 2 needed	yes/no	no
type 3 needed	yes/no	no
type 4 needed	yes/no	no
fuel cells needed		
volume of fuel cells needed for normal power	L	0,213445744
weight of fuel cells needed for normal power	kg	0,309278527
volume of fuel cells needed for peak power	L	0,601765319
weight of fuel cells needed for peak power	kg	0,868611479
total volume fuel cells needed	L	0,601765319
total weight fuel cells needed	kg	0,868611479
hydrogen tank		
electric energy per mol H2	J/mol	237380
mol hydrogen fuel per kg	mol/kg	55,5062167
energie per kg hydrogen gas	J/kg	13176065,72
energy per L hydrogen gas, under normal pressure	J/L	10597,32143
erergy per L hydrogen in tank	J/L	3709062,5
weight of fuel needed for trip	kg	0,038057609
volume of fuel in tank needed for trip	L	0,135195771
total volume of H2 fuel cells and fuel for trip	L	0,73696109
total weight of H2 fuel cells and fuel for trip	kg	0,906669089
solar energy		
energy each day won by m^2 solar panel worst sublight month	kJ/d	109,1612903
energy each day won by m^2 solar panel worst sublight month	kJ/d	1625,806452
amount of m^2 solar panels needed for 1 trip/day worst sunlight month	m^2	4,593657343
amount of m^2 solar panels needed for 1 trip/day best sunlight month	m^2	0,308431279
amount of m^2 nanosolar foil needed for 1 trip/day worst sunlight month	m^2	9,187314687
amount of m^2 nanosolar foil needed for 1 trip/day best sunlight month	m^2	0,616862558
length of trip each day with certain area of solar panels in January	km	4,898057978
length of trip each day with certain area of solar panels in February	km	14,58995994
length of trip each day with certain area of solar panels in March	km	36,99596984
length of trip each day with certain area of solar panels in April	km	40,12238982
length of trip each day with certain area of solar panels in May	km	72,94979968
length of trip each day with certain area of solar panels in June	km	57,31769975
length of trip each day with certain area of solar panels in	km	57,31769975

July		
length of trip each day with certain area of solar panels in August	km	57,31769975
length of trip each day with certain area of solar panels in September	km	50,02271978
length of trip each day with certain area of solar panels in October	km	31,26419986
length of trip each day with certain area of solar panels in November	km	10,94246995
length of trip each day with certain area of solar panels in December	km	8,337119963
wind energy		
energy profit each day from standard wind turbine	kJ/d	35589037,81
energy profit each day from tulipo wind turbine	kJ/d	49315,06849
energy profit each day from turby wind turbine	kJ/d	49315,06849
energy profit each day from venturi wind turbine	kJ/d	4931,506849
amount of trips feed by standard wind turbine each day	trips	70972,31794
amount of trips feed by tulipo wind turbine each day	trips	98,3450224
amount of trips feed by turby wind turbine each day	trips	98,3450224
amount of trips feed by venturi wind turbine each day	trips	9,83450224
reduce factor of turby for feeding one trip each day	1	4,615840512
reduce factor of venturi for feeding one trip each day	1	2,142483378
axis width reduced turby for feeding one trip each day	cm	54,16131674
diameter rotation reduced turby for feeding one trip each day	cm	43,32905339
axis lenth reduced venturi for feeding one trip each day	cm	51,34228864
diameter rotation reduced venturi for feeding one trip each day	cm	51,34228864

legend	
-	
cm	centimeter
m	meter
km	kilometer
s	second
h	hour
d	day
N	newton
W	watt
kWh	kilowatthour
J	joul
kJ	kilojoul

Formulas behind group IV of total model (part 1)

C72	77	=IF(C3="yes";C18+C19;IF(C3="no";C18;"no indication for the presence of a passenger"))
C73		
C74	182	=C72+C2+C17
C75	5,277777778	=C5/3,6
C76	12,49794	=COS(C85)*C22*C29*C74
C77	19,91628086	=0,5*C4*C21*C28*C75^2
C78	0	=C29*C74*SIN(C20)
C79	1,4	=28*0,05
C80	33,81422086	=C76+C77+C78+C79
C81	178,4639434	=C80*C75
C82	45,46394345	=IF(C81-C8<=0;0;C81-C8)
C83	25,2	=C8/C75
C84	9,5	=Sheet2!J13
C85	0	=RADIANS(C20)
C86	120	=C6+C7
C87	2,742330527	=Sheet2!L9
C88	329,0796632	=IF(C87="not enough power for accelerating to normal speed in 60 s";"not enough power for accelerating to normal speed in 60 s";C86*C87)
C89	137,1165263	=IF(C87="not enough power for accelerating to normal speed in 60 s";"not enough power for accelerating to normal speed in 60 s";C7*C87)
C90	191,9631369	=IF(C87="not enough power for accelerating to normal speed in 60 s";"not enough power for accelerating to normal speed in 60 s";C6*C87)
C91	191,9631369	=IF(C87="not enough power for accelerating to normal speed in 60 s";"not enough power for accelerating to normal speed in 60 s";MAX(C90;C82))
C92	1,843956022	=C88/C81
C93		
C94	9473,684211	=C9*1000/C75
C95	26,05214001	=Sheet1!C87*Sheet1!C84
C96	7,916666667	=0,5*C75*C30
C97	339,6880667	=(C95+C96)*C23
C98	3396,880667	=C97/5*C9
C99	46,60311933	=C9-(C98/1000)
C100	8830,064716	=C99*1000/C75
C101	147,1677453	=C100/60
C102	20,83333333	=C103-C101
C103	168,0010786	=(C100+(C84+C30)*C23/5*C9)/60
C104	401,4495629	=C100*C82/1000
C105	1,8236498	=IF(C87="not enough power for accelerating to normal speed in 60 s";"not enough power for accelerating to normal speed in 60 s";C90*C84/1000)

Formulas behind group IV of total model (part 2)

C106	100	=C23*C9/5
C107	501,4495629	=C104+C106
C108		
C109	501449,5629	=IF(C10="yes";C107*1000;"no use of battery")
C110	0,475088781	=C109/C25
C111	0,809667933	=C109/C24
C112		
C113	yes	=IF(AND(C82<=C32;C91<C31);"yes";"no")
C114	no	=IF(AND(C82<=C34;C91<=C33;C113="no");"yes";"no")
C115	no	=IF(AND(C82<=C36;C91<=C35;C114="no";C113="no");"yes";"no")
C116	no	=IF(AND(C82<=C38;C91<=C37;C113="no";C114="no";C115="no");"yes";"no")
C117		
C118	0,213445744	=C82/C53
C119	0,309278527	=C82/C54
C120	0,601765319	=C91/C55
C121	0,868611479	=C91/C56
C122	0,601765319	=MAX(C118;C120)
C123	0,868611479	=MAX(C119;C121)
C124		
C125	237380	=C57*C58/100
C126	55,5062167	=1000/C59
C127	13176065,72	=C126*C125
C128	10597,32143	=C125/C60
C129	3709062,5	=C128*C13
C130	0,038057609	=C107*1000/C127
C131	0,135195771	=C107*1000/C129
C132	0,73696109	=C122+C131
C133	0,906669089	=C123+C130
C134		
C135	109,1612903	=C39/31*3600
C136	1625,806452	=C40/31*3600
C137	4,593657343	=C107/C135
C138	0,308431279	=C107/C136
C139	9,187314687	=C137*2
C140	0,616862558	=C138*2
C141	4,898057978	=C$14*50/(C$107/(C41/31*3600))
C142	14,58995994	=C$14*50/(C$107/(C42/31*3600))
C143	36,99596984	=C$14*50/(C$107/(C43/31*3600))
C144	40,12238982	=C$14*50/(C$107/(C44/31*3600))
C145	72,94979968	=C$14*50/(C$107/(C45/31*3600))
C146	57,31769975	=C$14*50/(C$107/(C46/31*3600))
C147	57,31769975	=C$14*50/(C$107/(C47/31*3600))
C148	57,31769975	=C$14*50/(C$107/(C48/31*3600))
C149	50,02271978	=C$14*50/(C$107/(C49/31*3600))
C150	31,26419986	=C$14*50/(C$107/(C50/31*3600))
C151	10,94246995	=C$14*50/(C$107/(C51/31*3600))
C152	8,337119963	=C$14*50/(C$107/(C52/31*3600))
C153		
C154	35589037,81	=C62/365*3600
C155	49315,06849	=C63/365*3600
C156	49315,06849	=C64/365*3600
C157	4931,506849	=C65/365*3600
C158	70972,31794	=C154/C$107
C159	98,3450224	=C155/C$107
C160	98,3450224	=C156/C$107
C161	9,83450224	=C157/C$107
C162	4,615840512	=C160^(1/3)
C163	2,142483378	=C161^(1/3)
C164	54,16131674	=C66/C162
C165	43,32905339	=C67/C162
C166	51,34228864	=C68/C163
C167	51,34228864	=C69/C163

Appendix F

Acceleration with formula for help engine (beginning showed)

pedel force	Cor-rec-tion force help engine	force help engine	total force	F pedal / 0,7	*calcu-lated a needed*	power help engine	time s	speed m/s	roll resis-tance	air resis tance	*accele-ration m/s^2*
40	0	0	40	57,1		0	0	0	0	0	*0*
40	3	0	40	57,1	*0,57*	0	0,1	0,0148	12,7	0	*0,15*
40	3	3	43	57,1	*0,57*	96,37	0,2	0,0311	12,7	0	*0,16*
40	3	6	46	57,1	*0,57*	122,1	0,3	0,0491	12,7	0	*0,18*
40	3	9	49	57,1	*0,57*	130,9	0,4	0,0687	12,7	0	*0,2*
40	3	12	52	57,1	*0,57*	133,4	0,5	0,09	12,7	0	*0,21*
40	3	15	55	57,1	*0,57*	132,9	0,6	0,1128	12,7	0,01	*0,23*
40	3	18	58	57,1	*0,57*	131,1	0,7	0,1373	12,7	0,01	*0,24*
40	3	21	61	57,1	*0,57*	128,5	0,8	0,1634	12,7	0,01	*0,26*
40	3	24	64	57,1	*0,57*	125,6	0,9	0,1911	12,7	0,02	*0,28*
40	3	27	67	57,1	*0,57*	122,5	1	0,2205	12,7	0,03	*0,29*
40	3	30	70	57,1	*0,57*	119,3	1,1	0,2514	12,7	0,04	*0,31*
40	3	33	73	57,1	*0,57*	116,2	1,2	0,284	12,7	0,05	*0,33*
40	3	36	76	57,1	*0,57*	113,1	1,3	0,3182	12,7	0,06	*0,34*
40	3	39	79	57,1	*0,57*	110,2	1,4	0,354	12,7	0,08	*0,36*
40	3	42	82	57,1	*0,56*	107,3	1,5	0,3914	12,7	0,1	*0,37*
40	3	45	85	57,1	*0,56*	104,6	1,6	0,4304	12,7	0,12	*0,39*
40	3	48	88	57,1	*0,56*	101,9	1,7	0,471	12,7	0,14	*0,41*
40	3	51	91	57,1	*0,56*	99,37	1,8	0,5132	12,7	0,17	*0,42*
40	3	54	94	57,1	*0,56*	96,94	1,9	0,5571	12,7	0,21	*0,44*
40	3	57	97	57,1	*0,56*	94,61	2	0,6025	12,7	0,24	*0,45*
40	3	60	100	57,1	*0,56*	92,37	2,1	0,6495	12,7	0,28	*0,47*
40	3	63	103	57,1	*0,56*	90,24	2,2	0,6982	12,7	0,33	*0,49*
40	3	66	106	57,1	*0,56*	88,19	2,3	0,7484	12,7	0,38	*0,5*
40	3	69	109	57,1	*0,56*	86,23	2,4	0,8002	12,7	0,44	*0,52*
40	3	72	112	57,1	*0,56*	84,35	2,5	0,8536	12,7	0,5	*0,53*
40	0	75	115	57,1	*0,56*	82,54	2,6	0,9086	12,7	0,57	*0,55*
40	0	75	115	57,1	*0,56*	77,84	2,7	0,9635	12,7	0,64	*0,55*

Formulas behind cells

A22	40	
B22	3	=IF(J22>$B$10;$B$12*-1;IF(F22-M22>$B$11;$B$12;IF(M22-F22>$B$11;$B$12*-1;0)))
C22	18	=IF(C21+B21>0;C21+B21;0)
D22	58	=A22+C22
E22	57,14285714	=A22/0,7
F22	0,5660872	=($E$17-$J$11*$B$9*9,81-0,5*$J$8*$J$9*J22^2*$J$10)/$B$9
G22	31,03448276	=IF(D22=0;0;C22/D22*100)
H22	131,0767626	=C22/J22
I22	0,7	=I21+$J$3
J22	0,137324112	=J21+((D22-K22-L22)/$J$7)*$J$3
K22	12,70395	=$J$11*$J$7*Sheet1!$C$28*COS($J$12)
L22	0,009932538	=0,5*$J$8*$J$10*$J$9*J21^2

Appendix G

Final variables and function for calculating the power of the help engine in Java language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