Biomimicry of cables and pipes in the subsurface of Rotterdam

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Abstract

‘’Het ondergrond LAB’’ has been set up by people from the municipality of Rotterdam, SWECO and Saxion, to interest students in the subsurface. One of the problems that this cooperation agrees upon is that the subsurface is too full, with a lot of stakeholders that don’t agree with each other. Communication is difficult, and standard engineering solutions don’t work anymore. That’s why biomimicry is presented as a new method with potential to lead these stakeholders in the right direction. The stakeholders are currently basing communication on self interest and competition, and rules and laws for one sector don’t match with those of a different sector. Having a symbiotic system that benefits all stakeholders has potential, but being a new method there is still a lot of uncertainty if it can succeed or not.

Keywords

Subsurface, underground, biomimicry, cables, pipes, digging, symbiotic construction, stakeholders, network, SWECO, Rotterdam, vol onder maaiveld

Table of contents

Introduction

Society is becoming increasingly complex, and with it the subsurface as well (Taselaar, 2009). There are more people sharing less space, and more resources need to find their way to them. Cables and pipes are being managed by companies and stakeholders whom all make decisions based on their own perspective. People don't know how to cooperate, and this shows in practice when looking at the infrastructure in the ground underneath our feet. In this field, competition has become the standard, and collaboration a problem. (Ton, 2018)

According to Geert Roovers people have become used to operate control over a system and planning, to map everything out into the far future. But what if that future is uncertain and changing? What if the complexity of stakeholders, timelines and assets is becoming too large to handle? Global warming has shown us that the forces of nature are strong and growing. So maybe it's time for us to stop pushing against that, and start growing together with it, and integrate it in a system. That means we have to learn how to collaborate. With each other, and with nature.

Stakeholders

The municipality of Rotterdam has been looking into using biomimicry to advance the cities engineering problems. Together with SWECO and Saxion they are part of ''het Ondergrond LAB'' set up by KOBO, which focusses on raising interest in the underground constructions among students. The enthusiasm regarding biomimicry has been brewing and growing as a result from the ondergrondLAB, but hasn't been set to action yet. (Koek, 2020) Now they want to reach other municipalities and parties to share their new perspective by making it concrete and showing them what is possible. This will be done by looking at a problem

that is facing a wall using the traditional engineering troubleshooting: the underground space scarcity. (Taselaar, 2009)

Wil Kovacs is from the municipality of Rotterdam and he began with John Driessen from SWECO on their goal to spread the concept of biomimicry in the field of subsurface construction. Rotterdam is a large city with a lot of construction going on both above ground as well as underneath it. As part of the municipality, Wil is one of the stakeholders in the cables and pipes in the subsurface, and also responsible to make it all fit in the ground.

SWECO is a consultancy and engineering firm located in de Bilt, Utrecht. It has multiple locations over the world located in Sweden, Norway, Finland, Denmark, Estonia, Lithuania, Bulgaria, Czech Republic, Germany, Belgium, the Netherlands, the United kingdom, Poland and China. The firm focusses on building cities on different aspects, this can be regarding water supplies, energy transmission, infrastructure or buildings. (SWECO, 2020a) The interest of biomimicry in the subsurface comes from John Driessen when it was implemented as a solution to ‘vol onder maaiveld’, an initiative of COB to engage parties to come up with solutions for the commotion in the subsurface. (SWECO, 2020b)

The Saxion is included in ‘het ondergrondlab’ in order to involve and interest students in the field of ground and subsurface. Dr. Ir. Geert Roovers is a lector at Saxion and is expert regarding the space underground and the collaborations that involve the decisions underneath our feet. His interest lay primarily in the turmoil of the underground, where the pipes and cables are just one part of a large problem.

Context/Relevance

The subsurface

The underground has had a space issue for a while, with cables, pipes, water, trees, garbage containers and more taking up space next to and above each other, and different parties can't seem to agree with each other how to collaborate. This has been defined by COB (2020c), a network organisation that brings different stakeholders in the subsurface together. The Cables and pipes underground each need maintenance, and during that maintenance other pipes and cables get damaged because of the digging activity (COB, 2020a). This causes a lot of annoyance and costs a lot of money on every side. Technology is advancing and growing faster than ever, but for all aspects of it to fit seems to be impossible. (Ton, 2018) Multiple organizations have looked for a solution to this problem, and some even tried, but this has all been done from an engineering point of view, according to Wil Kovacs.

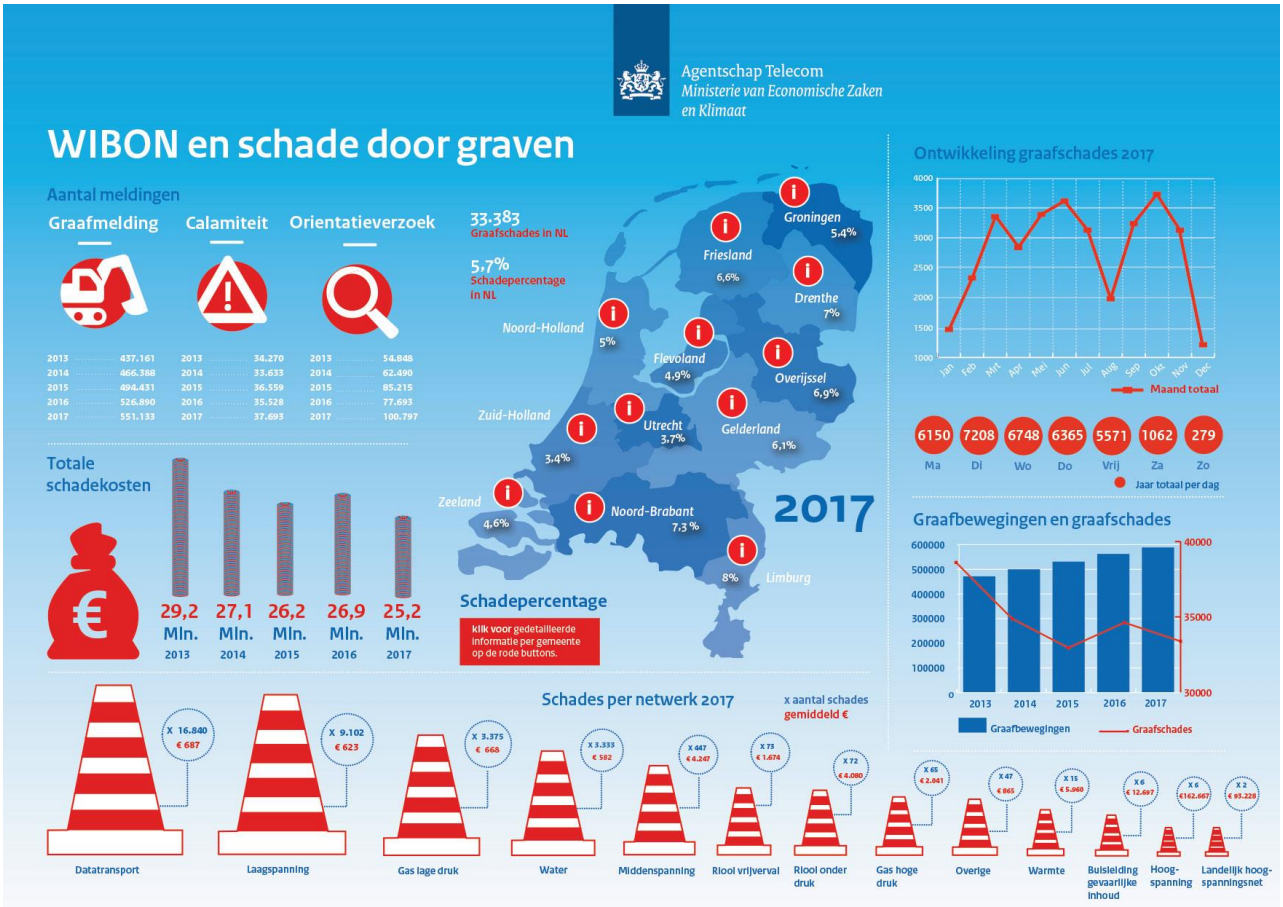


Figure 1. The statistics above show the recent development of digging damage, recorded by the ministry. (Ministry of Economic Affairs and Climate, 2018).

Biomimicry

Now what If we look at the best engineer with 3.8 billion years of experience? Nature itself has been dealing with problems, trying them out and selecting the good solutions for as long as life itself exists. Looking at those solutions as a blueprint for our own problems, helps us solve them in a way that is called Biomimicry. (Stevens et al., 2020) By concentrating the problem down to its core, it is possible to find one or more tactics that reoccur in nature itself. And the context can be viewed as the ecosystem.

How this will happen in practice is that the problem will be dissected to it's core. It is necessary to find the exact problem and define it in a way that doesn't just make sense in the context of itself. This problem can be translated into problems that can be found in nature: organizing in order to gain the most light, adjusting temperature in a desert, finding the fastest route to use as little energy as possible. Organisms and ecosystems have found solutions for endless problems and in varying contexts. Looking at the organism and using it's tactics, not just it's appearance is what can solve the problem as well. This solution can be rooted on a function, form, process or system. Looking at the size of the problem instead the proportion can be the size of an organism, their behaviour or an entire ecosystem.

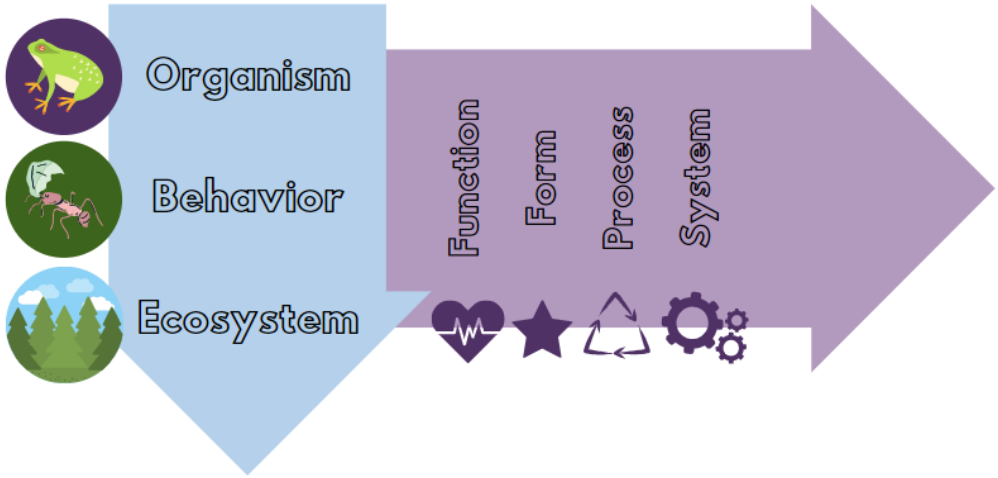


Figure 2. Biomimicry levels, image based on biomimicry design thinking (Stevens et al.2020)

Applying biomimicry should also be done responsible and circular. What is the concept going to have as an impact on the environment? And what happens with the materials after the use? Especially when developing something that needs to be able to grow with the global warming and changes in nature, it is important to realize it's impact and make sure it moves with, instead of against it. (Ellen MacArthur Foundation, 2017).

One method used in order to apply biomimicry are the life principles. The life principles are the overarching patterns in nature that all Life uses that nature uses in order to survive. (Stevens et al, 2020). The better the organism is adapted to it's surroundings using these principles, the higher it's survivability rate. Using these principles in design will help a design to survive within it's context, and can be used as a starting point for circular design. These principles can be seen in figure 14. (Biomimicry 3.8., 2016)

Methodology

Research questions

What are the current organisational problems and technical requirements in the underground up to 5 meter depth of the square in front of Rotterdam Central Station that have the greatest impact, and which organism or ecosystem can lead as an inspiration for cables and pipes to solve the current and future space shortage?

This main question can be divided into numerous of sub questions to answer the overall goal of this research.

- Current **requirements** for organizing pipes and cables up to 5 m underground
- Which **systems** are currently present underneath the square at Rotterdam central station, and what are their functions, how many outputs and how many inputs do they have.
- **Which** stakeholders in the underground building and organisation have key roles and what are those roles?
- What are the **problems that reoccurred** with previous attempts in the last 10 years at reorganizing the underground cables and pipes.

- What are **current solutions** for (part of) this problem and **where** do they apply in the system?

Methods

Explorative research is done in order to lay out a ground level of information and context regarding the subsurface in Rotterdam. The research will be supported by conversations with experts on the field, and networking within SWECO, the municipality of Rotterdam, Saxion and COB. These interviews and feedback will be held through meetings through teams, email exchanges and telephone conversations.

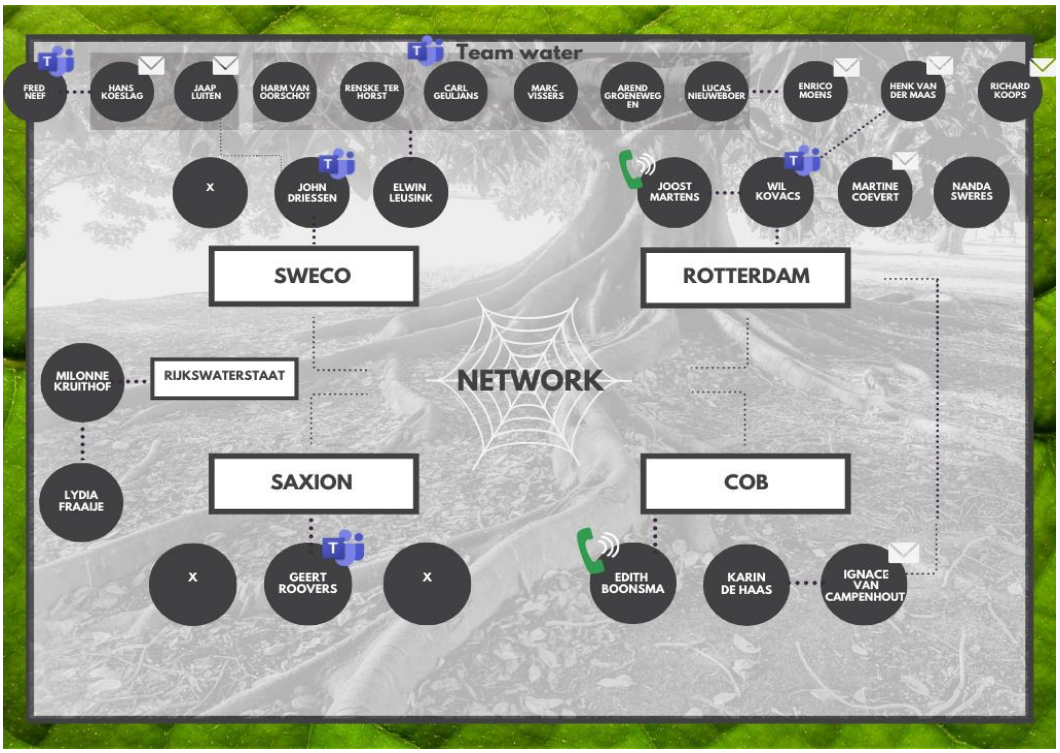


Figure 3. network and contacting methods during internship research

<u>Chapter 1: Literature review,</u> in this literature review the requirements, systems, problems and current solutions will be researched and summarized. Discussion from professionals regarding regulations will be included.

Chapter 2: Stakeholder analysis, 2 charts will be presented with the stakeholders, their roles and their demands listed alongside each other. An interview with Henk van der Maas will be held in order to complete the list based on literature.

Chapter 3: Function analysis, in the function analysis an example of a NEN norm that applies to cables and pipes will be presented and discussed. And a function analysis will be made using the biomimicry taxonomy. This means that the cables and pipes will be described as if they were an organism or ecosystem. With this the basic functions of it can be perceived instead of already integrating the form that function currently possesses. An interview with Fred Neef will be held about the different functions in the subsurface.

Chapter 4: Trend analysis**,** for this trend analysis there will be looked at how the future will look like for cables and pipes in 2050. Estimated by professionals and supported by literature based on interviews.

Chapter 5: Problem definition, the problem definition will be defined based on the foregoing research and it's discussion. Allowing for a selection criteria on which an organism or ecosystem can be chosen.

Chapter 6: Nature Tech summary (NTS), following this problem definition, an organism or ecosystem will be selected of which an NTS will be made, dissecting the solution of given organism or ecosystem in a technical definition.

Hypothesis

The expected answer to the question:

'' What are the current organisational problems and technical requirements in the underground up to 5 meter depth of the square in front of Rotterdam Central Station that

have the greatest impact, and which organisms or ecosystem can lead as an inspiration for cables and pipes to solve the current and future space shortage.''

Is estimated to be the following:

The current organization of cables and pipes is cohabitation of the same space, and as more participants want to join competition occurs over who goes where. Requirements restrict pipes and cables from connection with one another, without taking in mind whether future constructs need to fit. During maintenance a lot of inconvenience for the civilians occurs, as well as damage to other cables and pipes, trying to work around one another while still trying to reach the one that needs repairing or maintenance.

The only way to solve this is if cables and pipes are organized as an organism and all contribute to each other. Being adaptable and combining functions where possible, and being responsive to one another where this isn't possible.

Results

Chapter 1: Literature review

In this literature review different sections of the research question will be researched and iterated upon. Looking at papers from both research databases and internally from SWECO and Rotterdam.

- Section 1.1 describes the layers of the subsurface and the construction among them.
- Section 1.2 lists the requirements that the municipality has set up regarding the construction of cables and pipes in the city.

- Section 1.3 is a list of the types and quantity of cables and pipes underneath the city of Rotterdam. And of the specific 30 x 30 m section in front of the Central station.
- Section 1.4 elaborates on the policies and norms that apply with the construction of cables and pipes.
- Section 1.5 explains current solutions and problems that have been faced with projects in the past 10 years.

1.1 Layers of the subsurface

In the past, urban planners did not consider the subsurface of Rotterdam as important while constructing the city. Archaeology and soil pollution were the first thing to be taken into account when it did occur, (Dick, Eriksson, de Beer, Bonsor, & van der Lugt, 2017, p. 331). Groundwater, geotechnical issues and space scarcity were only considered during the construction phase of a project. It has only been 8 years since the underground has been seen as important to integrate during the planning process.

The top layer up to a few meters deep is where the cables, pipelines and archaeology are located and conducted. The layer underneath that is reserved for civil constructions, meaning tunnels and stations. But also parking and water storage are placed in this layer. It is a sandy layer which is used for the foundation for building structures. (van Campenhout, de Vette, Schokker, & van der Meulen, 2016)

From 50 m and deeper is the third layer located, containing the drinking water storage and storage for shallow geothermal energy (SGE) for heating and cooling down buildings.

The forth layer contains oil and gas, CO2 storage as well as the rest of the geothermal activity. This is below 500 meters, and geothermal energy is regarded as a sustainable form of energy in contrary to gas and oil. (van Campenhout & Bacic, 2017)

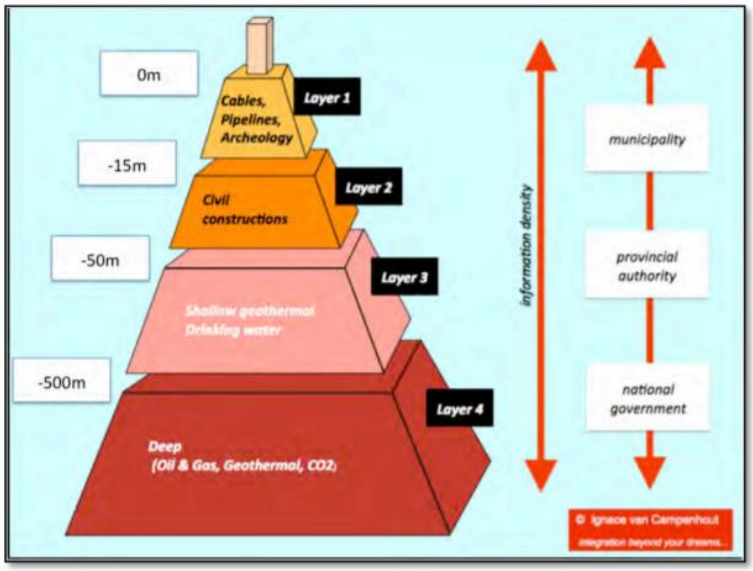


Figure 4. Layers of the subsurface (van Campenhout, de Vette, Schokker, & van der Meulen, 2016)

The surface itself is also to be considered into urban planning, since a lot of requirements for locations and connections for the pipes and cables are determined by what is build above ground. The pipes and cables need to be accessible for whatever structure is placed above, and also in order to apply maintenance. The buildings in Rotterdam, due to the soft soil in most of the Netherlands, need a lot of foundation.

1.2 Requirements

In 2013, the municipality has also taken steps to make the city climate proof before 2025, and has set up the The Rotterdam Climate Change Adaptation Strategy (Municipality of Rotterdam 2013)

- By 2025, measures will have been taken to ensure that every city region is minimally affected by climate change and will receive optimal benefits from climate change adaptation measures in 2025 and onwards.
- Rotterdam will systematically account for the long-term foreseable climate change in all spatial development of the city, and is resilient to any associated uncertainties.

The policy for cables and pipes have both an operational and tactical level, which each have different requirements. (S.Lensing, 2018). After a decision is made about an action, it first undergoes different phases before it can be executed. These phases are clustered in the following 4 blocks: (COB, 2018)

1. Policy making
2. Variant Weighing
3. Plan development
4. Execution

Whereas this research focusses on cables and pipes, it does need to be considered that the layers underneath it also affected by what happens above it. The same goes for the urban construction above ground. These requirements will not be listed in this research, but the requirement does consist that the pipes and cables need to be accessible and flexible for the functions and changes of the surface and the layers of subsoil underneath it.

For this we will look at an area of 30m by 30m at the front of Rotterdam Central station.

Figure 5. the subsurface in front of Rotterdam central station *(Leidingenbureau Municipality of Rotterdam, 2020)*

We can see that this is a crossing with lots of cables and pipes. Looking at the colors and shapes we can see the following:

- A lot of parallel electricity cables
- Electricity cables from different directions joining and splitting
- A lot of parallel and overlapping telecom cables from a lot of different stakeholders
- A Sewer system that crosses each of the paths of cables and pipes
- The gas pipelines that bend around the corner with a curve

- Multiple sewer pits: connections from the surface to the sewer system
- Pipes of the drinking water laying on the outer part of the clump
- The city heating leads through this as well, taking the same direction as the rest of the cbles and pipes.

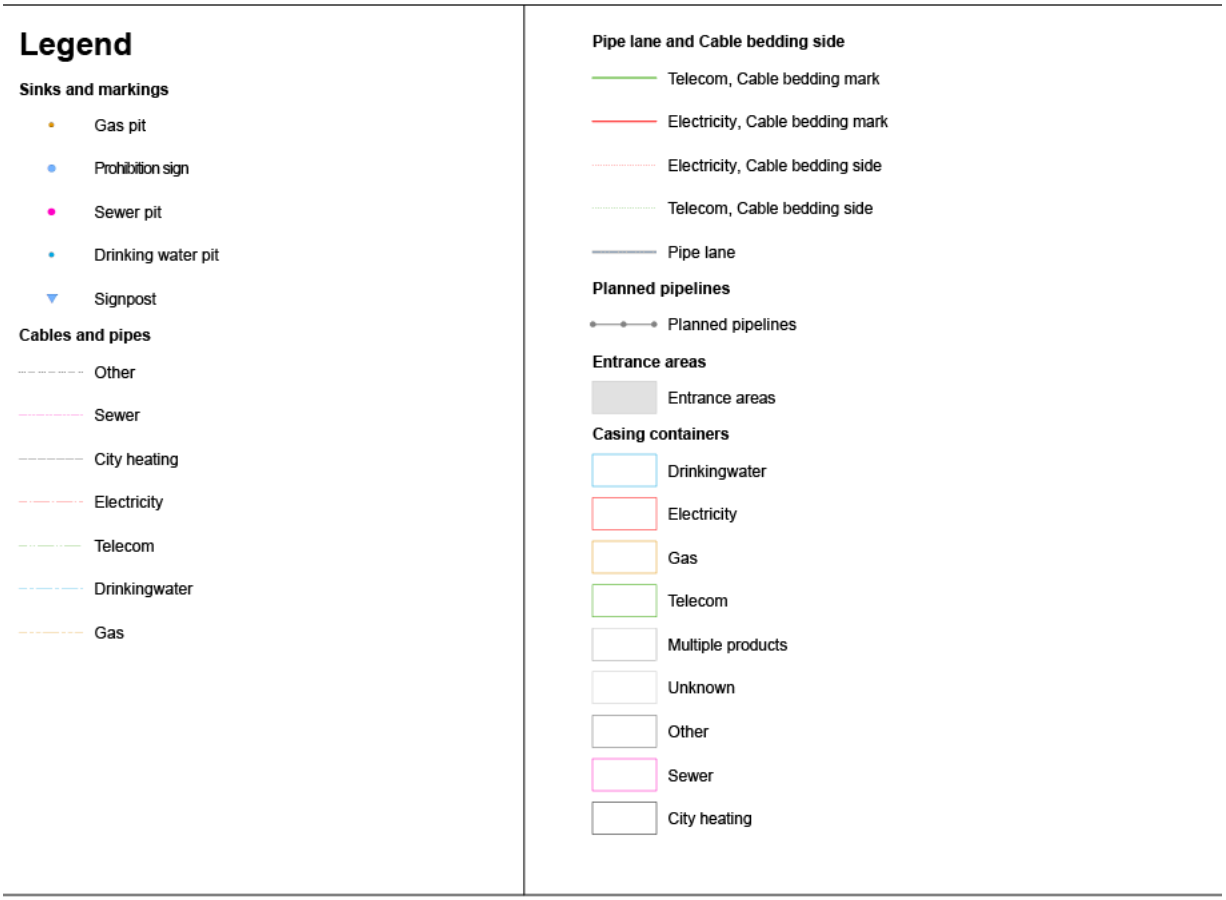


Figure 6 Legend of plot of Rotterdam central station *(Leidingenbureau Municipality of Rotterdam, 2020)*

The different requirements have led to rules that determine the location and physical aspects of cables and pipes are the following.. The requirements and laws can be divided into 4 sections: (1) Sectoral regulation, (2) Network installation regulation, (3) Norms and guidelines and (4) the coordinating role of the municipality. These NEN-norms will be iterated upon in chapter 3.1.

In this summary I show the most prominent requirements of the above sections that apply to cables and pipes, as listed by Taselaar, F. (2009) in his book.

1. The temperature of drinking water at a tapping point should not be above 25 degrees Celsius.
2. Drinking water should have a security of supply and quality. The distributing party has a obligation to supply drinking water in the area to those that request it. The latter also applies to electricity and telecommunication.
3. Contact with mechanical forces like tree roots and constructions should be avoided in order to prevent physical damages.
4. Digging damage should be prevented as much as possible by the digging party.
5. The placement of cables and pipes should be coordinated and communicated with the different parties.
6. The network operator needs to make sure that the cables carry enough capacity to provide their area of the needed electricity.
7. Transport of electricity of a voltage higher than 110 kV is the responsibility of the government, for the cross-border network the same applies for voltages above 500 V.
8. Sewer water should be collected and transported to a sewage purification plant after which it shall be processed.
9. The groundwater level should be as little as possible negatively influenced.
10. Gas, oil, warmth and salt extraction should all be done according to NEN 3650
11. There should be legal permission and communication between the parties that own the land and the parties that place the cables and pipes underneath the ground.

12. For most cables and pipes, with the exception of telecom networks, there is no national legislation about the organisation of the coordination of cables and pipes construction.
13. The government has located routes in which cables an pipes are allowed to be placed.
14. It is mandatory to record the placement of the cables and pipes which are being moved or added to the public network. (according to the WION)
15. The following cables and pipes are high risk and should be mapped:
    a. Earthgas pipes with an outer diameter over 50 mm and a pressure above 1,6 MPa (16 bar)
    b. Pipelines for transport of combustibel fluids of category K1, K2, or K3. With an outer diameter over 100 mm
    c. Pipelines for other dangerous substances other than mentioned at a. and b., of which the risk from a distance of 5 meter from the heart of the pipe is above 10^{-6} a year.
16. Pipes and cables should be safe for humans, environment and transported goods.
17. Pipes and cables should be sustainable, efficient and effective.
18. NEN norms 3650/3651, NEN 7171-1/NPR 7171-2, het ‘’ Witte Boekje’’, NTA 8000, WION, CROW, Informatiemodel kabels en leidingen (IMKL). Apply to cables and pipes but can be altered.
19. Outside physical influences should not cause a leak in cables in pipes or restrain the transport within them.

These are the current requirements, the requirements applicable to the project and their importance will be listed in the design brief.

1.3 Quantity and kinds of cables and pipes

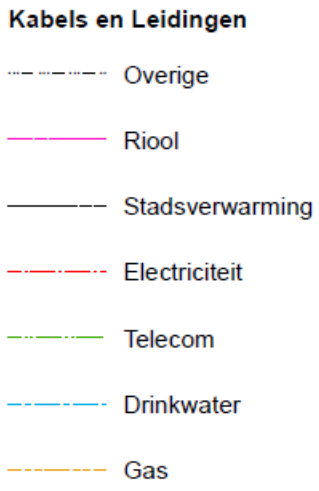
The following image from van Campenhout, de Vette, Schokker, and van der Meulen (2016) shows the total amount of meters of pipes an cables in Rotterdam. From this chart we can see that a large part of the meters of cables consist of telecommunication.

Operator	Product	M' in Urban area	M' in Port area	Totaal
Eneco	Public lighting	1.224.100	312.300	1.536.400
	Gas	1.763.100	336.000	2.099.100
	District heating	284.900	41.400	326.300
	Electricity	4.923.400	2.764.500	7.687.900
Evides	Water	1.763.400	419.600	2.183.000
Municipality	Gravity sewer	2.270.300	260.600	2.530.900
	Pressurised sewer	193.100	38.300	231.400
Other (pipes)	Gas, Oil, Kerosine, Oxygen, Nitrogen, etc	126.500	1.255.100	1.381.600
Other (cables)	Electricity	444.200	757.300	1.201.500
KPN	Telecommunication KPN	10.134.400	2.141.500	12.275.900
UPC	Telecommunication UPC	1.717.600	187.300	1.904.900
	Cable television	1.329.500	51.400	1.380.900
Remaining	Telecommunication	5.679.300	1.350.300	7.029.600

Figure 7 City of Rotterdam: cables and pipelines in numbers, length in metres. (Stadsbeheer Rotterdam, 2015)

In the legend of figure 9, shown in figure 6 we can see that the cables and pipes underneath the square in front of Rotterdam Central station consist of the following:

- Sewer system
- City heating
- Electricity
- Telecom
- Drinking water
- Gas
- Pipe strips



The drinking water also has multiple wells which are marked on the map, and the gas has multiple sinks marked as well. The sewer system has sewage pits market on the map which redirect rainwater to the sewer system.

If we zoom into different parts, we can already see that a lot of pipes and cables overlap and cross each other. Seeing this it is not hard to imagine how difficult it can be to dig into the ground in order to access certain pipes and cables for maintenance, without damaging or moving others.

Figure 8 selection of plot map (Leidingenbureau Municipality of Rotterdam, 2020)

Figure 9. Slate plot for plaza in front of Rotterdam Central Station. (Leidingenbureau Municipality of Rotterdam, 2020)

1.4 Policies and Norms

The policies that are developed for building in the subsurface, all differ depending on which sector you look at. If a network follows the rules of pipes and cables, it looks different than when it follows the rules of urban management. When all of the sectors needs and rules are combined, a large overlap and competition of space will occur. This dilemma makes it impossible for all different sectors to follow their own rules and to still have enough space for their own assets and other projects and stakeholders, and find room for other changing conditions.

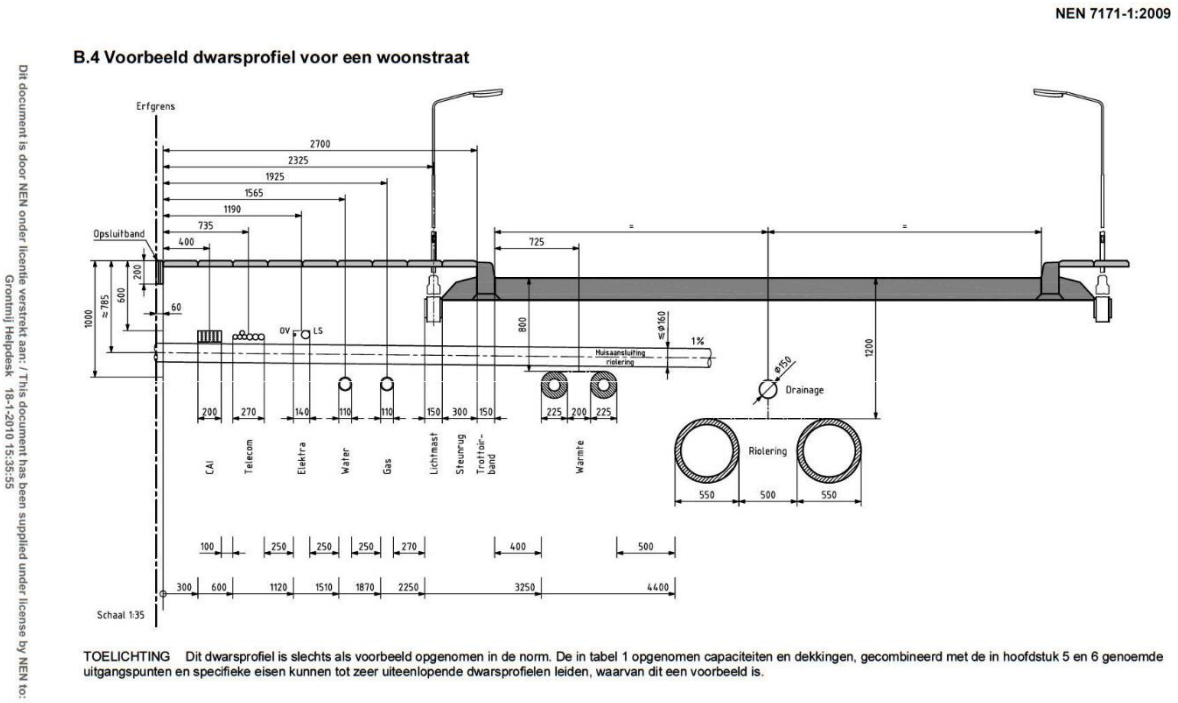


Figure 10 NEN - norms for cables and pipes in the Netherlands

Looking at the rules and laws of other sectors, we see that a lot of them work against themselves when layering them over each other. Layering all the different rules of sectors it seems like they cannot co-exists without competition for space. But looking at these rules, a lot of them seem to be outdated (according to COB, (2020b). A lot of stakeholders actually see opportunity to innovate the rules and norms in order to better cooperate. And to be more effective by combining tasks from different sectors in an integral manner.

An important law is the WIBON, that states that the digging party is always responsible for digging damage, that network operators need to register their pipes up to an accuracy of 1 meter at the Kadaster. And that for every project that includes digging in the subsurface the digging party needs to have requested a map at the Kadaster. (Rijksoverheid, 2019) This map is known under the name ‘’KLIC-meldingen’’.

Local important ordinances from the municipality of Rotterdam, that influence projects in the subsurface are

- ‘’de Verordening Beheer Ondergrond Rotterdam’’ (VBOR)
- ‘’het Handboek Beheer Ondergrond’’ (HBOR)
- ‘’de Telecomverordening’’
- ‘’de Schaderegeling Ingravingen Rotterdam’’ (SIR)
- ‘’Verordening Bodemenergiesystemen’’

The network operators themselves are independent companies that origin from public utility companies, with exception from the telecom companies. These different operators have each their own rules and regulations depending on the kind of pipes and cables they own. The different operators compete over the space of the subsurface, and usually multiple telecom companies exists in one town as they fall under the telecom law instead of the laws that apply for the other cables and pipe operators.

The laws of these operators are often mutually exclusive and make it difficult for them to interact with one another. Several stakeholders are looking into the possibilities of reformulating and rewriting the norms to make collaboration easier.

1.5 Current problems

The current most common problems that the subsurface experience when building with cables and pipes are the following, according to COB (2018):

- Excavation damage
- Digging overload
- Calamities

- Space scarcity

A lot of information is divided among different sectors who each have their own standard and database. For projects to succeed, these different disciplines need to communicate and cooperate. Or the structure and rules need to be formed in such a way that there is no other option than to work together with the space there is.

Another technical problem that reoccurs with the space scarcity is that strategic main structures, buildings and foundations get in the way of underground use of space. These concrete walls and foundations are physical hinderances.

The use of the subsurface is elaborate and doesn't just restrict itself to cables and pipes. For any solution it is needed to look at the influence of other structures (both natural as well as human made) as well. Therefore a solution could not be complete when looking at an organism for inspiration, but instead we can look at an ecosystem in order to be inspired. In an ecosystem there is competition for resources, but the organisms maintain a mutual relationship. If the rules of an ecosystem would be applied badly to the subsurface, then some functions wouldn't survive. This is not what we want to achieve. Cooperation is the key in this problem, and problems with this cooperation are both rules, norms, and language.

In any eco system an organism has their place and functions that isn't just for themselves. They feed upon sources from other plants and pass energy on to maintain life. Combining functions is one of those things that happens in nature all the time to preserve energy and space.

1.6 Previous projects

''Mantelbuizenputconstructies'' casingcontainerconstructions – this method has contributed a lot to the safety of the environment and offers a lot of construction possibilities of

the networks. Arranging, less damage and less nuisance for the civilians has been the main goal of this construction, (COB, 2017) This is a technical solution but doesn't focus on the space scarcity.

Hart van zuid – ''Hart van zuid'' is a project from Heijmans in cooperation with Rotterdam to integrate the stored water in a symbiotic system that can grow with it's environment, and carries multiple functions. This project is a good example of integrating circularity and creating a mini eco- system that will grow with it's environment instead of being limited by the space or capacity. "Using the city as a sponge", is what they call it, has multiple advantages for all of the stakeholders. The system is build to be flexible and to take global warming into consideration, and on top of that it saves time and money. Being able to do more with less digging also reduces the nuisance that the civilians often experience, and makes risks less likely, as the ground is less often disturbed. It integrates the multiple water stakeholders and puts them into the same system, forcing them to work together on a single cycle. Diender, H., & Heijmans. (2020). This project has been focussing on sustainability and cooperation, showing a good example of symbiotic construction.

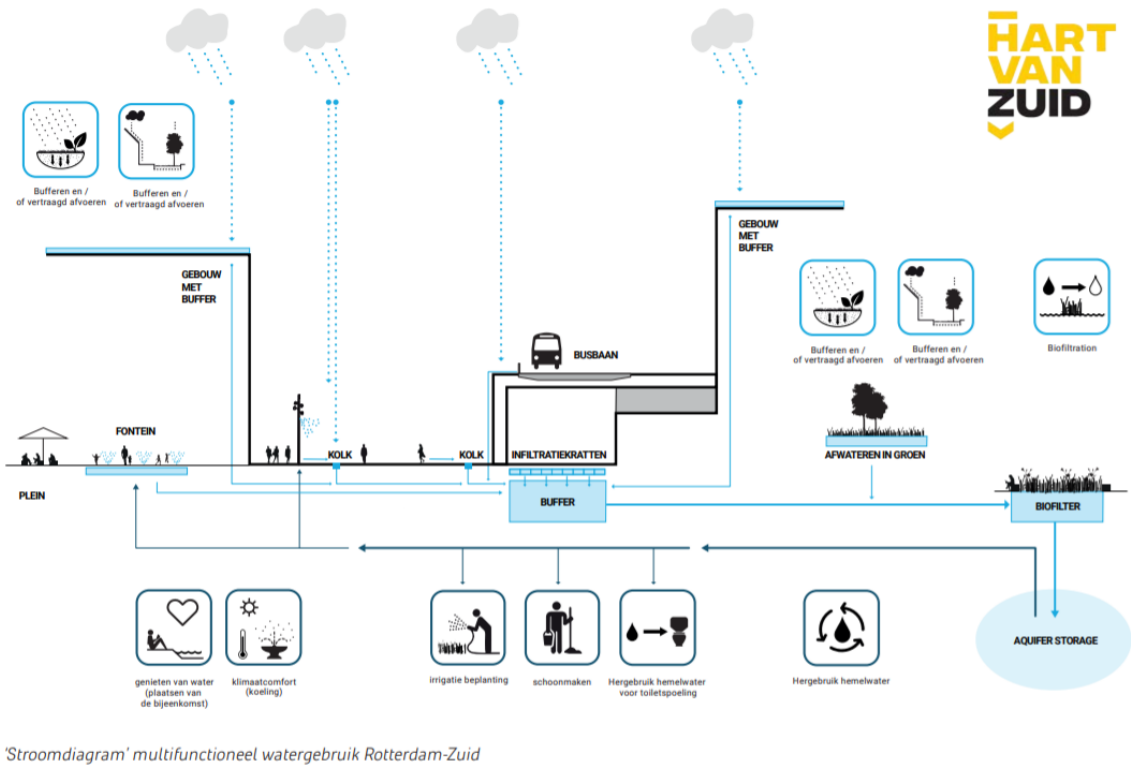


Figure 11 Overview project ''Hart van zuid'' (Heijmans, 2020)

<u>Language in urban and subsurface planning</u> - According to van Campenhout et al. (2016), the biggest problem with organizing the subsurface is the communication between different disciplines. Each of them have a different way of keeping information, and each in a different format. When information is transferred from one sector to another, part of it is lost in translation, as different terms are being used. This research shows that communication within the subsurface is difficult between stakeholders.

<u>Ontsluiting Bio Science Park (OBSP)</u> – Gonlag, F. et al. (2017, January). The municipality project team has developed a new cooperation concept in this project for cables and pipes in the bio science park. In this concept cooperations and stakeholders had to communicate

for the shifting of cables and pipes. Integrating this cooperation has reduces risks and made the execution of the project faster and safer than the traditional method. The fast execution minimalized the nuisance for the civilians, and the cost reduction made it worth it for the stakeholders. This effective management also caused for a lot of clarity and effective scheduling in the organization. The project has put the following as recommendations when applying the same management for similar projects:

Preparation:

1. Make sure for continuity in the persons that are participating in the teams of the stakeholders.
2. Spend enough time on the preparations.
3. Involve the network operators in an early stage.
4. Weigh the different interest of the participating parties.
5. Be unambiguous about the responsibilities and tasks of the parties involved, and record it on black and white.
6. Assign tasks and risk to the parties that are best in managing it.

Project itself:

7. Involve the replacement of cables and pipes as an integral part of the main challenge.
8. Make sure that network operators agree with the cables and pipes trace plans before they register.
9. Make the tracing plans discussible during the tender phase, with as much direct contact as possible.

10. Make technical coordination with the network operators mandatory in the design- and execution phase, by stating it in the contract with the contractor.
11. Guarantee integrality, a 3D model could provide a helpful tool for this.
12. Tune in periodically between client and network management about design resolutions and overlapping area's with the cables and pipes to guarantee quality.

This project and research is a good starting point of advice regarding cooperation, but doesn't address other technical issues in the subsurface.

Integrating biomimicry in urban planning. In a Thesis by Snellen, B. (2019), the possibilities of biomimicry in the urban organization has been researched. The research shows the value of using biomimicry as a planning approach in both it's complexity and sustainability. The problem with using this approach was that it is very new method, so the outcomes are all based on assumptions and hypothetical situations, especially on an urban scale.

According to Lee (2017), decision making with biomimicry might be hard as it lacks a solid cause and effect base that is often vital for rational decision making. Adding to that the amount of time it takes to analyse adaptive systems, engineers are not always fond of using biomimicry in their project, especially not on a larger scale like urban planning, where the consequences can be elaborate. This research shows that biomimicry has potential in urban planning, but still has uncertainties.

The Bio-brainstorm work sessions that got introduced at SWECO showed how to bring multiple fields together for problem solving from a biomimicry perspective. In this project a

group of participants of multiple fields work together on a problem by integrating biomimicry together with a biomimicry expert to lead the session. Lesson learned is to involve more knowledge from more fields in order to prevent mistakes and miscommunication. This project also showed a new interest and willingness in different fields for biomimicry. (SWECO, 2020b)

Vol onder Maaiveld

In 2019 and 2020 14 municipalities, with Amsterdam and Rotterdam as initiators, started a process called Vol onder Maaiveld. They asked the Bouwcampus and the COB to organize an innovation challenge to come up with solution for the crowded subsoil. 7 innovations were presented at the Flexival(spring 2020). Among them was Biomimicry, but also very practical solutions such as a clickable framework for cables and pipes (VKLS, ONGOING) and several planning solutions using algorithms. These solutions were all focusing on the space shortage, but didn't include other technical or organizational problems. (COB, 2020c)

Chapter 2: Stakeholder analysis

For this stakeholder analysis two tables will be shown, one containing the stakeholders from cables and pipes and the following from all the stakeholders concerning the subsurface. The space issue doesn't just concern the cables and pipes but also the other involved parties that are competing for space underground.

The WIBON that is previously mentioned is set up by the National government, and sets up different laws regarding the building in the subsurface that assigns responsibility to different parties.

2.1 Stakeholders cables and pipes

The stakeholders of cables and pipes all have a different relation to the problem, and are each active in a different stage, from regulations to execution. The largest directing role is usually pointed toward the municipality. The division of tasks and responsibility makes it difficult to have all of the stakeholders following the same direction. The relation to the problem listed in the table below describe this role for each stakeholder, the demands are the requirements for each of them, what they are most interested in. Sources used for this table are COB, & Boonsma, E. (2019), COB (2018) and from an interview with Henk van der Maas of the municipality of Rotterdam. This interview can be found as Appendix A. The responsibility and demands on different fields is sourced from Kovács, W. (2014).

Stakeholders cables and pipes		
User/stakeholder	Relation to problem, Function	Demands
Higher government ➢ **Legislator**	• Laws • Determining conditions that have to be met • Requirements • WIBON-law • ARBO-law • Environment law	• Safety • Levelling the playing field
Local government ➢ **Municipality of Rotterdam** ➢ **Mayor and Aldermen**	• Visionary role • Guiding role • Facilitating role • Assessing role • Executive role • Directing projects • Issuing permits	• Sustainability • Integrating Biomimicry • Safety for people and environment • Representing citizens • Accessibility of the city • Communication • Security of supply

	• Ordinances: VBOR, HBOR, telecomverordening, SIR, bodemenergiesystemen etc. • Responsible and supporting decision making.	• Organisation
System/Network operators (netbeheer) ➢ **All independent (non-governmental except for sewer system)**	• Supporting role • Initiating role • Facilitating role • Executive role • Legislation • Numerous different owners depending on the situation	• Quality • Safety • Economic benefit • Formal public utility companies • Telecom more free • Private interest
Operational parties ➢ **Contractors (uitvoerende partijen)**	• Supporting role • Initiating role • Guiding role • Physical execution of the project • Responsible for digging damage	• Clear instructions • Communication • Risk management
Workers	• Redirecting traffic • Maintenance (without damaging other pipes/cables)	• Safety • Accessibility
Residents and passers-by	• Nuisance experience • Traffic hinderance • Sound nuisance • Damage result hinderance	• Comfort • Security of supply • Safety

2.2. Other stakeholders subsurface

The subsurface doesn't consist of only cables and pipes, but also of numerous other stakeholders that want their own piece of space in in the underground. Often the governing and policy making parties of the different sectors only share or exchange limited information. (COB, & Boonsma, E., 2019). This causes regional differences in rules and approaches. The relation to

the problem in the table below describes the role of each stakeholder in the subsurface, the demands show the specific interest they each have.

The data in the following chart comes from COB, & Boonsma, E. (2019), COB (2018), and from an interview with Henk van der Maas of the municipality of Rotterdam. This interview can be found as Appendix A.

Other stakeholders subsurface		
List of other stakeholders in the subsurface	Relation to problem, Function	Demands
Higher Government ➢ **Provinces**	• Legislations • Local agreements	• Making sources available • Making use of waste and earth heath
Higher government ➢ **Water authorities**	• Flooding • Water storage • Drinking water • Sewer system management	• Responsive actions to global warming • Water storage • Rainwater to manage heat • Drinking water facilities • Preventing water damage
Local government Municipality of Rotterdam	• Sewer • Water storage • Fibre optic network	• Voice of the citizens
Green planning	• Space for tree roots that can grow • Sustainability • circularity	• Space for global warming projects. Protecting against forces of nature • Responsible use of nature
Urban construction	• Concrete parking space • Foundations • Cellars/basements • Waste storage • Underpasses • Koopgoot (lower surface shopping center)	• Growing space demand, urbanisation (growing density) • Strong ground to support structures • Accessibility in important places

	Infrastructure	• Tunnels • Subway • Trains and busses • Mobility • RET (subway tubes)	• Space • Fast connection to surface infrastructure
	Harbour area	• Transportation pipes and tubes	• Security of supply • Accessibility

Chapter 3: Function analysis

The function analysis is divided up into the technical functions described by the official NEN norms, as well as a biomimicry taxonomy to describe the functions of cables and pipes in the subsurface in broader terms.

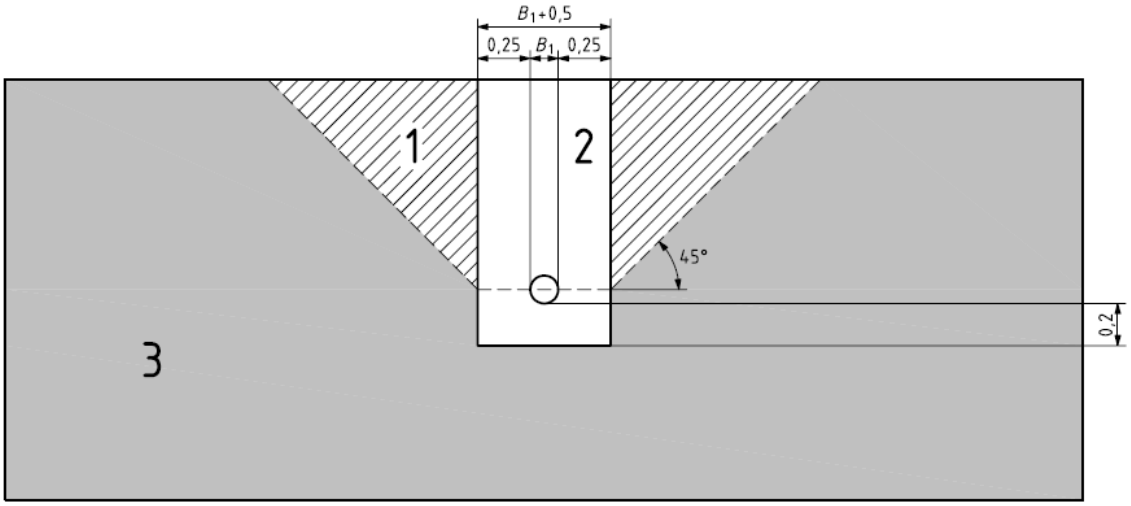
3.1 NEN 7171-1

Nen norms are the official technical norms that physical objects should be designed towards. It are the technical requirements put into a set of rules based on safety for people and planet, and to prevent accidents. It aren't laws but they are agreements on international and national levels, governments and markets use the norms when using them for clarity and trust between parties. (NEN, n.d.)

According to the NEN, contact with sharp objects and waste needs to be avoided with the outside of the cables and pipes. Contact with other mechanical forces like tree roots and constructions should be avoided. The following table is an overview of the NEN norms of cables and pipes and their placement in the subsurface, regarding to their distance from each other, location and temperature.

	Temperature	Distance to other cables and pipes	Location

Electricity cables.	< 40 Degrees	No bundling with each other unless permission	Closer to surface near street cabinets and technical buildings.
		Next to gas < 25 kV 0,30 m	
		Next to gas > 25kV >5 m	
Telecommunication and CAI cables	< 40 Degrees	Copper core, Hybrid core, LS-Cables: 0,50 m each other	
Sewer pipelines	< 40 Degrees		Underneath the middle of traffic lane
Water pipelines	Drinking water: < 20 degrees		Coverage of 800 mm tot 1000 mm to protect against frost
	Rest: < 40 Degrees		
Warmth pipelines	< 40 Degrees	A layer of sand of 200 mm	Coverage of 700 mm tot 1000 mm as counterpressure to expension
Gas pipelines	< 40 Degrees	Next to electricity < 25 kV 0,30 m	
		Next to electricity > 25kV >5 m	



Figuur 2 — Gebied waarin speciale maatregelen moeten worden getroffen om verspreiding van gas bij lekkage tegen te gaan

Legenda

1 Gebied waarin wel speciale maatregelen moeten worden getroffen
2 Gebied waarin geen andere kabels en leidingen mogen liggen
3 Gebied waarin geen speciale maatregelen moeten worden getroffen

Figure 12 NEN - norms for cables and pipes in the Netherlands

3.2 Biomimicry taxonomy

A biomimicry taxonomy translates all of the above technical problems into biological terms. This way the biological terms can be searched upon through organisms, ecosystems and behavior. Which on their turn gets translated to technical terms through a Nature Tech Summary (NTS). This way it is possible to boil a complex problem down to it's inherit function.

So what if we look back at why the pipes and cables are actually underground. What is the function of storing the cables and pipes there and what is the function of the cables and pipes itself? In all cases the function of cables and pipes is transport. To distribute and expel gas, water etc. or to send and receive information in the case of the telecommunication.

These are the functions of the cables and pipes, which each carry a different substance or different information. So now what is the function of the subsurface in this matter? This can be dissected into a few biomimicry taxonomy functions.

1. Stay put – to store the pipes and cables and make sure that they stay in one place
2. Protect from physical harm – the ground protects from
    a. non living threats (chemicals, frost etc)
    b. structural forces (impact, compression etc)
    c. structural failure (deformation, fracture, etc.)
3. Maintain community - to manage disturbance in a community, the cables and pipes are out of sight of the civilization, except during the maintenance (when nuisance occurs)

Chapter 4: Trend analysis

Looking at the subsurface we have to look at the future and see where technology, nature and society is heading. Are cables and pipes actually necessary for future technology? Or will they become unnecessary in energy, substance and information transport? It is never certain what the future may hold, but taking unexpected or expected chances into consideration with designing is important in building an adaptable network.

In the research of KPMG (2016) about the UK gas networks there are four scenario's for energy and particularly heat demand and distribution in 2050. In two of those the gas distribution network is not used, in one only half of the network is used and in the last the network is repurposed for a different type of gas.

According to COB, & Boonsma E. (2019) the underground network is going to experience development for the following: energy transition, climate adaptation, ongoing

urbanisation and expansion of 5G, and therefore needs to adapt to be able to fit in the system. The development in regards of amount, space and technology that pipes and cables will experience cannot be quantified yet, and the poor insight in that future makes anticipating it difficult. This makes choices hard as they have to be made without a full understanding of the consequences. It makes communication between sectors even more important, since communication is necessary to be able to adjust to changing conditions.

The advantage of looking at nature as inspiration is that ecosystems are flexible for changes. The balance will be retained over the long term. Damages and changes that are made will be integrated or restored in the system. Harmful substances will always be broken apart and destroyed. Surfaces will repair itself as long as the time to do so is provided.

The opportunities for electricity storage will rise to 2050, and gas will be used when there is a low electricity production from sun and wind energy. Hydrogen is an energy source that is made out of the excesses of sun and wind energy, and has potential in playing a big role in the future. It is important to combine it with the sources of sun and wind energy in order to keep it sustainable.

The one thing that reoccurs with all future scenario's is that the demand for electricity transport will grow. Expanding the network is necessary for this, meaning that the space this will take up will grow in the future. (COB & Boonsma, 2019) The energy transition to more climate friendly sources will highly depend on the space problem that will grow with the urbanisation and population density. This energy transition will cause major changes in the subsurface infrastructure, and so the subsurface needs to be prepared to combine functions or make space for it in order to become sustainable.

In order to anticipate the changes caused by the global warming, structural changes and additions need to be placed in urban area's as well. Causing for more space scarcity in the future in order to protect ourselves from the forces of nature.

Chapter 5: Problem definition

Using the research it is possible to form a problem definition that boils down the problem needing a solution to a single sentence. The concept of this problem definition is that if all the stakeholders listed at the stakeholder analysis are defined by a single solution that works according to the functions mentioned in the function analysis, that the organisational problem will also be partly solved. This problem definition includes the biggest problems that overlap with the stakeholders in the subsurface up to 5 meter in depth based on the literature reviews and read as follows.

'' How to reorganize the underground cables and pipes of Rotterdam in a way that it can be flexible in functions without taking up more space, and make maintenance itself easier and safer (for the operational parties) and cause less nuisance (for the residents).''

Problems that occur with cables and pipes underneath the city are both on operational and tactical level. Meaning that there are both problems with organizing the system between stakeholders, as well as physical problems when trying to build said systems. A number of problems are:

- Excavation damage
- Digging overload
- Calamities
- Space scarcity

These big problems concern all the stakeholders, and cause different problems depending on the stakeholder. As these are the sources of the problems these should also be addressed accordingly, hence they are included into the problem definition. Excavation damage to ‘maintenance easier’, digging overload to ‘cause less nuisance’, Calamities to ‘and safer’ and space scarcity to ‘without taking up more space’and ‘reorganize the underground cables and pipes’.

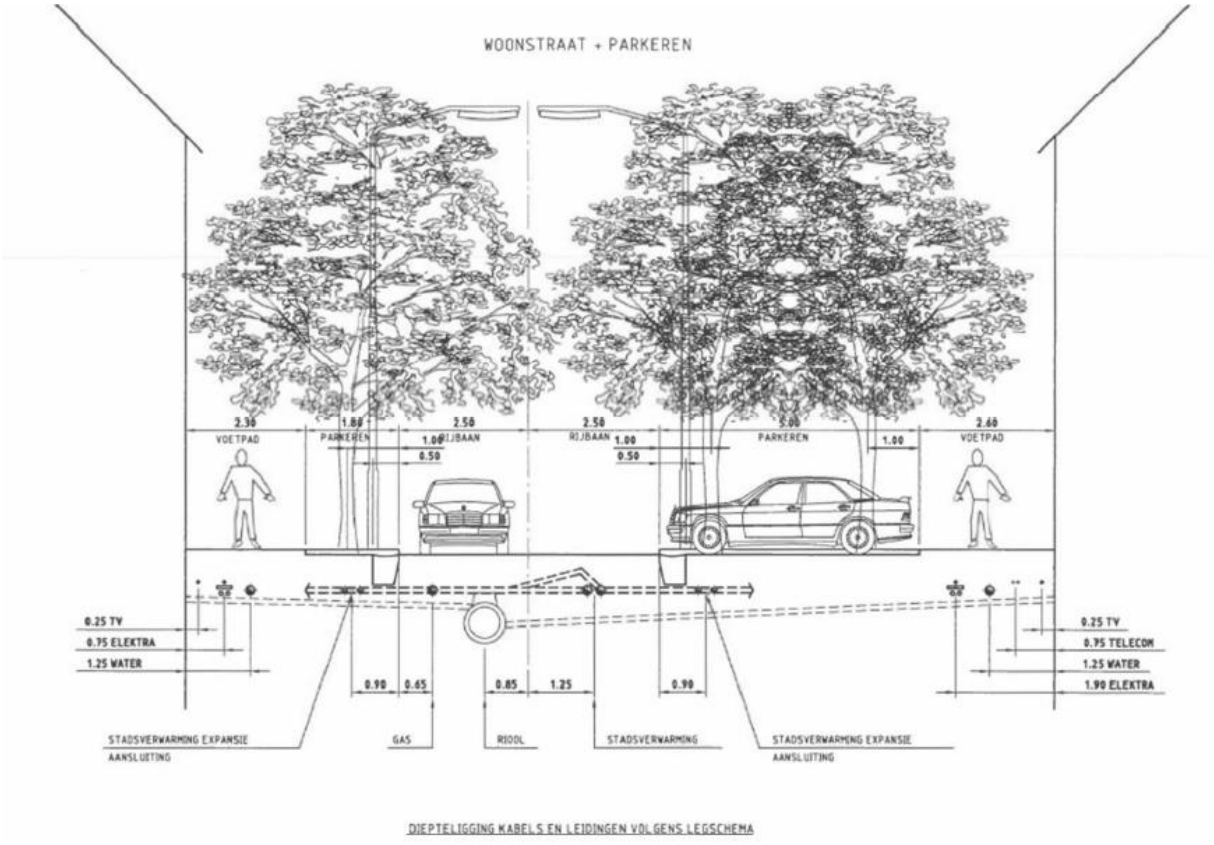


Figure 13 NEN - norms for cables and pipes in the Netherlands

Life principles are tactics from nature that we can learn from. The solutions that can be found in nature can each be connected to one or more of the life principles. Designing with these principles in mind can help to set up an ideal based around the fundamentals that life needs to live.

Life principle connected to this problem:

1. Use low energy processes
2. Cultivate cooperative relationships (on an organisation level with the different stakeholders)
3. Maintain integrity through self-renewal (reducing the amount of maintenance)
4. Self-organize (competition for space)

Figure 14 Biomimicry 3.8. (2016). DESIGNLENS: LIFE'S PRINCIPLES

Chapter 6: Nature Tech summary (NTS)

A nature tech summary (NTS) is sort of a translation from biology into technology, it takes an organism and explains it into blocks for methods and functions. Explaining how and why an organism, system or behavior works the way it does. This way a part of an ecosystem can be looked at and compared with the current cables and pipes.

6.1 NATURE'S TECHNOLOGY SUMMARY | (Fungi)

Contact*: Emma de Bloois

Natural History*: Habitat and background information about organism or technology. Mushrooms can be found everywhere during autumn, they appear out of nowhere popping out of the ground and feeding on dead material. In a forest they are part of the core of the ecosystem, decomposing dead material and making it possible for the cycle to start anew. Their function is completely unique to the fungus species, and it is an organism that can be found in a lot of different ecosystem. The mushrooms themselves are only a small part of the organisms, as most of it exists underground, hidden from sight. Molds and yeast are also part of the fungus family, usually being too small to see by the naked eye, unless a large colony of them have formed. In an ecosystem, fungi are more related to animals than plants, and do not synthesize, and their main mode of transportation is growth. This causes them to stretch out to large parts underneath the forest.

Function*:	Garbage eaters, converting dead material into food and transporting it
Strategy*:	Mycelium structure transports resources throughout the ecosystem, changing direction and storage.

Champion*:	Fungus – Eumycota The larges organism on earth is a single fungal structure that spreads across 3.8 km across Oregon. This species is called the honey mushroom, or Armillaria Solidipes
Other Champions:	Ectomycorrhizas / mycorrhizal fungi – is a symbiotic relationship between fungi and tree roots, where the fungi exchanges nutrients and water with trees, most commonly pine and birch trees, without harming the roots. (Soares, 2019)

Description Text*:

The ecosystem in most forests and rainforest have fungus as their cleaners of dead material. This group of organisms has a large role in not only getting rid of waste material, but also in transporting nutrients and water through an intricate system underground and exchanging it with other organisms like trees. The growth of mushrooms pushes through the dirt and makes a path for other plants to access water, the same way that tree roots do.

Microcolonial fungi are very adaptable to extreme conditions, as well as having a high resilience because of their decentralizations. Fungi can adapt their metabolic activity, structure and tactics depending on changing conditions.(AskNature, 2016) Certain species can create protective coatings, skins and shells to protect from extreme weather conditions. Some fungi can ‘’pause’’ their metabolism during hard periods until favourable conditions reappear. Others can replace dead cells internally with new buds, regrowing as the outer layer dies off. Rock fungi can dig themselves into crevices by forming filamentous hyphae, that extend and slim down to fit into small spaces.

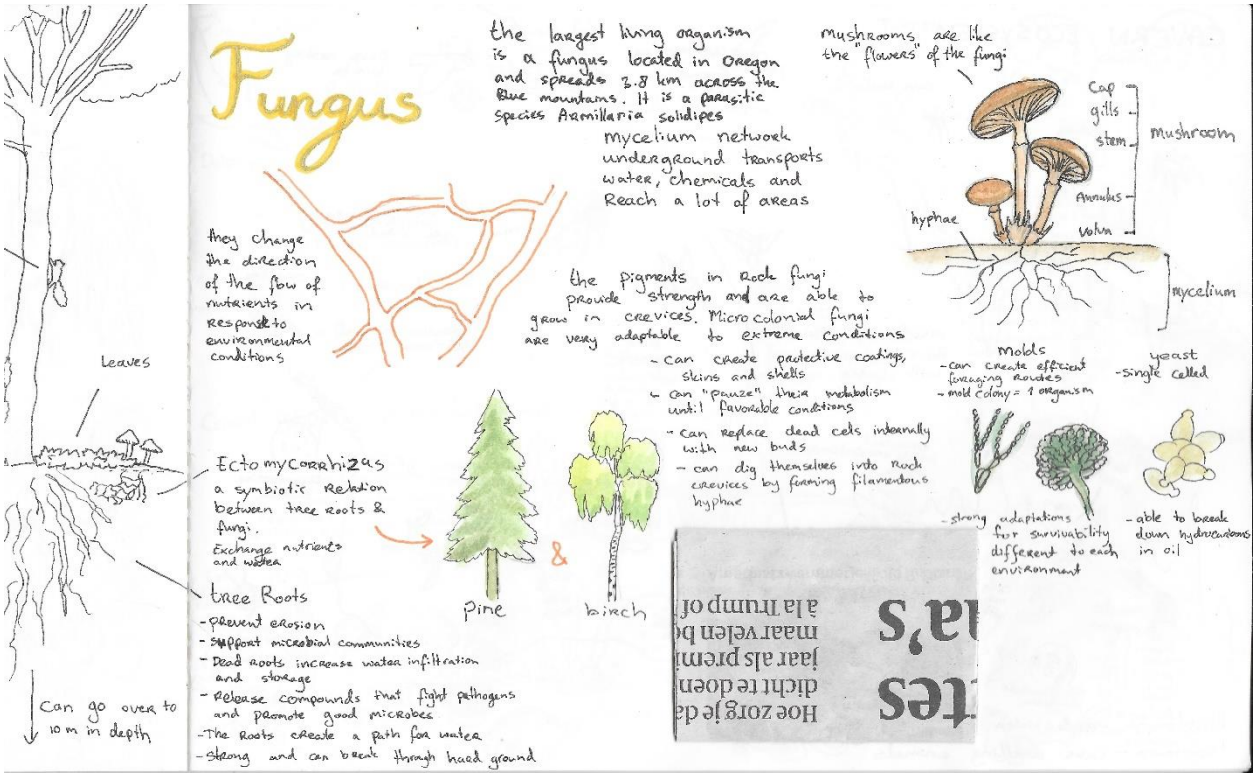
Smaller fungi like molds and yeast have similar adaptations to each environment. Yeast is unique in the sense that it’s single celled, but it has the ability to break down hydrocarbons in oil. Mold spread out in what seems to be very efficient foraging routes. Covering the places with most nutrients to convert.

The process of changing directions of transport is possible as the hyphae inside the mycelium lacks the dividing walls called aseptate within its structure. Making transport to each direction possible. (Whiteside et al., 2019, p. 61)

Succinct summary of the strategy and mechanism:

Fungus can extend in large colonies, raising their survivability by adding numbers. The mycelium of mushrooms is an intricate structure that is able to change the direction of the flow of the nutrients, in response to the needs and environment. (Whiteside et al., 2019, p. 61) It takes out phosphorus and nitrogen out of the soil and microbes helps plants to access water. (Soares, 2019) The fungus exchanges resources in times of scarcity with not only within itself, but also with tree roots. The distribution of resources through the hyphae (the vessels of the mycelium) can adapt in speed, distribution and storage.

Organism Mechanism Image 1:

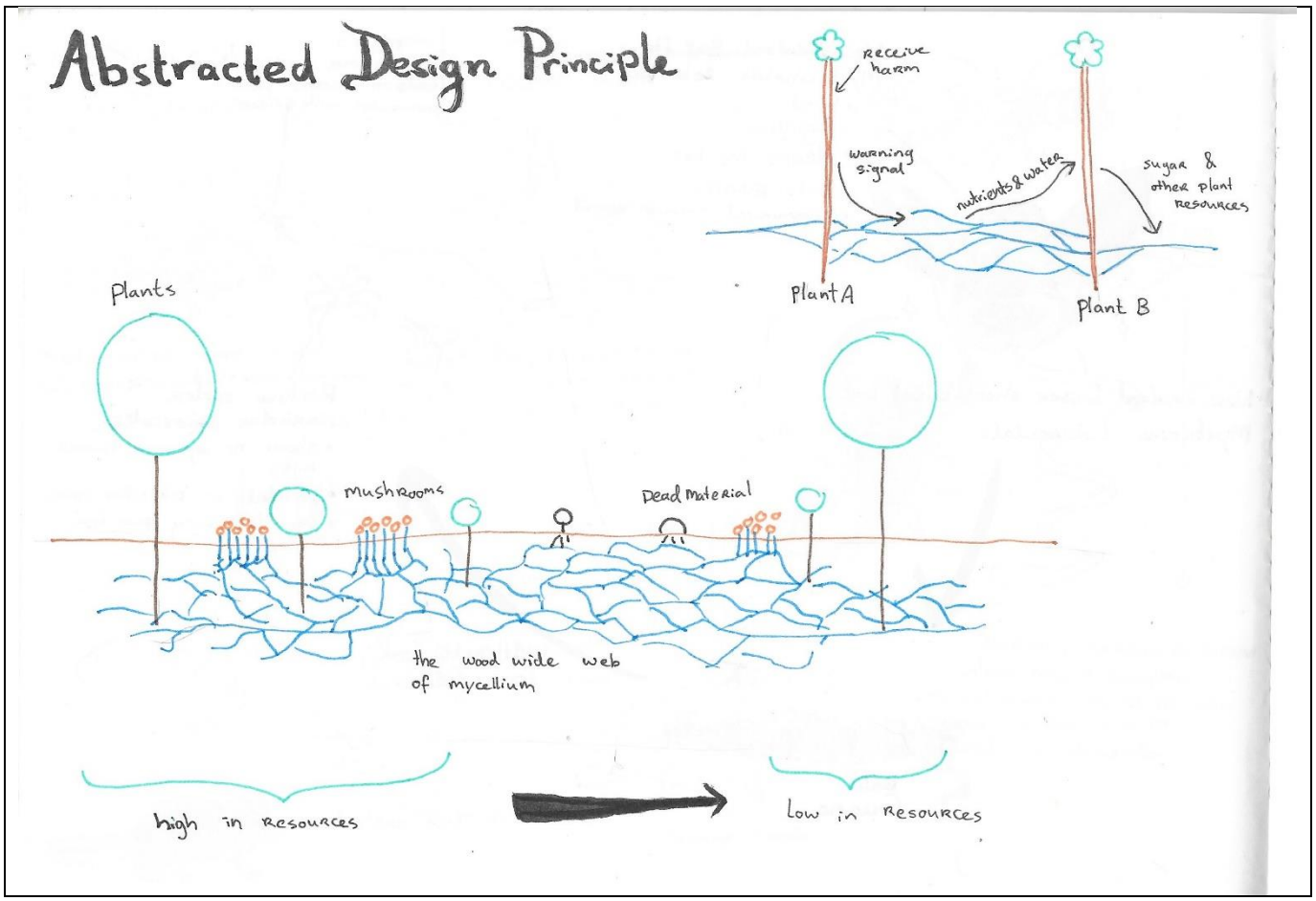


Abstracted Design Principle

Vibrations cause for resources to be transported over an intricate system that covers the entire ground that provides those resources, and can change direction depending on which part is lacking these resources, also providing them to the rest of the system through contact with other parties.

Abstracted Design Principle Image(s):

Fungus grow in size in order to move from one place to another. This makes it possible to gain resources over the entire length throughout which it moves. The movement and placement of the fungi also helps other plants to access their own resources, by loosening ground and providing a path. Attaching to other plants through their roots, the fungi is able to transfer and extrude resources throughout their surface. The fungi lives on resources provided by dead materials and waste from the ecosystem above ground.



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Research Excerpts

'' *Fungi responded to high resource variation by: (1) increasing the total amount of phosphorus distributed to host roots; (2) decreasing allocation to storage; (3) differentially moving resources within the network, from rich to poor patches.''* . (Whiteside et al., 2019, p. 61)

"what really distinguishes the fungal world is its diversity and complexity. A spoonful of soil contains more microbial individuals than there are humans on Earth. "It's the most species-dense habitat we have," said Edith Hammer, a soil ecologist at Lund University in Sweden. A single plant might be swapping molecules with dozens of fungi — each of which might in turn be canoodling with an equal number of plants.'' (Popkin, 2019)

6.2 NATURE'S TECHNOLOGY SUMMARY | (Cavern)

NATURE'S TECHNOLOGY SUMMARY | (CAVERN)

Contact*: Emma de Bloois

Natural History*: The ecosystem of Caves surround around plant materials that are brought inside. One of the main sources of life and activity happens around the high in resources excrements of the bat. This Guano functions as a fertilizer for fungus and underground life and bacteria. And is a source for insects to live and eat, which on their turn provide a food source for bigger creatures.

Function*:	Cultivate cooperative relationships between different species
Strategy*:	Cave spiders form a cooperative relationship with bats and mites.
Champion*:	New Zealand bat fly (Mystacinobia zelandica) & New Zealand lesser short-tailed bat (Mystacina Tuberculata) Recluse spider (Sicariidae Locosceles) & Mites (Callidosoma Cassiculophylla)
Other Champions:	Amazon Frog (Microhylid Chiasmocleis ventrimaculata) & amazon tarentula (Theraphosidae Pamphobeteus) Peaceful Cohabitation of otherwise prey and hunter. The spider protects the frog that it can recognize by the chemicals on its skin, and the frog eats parasites keeping the spider healthy. (Tomasinelli, 2013)

Description Text*:

The mites live on the spiders web and eat food together with the spider, the bats feces (guano) attracts insects that the spiders feed on. (Bernardi et al., 2017, p. 458) The spider doesn't show any aggression towards the mite, and lets them stay permanently in their home. The benefit to the spider is unclear, but according to Bernardi et al. (2017) there is a symbiotic relationship between the mite and spider. By their test they placed moths in an environment with the spider and mites, where the spider killed the prey, and later the mite would join the spider in eating the prey. The mites did refrain from eating any invertebrates that got caught. The experiment did not confirm nor deny that the mites located the prey by the vibrations of the web. The size of the mites (0.14 by 0.08 cm) could contribute to the spider (approximate 5 cm) not viewing the mite as either competition or prey, according to Robert Pape from the University of Arizona Insect Collection in an article by Malhotra (2017).

In new Zealand a certain bat species and the wingless ''New Zealand bat fly'' live in a symbiotic relationship as well. In contrary to other batflies this one does not suck the blood of it's host but eats access and guano instead. (Hunt, 2016) The blind and flightless batflies seem to communicate with the bats by a high pitches sound that the bats are able to pick up. The bat profits from this as the little creatures keep their fur clean, and the bats provide a warm habitat and food.

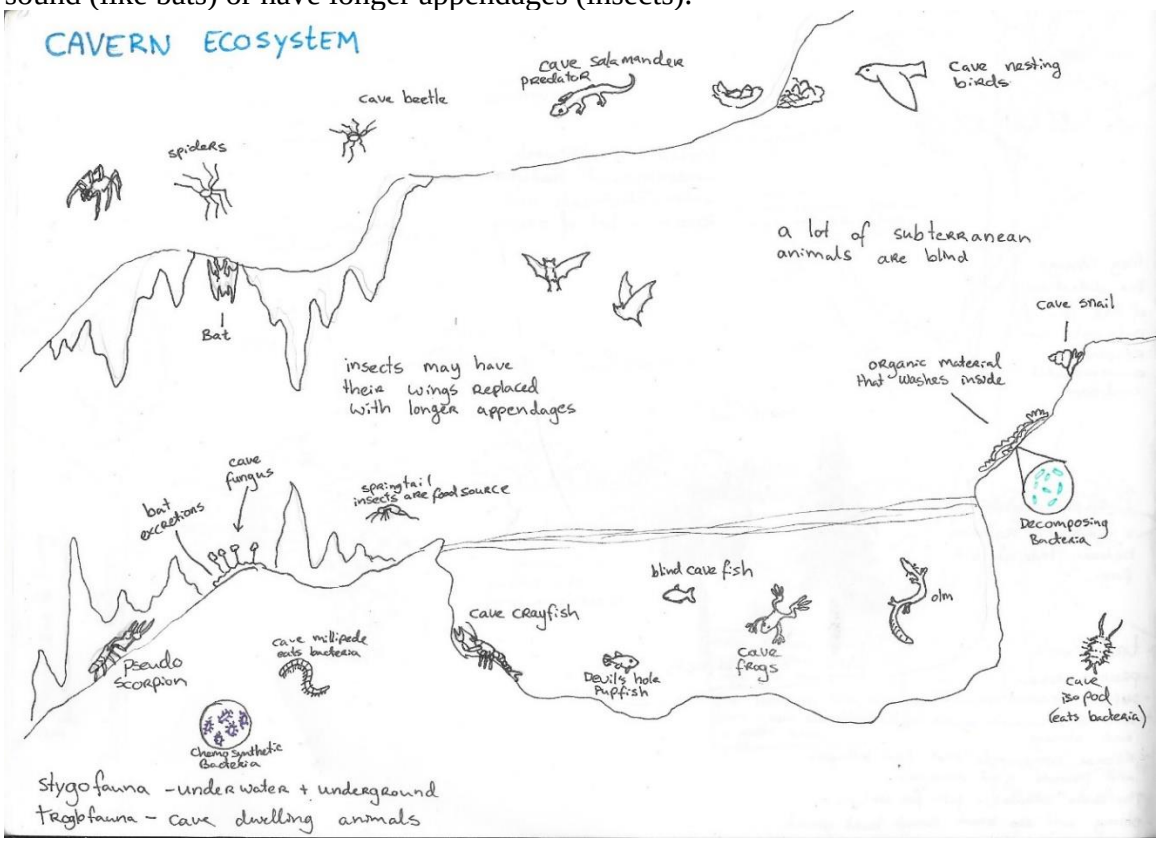
As most of the creatures in caves are either blind or have bad eyesight, a lot of communication is by touch or sound. Bats have echolocation with the batflies use to emit a high pitched sound, and creatures are covered in hairs and posses long limbs to feel around for their environment.

Succinct summary of the strategy and mechanism:

Bats use minimal communication to benefit from the cleaning properties of the blind and flightless flies that live on their fur. High pitched noise makes bats aware of their presence (Hunt, 2016). The bats excrements make for a highly attractive environment for insects. These insects are prey to spiders such as the recluse spider (Bernardi et al., 2017, p. 458) that share their web with mites that also eat from their caught prey. The lack of any threat or big enough size communicates to the spider that they are harmless and thus does the spider not attack them. (Malhotra, 2017)

Organism Mechanism Image 1:

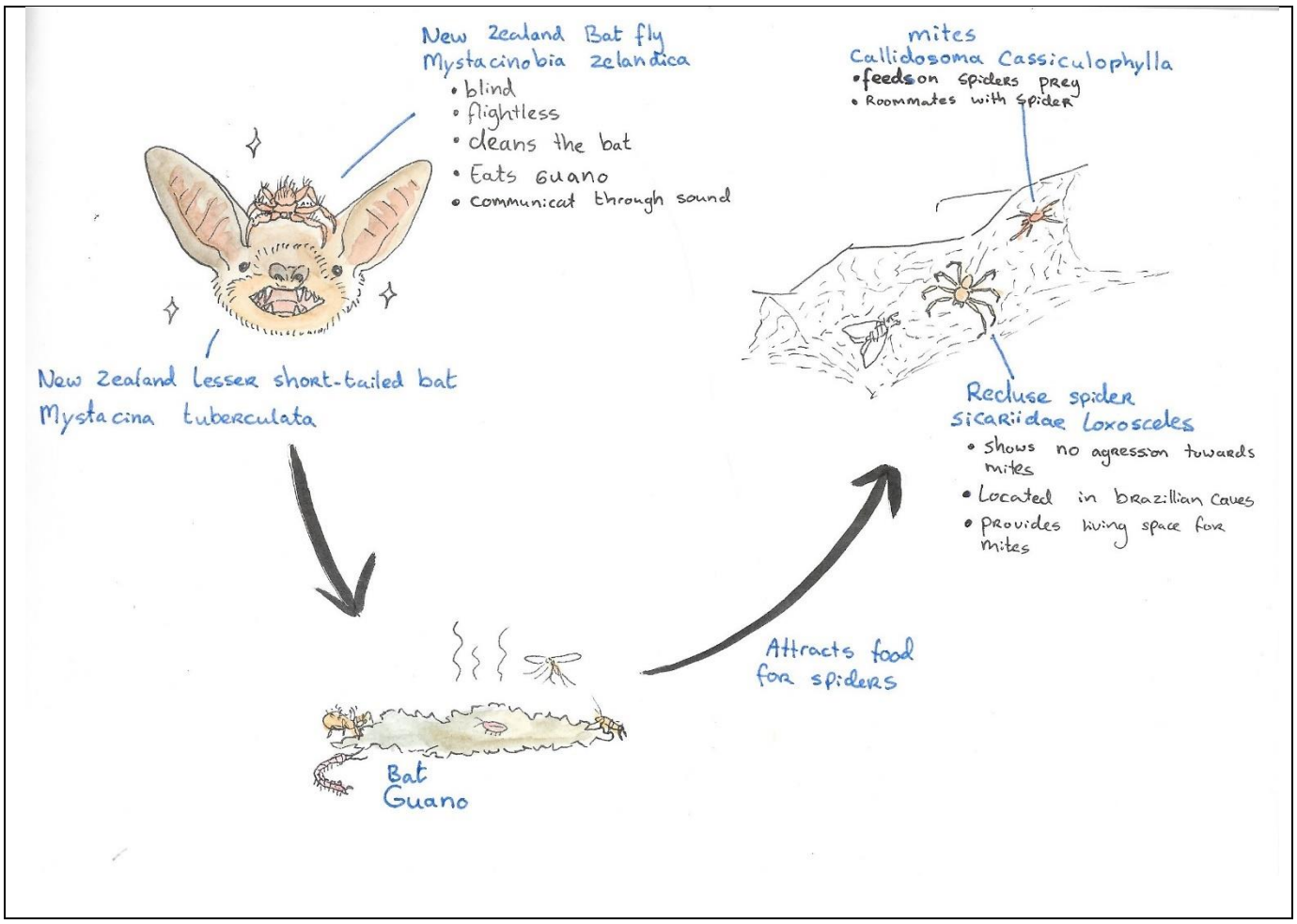
The communication in the ecosystem of a cave is dependent on other senses than sight, as most of the animals are blind to the lack of sunlight. This has caused organisms to grow more sensitive to sound (like bats) or have longer appendages (insects).



Abstracted Design Principle

Communicate intentions and cultivate cooperations through senses other than sight.

Abstracted Design Principle Image(s):



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Research Excerpts

"The mites are too small to be useful prey for the spiders, and are not large enough to be a potential predator," says Pape. "I suspect the spiders are not adversely affected by the small amount of nutrients consumed by the mites." (Malhotra, 2017)

''Now given that a bat's diet included insects as well as nectar, fruit and pollen, Bev was led to consider whether a succulent batfly might not be a tempting proposition; yet she'd found no digested batfly remains in the mountains of guano she'd trawled through. Could it be that a big male batfly's job was to "yell" a warning to remind bats to tread carefully around the batfly colony and resist the temptation to nibble its residents? Bev thought so. At the same time, the hefty lookout was probably telling its fellow batflies: "Stand clear. Big clumsy warm-bloods coming through.'' (Hunt, 2016)

Discussion

From the analysis it is clear that a lot of different stakeholders have different interests that don't always overlap. Picking those things that do overlap and making them possible for the stakeholders to accomplish, could provide a solution on itself. An organism usually doesn't change in functions the way that each area in the subsurface has different and shifting

stakeholders. Therefor it would make more sense to look at the subsurface as an ecosystem with cables and pipes as a part of it.

The research has put into perspective the two main problems: communication and space scarcity. With those two resulting in a lot of other large issues as well, like digging overload, excavation damage and calamities. Projects that have tried to combine stakeholders and improve stakeholders have done so to limited degree by only looking at one of the two problems, except for the symbiotic project 'Hart van Zuid' that has proven to be successful.

What hasn't been proven by this research is the effectiveness of biomimicry in the subsurface. This is due to a lack of practical applications and thus it is not possible to know the results of the application of biomimicry in the subsurface urban planning yet.

The nature tech summaries bring forth 2 different perspectives on this: one is about an underground system that changes and stretches out, the other talks about communications between species that usually are not found together.

Conclusion

'' What are the current organisational problems and technical requirements in the underground up to 5 meter depth of the square in front of Rotterdam Central Station that have the greatest impact, and which organisms or ecosystem can lead as an inspiration for cables and pipes to solve the current and future space shortage.''

The answer to the main question is that a lot of different stakeholders each have their own rules that don't overlap well with each other. Communication between different levels is minimal and parts of it gets lost in translation. The technical problems that occur are digging overload (the ground gets opened up too often), excavation damage (cables and

pipes get damaged during maintenance), calamities (accidents that harm both people and nature) and, all of which are as well part of, space scarcity (lack of communication causes conflict between stakeholders). The size and communication issues point that an organism cannot be sufficient as an example, an ecosystem instead could provide a better example on that scale.

Current requirements of the municipality of Rotterdam are to adapt to the climate change for 2025. It is important to take the other constructions in the subsurface in mind during designing. Rules and decisions of a project each undergoes multiple stages before they come to fruition. Some of these policies that have been made in the past may be ready for change.

The different cables and pipes in the subsurface consist of:

Public lighting, Gas, District heating, Electricity, Water, Gravity sewer, Pressurised sewer, Gas, oil, kerosine, oxygen, nitrogen, etc. (other pipes), Electricity (other cables), Telecommunication KPN, Telecommunication UPC, Cable television and Remaining telecommunication.

The function of the cables and pipes itself is to transport. The function of the subsurface and location is to make the cables and pipes stay put, to protect them from physical harm and to maintain the quality of the surface.

The stakeholders of cables and pipes consist of the Municipality of Rotterdam, System operators, operational parties, workers and residents. The other stakeholders in the subsurface are Green planning, Rijkswaterstaat, urban construction and infrastructure. The ones involved into a specific area change depending on the project. But the four current problems that seem to reoccur the most are: Excavation damage, Digging overload, Calamities, Space scarcity.

Communication is key and all working on a single integrated system seems to be working the best, where network operators should be updated in every step. Symbiotic building should be

possible, but integrating biomimicry comes with a lot of unknow territory that hasn't been explored yet. An integral plan could help save a lot of time and money, as well as taking global warming and nuisance in consideration.

Demand for electricity and network expansion will grow in the future, and biomimicry can provide a system that grows with change.

Acknowledgement

This research was executed as part of the final thesis of Emma de Bloois at The Hague university of applied sciences, for the study of Industrial design and engineering. I would like to thank Laura Stevens who served as my tutor for this thesis and introduced me to biomimicry. The internship that this research is performed under supervision of Wil Kovacs of the municipality of Rotterdam and John Driessen from SWECO. Additional feedback and information is provided by Geert Roovers from Saxion, all of which are members of the ondergrond LAB. I would like to thank the three of them for their feedback and access to information and networks. Additionally I would like to thank the COB for providing a network and knowledge database.

Appendices

Appendix A: interview with Henk van der Maas

This interview was held through the following emails.

Van: Maas H.A. van der (Henk)
Verzonden: dinsdag 29 september 2020 20:18
Aan: emma de bloois
Onderwerp: RE: Stakeholders in de ondergrond

Natuurlijk vind ik dat leuk. Ik ben heel benieuwd hoe de methode van biomimicry je aanzet om innovatief/anders te denken. Omdenken.

Henk

Ik ben donderdag weer aan het werk. Ben een paar daagjes vrij.

Van: emma de bloois <emmadebloois@hotmail.com>
Verzonden op: donderdag 24 september 2020 18:20
Aan: "Maas H.A. van der (Henk)" <ha.vandermaas@Rotterdam.nl>
Onderwerp: RE: Stakeholders in de ondergrond

Beste Henk,

Heel erg bedankt voor deze uitgebreide uitleg! Ik heb alles verwerkt in mijn onderzoek en in de stakeholder analyse. Vind u het leuk om later ook op de hoogte gehouden te worden?

Met vriendelijke groet,

Emma de Bloois

Van: Maas H.A. van der (Henk)
Verzonden: donderdag 24 september 2020 16:00
Aan: 'emma de bloois'
Onderwerp: RE: Stakeholders in de ondergrond

Hier een Ketenalalyse die door het COB gemaakt heeft voor Common Ground in 2018
Het gaat vooral natuurlijk over Veel invloed, veel belang
Ik zou ze indelen in:

- Hogere Overheid (wetgever)
- Lagere Overheid (gemeente, regie)
- Leidingeigenaren (tevens opdrachtgevers voor leidingwerk)
- Uitvoerders (aannemers)
- Burgers, omwonenden, weggebruikers

- Hogere overheid stelt eisen ihkv algemeen belang: wetgeving.

Dat zijn eisen die opgelegd worden. De wetgeving veelal uit het oogpunt van veiligheid en gelijk speelveld.
Een belangrijke wet is de WIBON, die zegt dat de graver altijd verantwoordelijk is voor graafschades, dat leidingeigenaren hun leidingen aan het Kadaster moeten opgeven (nauwkeurigheid 1 meter) en dat de graver voor elke graafbeweging een kaart bij het kadaster opgevraagd moet hebben van de ligging van de leidingen. (de KLIC-melding). Maar ook de ARBO-wet en de Omgevingswet zijn hogere wetgeving
Provincie en waterschappen vallen ook over hogere wetgeving op de terreinen waar zij over gaan.

- Lagere overheid (gemeente) heeft een centrale rol.

Ze wordt gezien als regisseur, maar wat een regisseur precies moet doen staat nergens. Geert Roovers heeft daar wel over geschreven. Die rol heeft de gemeente alleen omdat leidingen vooral in gemeentegrond liggen en omdat de gemeente over de veiligheid moet waken. In elke gemeente wordt die rol ook weer anders ingevuld. Bijgevoegd een discussiestuk van GPKL over de regierol. Ook Geert Rovers heeft daar veel over geschreven. De Gemeente is ook de vertegenwoordiger van de burgers en gebruikers van de stad, dus moeten er voor waken dat het verkeer zo weinig mogelijk gehinderd wordt. (hulpdiensten/veiligheid), de winkels en bedrijven bereikbaar blijven, de veiligheid geborgd blijft, de communicatie goed verloopt, toezicht gehouden wordt, noem maar op. De gemeente geeft ook de vergunningen af en houdt natuurlijk toezicht.
De "Gemeente" is natuurlijk feitelijk B&W, maar de ambtenaren moeten het wel uitvoeren. B&W is verantwoordelijk. Wij hebben ook veel eigen verordeningen. Belangrijkste zijn de Verordening Beheer Ondergrond Rotterdam (VBOR) het Handboek Beheer Ondergrond (HBOR, de Telecomverordening, de SIR (Schaderegeling Ingravingen Rotterdam), Verordening Bodemenergiesystemen en nog zo wat.

- Leidingeigenaren zijn de "echte" stakeholders.

Het zijn hun leidingen die de drukte veroorzaken, maar de gemeente is vergunningverlener. Vroeger waren de leidingeigenaren oog gemeentelijke bedrijven (GEB, PTT, Gemeentelijke waterbedrijven) maar nu zijn ze allemaal verzelfstandigd. Op 1 na: De gemeente blijft eigenaar van de riolering en is dus feitelijk ook leidingeigenaar. De andere leidingeigenaren zijn weer te verdelen in voormalige nutsbedrijven (Stedin, EVIDES) gas, electra, water, de noodzakelijke zaken. Ze zijn aan allerlei (kwaliteits)regels economische regels gebonden maar hebben daardoor ook rechten. Ze "denken" daardoor nog een beetje als nutsbedrijf
De Telecommers zijn echte vrije jongens. Zij vallen onder de Telecomwet en het kan gebeuren dat er meerdere providers zijn in een stad, en dus ook meerdere telecomleidingen naast elkaar. Door 5G komen er waarschijnlijk nog meer leidingen in de stad, maar misschien ook wel helemaal niet. Who knows? Ook bijv. de RET is een leidingeigenaar. Er liggen nog veel gelijkspanningskabels van de RET onder de wegen. En natuurlijk de Metrobuizen zijn nu van de RET. Wel hele grote leidingen!!!!
In het havengebied zijn er ook heel veel andersoortige leidingen van grote bedrijven, die de gekste zaken vervoeren. In het lange havengebied ligt een zeer brede "leidingenstraat". Van boven een lang grasveld, van onder een wirwar/spaghetti van grote en gevaarlijke leidingen met speciale regels
De gemeente is zelf ook leidingeigenaar van de rioleringen waterbergingen, een eigen geschermd glasvezelnet, Verkeersregelinstallaties, e.d.
En de gemeente heeft heel veel andere ondergrondse objecten: Ondergrondse parkeergarages, vuilcontainers, boomwortels, wegtunnels en onderdoorgangen, Koopgoot, We hebben lijsten van tientallen soorten ondergrondse objecten, van groot tot klein.

- Uitvoerders (aannemers).

Die voeren uit in opdracht van de leidingeigenaar. Volgens de WIBON zijn zij altijd verantwoordelijk voor de graafschades. Maar verder hebben wij als gemeente altijd de opdrachtgever (leidingeigenaar) als aanspreekpunt.

- Burgers.

Ja, daar doen we het allemaal voor. Zij zijn onze klant. Indirect natuurlijk via het gemeentebestuur, maar wij doen het allemaal voor de burger. En de bedrijven in Rotterdam.

Henk van der Maas
Beheerder
Gemeente Rotterdam
Stadsbeheer
Afdeling Ondergrond-LBBO
Ondergrond-LBBO Beheer & Advies
De Rotterdam, Wilhelminakade 179
Postbus 10902 3004 BC Rotterdam
Telefoon 010 - 489 47 43
Mobiel 06-51246842
Website www.rotterdam.nl

Van: emma de bloois <emmadebloois@hotmail.com>
Verzonden: maandag 21 september 2020 16:02
Aan: Maas H.A. van der (Henk) <ha.vandermaas@Rotterdam.nl>
Onderwerp: FW: Stakeholders in de ondergrond

De bijlagen waren te groot maar als het goed is is er nu een WeTransfer verzonden

Groet,

Emma

Verzonden vanuit Mail voor Windows 10

Van: emma de bloois
Verzonden: maandag 21 september 2020 15:52
Aan: ha.vandermaas@Rotterdam.nl
Onderwerp: RE: Stakeholders in de ondergrond

Beste Henk de Maas,

Sorry voor de late reactie, in de research report is hoofdstuk 2.1 en 2.2 de stakeholder analysis. Ik kan op dit moment niet bellen (ben door mijn bundel heen) maar kan wel via whatsapp audio bellen of chatten. Ik ben benieuwd wat u er van vindt.

Met vriendelijke groet,

Emma de Bloois

Verzonden vanuit Mail voor Windows 10

Van: Bloois E.A. de (Emma)
Verzonden: maandag 21 september 2020 15:45
Aan: 'emmadebloois@hotmail.com'
Onderwerp: FW: Stakeholders in de ondergrond

Met vriendelijke groet,

E.A. Bloois
Stagiaire
Gemeente Rotterdam
Stadsbeheer
Ondergrond-LBBO Operationeel Beheer

Van: Maas H.A. van der (Henk) <ha.vandermaas@Rotterdam.nl>
Verzonden: vrijdag 18 september 2020 19:43
Aan: Bloois E.A. de (Emma) <ea.debloois@rotterdam.nl>
Onderwerp: RE: Stakeholders in de ondergrond

Hoi Emma,

Ik heb gisteren (laat) al gereageerd op je bericht op de LBBO-groeps-App.
Help je graag.
Stuur me op wat je hebt. Help ik je mee te zoeken naar een vollediger overzicht.
Bel je me maandag op? 06 51246842
Niet tussen 11.30 uur en 14.00 uur, want dan ben ik in (video)overleg.

Met vriendelijke groet,

Henk van der Maas
Beheerder
Gemeente Rotterdam
Stadsbeheer
Afdeling Ondergrond-LBBO
Ondergrond-LBBO Beheer & Advies
De Rotterdam, Wilhelminakade 179
Postbus 10902 3004 BC Rotterdam
Telefoon 010 - 489 47 43
Mobiel 06-51246842
Website www.rotterdam.nl

Van: Bloois E.A. de (Emma) <ea.debloois@rotterdam.nl>
Verzonden: vrijdag 18 september 2020 14:52
Aan: Maas H.A. van der (Henk) <ha.vandermaas@Rotterdam.nl>
Onderwerp: Stakeholders in de ondergond

Geachte Heer de Maas,

Ik ben een stagiaire onder Wil Kovacs die voor een eindproject een concept gaat (proberen te) ontwikkelen voor de drukte in de ondergrond van kabels en leidingen, vol onder maaiveld. Dit vanuit het oogpunt van Biomimicry waarin gekeken wordt naar de natuur en deze gebruikt als inspiratie om tot oplossingen te komen. Ik ben dit project begonnen met een onderzoek naar de globale context en problemen, om uiteindelijk tot een probleemstelling te komen. Als locatie heb ik het plein voor het centraal station van Rotterdam gekozen.

Nu heb ik in mijn onderzoek een stakeholder analyse gemaakt, van zowel de kabels en leidingen, als de andere stakeholders die in de ondergrond tot 5 meter diepte moeten zijn. Maar het lastige vind ik hier aan dat die verschillende project eigenaren vaak een eigen kennisbank hebben, waardoor ik lastig een goed overzicht kan maken van wie er nou eigenlijk allemaal echt betrokken is. Ik vroeg aan Wil Kovacs misschien iemand wist die een lijst heeft of er kennis van heeft wat ik kan gebruiken voor mijn onderzoek rapport.

Ik ga hierbij niet zozeer de diepte in maar eerder als een soort overzicht van hoeveel en wat voor een soort betrokkenen er zijn en rekening mee gehouden moeten worden.
Hierbij schrijf ik de betrokken partij, de relatie tot het probleem van de volle ondergrond, de functie en de specifieke eisen op. Ik hoop dat u mij hierbij kan helpen om een kloppend en compleet overzicht te maken.

Met vriendelijke groet,

E.A. Bloois
Stagiaire

Appendix B: interview with Joost Martens

Starting off a conversation regarding the research with John Driessen from SWECO:

- Most of the cables and pipes are dug shallower than 5 meter in the subsurface.
- With the exception of sewers that use gravity for transportation to save energy. Those are placed deeper with a slope.
- Other pipe systems use pressure to transport their components (Pressure pipes)
- Different pipelines have different systems
- Diameter changes and is different for each system. Each system can have different corners depending on the material it is transporting and made out of.

He referred me to Edith Boonsma in order to find out more about which specific street I could use for research.

I contacted Edith Boonsma from the COB in order to lead the research in the right direction and to determine a spot in Rotterdam which I would research, and asked which project she knows in the subsurface that have already been going on. Suggested was that I could used the Robert Fruimstraat as a research subject, as it was a project in which they tried to combine all stakeholders. This project failed due to some stakeholders not being willing to participate. Further project that I could look into could be found on the knowledge database at COB. She also suggested that I should talk to Joost Martens and listen to his advice on the matter.

Joost martens on the phone elaborated on the Robert Fruimstraat, it has been researched a lot, and it has been a traditional integral project that failed. A good example why this problem should be solved with a different vision like biomimicry. The Coolsingle could provide a good research location as it is an important traffic center, the underground shopping mall had had a lot of space issues due to it being so crowded. The problem with this location is that the solution

they applied to this location is to not allow any digging for 15 year, to prevent any damage or nuisance. The ground in front of train station Rotterdam Blaak, de binnenrotte, is the busiest subsurface in Rotterdam. This could present an example for looking at extremes. Discussing the research the conversation concluded with that the square in front of Rotterdam central station would be the best for this research. As it is largely researched, and poses a good representation for the busy subsurface in Rotterdam.

Appendix C: Interview with Fred Neef

Questions

- What are reoccurring problems in the subsurface with cables and pipes?

the space issue is definitely the biggest one, that Is also intertwined with other stakeholders.

- Is there a possibility in combining functions?

Answer: With cables and pipes there are a lot of technical prerequisites that need to be met, if combining functions is the direction you want to go with the project than you should not take into consideration those requirements. As those are made for the cables and pipes to function in the current way, not in a new way.

- What are technical walls that people face?

Answer: the biggest technical walls are the literal walls of buildings and strategic main structures. A lot of construction underground is made with concrete, and buildings have foundations that often get in the way with suburban planning.

- You have heard what biomimicry is with your involvement with John Driessen, what do you see as an opportunity in the subsurface with biomimicry with regards of so many different stakeholders?

Answer: the stakeholders are currently competing for the space underground, it would be ideal if we could change the circumstances and view the earth herself as an organism. But the hard thing with nature is, like you said, that competition is also present in nature. Weeds are also part of nature, but they don't leave space for other organisms, that's what makes it a weed. For most people, especially me as I work in urban greenery, cables and pipes are considered a weed that choke all other organisms in the ground.

- Are there any methods that the stakeholders are currently stuck in that seems to be the organisational problem?

Currently the focus in the subsurface is sectoral, while the complete picture is integral. The planning of 1 of the stakeholders sets the planning of the others in stone. This is a problem as most of those don't communicate, leading them to clash.

- Thank you for your time, do you have any last words of advice?

I think you should define in which direction you want to take this project, to not get overwhelmed with the restrictions. Prevent the weed from taking over, and make space for other organisms.

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