

# Towards more sustainability to challenge the nitrogen crisis

The path towards sustainable innovation in the construction phase of  
Dutch residential area development.



## **Colophon**

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<b>Date:</b>	October 11, 2020
<b>Word count:</b>	28.588 words (excl. appendices and references)

## Abstract

In this research the transition towards a sustainable construction phase in Dutch residential area development is central. On May, 2019 the PAS was declared invalid by the council of state (Raad van State) which led to shutting down the majority of projects in Dutch residential area development. This is problematic since these projects are in the public interest because of the current housing shortage. To overcome this challenge a long- term solution focusing on sustainability is necessary. Despite that the user phase is responsible for more nitrogen emission compared to the construction phase the focus in this research is on the latter. Reason is that the user phase is already central in practice and the user phase is still left behind, meaning that most steps can be made in this phase. Thus, the nitrogen crisis should be seen as an incentive for a structural change towards more sustainability in Dutch residential area development. This structural change can be seen as a transition.

The goal of this research is to provide a contribution to innovative aspects within the construction phase of Dutch residential area development towards a transition to diminish the nitrogen emission. A multiple case study is used to see projects as niches where innovations are researched which can contribute to a transition. Within niches different stakeholders work together on micro level to start a change. Linked to the goal of this research is the main question: *How can innovative aspects within the construction phase of residential area development contribute to a transition to diminish the nitrogen emission in the Netherlands?*

Transitions are complex processes which are shaped by development on different scale levels. These different scale levels are: macro, meso, and micro. In this research the focus is on the micro scale level, which relates to niches. Niches can be seen as a protected space where innovations are able to develop. The success of a niche is influenced by several internal processes: the formation and stabilization of a social network, the formation and stabilization of strategies and expectations, and learning processes. It is important that niches get enough space to develop. Only successful niches can contribute to a transition. This contribution can be indicated with the following terms: deepen, broaden, and scaling.

The link between the quality of the internal processes and the contribution to a transition has been researched for the projects De Groene Loper, Lage Heide, Arce Novum, and Lindenkruis. This means there has been chosen for a multiple case study which makes the research qualitative. For each case 1 or 2 interviews have been conducted by phone in order to gain more knowledge about which aspects they see as potentially innovative, their internal processes and their contribution to a transition.

In the conclusion it became clear that the aspects machines and transport are seen as most contributing polluters to the nitrogen emission in the construction phase. Thus, these are the aspects that need to innovate and therefore need to develop within a niche. For a niche to develop successful it is important to determine the quality of the internal processes, this also determines their contribution to a possible transition. The project De Groene Loper has the largest contribution to a transition through the process of broadening. The projects Lage Heide, Arce Novum and Lindenkruis share the same contribution to a transition through the process of deepening. Since the projects are selected based on their size this is a criteria that should be considered. The two large projects, De Groene Loper and Lage Heide, differ from each other on every aspect that has been analyzed in this research. Therefore, it can be concluded that there is no link between the size of the project when they can be considered large and those aspects. However, the two medium projects, Arce Novum and Lindenkruis, are similar on most aspects. Therefore, it can be concluded that there is a link between the size of the project when they can be considered as medium projects and those aspects. It can be concluded that the supposed link between the quality of the internal processes

within a niche and the contribution of this niche to a transition can be confirmed. The more the internal processes are valued, the bigger the contribution to a transition in terms of deepen, broaden, and deepen is. So for the innovative aspects machines and transport to contribute to a transition to diminish the nitrogen emission in the construction phase multiple important aspects are relevant: 1. the composition of the social network, 2. a clear final image based on transcending the legal requirements, 3. main focus on results, 4. considering obstacles outside of the niche.

**Keywords**

Residential area development, construction phase, sustainable transition, nitrogen crisis

## Preface

This is the end result of my master's thesis to complete the master Spatial Planning: Planning, Land and Real Estate Development at Radboud University, Nijmegen. This thesis is about sustainable innovation in the construction phase of Dutch residential area development. In this research the focus is on the cases De Groene Loper, Lage Heide, Arce Novum, and Lindenkruis. Based on interviews with relevant stakeholders from these projects the analysis and an answer to the main question were formed.

The plan was to write this master's thesis in combination with an internship at Lievense|WSP, Maastricht. Unfortunately due to COVID- 19 this internship has been suspended. This created some challenges during the research process. I would like to thank Franci Vanweert from Lievense|WSP for the guidance during the few weeks' internship. Also, I would like to thank my thesis supervisor dr. P.J. Beckers for the guidance and feedback the past few months. Of course I would like to thank my friends, family and connections for sharing their network with me to increase the range of relevant projects. As last I would like to thank all the stakeholders for making time during this hectic period and sharing their information with me.

Enjoy reading!

Geleen, October 2020

Noor Simons

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# 1. Introduction

## 1.1 Research problem statement

On May 29, 2019 the PAS was declared invalid by the council of state (Raad van State). Reason for this is that the anticipation aspect on the positive effects of mitigation measurements is in violation with the European Habitat Directive (Rijksoverheid, n.d.). This resulted in shutting down the majority of projects in different sectors that cause an increase in nitrogen deposition.

To overcome the nitrogen crisis an Emergency Law was introduced in November 2019. These measurements should reduce nitrogen deposition in order to create more room for the most urgent projects (Ministry of Agriculture, Nature and Food Quality, 2019a). The government chose for measurements which can be implemented short- term and also lead to a nitrogen reduction short-term (Ministry of Agriculture, Nature and Food quality, 2019b).

The situation is especially problematic for residential area development. Projects in this sector are on lockdown despite their low nitrogen contribution of 0.6% (RIVM, 2019). This is the central problem in this research. These projects are in the public interest because the current housing shortage can only be solved by building 75.000 dwellings per year. According to EIB (as cited in NRC, 2020), with the current Emergency Law the total new build homes in 2020 and 2021 will decrease with 5%, and even in 2024 the goal of 75.000 will not be reached. Since residential area development is more complex and therefore long- term focused, nitrogen reduction in this sector is not named in the Emergency Law. However, a long term solution is more efficient and also necessary for a more sustainable future. According to Van den Dobbelsteen (as cited in De Voogt, 2019) the residential area development sector should take responsibility for their own actions and nitrogen emission. Also Bastmeijer (2019) advocates for reducing nitrogen emission in their own sector to create room for their own projects.

According to Sandanayake, Zhang, and Setunge (2016a) the user phase is responsible for 80-90% of the nitrogen emissions, while the construction phase is only responsible for 0.4-12%. The government and residential area development sector already made steps in reducing emissions during the user phase. Since the construction phase is more complex, because of the involvement of many stakeholders and steps leading to a product, they are left behind in terms of sustainable innovation (Pollo & Rivotti, n.d.). This is the place where there is still room for sustainable innovation to reduce the nitrogen emission (Climate Neutral Group, n.d.). Therefore, the focus in this research is on the construction phase. Another link to become more sustainable in the construction phase is the goal named in the Climate Agreement to reduce the emissions in the building sector from 330 megaton per year to 0.4 megaton per year by 2030. This objective has accelerated due to the nitrogen crisis (De Leeuw, 2020).

For the construction phase within residential area development to reduce their nitrogen emission their innovations need to develop within a niche. Niches build up internal momentum with the creation of innovations, changes at the landscape level put pressure on the regime, and this pressure leads to destabilization of the regime, which creates windows of opportunity for the niche innovations (Schot & Geels, 2008). The successful development of a niche and their contribution to a transition is central in this research.

## 1.2 Research aim

The goal of this research is to provide insight into innovative aspects in the construction phase of residential area development contributing in the transition towards reduction in the nitrogen emission. This is done by consulting diverse stakeholders involved in the construction phase of the four residential area development projects that are central in this research.

## 1.3 Research question

*How can innovative aspects within the construction phase of residential area development contribute to a transition to diminish the nitrogen emission in the Netherlands?*

In order to make a transition towards nitrogen reduction in the construction phase of residential area development possible it should be known which aspects contribute most to nitrogen emission. When this is known it is clear which innovative aspects contribute to nitrogen reduction, and also what is meant with innovative aspects in the main question.

1. Which aspects in the construction phase of residential area development influence the nitrogen emission?

As soon as it is clear which innovative aspects contribute to nitrogen reduction, it is important that these innovative aspects can develop in a protected space. This space is also called a niche; here the innovative aspects are protected from reality. Eventually the development of niches can lead to replacing the leading and dominant structure and rules (Schot & Geels, 2008). However, niches are most often not very successful; the experiments at niche level remain there and are unable to scale up (Caniëls & Romijn, 2008). For a niche to develop successful there are three internal processes that need to be optimized; the social network, the strategies and expectations, and learning processes. In the formation and stabilization of a social network the social network can be recognized as the collected group of actors who are committed to start an innovation together. In the formation and stabilization of strategies and expectations from stakeholders the strategies and expectations offer structure and guidance in the project. It gives a view on the goal of the niche and how this will take shape eventually. The learning processes for stakeholders about experiments are important since the experimenting within the niche causes a lot of uncertainty. Therefore, learning is an important process for a niche. By learning a niche is able to stabilize and develop further (Kemp et al., 1998).

2. How does the social network of diverse stakeholders in a project influence these innovative aspects?
3. How do strategies and expectations from stakeholders in a project influence these innovative aspects?
4. How do learning processes for stakeholders about experiments in a project influence these innovative aspects?

When the above three internal processes are optimized the niches develop well. This means that the innovative aspects can develop in a protected space and get the highest chance to develop successful (Schot & Geels, 2008). It is demonstrated that practices within niches are difficult to translate to the dominant regime (Smith, 2007). This means that the innovative aspects that are developed within a niche struggle to be implemented on a larger scale. Niches can improve this struggle by providing a contribution to a transition. The way for niches to contribute maximum to a transition is described by the three mechanisms explained by Kemp and Van den Bosch (2006). They refer to deepen, broaden and scaling. Deepen is the process where there is learned about the possibilities and obstacles of an innovation within a certain context. Broaden refers to the expansion from one niche to other contexts. The innovation is tested and repeated within other contexts which results in new learning experiences. Scaling refers to the development of new structures and ideas

within a niche, which get implemented and established on a higher level (Kemp & Van den Bosch, 2006).

5. How does deepen, broaden and scaling affect the contribution of these innovative aspects to a transition?

## 1.4 Societal relevance

According to Van Thiel (2014, p. 187) societal relevance refers to the extent to which a study is expected to contribute to the solution of societal problems and questions.

The projects in residential area development are challenged by the nitrogen crisis. Since the PAS is declared invalid it is problematic for projects in these sectors to get their permits since they expel too much nitrogen according to the law. Because these projects are in the public interest there is a need for these sectors to start building again to respond to the current demand of 75.000 new built dwellings each year (EIB, in NRC, 2020). Also there is the threat of losing jobs and the effect of rising prices (Tweede Kamer, 2019). The importance of residential area development for the public interest creates urgency for a long- term solution. According to Bastmeijer (2019) the residential area development sector should reduce their own nitrogen emission to create room for their own projects. Sandanayake et al. (2016a) focus on the construction- and user phase of residential area development, where the user phase is responsible for most emission. Nowadays, most measurements regarding sustainability are taken in this phase. This means that most steps can be taken in the construction phase, making this more relevant for new research. Achieving this goal means putting the focus on sustainable innovation within niches. Also, innovations towards more sustainability are in line with the importance of the current climate goal in the Climate Agreement to reduce emissions. The nitrogen crisis has put this objective into acceleration (De Leeuw, 2020).

The transition that is central in this research concerns the whole society. Especially the involved stakeholders in the niches will need to change their behavior in order to make this step towards sustainability. This research provides awareness about transitions and the support for niche development. Recommendations can be done about how a societal transition can be eased. For the stakeholders who are involved in the niches this research provides insights on how to manage a niche and improve its functioning.

## 1.5 Scientific relevance

According to Van Thiel (2014, p. 186) scientific relevance refers to the degree to which the knowledge to be acquired will contribute to the existing body of knowledge. Two aspects should be discussed: (1) there should be a review of the existing knowledge relating to the specific topic and then (2) there should be explained how this specific research will contribute to gather more additional and new knowledge.

In order to reduce the nitrogen emission to create room for urgent projects within the construction phase of residential area development sustainable innovations are necessary. In the policy report 'Niet alles kan' (Ministry of Agriculture, Nature and Food Quality, 2019c) they argue that the building sector should focus more on the use of innovative techniques and materials to reduce their emission. They mention that long- term solutions should include all sectors and not only the sectors mentioned in the Emergency Law 2019 (Ministry of Agriculture, Nature and Food Quality, 2019ab). Research on sustainable and long- term innovations within the building sector does not exist yet. However, research about how the building sector contributes to the nitrogen emission already exists. Most research focuses on the user phase instead of the construction phase. For example, Sandanayake et al. (2016a) focus mostly on the user phase arguing that this phase is responsible for most emission. Also, Huang, Krigsvoll, Johansen, Liu, and Zhang (2018) argue that the user phase dominates the building energy research already for many years. Pollo and Rivotti

(n.d.) argue that the popularity of researching the user phase has a reason. The construction phase is more complex due to fragmentation of the actors involved and there are too many steps that lead to a product. This leads to nobody being accountable for these emissions. Also, research about the construction phase is increasing in significance since the emission in the user phase is expected to decrease in the future, due to the implementation of more efficient and sustainable technologies (Huang et al., 2018, p. 6). The little research available about the construction phase focuses on influencing top- down. For example, the research of Robichaud and Anantatmula (2011) focuses on influencing the construction phase top- down through policy. Developing sustainable innovations within niches is little knowledge available about.

Concluding, research with emphasis on developing sustainable innovations within niches for the construction phase within residential area development can contribute to this existing knowledge gap. Also, this research contributes knowledge about the role of niches within a transition. By criticizing the contribution of a niche to a transition knowledge is gathered about the functioning of a niche and the related assets and/or obstacles. This provides a more profound image of a transition with the focus on a specific scale.

## 2. Theory

### 2.1 Theoretical framework

#### 2.1.1 Phases in the development process

The residential area development sector represents the industry within the building sector that produces dwellings to live in. In the Netherlands there is social housing and the private sector. The private sector means that the sector is formed by the market. Owner-occupied houses as well as rental houses are part of the private sector. These rental houses in the private sector can be owned by a housing corporation; condition is that the rent needs to be above a certain threshold value. When the price of the rental house is below this threshold value, it can be identified as social housing (Kullberg & Ras, 2018; Esteon, 2017).

Nowadays the demand in residential area development is high, which should lead to more production (EIB, 2010). But as result of the nitrogen crisis the initiators of projects are not able to respond to this demand since most projects are not able to get their permits as a result of their too high nitrogen emission. These initiators can be private or public parties; each of them has their own interests. Public parties want to solve a public problem; for example solving the housing shortage and making sure that people have a place to live. While a private party, a developer, wants to achieve the highest possible return (Vos, 2001, p.10).

According to Wentzel, Van Eekelen, and Rip (2005) residential area development follows multiple phases in the development process. According to Sandanayake et al. (2016a) a building project has different phases; design (D) -, realization (B) - and exploitation phase (M-O). These phases can be seen in figure 1. The design phase (D) is the starting point of the development process in residential area development. The design phase starts with a sketch design. This sketch design needs to give a general idea of the plan on how the development will take place. Using the critical feedback delivered by the involved stakeholders the sketch design results into the prototype. The prototype is tested and adjusted to eventually result in the final design. When all three steps in the design phase are done, the realization phase (B) starts. The realization phase begins with the work preparation; all building activities that need to happen in practice need to be prepared in order to reduce mistakes, doubts and delay. After work preparation the performance takes place. All building activities will be carried out in practice. When the building activities are finished, the finished product in residential area development gets delivered. This means that people who buy or rent the building can start occupying it. This is the start of the exploitation phase (M- O). This phase concerns the use of the building by the buyers or renters, but also the maintenance during the exploitation period (Wentzel et al., 2015).

Relating to nitrogen emission especially the realization- and exploitation phase are important (B and M-O), since they produce most nitrogen. These phases describe the construction (B) and the use of the building (M-O). A synonym for realization phase is construction phase and a synonym for exploitation phase is user phase. During the construction- and user phase there is nitrogen emission. According to Sandanayake et al. (2016a) the user phase is responsible for 80-90%, while the construction phase is only responsible for 0.4-12% of the emissions. However, the government and building sector already put a lot of effort in making the use of the building itself as energy- neutral as possible, which refers to the user phase. Since less attention is given to the construction phase most steps to reduce the nitrogen emission can be taken in this phase. Therefore, the focus in this research will be on the construction phase (B). The choices for innovative ways to reduce the nitrogen emission in this phase are already made in the design phase (D).

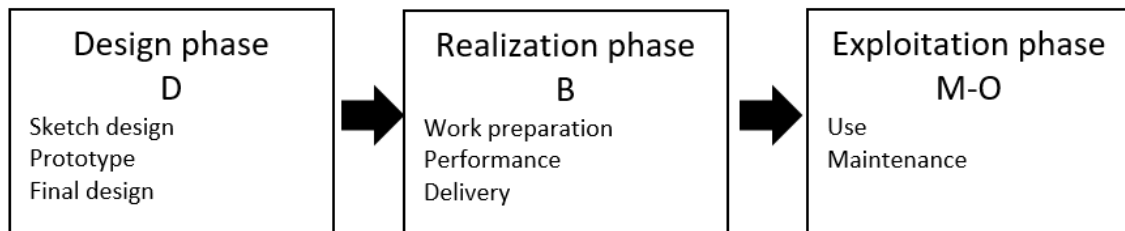


Figure 1. [Development process]. Own design based on Wentzel et al., 2005.

#### 2.1.1.1. Construction phase

Everything in the built environment is the fundament of economic and social development. The whole life cycle of the built environment can be divided in two parts. First, there is the operational energy. This is the energy that is used during the occupation period of buildings. For example, the heating and cooling, ventilation and hot water use. Second, there is the embodied energy. This represents the energy used during the construction, maintenance, renovation and demolition period of buildings. Thus, the construction phase that is central in this research expels embodied energy. The embodied energy includes direct energy and indirect energy. The direct energy is the energy that is necessary for the construction part on-site. The indirect energy is the energy necessary for providing products and services for the construction operations (Huang et al., 2018, p. 6-7). The latter one is the focus of this research.

According to Sandanayake et al. (2016a) the construction phase of buildings can be divided into two stages: foundation and structure construction. Both of these phases use material and equipment which leads to embodied energy.

During the foundation stage of construction concrete and reinforcement steel are the two biggest materials used (Sandanayake et al., 2016a). Especially during the foundation stage heavy equipment and machines are used which produces the most emission (Guggemos & Horvath, 2006). The structure stage is about the building core and other elements relating to the construction such as walls, beams and windows. During this stage most emissions are produced because of the use of many materials which also leads to a high emission relating to transport. Overall the total amount of emissions is generated over a smaller span of time at the foundation stage than at the construction stage (Sandanayake, Zhang, Setunge, Luo, & Li, 2017).

The amount of nitrogen and emissions during the construction phase is very high and results from multiple factors. Machines and equipment need fossil fuels to work. The burning process of the fossil fuel produces nitrogen. According to Sandanayake, Zhang, Setunge, Li, and Fang (2016b) this can be called indirect emissions (similar to indirect energy from Huang et al., 2018). The use of type of equipment and machines is important to know, especially their age. The older equipment and machines are, the more unsustainable they are. Besides this, the hours of operation matter as well for the amount of emission. Also, the type, amount and distance of transportation of the equipment and materials are important (Sandanayake et al., 2016a). According to Zhang, Shen, and Zhang (2013) emissions during the construction phase are mainly generated from the fuel used for equipment and the transport of waste.

It is possible to reduce nitrogen emission by using electric material and machines, but not every material can be made electric or it is still in the try-out phase. According to Frissen (2020) from Bouwend Nederland and involved in the Groene Koers making equipment and material relevant for construction more sustainable is not easy, but the sector does have the ambition to focus on it. She states that only 5% from the 115.000 different construction tools is electric. Thereby, those 5% is mainly the smaller material (excavators) and not the heavier material (cranes). The heavier material is a long term process; a battery for the energy they use does not exist yet. According to Lokkerbol (as cited in Frissen, 2020) from Emissieloo's Netwerk Infra the building sector

really wants to become more sustainable. He also states that the market is the obstacle, since there is too less material and equipment available to invest in sustainability. And the material and equipment that is more sustainable is 30% to 70% more expensive than material and equipment running on fossil fuels. Another relevant obstacle is that the building locations are not suited for electric material since they lack the presence of electric infrastructure. This means that it is still very difficult to build energy neutral in the construction phase. In order to eliminate these obstacles the demand needs to be increased, suppliers need to be motivated to introduce electric material faster on the market and the government needs to act as 'launching customer' (Frissen, 2020).

Resulting from the research by Sandanayake et al. (2016ab) the aspects that contribute most to nitrogen emission during the construction phase are the machines, the transport and building time. According to a research from the Climate Neutral Group (n.d.) 78% reduction is achievable through changes in these aspects. Therefore, these aspects are the focus of the innovations in the construction phase towards a transition to reduce nitrogen emission.

### 2.1.2. Transitions

To make a transition towards nitrogen reduction in the construction phase possible it is necessary that innovations take place at the system level. These innovations relate to the aspects that contribute most to the nitrogen emission during the construction phase. These aspects are discussed in the previous paragraph 2.1.1.1. *Construction phase* and are the following: machines, transport and building time (Sandanayake et al., 2016ab). Rotmans (2006, p.14) describes a system as an interconnected structure of parts which influence each other in a certain direction. A system innovation consists out of innovations which come together on a smaller scale. In order to understand a transition it is important to study the three fundamental dimensions of it: time, scale and the nature of change.

The multi- phase concept explains the time dimension of a transition. A transition takes place through periods of relative fast and slow change (Dirven, Rotmans & Verkaik, 2002, p.11). This means that a transitional process is not linear. It is the shift in a system from one period of equilibrium to another period of equilibrium that requires breaking boundaries and barriers. During this shift there are four successive phases which can be seen in figure 2: the pre-development phase, the take-off phase, the breakthrough phase and the stabilization phase. The pre- development phase is a period of dynamic balance with no visual change; the status quo remains. In the take- off phase the condition of the system shifts which means that change is happening. The breakthrough phase is characterized by visual and structural changes because of interacting social- cultural, economic, ecological and institutional changes. Collective learning processes, diffusion and embedding go along with this phase. As soon as the speed of social- cultural change diminishes a new dynamic balance will be reached. This is called the stabilization phase. These phases go along with periods of slow and speed developments. The concepts of speed and acceleration are relative notions (Rotmans et al., 2000).



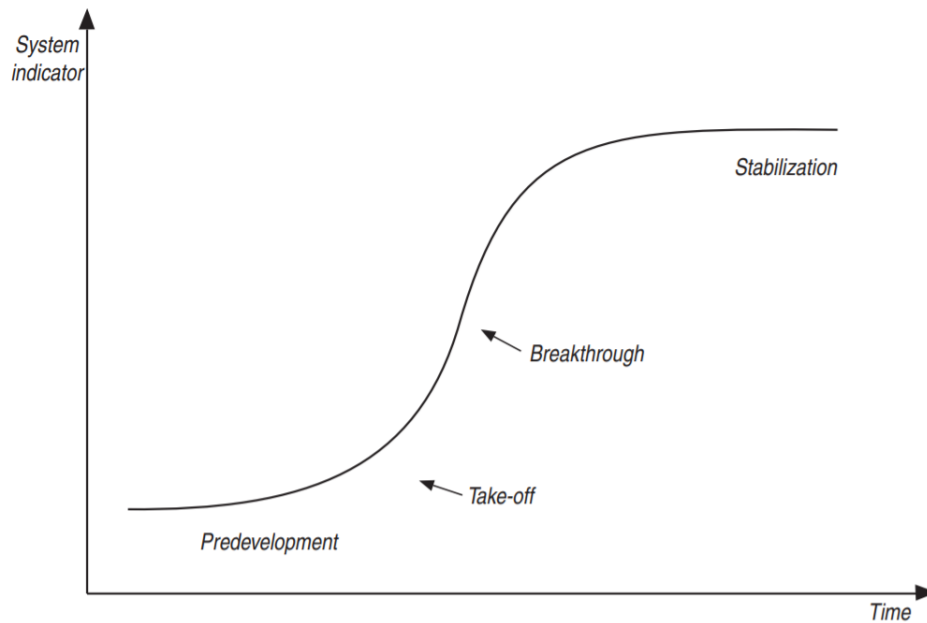


Figure 2. [Four phases of transition]. Own design based on Rotmans, 2006.

According to Rotmans (2006) the nature of change is another dimension within a transition. He points to the study about the dynamic behavior of ecosystems of Gunderson and Holling (as cited in Rotmans, 2006). Four different phases in the development of ecosystems are named: exploitation, conservation, disturbance and reorganization. These are represented in figure 3. Based on this adaptive cycle the nature of change in every phase of a transition can be described in terms of 'degradation' and 'demolition' versus 'structure' and 'innovation'. During the exploitation phase capital is accumulated, which will be exploited in the conservation phase. In this relative slow phase of exploitation and conservation there is a competition between the entrepreneurs, and an increasing rigidity and connectedness between the parts of the system, which create relatively stable patterns. After this a disturbance occurs, often from outside the system, which stimulates the system to search for a new structure. Then reorganization takes place. The relative fast phase from disturbance to reorganization is characterized as an unstable period with destabilization caused by powerful feedbacks between insurrectional elements and representatives of the current order. Based on this adaptive cycle Rotmans (2006) explains the nature of change in every phase of a transition in the terms of 'degradation' and 'demolition' versus 'structure' and 'innovation'; capital is broken down after which it is rebuilt again.

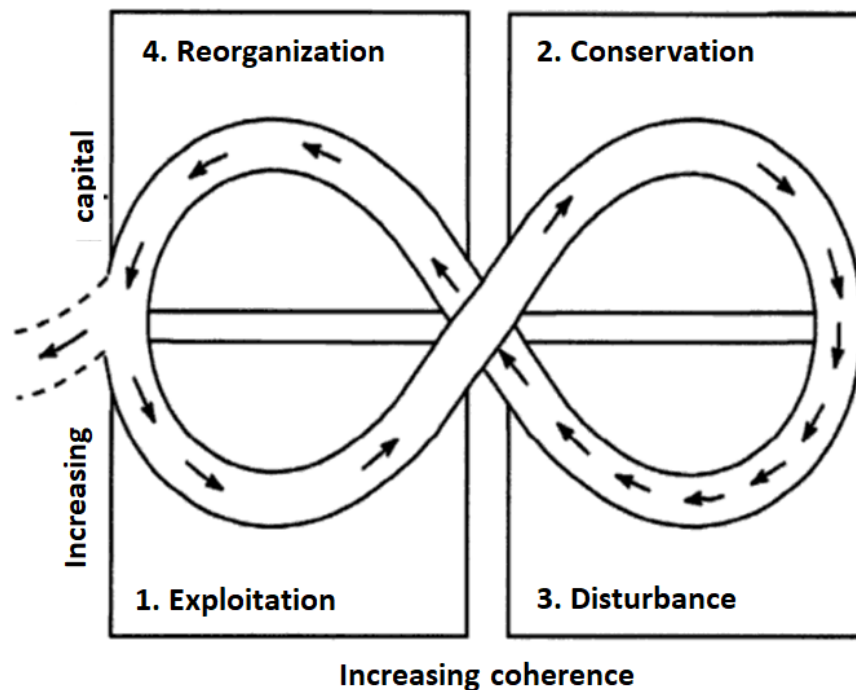


Figure 3. [The adaptive cycle]. Own design based on Gunderson and Holling, 2002.

A transition is the result of different developments on different levels. Rotmans (2006), Dirven et al. (2002) and Loorbach (2007) state that transitions are the result of developments and events on a large scale as well as on a small scale. According to the multi-level perspective transitions will only be realized if developments at the three different levels are linked to each other and reinforce each other in the same direction. These three different levels are (Geels & Kemp, 2000):

- At the macro level landscape changes play a role, for example on politics, culture, worldviews and paradigms. At this level trends and developments form an undercurrent and are relatively slow. On the contrary they can also occur suddenly as a consequence of a flood for example. Developments on this level are external to regimes and niches, but they do influence them (Fischer, 2004, p. 15; Rotmans, 2006, p. 18).
- At the meso level there are regimes; systems of dominant practices, rules and interests shared by groups of actors. There is a lot of resistance at this level against innovation, because existing organizations and institutions want to maintain existing rules, methods and interests (Rotmans, 2006, p. 18).
- At the micro level niches develop. Within these niches deviations from the existing can arise, such as new initiatives and new forms of culture and governance (Rotmans, 2006, p. 18). There is room to learn about innovations, new practices or ideas. Here, the first steps towards a transition to reduce nitrogen in the construction phase related to the aspects machines, transport and building time can be made (Fischer, 2004, p. 16; Sandanayake et al., 2016ab).

In this research the focus is on the contribution of niches which refers to the multi-level perspective or scale dimension of transition, therefore this concept will be further elaborated on. The pattern of a transition is formed through the interaction of processes on the three levels: niches build up internal momentum through the creation of innovations, changes at the landscape level put pressure on the regime, this pressure leads to destabilization of the regime, which creates windows of opportunity for the niche innovations (Schot & Geels, 2008). This can be seen in figure 4.

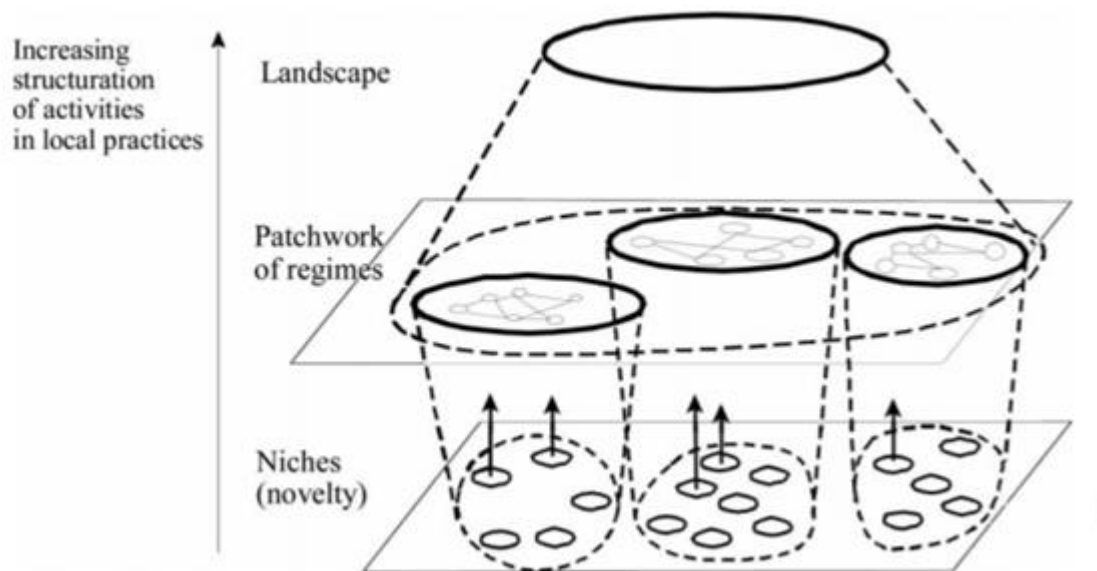


Figure 4. [Multiple levels as hierarchy]. Retrieved from Geels, 2002.

### 2.1.3. Strategic Niche Management

#### The role of niches

Niches can be defined as the place where deviant developments take place, different than the developments within the regime. Niches form the place where innovations and radical changes are shaped (Paredis, 2009, p. 20-21). Innovations get the space to develop by protection from reality. This is important, because when a niche is not developed well enough and is introduced to the market, there is a bigger chance of failure (Geels & Schot, 2007, p. 2). They need a group of ambitious actors who want to accomplish this innovation. This makes it important for the aspects machines, transport and building time (Sandanayake et al., 2016ab) to develop within a niche. Kemp and Van den Bosch (2006, p. 11) argue that innovation does not start within niches, but is formed there. The start of innovation takes places in a broader societal context, through bottom- up initiatives. This creates the sense of urgency that is needed for innovation to happen.

The idea is that bottom- up initiatives create that sense of urgency about the aspects that contribute most to nitrogen, machines, transport and building time, and need to innovate in order to reduce that emission (Sandanayake et al., 2016ab). For these aspects to innovate they need a protected space, which is the niche. Eventually the development of niches can lead to replacing the dominant technology. This would be the development of a new regime that carries new rules. The process of developing niches is a bottom- up process, in which novelties emerge, they conquer market niches, and eventually replace the existing regime (Schot & Geels, 2008). However, these niches are most often not very successful; the experiments at niche level remain there and are unable to scale up (Caniëls & Romijn, 2008). Therefore, it is important to elaborate on the three important internal processes for a successful niche development: formation and stabilization of a social network, formation and stabilization of strategies and expectations, and learning processes (Kemp, Schot, & Hoogma, 1998). In the formation and stabilization of a social network the social network can be recognized as the collected group of actors who are committed to start an innovation together. In the formation and stabilization of strategies and expectations the strategies and expectations offer structure and guidance. It gives a view on the goal of the niche and how this will take shape eventually. The learning processes are important since the experimenting within the niche causes a lot of uncertainty. Therefore, learning is an important process for a niche. By learning a niche is able to stabilize and develop further (Kemp et al., 1998). These three dimensions

determine the success of the niche development. The amount of successful niche development influences the process of how well the aspects, machines, transport and building time can innovate (Sandanayake et al., 2016ab). This means that these three dimensions indirectly determine the successful innovation of these aspects within the niche.

#### 2.1.4. Deepen, broaden and scaling

When niches develop well this positively influences the experiments within the niche. In this case experiments are related to the aspects machines, transport and building time (Sandanayake et al., 2016ab). Successful niches can contribute an important role to a possible transition. The way for niches to contribute maximum to a transition is described by the three mechanisms explained by Kemp and Van den Bosch (2006). They refer to deepen, broaden and scaling. Deepen is the process where there is learned about the possibilities and obstacles of an innovation within a certain context. Broaden refers to the expansion from one niche to other contexts. The innovation is tested and repeated within other contexts which results in new learning experiences. Scaling refers to the development of new structures and ideas within a niche, which get implemented and established on a higher level (Kemp and Van den Bosch, 2006).

It is demonstrated that practices within niches are difficult to translate to the dominant regime (Smith, 2007). This means that the aspects (machines, transport and building time (Sandanayake et al., 2016ab)) that innovate towards nitrogen reduction and are developed within a niche struggle to be implemented on a larger scale. This indicates a paradox; niches provide a good context for experiments, but at the same time adaptation to this specific and deviant context makes it difficult to scale up experiments to regime level. The step from niche to regime cannot be seen as a single step, but consists out of many. Therefore, broadening is an important intermediate step between deepening in a context specific niche and scaling up to the regime context. By repeating the experiment in different contexts and linking it to other functions, broadening helps to strengthen learning experiences (deepening) and increase the influence and stability that can eventually grow into a niche- regime (scaling). This fills the gap between the niche and the regime, which challenges the existing regime in fulfilling a societal need (De Haan & Rotmans, 2008). An important condition for this to be successful is the interaction between different levels; the step from local projects to niches and eventually regime- shifts (Van den Bosch & Rotmans, 2008).

## 2.2 Conceptual framework

Sustainable innovation within residential area development to diminish the nitrogen emission in the construction phase can be seen as a bottom- up initiative. The aspects that contribute most are the machines, the transport and building time (Sandanayake et al., 2016ab). For these aspects to have a chance to innovate towards nitrogen reduction they need a protected space, a niche. The successful development of a niche depends on three internal processes which come from Strategic Niche Management. These are formation and stabilization of a social network, formation and stabilization of strategies and expectations, and learning processes. In this research the development of a niche concerns the innovation of aspects towards nitrogen reduction. The aspects that can innovate are machines, transport and building time. The contribution of the niche to a transition depends on deepen, broaden and scaling. This is visually summarized in figure 5, the conceptual model.

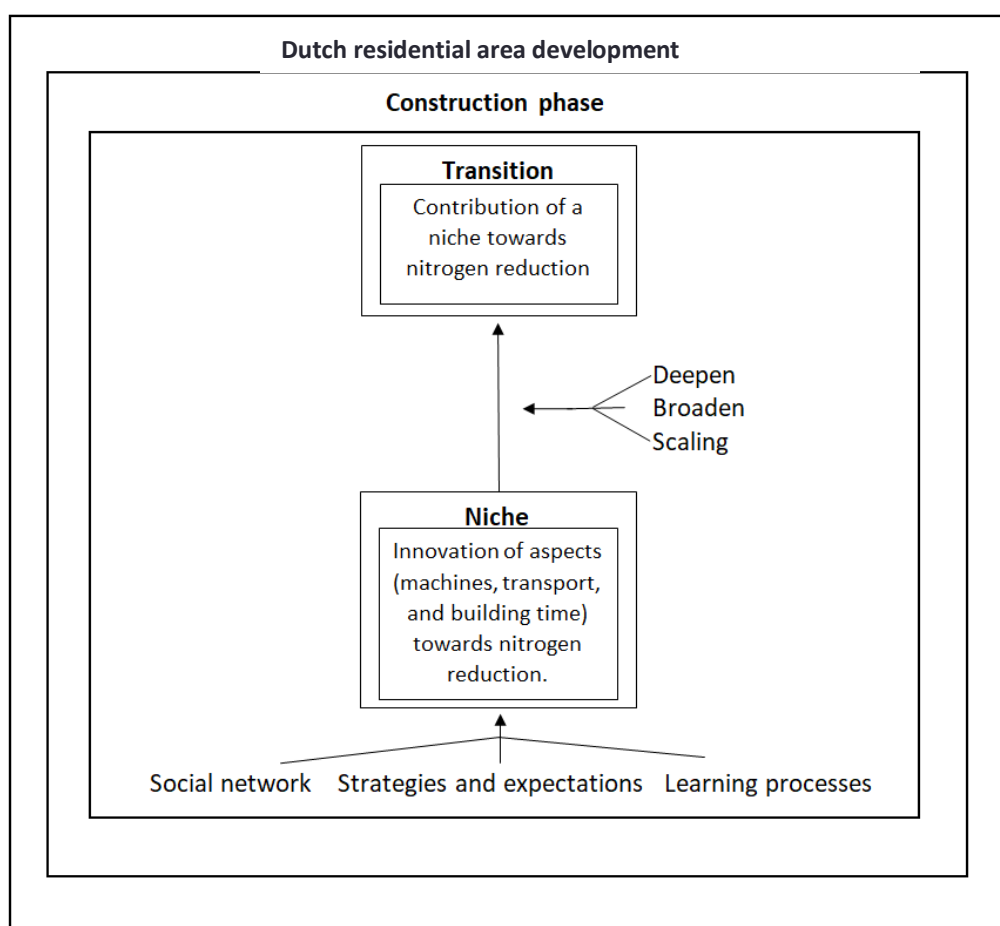


Figure 5. [Conceptual model].

### 2.2.1 Operationalization

#### Innovation in the construction phase

##### Machines

The machines are an important aspect of the construction phase. They are indispensable for building processes. There are some factors that determine the amount of nitrogen they expel. First, there is the age of the machines that are used. According to Sandanayake et al. (2016ab) the older the machines are the more nitrogen they expel. In order to reduce the nitrogen emission newer machines need to be used. Second, the hours of using the machines determine the amount of nitrogen emission. The longer machines are used, the more nitrogen they expel. As third it is also important to consider the energy source used for the machines. Whether they are fuel based or run on electricity can make a difference. This is also linked to the age of machines; the older the machines are the bigger the chance that they are fuel based (Sandanayake et al., 2016ab).

##### Transport

Transport is also indispensable for building processes. Transport refers to delivering materials and machines necessary to the construction site. But it can also refer to the working people on the construction site who need to travel there from home or from the company they work for. The nitrogen emission they expel depends on several factors. First, there is the amount of transport needed (Sandanayake et al., 2016ab). When more transport is needed, more nitrogen will be expelled. This creates a link with the number of kilometers the vehicle needs to travel to get to the construction site which brings us to the second aspect. The longer the distance the transport needs to discard, the more nitrogen they will expel. The type of transport also determines the amount of nitrogen (Sandanayake et al., 2016ab). According to CBS (2017) every type of transport contributes a different amount of nitrogen emission. Ships contribute most, followed by road traffic, inland shipping, airplanes and trains. The last aspect is the energy source used for the vehicles. Whether they are fuel based or run on electricity can make a difference (Sandanayake et al., 2016ab).

##### Building time

According to Sandanayake et al. (2016ab) it is important to determine how long a building process will take time. The total time necessary to build influences the period that machines and transport are needed which influences the nitrogen emission. It should be mentioned that a shorter building period does not automatically mean less machines and transport, thus less nitrogen emission. The same amount of machines and transport can be used more intensive in for example six months instead of one year. This means that the nitrogen emission will stay the same when using the same amount of machines and transport. It can even be more beneficial to indicate a longer building time, for example from six months to one year. The nitrogen emission expelled by the same amount of machines and transport can spread over a longer time giving the surrounding environment more time to absorb the nitrogen (Sandanayake et al., 2016ab).

#### Successful development of a niche

##### The formation of a social network

Social networks are important to create support for the niche. They do this through interactions between relevant stakeholders and provide the necessary resources like money, people and expertise (Kemp et al., 1998). Social networks contribute more to niches when they are broad and deep. Broad refers to different kinds of stakeholders involved in the articulation of certain visions. The involvement of outsiders can be important to broaden frames and facilitate second- order

learning. This refers to the composition of the social network and if there is a shared problem definition. Deep means that people, who are representatives of their organization, are responsible to mobilize support within their own network (Hoogma, Kemp, Schot, & Truffer, 2002).

#### The formation of strategies and expectations

Expectations can be seen as crucial for the development of a niche. They provide the learning processes, attract necessary attention and legitimate protection (Kemp et al., 1998). Expectation management concerns about how the niches present themselves to external actors and whether they keep the promises they make about performance and effectiveness. Expectations contribute more to a niche when they focus on a few aspects: robustness, specific and innovative. Expectations being more robust mean that they are shared by more actors. Being specific in expectations means that there is more guidance than when there are too general (Hoogma et al., 2002). Expectations need to be innovative and in this case based on sustainability if they want to come to a transition. Therefore, innovative is the most important aspect the projects need to focus on when trying to contribute to niche development.

#### Learning processes

Learning processes contribute more to niches when they do not only focus on first- order learning, but also on second- order learning. First- order learning is directed at facts and data, while second- order learning focuses more on frames and assumptions (Schot & Geels, 2008). Within a niche experiments play an important role. This shows the application and feasibility of a certain niche. When the experimenting is successful it is easier to increase the network and resources, and stabilize the niche. In order to know whether a certain experiment is successful, evaluation is an important part (Geels & Kemp, 2000, p. 14).

#### Contribution of a niche to a transition

##### Deepen

Deepening is defined as a learning process through which actors can learn about the possibilities and obstacles related to the experiment within a certain context. The learning process is characterized as context- specific since the same experiment in another context with different actors, institutions and cultures would produce a different outcome (Van den Bosch & Taanman, 2006). Also, learning in an experiment is partial, because it is limited to the specific context and only on small scale. Therefore, variation can be important; different experiments in different contexts to learn as much as possible. It is important to learn to gain experience and adapt to this. The learning process that is central in deepening is also central in niche development. There is a recursive relation between niche and experiment: niches enable learning processes in experiments but are also shaped by these learning processes (Van den Bosch & Rotmans, 2008).

##### Broaden

Broadening is defined as repeating an experiment in other contexts and linking this to other functions and aspects regarding the same societal challenge. These experiences can only be used when there is enough knowledge about the possibilities and obstacles of the experiment within the existing context (Kemp & Van den Bosch, 2006). In other words, the repeated experiment is the new deviant constellation of culture, practices and structure, which is the outcome of the deepening. When the niche seeks to broaden successfully then it needs to adapt to become optimal. This

broadening increases its influence and stability. Broadening does not refer to repeating without any variation; each experiment adds to a new adventure (Van den Bosch & Rotmans, 2008).

### Scaling

Scaling can be seen as anchoring new structures and ideas on a higher level, which come forward out of learning processes related to the experiments within the niches. A new and influential regime develops which can replace the existing regime or can become the alternative. The focus will be on the importance of niche development and their interaction with the regime. Scaling up can be seen as the translation of sustainable practices in niches to mainstream practices in the regime, the societal embeddedness of experiments or the embedding of experiments in the existing regime (Kemp & Van den Bosch, 2006; Van den Bosch & Rotmans, 2008). For this to happen it is important that there is support from other important stakeholders and figures from the existing regime.



<b>Concept (Sandanayake et al., 2016ab)</b>	<b>Dimensions (Sandanayake et al., 2016ab)</b>	<b>Indicators</b>
Innovation of construction phase	Machines	Age
		Hours of use
		Energy source
	Transport	Amount
		Distance
		Type
	Time	Energy source
		Total building time
Concept (Rotmans, 2000, 2005, 2006)	Dimensions (Kemp et al., 1998)	Indicators
Niche	Formation and stabilization of a social network	The composition of the social network
		Shared problem definition
		Support base
	Formation and stabilization of strategies and expectations	Innovative and sustainable expectations
		Clear final image with intermediate goals
	Learning processes	Experimenting
		Evaluation
Concept (Rotmans, 2000, 2005, 2006)	Dimensions (Kemp & Van den Bosch, 2006)	Indicators
Transition	Deepen	Learning about the innovation only within the given context
		Improving the innovation and adapt it within the given context
	Broaden	Replicating the innovation within the given but also in other contexts
	Scaling	New structures and ideas anchored at higher level
		Support of the key figures on regime level

Figure 6. [Operationalization].

## 3. Methodology

### 3.1 Research philosophy

Research philosophy is used to find out how the data should be collected and analyzed. This relies on how a researcher views the world and it also influences which approach and strategy are chosen to conduct the research (Thornhill, Saunders, & Lewis, 2009). In this research the aspects that need to innovate to reduce nitrogen emission are objective, but the experiences surrounding this process are subjective. The research philosophy in this research is interpretivism. The data related to the experiences of stakeholders' related to innovations in the residential area development incorporates that reality relies on the stakeholder's view on the situation that is being studied. This embraces the constructivist ontology (Thornhill et al., 2009). The ontology asserts that no rigid social order exists out there but is derived by the people. The data that has been collected does not know one objective truth, but represents multiple realities.

### 3.2 Research approach

This master's thesis is performed through a qualitative approach since it allows to gain an in- depth, qualitative understanding of a given phenomenon. Qualitative research focuses on meanings, definitions, characteristic and description of things. While, quantitative research focuses on the count and measurement of things (Berg, as cited in Goodman, 2011). Qualitative research attempts to develop understandings of the phenomena under study, based on the perspective of those being studied (Elliot et al., as cited in Goodman, 2011). This research focuses on underlying reasons, motivations and opinions in reaching innovations to reduce nitrogen emission. It is important to understand how stakeholders think about innovation and why. A more in- depth and human analysis is necessary. Numbers and measurement are not important to gather this kind of information. Therefore, the qualitative approach is the best way to study things in their natural setting and reflect on the stakeholder's perspective.

### 3.3 Research strategy

#### 3.3.1 Desk research

Desk research is to gather information about the topic and provide an answer to multiple sub questions. These questions will be answered through using already existing information on the topic. This is also called secondary data and can be seen as an addition to the field work. The benefit of desk research is that there is no dependency on respondents which leads to reaching goals faster. Since there was a limited amount of time for doing this research this was favorable. However, there are also some disadvantages: the information needed needs to be accessible and there is no full transparency about the creation of certain information (Tubbing, 2014). In this master's thesis in all sub questions desk research is used.

#### 3.3.2 (Multiple) case study

Besides the desk research there will also be field work. This is used to provide additional information to the desk research. The data collected through field work is called primary data. This is a way of collecting new data, analyzing it and interpreting it.

Four different case studies are central in this research. The choice for a multiple case study is to gather more information about certain aspects in a real- life setting (Van Thiel, 2014). First, it gives an integral and in- depth vision of the research object. This provides more insights in the changing existing situation, which is at the core of this situation (Doorewaard & Verschuuren, 2007).

Second, a case study brings up the complexity of a situation and then clarifies it; this is not the case with for example an experiment or survey. Case studies are challenging since it is very dependent on the capacities of the researcher. The lack of routine asks for creativity as solution. Also the researcher needs to be open minded about other perceptions, even if they contradict with previous findings (Yin, 1994, p.55). Also, it is difficult to generalize the outcomes.

The case studies were planned to be chosen in consultation with Lievense|WSP. The plan was to discuss this in the beginning of the internship in order to choose the case studies carefully and meet certain criteria to be able to compare the outcomes. But because the internship was interrupted early and their work also got less, there were fewer projects available to conduct research. To reduce delay the research was already started with the case studies available and also without the help of Lievense|WSP.

The multiple case studies focus on the construction phase and their process towards innovation. This means that only certain aspects will be studied and not the case as a whole; this is useful to compare the outcomes.

The cases are heterogeneous; this is to compare several cases and try to find out what the effect is of the variation in certain variables (King, Keohane, & Verba, 1994, p. 141– 143). Some criteria are developed to argue the choice of cases. The first criterion is that the cases need to be a project related to residential area development. The second criterion is size of the project. According to Burgan and Burgan (2014) the size of the project represents the magnitude of the project. The size of the multiple central cases is determined through the indicator amount of end users. Cases with less than 25 end users can be seen as small, cases with 25 to 250 end users are named medium, and cases with 250 or more end users are named large. This can be seen in the project sizing matrix in figure 7. According to Burgan and Burgan (2014) the size of a project is an important aspect for the project approach and project management since a “one size fits all” approach is not effective. A “one size fits all” approach is not effective since the nature and characteristics of different sized projects are not similar. This means that the different sized projects differ in their management approach and policy. This makes the size of the project a relevant criterion to argue the choice of cases. In the results chapter it becomes clear whether the different sized projects really differ from each other on the different dimensions or if they share some aspects.

In this master’s thesis two medium projects and two large projects are used. This means that small projects are not central in this research. Reason is that projects with less than 25 end users focus less on innovation due to their lack of budget.

Small Project	Medium Project	Large Project
<ul style="list-style-type: none"> <li>• Project duration less than six months</li> <li>• Project budget less than \$100,000</li> <li>• Project team fewer than five people</li> <li>• Minimal integration with other business units</li> <li>• Impacts fewer than 25 end users</li> </ul>	<ul style="list-style-type: none"> <li>• Project duration between six months and 12 months</li> <li>• Project budget between \$100,000 and \$500,000</li> <li>• Project team between five and 20 people</li> <li>• Moderate integration with other business units</li> <li>• Impacts 25 to 250 end users</li> </ul>	<ul style="list-style-type: none"> <li>• Project duration greater than 12 months</li> <li>• Project budget greater than \$500,000</li> <li>• Project team greater than 20 people</li> <li>• Significant integration with other business units</li> <li>• Impacts more than 250 end users</li> </ul>

Figure 7. [Indicators determining the project approach]. Retrieved from Burgan and Burgan, 2014.

## 3.4 Research method

### 3.4.1 Literature research

Before and during the research a literature research took place. In this step scientific articles, policy documents, papers and articles about the nitrogen crisis, sustainability and innovation within residential area development were analyzed. This literature had been searched by using keywords in Google Scholar, GreenFILE, RUQuest, and scientific articles from previous study years. Some keywords were: sustainability, construction phase, nitrogen emission, transition, housing sector, residential area development. Once a relevant article had been found, the authors named in the article were used to conduct further research. Doing literature research the knowledge about the subject increased. The introduction, theory and conceptual model are based on the analyzed literature. The sub questions are partially answered through literature research.

### 3.4.2 Interviews

To complement information from literature with new insights in- depth interviews took place. This is a successful way of collecting data since it provides insight in varying visions (Strauss, 1987). The interviews were semi- structured. This means that a guide was made in advance of the interview itself. This provides the concepts that need to be addressed, without formulating all the exact questions. It leaves some room to deviate if other important aspects are addressed by the interviewee. The interview guide can be found in Appendix 1. The interview guide is structured on the bases of the sub questions central in this masters' thesis. The interview starts with introductory questions about the interviewee and the project. This is followed by chapter one, which represents sub question one. After that there is chapter two which represents sub question two. Ending with chapter three, which represents sub question three.

The nitrogen crisis but also sustainability is a very current issue with a lot of challenges, but it does not have a sensitive aspect. Therefore, face- to- face interviews are not necessary to conduct them. A study about the comparison of telephone and face-to-face interviews by Hanrahan and Sturges (2004) has shown that respondents appreciate a telephone conversation more if it concerns a sensitive subject. Respondents are then often inclined to give a fairer answer because of their anonymity. Also, related to COVID- 19 it was not possible to conduct face- to- face interviews. The best way to get information was via phone calls or Skype. The interviews were conducted in Dutch, to make it easier and more accessible for the interviewees and the interviewer.

### 3.4.2 Participants

The most important source of information has been semi- structured in- depth interviews with relevant stakeholders in all cases complementing the literature research. Participants can be private parties but also public parties. Private parties are project members from the business side; for example the project developer or contractor. A project developer is the initiator of the project who is responsible for the design, the finances, requiring the grounds, permits needed and a contractor. The contractor has a contract with the project developer, which makes him responsible for the development of the project. He delivers the central product through analyzing the architect's drawings and providing the necessary employees, material and machines. Both of them are close to the project which leads to a lot of knowledge about the development but also about the issues they face relating to deposition and innovation. Public parties refer to a project member from the governmental side; for example the province or municipality. In this master's thesis all interviewees are part of private parties. The interviews conducted with the public parties turned out to be not useful because they did not had the relevant information.

A table of all stakeholders that have been interviewed for the case studies can be seen in figure 8. In the following paragraphs the participants are shortly introduced to provide a more detailed overview of their function and relations towards the different projects.

Case	Stakeholders	Date interview
De Groene Loper	Project Developer	May 14, 2020
	Project manager Area development	August 3, 2020
Lage Heide	Project Developer	June 11, 2020
	Advisor	June 26, 2020
Arce Novum	Contractor	June 26, 2020
Lindenkruis	Contractor	July 16, 2020

*Figure 8. [Participants].*

#### 3.4.2.1 Case: De Groene Loper

Two stakeholders were interviewed for this case. The first participant that was interviewed for this case is a project developer at Ballast Nedam Development and thereby closely connected to the project De Groene Loper. As project developer he is responsible for the construction of the dwellings related to De Groene Loper. Because of his involvement with the project from the beginning until now he knows all the details about the construction phase. This makes him a relevant stakeholder to De Groene Loper. This stakeholder was contacted through mail and phone. The interview took place on May 14, 2020. The second interview was with a project manager Area development at Projectbureau A2. His role to this project is to make sure that the original plan is realized according to the intended quality and standards, but also to tackle obstacles during the building process. An example is that they gave advice when the nitrogen crisis turned out to be an obstacle for this project. The contact details of this stakeholder are obtained via another stakeholder from this project, the municipality Maastricht. Unfortunately they were not willing to do an interview, but they did have the contact information of this stakeholder. The projectmanager Area development at Projectbureau A2 was contacted through mail and phone. The interview took place on August 3, 2020.

#### 3.4.2.2 Case: Lage Heide

Two stakeholders were interviewed for this case. The first participant that was interviewed for this case is a project developer at Novaform. He is, together with some colleagues, responsible for the whole development of the plan Lage Heide. This makes him a relevant stakeholder to Lage Heide. A project developer has a lot of knowledge about the project in general, but not in details. As project developer he was able to sketch the background of the project and give more general information. This stakeholder was contacted through mail and phone. The interview took place on June 11, 2020. The second participant that was interviewed is an advisor at the engineering company DGMR. He, together with some colleagues, advises the contractor linked to this project through testing which permits are necessary and how they can get them. DGMR was responsible for the nitrogen tests for Lage Heide. Depending on the results they advised the contractor about which equipment should be used, how, and when. The contact details of this stakeholder are obtained via the first participant; the project developer at Novaform. This is called a snowball effect. Contact took place through mail and phone and the interview took place on June 26, 2020.

### 3.4.2.3 Case: Arce Novum

The person that was interviewed for this case is the deputy director at the department construction at H4A B.V. (Holding de Vier Ambachten B.V.). H4A B.V. is a contractor. As deputy director this person is in control of the department construction at H4A B.V. besides the director himself. In the project Arce Novum he is project leader. As project leader he is constantly working detailed on this project during all phases. The contact details are obtained via a stakeholder from another project who had no time to do an interview. Despite, their lack of time they wanted to help me. Therefore, they gave me the contact details of another interesting project. This stakeholder was contacted through mail and phone. The interview took place on June 26, 2020. Other relevant stakeholders in this project were not open for an interview.

### 3.4.2.4 Case: Lindenkruis

The person that was interviewed for this case is the planner at Heijmans. Heijmans is a contractor. As planner this person was involved from the beginning of the construction phase. As planner he is responsible for optimizing the technical design of the architect and constructor and he makes a plan for the construction phase related to time, products and subcontractors. The contact details are obtained via a stakeholder from the same project, the constructor. Unfortunately, the constructor did not have the relevant information. But he did have the contact information of this stakeholder working for Heijmans. The planner at Heijmans was contacted through mail and phone. The interview took place on July 16, 2020. Other relevant stakeholders in this project did not have any time to do an interview or did not respond to my emails.

## 3.5 Data analysis

To be able to answer the sub questions and the main question the data has been analyzed. The sub questions are answered through information provided by literature and interviews. Atlas.ti is used for the analysis of the interviews. The interviews are recorded and transcribed. Since the interviews are conducted in Dutch the transcription is also in Dutch. After transcribing the coding took place along with memoing; this took place to not lose explanations for choices that have been made. The coding took place in different stages. The first stage is open coding. This stage lies very close to the original text, but still gives an idea about the underlying subject. Important is that the complete text is coded. This means the focus is not only on the existing literature but also open for new visions. The second stage is axial coding. In this stage categories are made within the open codes which are based on the data. The third stage is selective coding. In this stage the created codes are organized into family codes which comply with the dimensions and indicators in the theory. It is also possible that new family codes arise; these indicate new findings (Corbin & Strauss, 2007). Every part of the analysis in Atlas.ti that is used in the master's thesis has been translated in English; this applies to the codes and quotes.

## 3.6 Validity and reliability

According to Boeije (2005), it is important that the researcher is involved but also maintains the necessary distance to remain as objective as possible. Ultimately, the validity and reliability of the research are important for this.

Validity is about whether the researcher has measured what he intended to measure. An investigation is invalid if the wrong was measured or if the results were interpreted incorrectly. Validity can be categorized into two types; internal and external validity. The internal validity is about whether the final conclusion with regard to the investigated relationship is correct, and whether the relationship found has been interpreted correctly. This concerns the credibility of the investigation. The internal validity is guaranteed because the interview guide is based on the

conceptual model and the operationalization schedule. The external validity is about the extent to which the research can be generalized. It is important that the respondents are chosen via a random sample (Boeije, 2005). The respondents are randomly selected in this study, which means there is diversity. However, the case studies concentrate only on a limited number of situations, this reduces the external validity. The less cases that are researched, the harder it is to apply the results to the whole (Flyvbjerg, 2006). The conclusions in this master's thesis will therefore be difficult to apply to other projects. Also, for each case study it is important to interview multiple stakeholders to get multiple perspectives on the situation and be able to compare them. The less stakeholders that are interviewed, the more difficult it is to create a complete view of the situation. However, this lower external validity is compensated by the high internal validity.

Reliability is about the replicability of the research. The point is that the measuring instrument used always gives the same results under the same conditions. This means that the research should be influenced as little as possible by systematic errors. An investigation is unreliable if the measurement is incorrect. If a measurement is reliable, this does not automatically mean that the measurement is valid (Boeije, 2005). The reliability of the research is guaranteed because the respondents are interviewed in a similar way and shared their conclusions.

### 3.7 Ethics

According to Kumar (2014) ethics can be described as *“the moral values of professional conduct that are considered desirable for good professional practice”*. According to Bryman (2008) there are four ethical principles in a research process:

- Whether to harm participants;
- Whether there is a lack of informed consent;
- Whether there is an invasion of privacy;
- Whether deception is involved.

Kumar (2014) adds to this that it is important to take different stakeholders in the research into account. Most common there are 1. the research participants or subjects; 2. the researcher; 3. the funding body. Ethical issues can be applied to these.

In this research all four of these ethical principles are protected. The participants are approached in an ethical manner by introducing them to the subject of the master's thesis and asked for cooperation via email or phone. It was completely their choice whether they want to provide information or not. They were also completely free in choice which information they wanted to share. During the interviews an introduction of the interviewer and the subject was provided. It is also asked if they were fine with the recording. To protect the participants' privacy their name is not used in the analysis. Each of them stays anonymous.



## 4. Case studies

All cases relevant in this research are selected through the selection criteria amount of end users; this is shown in figure 7 and also explained in the corresponding section 3.3.2. (Multiple) case study. The amount of end users determines whether the project can be identified as small, medium, or large. Figure 9 is a summary table of the projects according to these selection criteria. Since in this master's thesis only medium and large projects are central the size small is not represented in this figure.

	Medium	Large
De Groene Loper		
Lage Heide		
Arce Novum		
Lindenkruis		

Figure 9. [Size of the projects based on figure 7].

### 4.1 Case: De Groene Loper

#### 4.1.1. Context

The case 'De Groene Loper' is a project in Maastricht that concerns multiple aspects. This integral project concerns three main aspects. The first one is the construction of the new A2 tunnel and infrastructure. The second aspect is the public space and the third one is the realization of real estate and dwellings (Project developer, De Groene Loper, personal communication, May 14, 2020). The realization of the A2 tunnel in Maastricht should improve the traffic flow on the A2 and the inner city traffic, and relieve the inner city from noise, pollution and traffic disruption by guiding 80% of the traffic through the tunnel. Aspect one and aspect two are already finished, the real estate and dwellings are the last part of this project.

For this research the real estate is most important. On top of the A2 tunnel De Groene Loper is realized; this is a lane from North to the South of the city which creates room for nature, walking and cycling. But it should also cover space for around 1100 residential buildings and 30.000 square meters of commercial real estate. The main function is to connect the North to the South and create a connecting public space for people to move easier from East to West. The goal of the project can be summarized as following: create a connected structure between West to East and between the city and country (Vormgevingsvisie- C, 2017). Unique in this project is that the civil side and the real estate are inseparable.

De Groene Loper will be adapted to the already existing city image. This area is not uniform, but has its own character due to the adjacent neighborhoods with their own urban and architectural entities. From North to South the lane is divided into multiple areas where new and different developments will take place (Vormgevingsvisie- C, 2017). This can be seen in figure 8.

- North: Geusselt.
- Middle: Quixstraat- Voltastraat (indicated as Midden).
- Centre East: Cobbenhagenstraat- Koningsplein (indicated as Centrum- Oost).
- South: Europaplein and surroundings (indicated as Zuid).



Figure 10. [Plan areas]. Retrieved from *Vormgevingsvisie C*, 2017.

The North side of the lane is represented by the Geusselt. In this area the dwellings will be higher than average compared to the rest of the lane. They will be three to four layers and therefore more stately. Also, the architecture differs. This makes the area more present and overwhelming than the rest of the lane (Vormgevingsvisie- C, 2017). The middle is the area directly next to the Geusselt. This is the smallest part of the entire lane and will be known for its character; residential buildings at the city lane. Important for this area is that the divided neighborhoods Wyckerpoort and Wittevroutenveld become one connected area. The major part in this area will be single family homes, complemented with apartments and where possible deviant buildings in private commissioning (Vormgevingsvisie- C, 2017). Because of the new A2 tunnel the barrier of the A2 disappears which creates room for a new centre area, called Centre East. It cannot be compared with a classic inner city, but should be seen as an area with public services related to retail, education and culture (Vormgevingsvisie- C, 2017). The South part is characterized due to its central location near the A2, the University, Mecc, and station Wyck. The architecture of all residential buildings, single family homes and apartments will be similar to each other which creates an unambiguous atmosphere (Vormgevingsvisie- C, 2017).

2017 was the end of the construction of the A2 tunnel; this meant the beginning of all the work on top of the A2 tunnel and the design phase of the dwellings. In 2019 the sites got prepared after which the construction began. The project is divided in three phases, phase 1, phase 2a, phase 2c, each representing its own characteristic buildings. Each of these phases knows multiple steps before they can start with the construction phase; submitting the building permit, selling the dwellings, and getting the building permit. In July 2019 the construction of phase 1 was started, in March 2020 the construction of phase 2a was started, and the last phase 2c is planned to get started at the end of 2020. Phase 1 is represented with 53 city houses and 15 apartments among which one penthouse. In phase 2a 46 city houses are built. In phase 2c 10 houses and 32 apartments will be built (Ballast Nedam Development, n.d.).

#### 4.1.2. Sustainability aspects

De Groene Loper wants to be known for a healthy and sustainable life. Relating to this being energy neutral is an important goal. All buildings will be provided with solar panels and the gas network will not be used. These are some aspects of sustainability relating to the use of the building. But they also took into account to develop public services at walking distance to avoid car use as much as possible (Ballast Nedam Development, n.d.).

The new sustainability quality mark DGBC is the new evaluation for contemporary dwellings. The Dutch Green Building Council (DGBC) is a national societal organization in the field of sustainable

buildings and real estate. They fulfill a role in the transition to a sustainable built environment. In order to measure the sustainability level of dwellings they developed the sustainability quality mark BREEAM- NL. This certificate can be achieved for the design phase and the delivery phase. The total score is made up out of sub scores representing multiple sustainability categories. These sub scores lead to a total score, expressed in stars. In the project De Groene Loper they tested this BREEAM certificate, which resulted in a score of four stars out of five. That makes De Groene Loper the first new construction project to achieve this score. This confirms that De Groene Loper is one of the most sustainable developments in the Netherlands (Ballast Nedam Development, 2019).

#### 4.1.3. Stakeholders

In 2006 the clients Rijkswaterstaat, the Province of Limburg, the municipality Maastricht and the municipality Meerssen signed an agreement in the form of a cooperation to agree on one plan for city and highway. In 2009 they all agreed on the integral master plan De Groene Loper designed by Avenue2. Together they form the most important stakeholders in this project. Avenue2 is a project organization, represented by Strukton and Ballast Nedam Development. Strukton was responsible for the A2 tunnel and the public space. Ballast Nedam Development is as developer responsible for the new residential building located at De Groene Loper. Laudy Sittard is hired as the contractor in this project (Project developer, De Groene Loper, personal communication, May 14, 2020). Projectbureau A2 is also a stakeholder closely connected to the project. Their role is to make sure that the plan which has been agreed on in 2009 is realized according to the pre- arranged quality (Project manager Area development, De Groene Loper, personal communication, August 3, 2020). In 2017 the construction of the A2 tunnel and the surrounding public space were finished, this meant the beginning of the design phase of the real estate. In the design phase the architects and the developer Ballast Nedam Development are most relevant. The multiple architects designed the buildings in consultation with the developer to fit the overall plan. In the construction phase the contractor Laudy Sittard and the developer Ballast Nedam Development are most relevant. The contractor is responsible for the construction on- site, which is led by the developer. The municipality Maastricht is an important stakeholder during both phases, since they test the practicality to the theoretical demands in the law in order to give the permits needed.

## 4.2 Case: Lage Heide

### 4.2.1. Context

To the Southeast of Valkenswaard 330 dwellings are being built as part of the project Lage Heide. 80 lots are available for private commissioning (Lage Heide, n.d.). The project is built divided over four phases. The plan is characterized by a large variety of dwellings. Every house fits in the green and historical area. During the building process they try to preserve as much beech trees as possible. Therefore, the four sub areas are named after these trees; 'the red beech', 'white birch', 'pedunculate oak', 'blue spruce', 'silver lime', 'the green elder'. (Van Gisbergen, n.d.; Lage Heide, n.d.). Each of these areas is developed in multiple phases. In June 2017 they started with phase one of the sub areas, except the 'silver lime' and 'the green elder'. In July 2019 they started with the construction of phase two of the sub areas 'the red beech' and the 'white birch'. The 'red beech' was already completed after one phase. In March 2020 was the beginning of the construction phase of 'silver lime' and 'the green elder'. Like the sub area 'the red beech' these two sub areas will also be completed after one phase. And in July 2020 they started with the third and final phase of the 'white birch'. The 'pedunculate oak' and the 'blue spruce' are still in the selling part of phase 2. As soon as these dwellings are sold, or the majority, they will start building.

The urban plan, which can be seen in figure 9, is to develop a neighborhood combining sustainable and village living. The latter is met through focusing on diversity, meeting, green and simplicity. The already existing dwellings are formally not a part of the plan area, but spatially they are. Therefore, the plan is adapted to the already existing city image (Gemeente Valkenswaard & Buro 5, 2010).



Figure 11. [Urban plan]. Retrieved from Gemeente Valkenswaard & Buro 5, 2010.

### 4.2.2. Sustainability aspects

The goal of Valkenswaard is to be an attractive and climate resilient municipality by 2050. This means they need to focus on becoming resilient against flooding, heat and drought. Achieving this

means that Valkenswaard works towards becoming energy neutral and emission free. These statements also apply to the building sector (Gemeente Valkenswaard, 2019).

Lage Heide should develop as a residential- and nature area focusing on sustainability. Since the area is located between the stream valleys of Dommeldal and Keersopdal nature is very important. Preserving the present nature values is therefore priority. The dwellings need to be flexible in order to be life course resistant. This fits into the cradle- to- cradle principle. This principle indicates that all used products will be reused again and that as little material as possible should be used. This means avoiding toxic material, using local and compostable material, building demountable, applying of vegetation roofs and integral solutions. In the urban plan the sun- oriented parceling has been taken into account. The sun- oriented parceling ensures that passive solar energy can be used, which has a positive effect on the energy consumption of the dwellings. It also provides opportunities for active solar energy, such as solar panels for the generation of electricity (Gemeente Valkenswaard & Buro 5, 2010).

#### 4.3.2. Stakeholders

Buro 5 Maastricht has been commissioned by the municipality Valkenswaard with support of SRE Environmental service to develop a sustainable plan for this area (Gemeente Valkenswaard & Buro 5, 2010). The dwellings in Lage Heide are developed by the partnership VOF Zuid. This VOF consists out of real estate developer Novaform and the construction company Gebr. Van Gisbergen (Project developer, De Lage Heide, personal communication, June 11, 2020). The 80 from the 330 lots that are available for private commissioning are developed by the municipality of Valkenswaard. The rest is developed by the partnership VOF Zuid (Lage Heide, n.d.). In the design phase especially the architects and the developer Novaform are most important. During the construction phase the contractor Gebr. Van Gisbergen is more present, since they lead the construction works on- site. Normally, the municipality is mostly important for the approval of the permits needed and the public space. However, in this project the municipality Valkenswaard owns 80 lots, which gives them more interest during all phases.



## 4.3 Case: Arce Novum

### 4.3.1 Context

The project Arce Novum is a part of the bigger project called Othene- Zuid located in Terneuzen. The development of Othene- Zuid concerns 1200 dwellings, schools and shopping facilities. There are multiple sub areas, of which some already have been built, others are currently under construction, or are being sold. The sub areas that are currently being built can be seen in figure 10. The project Arce Novum is one of them. In this sub area 57 dwellings are being built, which means that the construction phase of this sub area has just begun (Contractor, Arce Novum, personal communication, June 26, 2020). Every sub area has its own architecture style and on the free lots can be chosen for a unique style. The diversity in these sub areas and free lots are combined to one cohesive neighborhood through roads, green structures and water features (Othene, n.d.).



Figure 12. [Sub areas]. Retrieved from Othene, n.d..

### 4.3.2 Sustainability aspects

The region Zeeland is the first one of the 30 regions who has drawn her Regional Energy Strategy (RES). This shows that they are very ambitious on the sustainability aspect. They are also working on the Transition Vision Warmth. This indicates the route to gasless and energy neutral neighborhoods. These two visions indicate the focus of Zeeland on making the built environment more sustainable (Voortgangsrapportage, 2020).

The dwellings in 'Arce Novum' have solar panels and heat pumps to become more energy efficient. This also contributes to becoming sustainable. During the construction more sustainable building materials are used, for example responsibly harvested wood (Othene, n.d.).

### 4.3.3 Stakeholders

AM Zeeland is a developer and develops in corporation with the municipality Terneuzen Othene-Zuid and is therefore also responsible for the sub area Arce Novum. AM Zeeland works with the business model 'I AM YOU'. They work together with interested people based on conceptual power, innovation, and co-creation. Sustainability is an important aspect related to this project. The contractor related to this project is H4A B.V., the biggest contractor in Zeeland, and the architect for this sub area is Hans- Jurgen Rombaut (Contractor, Arce Novum, personal communication, June 26, 2020; Othene, n.d.). The architect Hans- Jurgen Rombaut and the developer AM Zeeland are most important for the design phase. The contractor H4A B.V. has the responsibility for the construction on-site, which makes them most relevant for the construction phase.

## 4.4 Case: Lindenkruiis

### 4.4.1 Context

The project Lindenkruiis is located at the inner city of Maastricht in the neighborhood Statenkwartier and is part of the Belvédère project Maastricht. The Belvédère project is the urban development of an area of 300 hectares spread over the inner city from Maastricht till the border with Belgium. The sub project Lindenkruiis gives room to 247 dwellings. The goal is to match the tradition of urban renewal: sustainable with the focus on quality of architecture and the surrounding environment. The buildings should not become the main focus; however they should be seen as lifting up the already existing city image. This project is built in multiple phases. The planning of this sub project Lindenkruiis already began in 2003 (Lindenkruiis, n.d.). However, the first phase was delivered just in 2014 after which the construction of the second phase began in spring 2014. The third phase was delivered in April 2020. The construction of the final phase will be started during summer 2020 and delivered in the end of 2021 (Hurks, n.d.). The last phase has a different location than the previous ones. A map of where phase 4 is located and the rest of the project can be seen in figure 11.

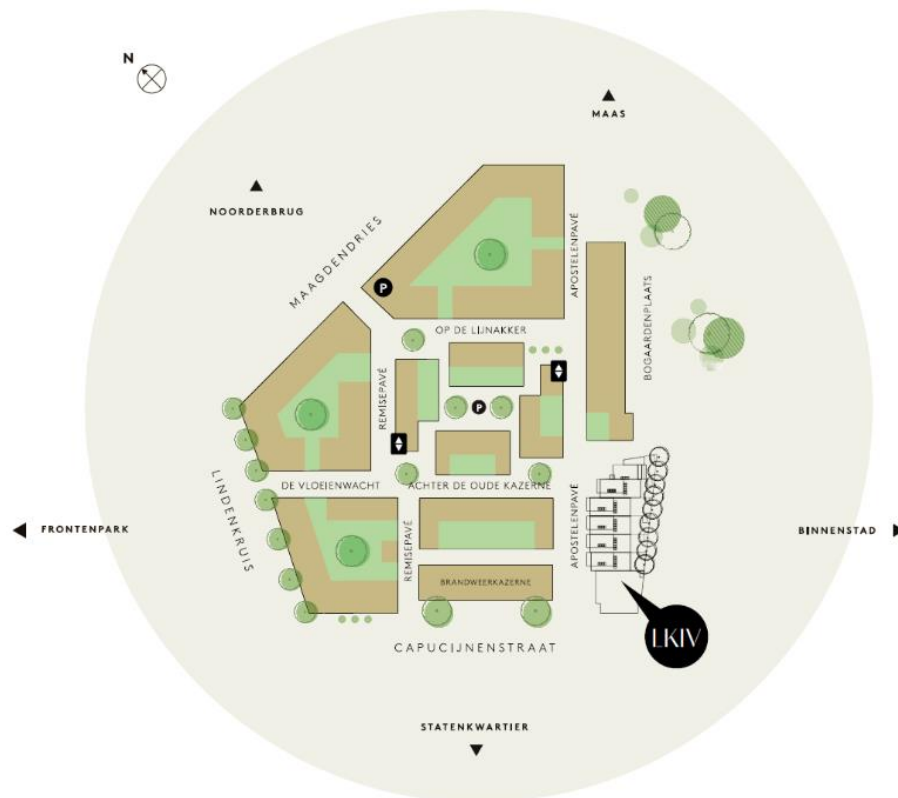


Figure 13. [Location of the project and phase 4]. Retrieved from Lindenkruiis, n.d.

### 4.4.2 Sustainability aspects

The project Lindenkruiis has its focus on sustainability since they are a part of the overarching project Belvédère. One of their focus points during construction is that the environmental burden should be as limited as possible by using innovative and integral concepts (Lindenkruiis, n.d.). The dwellings will be connected to the city heat network; this means that the inhabitants will make use of the residual heat from Sappi. This means one step towards the ambition of being energy neutral in 2030. The dwellings will not be connected to the gas network and there will be an experiment of sharing cars (Energy agreement Belvédère Maastricht, 2018).



#### 4.4.3 Stakeholders

The developer is Lindenkruis B.V. which consists of RO Groep and Hurks. RO Groep is the developing party and mostly responsible for the design phase. Hurks is the contractor, which makes them responsible for the construction phase. RO Groep is most important during the design phase together with the architects AWG Architects from Antwerp. AWG Architects focus on a philosophy based on five themes; building integral and environmentally conscious is one of them. The landscape architect MTD has been responsible for the urban plan and design plan of the public space since 2007. They collaborated mainly with AWG Architects (Lindenkrus, n.d.). The other three architects were: Verheijen Architecten, Inex Architecten and the Three Architects. The involved constructor was Brekelmans. And of course the municipality Maastricht was involved as supervisor and as responsible party for the construction of the streets, steps and greening. The contractor Hurks was only involved in the first three phases, after that their job was transferred to the contractor BAS Bouw. Therefore, BAS Bouw is the contractor during phase 4. This also meant the end of the Lindenkruis B.V.. RO Groep and the different architects that were involved were most present during the design phase. During the construction phase 1, 2 and 3 the contractor Hurks was responsible for the construction on- site. However, it should be mentioned that Hurks was only responsible for a part of phase 1. The project Lindenkruis was started with another contractor, but this was ended very soon and Hurks took over. For phase 4 this responsibility was given to the contractor BAS Bouw (Contractor, Lindenkruis, personal communication, July 16, 2020)

## 5. Results

In this chapter an answer will be formulated for every sub question based on the interviews and literature research. All case studies will be mentioned and analyzed. At the end of the descriptive analysis there is a discussion/reflection part that will discuss the findings for that sub question. Also the outcomes related to the projects will be compared based on the division which is shown in figure 7.

### 5.1 Sub question 1

#### **Which aspects of the construction phase influence the nitrogen emission?**

*In order to make a transition towards nitrogen reduction in the construction phase of residential area development possible it should be known which aspects contribute most to nitrogen emission. When this is known it is clear which innovative aspects contribute to nitrogen reduction, and also what is meant with innovative aspects in the main question.*

The construction of buildings is a significant contributor to the nitrogen emissions through different factors. A huge amount of energy and resources are used during this phase. According to Seo, Kim, Hong and Kim (2016) the whole process during the construction phase is responsible for around 40% of the emissions generated worldwide. The construction phase expels embodied energy with direct and indirect energy emissions. The direct energy is the energy necessary for the construction on-site. The indirect energy is the energy necessary for providing products and services for the construction operations (Huang et al., 2018, p. 6). According to a research from Yan, Shen, Fan, Wang and Zhang (2010) the energy consumption of machines and equipment, the transport from materials and the builders, and the building time are the main aspects responsible for emission during construction.

#### **Machines**

Direct energy can be linked to machines and equipment that is used on the construction site itself. According to Hong et al. (2015) machines and equipment used during construction can emit different amounts of emission depending on different factors. These factors are the age of the machines, the amount of machines and the energy source that is used by the machines. These factors eventually determine how much nitrogen emission is expelled. The machine produces emission from the internal combustion it has. That emission rises up in the air and deposits it a bit further away in nature areas. The amount of that emission depends on the machine (Contractor, Arce Novum, personal communication, June 29, 2020).

#### **Age**

When machines and equipment are older, they expel more emission and the chance of being electric gets smaller. On this indicator the projects have the same thoughts. In every project it is mentioned that they do not look specifically at the age of the machines in order to be progressive. However, they do implement the machines necessary to limit their nitrogen emission in order to get their necessary permits. Only the project De Groene Loper considers the sustainability aspect. In the project De Groene Loper the project developer mentioned that they do not look specifically at the age of the machines but they do try to implement equipment from as recently as possible. As the project developer said: *"No, there is, however, an explicit assignment to our contractor to use equipment on site as recently as possible."* The project manager Area development from the project De Groene Loper mentioned that first they used a certain crane in the construction phase which caused too much nitrogen in order to get the permit: *"It appeared that during the construction phase they used a crane at certain moments which caused a peak in nitrogen."* As result the stakeholders had to reconsider the machines and choose an alternative from a more recent year, because they cause less nitrogen. This project developer also mentioned that the role of availability

in machines is an important limiting aspect. However, he mentioned that the recent years a change took place towards more sustainability in the contractors and suppliers increasing the availability of these machines: *“The role of availability plays a big role. But you notice that both the contractor and the suppliers of equipment and cranes have seen a shift in the available equipment in recent years.”* In the project Lage Heide the project developer mentioned that they only consider the age of the machines in order to limit their nitrogen emissions to get their permits needed: *“But it is not that we want to be progressive in this. It has more to do with how we ensure that we have nitrogen emissions within what we are allowed to do.”* The advisor in Lage Heide mentioned that it is almost necessary to use the youngest machines in order to get a permit: *“If you want to meet the nitrogen boundaries in order to get the permit, then you are forced to use the most modern machines.”* In the project Arce Novum the director mentioned that they do not look at the age of the machines in order to become more sustainable, they only do what is necessary in order to get their permits: *“To be honest we do not have any extra measurements than necessary.”* The contractor in the project Lindenkruis mentioned that they do not focus on the age of the machines: *“We contact a crane company saying that we need a crane with certain specifications about how much weight they need to lift, and then they deliver the crane. But we do not look at the age.”* As reason the contractor mentions the costs: *“We make choices based on the costs. So the choice of cranes and materials is based on that.”*

#### *Hours of use*

Also, the longer the machines and equipment are used, the more nitrogen they expel. The projects are divided about this indicator. In the project De Groene Loper they consider the hours of use in order to decrease their emission. Both the project developer and the project manager Area development mentioned that they use the concept of prefabricated frames. The project developer gives as reason that they do this in order to decrease the use of machines: *“We use a concept where the frames of the houses are prefabricated in a fabric, brought to location on a truck and are put together on site. . . . The mobile cranes are used when needed, instead of running all the time.”* The project manager Area development mentioned that they did not expect to have problems getting their permit related to nitrogen since they use prefabricated frames: *“We thought the nitrogen would not cause any problems, since everything is prefab. This means that only a part of the building activities takes place on- site and an important part in the fabric and not on the building area itself.”* In the project Lage Heide the advisor said that their contractors use their machines as long as they need to complete the project. They only consider the hours of use in order to decrease their emission when this is necessary to get their permits: *“That is the time needed with the machines to complete the project. The contractor wants to comply with the limited values to get their permits.”* The project developer in Lage Heide mentioned that the hours of using the machines is only considered when they are not able to get their permit: *“. . . if the calculations shows that we are above the boundaries and the advisor mentions measurements in order to lower our emission, then we start looking at hours of use and age.”* In the project Arce Novum the same applies for the hours of using the machines as was the case for the age of the machines. The contractor mentioned this: *“Since extra measurements related to machines are not imposed on us by the government, we do not have a policy for that.”* The contractor in the project Lindenkruis mentioned that they try to reduce the hours of use by making an efficient planning: *“If things need to be carried on- site then we try to plan that as much as possible on one day, so we can use the crane to its fullest. So it will not happen that the crane is off for one hour or only used for half a day”*

#### *Energy source*

When fossil fuels are used for the machines the emission is much higher compared to being electric. During the construction phase 99.5% of the direct energy use comes from fossil fuel. Therefore, making the energy use more efficient and optimize the use of machines and equipment can reduce the direct energy emissions significantly (Huang et al., 2018, p. 18). All four projects would like to implement more electric material. However, several limitations make this very problematic for

them. In the project De Groene Loper the project developer mentioned that they would like to implement more electric material. But the problem is the availability and that the electric material is not efficient enough yet to carry the weight of the frames: *"We have had some meetings about that, those made clear that the available electric material is limited. . . . The cranes running on electricity which are able to lift up frames do not exist yet."* The project manager Area development from the project De Groene Loper mentioned that the crane which caused too much nitrogen runs on fossil fuels: *"It was simply using the cranes, those are heavy transport and it all runs on diesel which causes a lot of emissions."* However, he did mention that the nitrogen crisis is a push towards a transition to become more dependent on electricity: *"A lot of building logistics still depends on diesel, that nitrogen pushes a very conservative sector to renew towards electricity."* In the project Lage Heide both the project developer and the advisor mentioned that their contractor only considers electric material when there are problems getting a certain permit. The project developer mentioned that the energy source of the machines is only thought about when they face problems getting the permit: *" . . . if the calculations show that we are above the boundaries and the advisor mentions measurements in order to lower our emission . . . . And it is also considered if we need to take other measurements like for example an electric crane instead of a normal one on fossil fuel."* The advisor shared this opinion: *"If they cannot meet certain standards then we recommend electric material."* Both the project developer and the advisor in Lage Heide argued there are two limitations. The first one was also mentioned by the project developer in the project De Groene Loper; the availability. The second limitation is mentioned by the advisor connected to Lage Heide. He mentioned that a contractor is often not prepared to invest in electric material when the material running on fossil fuel still has a lifespan of several years: *"That is pretty hard since their availability is limited. . . . And besides, the machines the contractor already has have a certain depreciation time."* In the project Arce Novum the contractor argued that they see that the need for electric material is increasing, therefore they invest 10% in sustainability: *"Of course we see that there is need for electric material, which is also necessary in the future. We support that."* However, the contractor also mentioned two limitations. The first one is the obstacle of making all machines more sustainable, they do not have the resources to do that. The second limitation mentioned is charging the machines: *"The material cannot become sustainable overnight. . . . Think about charging the cranes. How do you want to do that; bring it back to the workshop every day or do we need to make electric charging points onsite."* In the project Lindenkruis the contractor mentioned that their material is not electric: *"We used mobile cranes. Since we did not need a crane very often, that was more interesting cost wise. And they are on fuel."*

## Transport

The indirect energy emission is more dominant in the construction phase. To provide the products and services necessary for the construction operations, transport is inevitable. The transportation can be divided into heavy transport and lighter transport. The heavy transport carries the building materials, construction equipment and construction waste. The lighter transport relates to the builders which travel from home- to- work or to the construction site. The amount of emissions they expel is the indirect energy. Transport is an important factor in the amount of nitrogen emission. The total amount of transport, the distance they need to travel, the type and energy source all determine the indirect energy that gets expelled in the end (Seo et al., 2016, p. 3).

### *Amount of traffic flows and distance travelled by heavy and lighter transport*

The more traffic flows and more distance travelled by heavy and lighter transport means more nitrogen emission. On both indicators the projects are divided. In the project De Groene Loper the project developer and the project manager Area development mentioned that they make use of the concept of prefabricated frames. This decreases the amount of heavy transport compared to the traditional building according to the project developer: *"Normally for every part of the house multiple truck movements are needed, with the prefabricated frames that is diminished to one for*

*each house.*" The project developer mentioned that since De Groene Loper is located in an urban area they also try to decrease the amount of employee transport through the implementation of two measurements: *"We ask our contractor, suppliers and employees to travel together to the construction site in order to diminish the traffic movements. . . . We have a central parking lot . . . to prevent that employees searching for a parking lot increase the traffic flows."* However, the project developer could not tell anything about decreasing the distance travelled by the transport and vehicles in this project. In the project Lage Heide the project developer and the advisor could not tell anything about what they do about decreasing the amount and distance travelled by the heavy transport or employee transport. They mentioned that they only consider these aspects when getting the building permit is threatened. The contractor in the project Arce Novum mentioned they are working on decreasing the amount and distance travelled by the heavy transport and the employee transport. Like in the project De Groene Loper they stimulate employees to drive together. But they are also analyzing the driving behavior of the heavy transport and their employees: *"We are working on a project to track all of our vehicles, analyze their behavior and then re- educate them."* Tracking the vehicles should lead to an analysis on the driving behavior of the heavy transport and the employees. This should provide insights in how their driving behavior leads to more emissions than necessary, when this is known it is also clear how they should drive to lower their emissions while driving. This can be used to re- educate them. In the project Lindenkruis the contractor mentioned that they use mobile cranes. This means that the crane is not present all the time at the construction site, but whenever the crane is needed they let it come: *"We did not had cranes present on the construction site. . . . If you need a mobile crane three times a week then it transported to you three times a week."* This increases the amount of traffic flows of the heavier transport. However, they do try to reduce the amount of traffic flows of the heavier transport by efficient planning: *"If we ask for materials, then we try to plan it in such an efficient way to make sure that the trucks are fully loaded instead of half full."* The contractor also mentioned that they try to limit the amount of employee transport by stimulating to drive together: *"It is stimulated to drive together, to make sure the cars are full."* According to the contractor they also try to limit the distance that needs to be travelled as much as possible for the heavier transport as well as for the employee transport: *"We work together with parties coming from the surrounding environment near Maastricht. So our products do not come from Turkey for example. And for our employees, most people come from near Maastricht. As close as possible to home to reduce the distance."*

#### *Type of transport and energy source*

Also the type of transport determines the amount of nitrogen. When the transport runs on fossil fuel the emission is much higher compared to being electric or hybrid. On the first indicator all projects had the same answer. All stakeholders in all of the projects mentioned that they only used road traffic in the form of both heavy transport and lighter transport. Related to the indicator energy source of the transport only the project developer in the project De Groene Loper said that they would like to implement electric transport but for them there is one obstacle: *"Transport that can carry the weight of these frames are not available yet."* The stakeholders in the other projects, Lage Heide, Arce Novum and Lindenkruis did not consider this aspect in their projects.

#### **Time**

The total building time is an important indicator that determines the total emission during the construction phase. The longer a projects takes time means that more machines and transport is necessary which will lead to higher emissions. A shorter building period does not automatically mean that fewer emissions will be expelled. The same amount of machines and transport that was planned to be used in 1 year can also be used in only 6 months when used more intensively. This indicates that the same amount of emissions are expelled, but in a shorter period. This means that shortening the total building time is only beneficial for the emissions expelled when also less machines and transport is needed. Expanding the total building time can be beneficial only when the use of the

same amount of machines and transport in for example 6 months is used during a period of 1 year. The amount of nitrogen expelled can be spread over a longer time, having less impact on the environment (Sandanayake et al., 2016ab).

In the project De Groene Loper the project developer mentioned that they do think about the building time during their building process. However, that is not related to becoming more sustainable: *"It is in everyone's favor to make a building process as efficient as possible. . . . However, the reason is not related to sustainability, but it is just about making the building process as efficient as possible."* In the project Lage Heide the advisor mentioned that it can be beneficial to spread the building time over two years instead of one: *"The nitrogen deposition is calculated over each calendar year. It can be beneficial to spread the building time over two calendar years in order to spread the emission also over two calendar years."* However, the project developer in the project Lage Heide mentioned that the intention is not in being progressive but about getting their building permit: *"But it is not that we want to be progressive in this. It has more to do with how we ensure that we have nitrogen emissions within what we are allowed to do."* In the project Arce Novum the building time is not thought of according to the contractor: *"Not a moment is spent thinking about changing the building time in becoming more sustainable."* In the project Lindenkruis the contractor mentioned that they wanted to limit the building time as much as possible. However, sustainability was not the main reason for them but the costs were: *"If we get the project, we want to deliver it as fast as possible. Because the longer we need, the more machines we need. So based on the costs we want to build as fast as possible."* However, their building time was longer than planned because of the difficult transport road due to the already existing buildings in the inner city of Maastricht. Therefore they had to start with one part, before they could start with the rest of the project: *"The transport road was very difficult because of the location in the inner city of Maastricht. There were already many existing buildings so we had to build the first part of the project before we could start with the second part. Otherwise we could not reach the first part with our trucks and cranes."*

### 5.1.1 Discussion

According to Sandanayake et al. (2016ab) the aspects machines, transport and building time contribute most to the nitrogen emission during the construction phase. According to the above descriptive analysis it can be mentioned that each project has its own ambitions in becoming more sustainable and therefore they focus on different aspects to reduce their nitrogen emission during the construction phase. The dimension machines is only seen as an important aspect that influences the nitrogen emission in the construction phase by the project De Groene Loper. They are the only project that tries to be more progressive on becoming sustainable on this dimension; they try to implement the newest material and use prefabricated frames in order to diminish the hours of use on-site. Reason for this is that they had to find an alternative for a certain crane they used since this crane expelled too much nitrogen. Being progressive means that they want to implement more sustainability than needed for the building permit. However, while reaching their goal of making their machines more sustainable there are two limiting aspects: the availability and the efficiency of electric machines. This is also mentioned by Frissen (2020). She states that only 5% from the 115.000 different construction tools is electric. Thereby, those 5% is mainly the smaller material (excavators) and not the heavier material (cranes). These facts state that the availability and the efficiency of electric material are still left behind. The other three projects, Lage Heide, Arce Novum and Lindenkruis, only invest in making their machines more sustainable when this is necessary to get their permit. This means that it is not their goal to reduce their nitrogen emission through their machines. However, sometimes they are forced to become progressive and implement the newest material, reduce the hours of use or consider the energy source in order to get their permit. The project Lindenkruis mentioned their budget as a limiting aspect for not being progressive on the dimension machines. This complies with Frissen (2020) where Lokkerbol states that material and equipment that is more sustainable is 30% to 70% more expensive than material and equipment

running on fossil fuel. They also mentioned that sometimes they reduce their emissions to reduce their costs; becoming more sustainable is more of a side-effect for them. The dimension transport is seen as an important aspect that influences the nitrogen emission in the construction phase by most of the projects. Only the project Lage Heide does not consider this dimension in becoming more sustainable. Because the other three projects do see transport as an important dimension to become more sustainable, this dimension is the most important aspect to influence the nitrogen emission in the construction phase. The project De Groene Loper invests in their transport to enhance sustainability; they use prefabricated frames to reduce the amount of heavy transport and stimulate their employees to drive together and constructed a central parking lot to reduce the amount of employee transport. They would like to be progressive on the energy source of the heavy and lighter transport. But the availability is a limiting aspect. Again this corresponds with Frissen (2020) who stated that only 5% from the 115.000 different construction tools is electric. The dimension transport is also considered in the project Arce Novum to reduce their nitrogen emission; they try to reduce the amount and distance travelled by the heavy transport and employee transport through stimulating the employees to drive together and analyzing the driving behavior of both to re-educate them. This effort and investment makes them progressive on this dimension. The same applies to the project Lindenkruis, they try to become more sustainable on the dimension transport; efficient planning to decrease amount of heavier transport, stimulating to drive together to decrease amount of employee transport and work together with parties and hire employees nearby to decrease the distance travelled by both. On the dimension time it can be mentioned that none of the projects value this dimension in becoming more sustainable. Therefore, the dimension time is not an important aspect influencing the nitrogen emission in the construction phase. This is deviating from the theory of Sandanayake et al. (2016ab) which stated that building time is one of the important aspects contributing to the nitrogen emission during the construction phase. However, the projects do mention the building time as an important aspect but for different reasons than sustainability. In the project De Groene Loper the building time is considered based on efficiency instead of becoming more sustainable. In the project Lage Heide the building time is only considered when it is needed to get their building permit. In the project Lindenkruis the building time is considered based on costs instead of becoming more sustainable. In the project Arce Novum the building time is not considered in general, not even to reach other goals like in the other projects. Briefly, the dimensions transport and machines are the most important aspects influencing the nitrogen emission in the construction phase. As mentioned earlier, this outcome is deviating from the theory of Sandanayake et al. (2016ab) where machines, transport and building time are claimed to be important aspects contributing to nitrogen emission during the construction phase. In the projects only two of those three aspects are seen as relevant contributors.

The project De Groene Loper and the project Lage Heide are large projects and the projects Arce Novum and Lindenkruis are medium projects based on figure 7. Both large projects emphasized the importance of the dimensions machines, transport, and building time differently. The project De Groene Loper valued the dimension machines and transport to reduce their nitrogen emission, while the project Lage Heide did not consider any of these dimensions to become more sustainable. Reason is that they focus on implementing the amount of sustainability needed to get their building permit. Since this project had no problems meeting the legal requirements there was no necessity to lower their nitrogen emission. The medium projects, Arce Novum and Lindenkruis, both emphasized the dimension transport in their process to reduce their nitrogen emission. Because the large projects differ from each other there is no relation between the size of the project and the dimensions (machines, transport, and building time) that are relevant to reduce the nitrogen emission in the construction phase.

## 5.2 Sub question 2

### How does the social network of diverse stakeholders in a project influence these innovative aspects?

As soon as it is clear which innovative aspects contribute to nitrogen reduction, it is important that these innovative aspects can develop in a protected space. This space is also called a niche; here the innovative aspects are protected from reality. Eventually the development of niches can lead to replacing the leading and dominant structure and rules (Schot & Geels, 2008). However, niches are most often not very successful; the experiments at niche level remain there and are unable to scale up (Caniëls & Romijn, 2008). For a niche to develop successfully there are three internal processes that need to be optimized; **the social network**, the strategies and expectations, and learning processes.

#### *Composition of the social network*

The project De Groene Loper has multiple stakeholders involved. In 2006 the clients Rijkswaterstaat, the Province of Limburg, the municipality Maastricht and the municipality Meerssen signed an agreement in the form of a cooperation to agree on one plan for city and highway. They are the client in this project. In 2009 they all agreed on the integral master plan De Groene Loper designed by Avenue2. Avenue2 is a project organization, represented by Strukton and Ballast Nedam Development (Project developer, De Groene Loper, personal communication, May 14, 2020). Ballast Nedam Development is as developer responsible for the new residential dwellings located at De Groene Loper. Laudy Sittard is hired as the contractor in this project. The municipality Maastricht is also involved as owner of the surrounding public space. During the whole project the process is monitored by projectbureau A2 in order to make sure that the agreed quality of the plan they agreed on in 2009 is met (Project manager Area development, De Groene Loper, personal communication, August 3, 2020). The last stakeholders are the subcontractors, the neighborhood network, the real estate agents and potential buyers. According to the project developer of project De Groene Loper they are more present at the background of the project: *“The surrounding environment and the potential buyers who are actively involved during the design phase are secondary involved.”* The project developer mentioned as the leading and most important stakeholders the client and the developer Ballast Nedam Development, directly followed up by the contractor Laudy: *“It is of course that our client and the developer are primary involved, followed up by the contractor.”* The project manager Area development mentioned that they were also very important during the process. They helped Ballast Nedam Development when they needed an expert to test the nitrogen emission during the construction phase: *“We did not think you are the builder so you need to fix it and come over when you are ready. As project agency we said, we probably have easier access to an expert than your own organization to look through your plan.”* The expert the project agency hired gave an independent advice which was beneficial: *“That advice was seen as independent advice at the municipality since the expert was hired and paid by the project agency and not by the builder himself. If the builder had hired an expert than the municipality thinks “those who pay also decide” and then they will hire a contra expert to check if everything has been done correctly.”* However, the project agency is not the most important one. According to the project manager Area development they only give advice to the developer which means they will not have a direct voice in the plan: *“Our role is more advisory, facilitating and supportive. But we cannot impose, and we will not force. We cannot do that and we do not want to do that. . . . But together you can look at good and innovative solutions.”*

The municipality Valkenswaard and SRE Environmental service are the clients in project De Lage Heide. They have commissioned Buro 5 Maastricht to develop a sustainable plan for this area (Gemeente Valkenswaard & Buro 5, 2010). The dwellings in Lage Heide are developed by the partnership VOF Zuid. This VOF consists out of Novaform and the construction company Gebr. Van Gisbergen. Novaform is the developer and part of the overarching business Clockholding. Novaform and the construction company Gebr. Van Gisbergen are the leading stakeholders according to the



project developer: *“The developer and the contractor. That is us and Gebr. Van Gisbergen.”* The advisor only mentioned the project developer Novaform as the most important stakeholder: *“... , the developer has contact with the most people in the project, like the contractor and the competent authority. So they are the biggest player in the project.”* Besides, they also mentioned the architect, the consultancy DGMR, the subcontractors and the real estate agents. The neighborhood network is also an active stakeholder (Project developer, De Lage Heide, personal communication, June 11, 2020). The project developer mentioned that they are more present at the background: *“The other stakeholders are more facilitating. Their input is needed for us to realize the plan.”*

The project Arce Novum is commissioned by the municipality Terneuzen and the Province Zeeland. AM Zeeland is the responsible developer and develops in corporation with the municipality Terneuzen Othene- Zuid, with Arce Novum as subproject. The contractor related to this project is H4A B.V., the biggest contractor in Zeeland, and the architect is Hans- Jurgen Rombaut (Contractor, Arce Novum, personal communication, June 26, 2020; Othene, n.d.). The contractor mentioned that the developer AM Zeeland and H4A B.V. are the leading stakeholders. The architect and the subcontractors are more present at the background: *“The leading stakeholder is of course the developer and besides that we are an important factor. The architect is more background, together with the subcontractors.”*

In the project Lindenkruis the developer is Lindenkruis B.V. which consists out of RO Groep and Hurks. RO Groep is the developing party and Hurks is the contractor. There are multiple architects involved. BAS Bouw is also a stakeholder; they replace Hurks as the contractor for upcoming phase 4. In phase 1 there was another contractor involved, of which the name is unknown (Lindenkrus, n.d.). The developer mentioned that the most important stakeholders depended on the phase the project was in: *“Hurks as contractor was most important during the construction phase. And the developer is the most important stakeholder during the design phase”*. Since Hurks got replaced with the contractor BAS Bouw for phase 4, they are also an important stakeholder. In phase 1 there was also another contractor involved. The stakeholders who were more present at the background are the architects, the constructor, the municipality Maastricht, the subcontractors and the real estate agents. These stakeholders were relevant until they were not needed anymore: *“There were also construction team meetings where the architects and constructor were present for as long as they were needed.”*

#### *Shared problem definition and support base*

In every project a variety of stakeholders is involved. All of them have their own perspective on how something should be done or how a certain goal should be reached. In the project De Groene Loper the project developer acknowledged that every stakeholder has its own perspective: *“... when multiple stakeholders are involved which all have their own perspective there will always be situations of disagreements.”* Therefore they find it very important to keep talking with all involved stakeholders: *“It is important to keep on talking with each other to explain why certain choices are made. . . . And involve them in the trade- offs to make them understand why certain wishes can be implemented or cannot.”* Implementing this during the project they made sure that there is a shared problem definition. This also resulted in a high support base in this project according to the project developer: *“The whole sustainability ambition is actively supported by our stakeholders. So also the aspects during the construction phase in this project.”* The project manager Area development from the project De Groene Loper also mentioned that communication and cooperation are vital since you want to achieve the same goal of implementing the plan: *“This project spreads over 20 years which supposes that the parties know each other: the public client and the private builder. And that they cooperate in a nice manner. Cooperation is that you look at issues and problems together since the common goal is that the plan which has been agreed on is carried out. You need to think that a problem of the builder will also become your problem sooner or later.”* In the project Lage Heide the project developer mentioned that there is also a shared problem definition: *“We all work together as one team.”* This shows that the overarching project goal is most important, despite personal

interests. However, the project developer did mention that they have had some obstacles in the past related to the neighborhood network: *"In the beginning . . . the neighborhood . . . also wanted to develop, but the municipality did not agree. By making objection to Lage Heide they tried to influence the municipality."* But besides this, the support base of all stakeholders is present. In the projects Arce Novum and Lindenkruis they could not mention anything negative about the relationship between the stakeholders. They never had any mutual problems concerning the shared problem definition or any lack of support during the project.

### 5.2.1 Discussion

According to Kemp et al. (1998) it is important for a social network that there is interaction between stakeholders to provide enough money, people and expertise. Analyzing the social network of the different projects it becomes clear that the same stakeholders are involved in every project. All the stakeholders that are involved have a different function which creates a large variety. This is very important to broaden the social network (Hoogma et al., 2002). Also, the project developer and the contractor are mentioned as most important stakeholders in every project. But the functioning of the social network of the projects is not equal. To explain and understand this difference it is important to analyze the presence and importance of a shared problem definition and support base. The project De Groene Loper mentioned their client, the project developer and the contractor as most important stakeholders. However, the other stakeholders are not forgotten in this project since communication between all relevant stakeholders is central. This interaction is central in providing resources necessary to accomplish a certain goal (Hoogma et al., 2002). They do realize that every stakeholder has their own perspective on how to reach a certain goal which can lead to discussion. This can make it very difficult to reach an agreement. However, the goal of every stakeholder is to eventually implement the plan. Therefore, discussing different perspectives and ideas about how to reach that plan can in the end lead to a better agreement. Cooperation and communication in this project led to a shared problem definition and support base. This means that in the end the shared problem definition was more important than the individual goals. Thus, in the project De Groene Loper the focus on communication and cooperation with all involved stakeholders formed a stable social network. They even expanded their social network by working together with an outsider; the Brightland Campus. This is an important aspect to broaden frames and facilitate second- order learning (Hoogma et al., 2002). In the project Lage Heide the project developer and the contractor are mentioned as most important stakeholders. In this project they had some challenges in the beginning of the project. The neighborhood network did not agree with the plans of the project Lage Heide. This stakeholder wanted to achieve its individual goals more than reaching a shared problem definition. This makes it more difficult to provide the necessary resources to accomplish a certain goal which created an unstable social network (Hoogma et al., 2002). Despite that the neighborhood network is a stakeholder more present at the background, the leading stakeholders still should take their perspective into account to broaden their social network (Hoogma et al., 2002). The project Lage Heide shows that it is very important to have the support of every stakeholder, leading or background, in order to create a shared problem definition and support base. Thus, in the project Lage Heide especially the cooperation and involvement of the stakeholders present at the background are needed to create a stable network able to focus on innovation. In the project Arce Novum the contractor and project developer are mentioned as most important stakeholders. During this project they never had any challenges related to creating a shared problem definition or a support base. This shows that the stakeholders understood that the common goal and shared problem definition was more important than their individual goals. Thus, this created a stable social network for this project. In the Project Lindenkruis the contractor and project developer are the most important stakeholders. However, in this project there were three contractors. The project was started with a contractor of which the name is not known. The first contractor wanted to achieve its individual goals more than achieving the overarching goal. Because of dissatisfaction and a poor relationship with this contractor they got replaced by Hurks. Hurks got responsible for phase 1,

phase 2 and phase 3. This shows that in phase 1 the lack of a shared problem definition led to a poor relationship between the stakeholders which eventually had replacement as consequence because of the lack of support. After the first three phases this contractor also got replaced. But this replacement had nothing to do with a poor relationship with this contractor or not being satisfied. Thus, in the project Lindenkruijs a good relationship between the stakeholders are needed to create a stable network able to focus on innovation. Briefly, the project De Groene Loper and the project Arce Novum are the two projects where the stakeholders all shared the same problem definition and considered that as more important than their individual goals. Besides the project De Groene Loper even expanded their social network with the stakeholder Brightland Campus to become more innovative. Therefore, their social network can be designated as stable. This is very important to enhance the successful niche development (Kemp et al., 1998). The project Lage Heide and the project Lindenkruijs both had stakeholders involved with different goals, and who put more emphasis on their individual goals instead of the overarching goal. Therefore, their social network functioned less well. This means that their social network is not stable enough to contribute to successful niche development.

The project De Groene Loper and the project Lage Heide are large projects and the projects Arce Novum and Lindenkruijs are medium projects based on figure 7. In the project De Groene Loper the social network functioned well, but in the project Lage Heide the social network is not stable enough to enhance successful niche development. The medium projects, Arce Novum and Lindenkruijs, also differ from each other based on the functioning of their social network. The project Arce Novum has a stable social network, but the social network in the project Lindenkruijs is not stable enough to enhance successful niche development. Because both the large projects and the medium projects differ from each other there is no relation between the size of the project and the stability of the social network.

### 5.3 Sub question 3

#### How do strategies and expectations from stakeholders in a project influence these innovative aspects?

As soon as it is clear which innovative aspects contribute to nitrogen reduction, it is important that these innovative aspects can develop in a protected space. This space is also called a niche; here the innovative aspects are protected from reality. Eventually the development of niches can lead to replacing the leading and dominant structure and rules (Schot & Geels, 2008). However, niches are most often not very successful; the experiments at niche level remain there and are unable to scale up (Caniëls & Romijn, 2008). For a niche to develop successfully there are three internal processes that need to be optimized; the social network, **the strategies and expectations**, and learning processes.

#### *Innovative and sustainable expectations, and clear final image with intermediate goals*

In the project De Groene Loper the project developer mentioned that their expectation is to implement more sustainability than necessary related to law and regulations: *“It led to the formulation that this project on all sort of themes wants to implement sustainability which rises above law and regulation.”* This is also their final image. The intermediate goals are that during the elaboration of plans these sustainability aspects are made concrete to specific measurements for the buildings or public space. However, the project developer mentioned that there is an obstacle related to this. Since the project extends over several years the law and regulation can also have been changed over the years. Therefore, they need to plan for the future and also be ahead of the then present law and regulation: *“... implement sustainability requirements based on the current law then that is obsolete at the moment that the project is finished.”* In the project Lage Heide according to the advisor their only expectation related to sustainability is to meet the law and regulations: *“Actually they only need to meet the legal requirements. That is the demand from the nitrogen perspective.”* Therefore, their final image is based on getting their building permit. The intermediate goals in this project are implementing sustainability to the extent that their building permit gets approved. The same applies to the project Arce Novum: *“We meet the legal requirements. That is the sustainability we follow.”* This means that their final image is not related to doing anything extra besides meeting the requirements needed to get their permits. Their intermediate goals are also based on that. The contractor in the project Lindenkruis mentioned that their expectations related to sustainability are to meet the law and regulations: *“Of course we need to meet the demands coming from law and regulation. So within those boundaries we need to act during the construction phase.”* This means that their final image is not based on scoring higher than needed on sustainability aspects. Whenever they do implement more sustainability than needed it is based on the related costs: *“We do not have a goal that we need to score on something. The expectations are more based on costs, and therefore we use fewer cranes and we think more about that. This unconsciously improves the sustainability.”*

#### 5.3.1 Discussion

Formulating strategies and expectations are important to offer structure and guidance in a project since they provide the central learning processes (Kemp et al., 1998). When the strategies and expectations focus on the aspects robustness, specificity and innovations they contribute more to a niche (Hoogma et al., 1998). Especially on the aspect innovation the strategies and expectations from the projects differ from each other. In the project De Groene Loper the stability of the social network is reflected in the strategies and expectations. Their stable social network means that they share the strategies and expectations which led to a clear formulation of the end goal and intermediate steps. This also shows that their strategies and expectations are robust. The project Groene Loper can be seen as innovative, in the sense of implementing more sustainability than needed according to the law. Their end goal and expectation is to rise above law and regulation

when it comes to implementing more sustainability during the construction phase. Since a project takes multiple years, they have the strategy to plan ahead. Due to their very specificity on their goals and focus on innovation they contribute to successful niche development according to Hoogma et al. (2002). The project Lage Heide has a very specific goal; they are innovative in the sense of achieving the sustainability needed to get their building permit. The expectation in this project was to get their building permit. This means their strategy and intermediate steps are focusing on implementing the sustainability needed according to law and regulation. Their expectations related to sustainability do not go any further than that. This means that it can be noted that the project did not or little contribute to innovation. Also, because their social network is not very stable their strategies and expectations do not focus on robustness. Due to their lack of innovation and robustness they do not contribute to niche development according to Hoogma et al. (2002). In the project Arce Novum their expectations and strategies are very specific; they are innovative in the sense of achieving the sustainability needed to get their building permit. This means that their strategy and intermediate steps to achieve this are focusing on implementing the sustainability needed according to the law and regulation. Therefore, the expectations in this project are not very high which limits the amount of innovation. This is shared by the stakeholders who are represented in a stable social network, which creates robustness. Despite that the project does focus on specificity and robustness they do not contribute to niche development because the most important aspect innovation is left behind (Hoogma et al., 1998). The project Lindenkruijs is innovative only up to a certain height. They are innovative in the sense of achieving the sustainability needed to get their building permit. This also reflects their specific end goal in this project. This means their strategy and intermediate steps to achieve this are focusing on implementing the sustainability needed according to the law and regulation. Whenever they implement more sustainability than needed they do not do this with the intention to be more innovative, but to reduce their costs. Therefore, the expectations in this project are not very high which limits the amount of innovation. Also, because their social network is not very stable their strategies and expectations do not focus on robustness. Due to their lack of focus on innovation and robustness they do not contribute to successful niche development according to Hoogma et al. (2002). Briefly, the projects Lage Heide, Arce Novum and Lindenkruijs all had the same specific strategy and expectation: implement the amount of sustainability needed according to the legal requirements. This means that their sustainability goal is related to getting their building permit. Since all building projects in the Netherlands need to have a building permit these cases cannot be seen as innovative. According to Hoogma et al. (2002) expectations contribute more to a niche when they focus on innovation; since these projects lack this aspect they contribute less to successful niche development. The project De Groene Loper is the only project that had the strategy and expectation to implement more sustainability than needed according to the law and regulation. This means they want to invest more in sustainability than needed to get their building permit. Due to their focus on innovation they contribute to successful niche development according to Hoogma et al. (2002).

The project De Groene Loper and the project Lage Heide are large projects and the projects Arce Novum and Lindenkruijs are medium projects based on figure 7. In the project De Groene Loper the strategies and expectations are robust, specific and innovative which means they enhance successful niche development. But in the project Lage Heide there is a lack of focus on robustness and innovation, which makes them deviant from the project De Groene Loper.

The medium projects, Arce Novum and Lindenkruijs, both do not contribute to niche development through their strategies and expectations. The project Arce Novum lacks a focus on innovation and the project Lindenkruijs lacks a focus on innovation and robustness. Because the large projects differ from each other there is no relation between the size of the project and the formation of strategies and expectations.

## 5.4 Sub question 4

### How do learning processes for stakeholders about experiments in a project influence these innovative aspects?

As soon as it is clear which innovative aspects contribute to nitrogen reduction, it is important that these innovative aspects can develop in a protected space. This space is also called a niche; here the innovative aspects are protected from reality. Eventually the development of niches can lead to replacing the leading and dominant structure and rules (Schot & Geels, 2008). However, niches are most often not very successful; the experiments at niche level remain there and are unable to scale up (Caniëls & Romijn, 2008). For a niche to develop successfully there are three internal processes that need to be optimized; the social network, the strategies and expectations, and **learning processes**.

#### *Experimenting*

In the project De Groene Loper the project developer mentioned they are not consciously working on learning processes: *"It happens unconsciously because we challenge ourselves each time to be a step further. . . . A learning processes is reactive, we want to be proactive with our sustainability ambitions. So being progressive instead of reactive."* The experiments take place mainly because they try to implement more sustainability than necessary according to law and regulation: *"There are all kind of measurements which are not mandatory where we try to implement new chances into the project."* To guide these experiments they also work together with the Brightland Campus: *"We consciously choose to implement experiments developed on the campus where we see opportunity in."* This shows that they are willing to learn, however results are still important in the end. The project manager Area development from the project De Groene Loper mentioned that a part of their job is to keep an eye on the building process that it fits the original plan ideas. But also to decide during the building process if certain aspects should change or can be done better: *" . . . as project agency from my role we make sure that the qualities of the plan which was agreed on in 2009 is realized. And at the same time we did not put the time on hold, we try to come to new insights with the developing party, especially related to sustainability."* The project manager Area development mentioned one aspect that can be seen as example. The building process produced too much nitrogen emission, therefore they needed to make a change during the building process to lower their nitrogen; they had to get less dependent on the cranes. Therefore they needed to experiment in changing their building process to fit the allowed norms: *"It was actually a matter of arranging the building process differently to get less dependent on the crane"*. According to this stakeholder the learning processes as well as the results are important in this project: *"Yes, actually both. The plan we realize together is the plan. . . . The buildings are realized according to certain architecture and urban planning. You try to implement that plan at two sides of the table and thereby you learn a lot from each other implicit or explicit but also how certain processes run or can be done better or different."* In the project Lage Heide the advisor mentioned that they experiment to meet certain boundary conditions. One concrete example of an innovative experiment is a nitrogen restrictor for machines: *" . . . developed a nitrogen restrictor. Those are developments that took place because of nitrogen emissions."* The experimenting does not go any further than moving between the boundaries of allowed nitrogen emission. However, the project developer did mention that whenever there are innovative experiments which lead to learning processes, they try to take that with them in next steps: *"The innovative developments we have are things we try to take further into new developments."* The project developer mentioned that the room for innovative experiments depends on the type of project: *"In some projects, which are brought in through a tender of the municipality, the sustainability aspect is very important. Then the municipality wants you to meet more sustainability requirements."* According to the advisor and the project developer in the end the results are more important than the learning processes in this project. The advisor gives as reason that small projects like Lage Heide have a small budget which gives little to no room for innovation: *"For all small projects with so little budget it is most important to realize the houses within this*

*budget. In this standard projects there is not a lot of room for innovation.”* The project developer mentioned that in theory you can demand and want a lot, but in practice there are more obstacles and other aspects that are more important: *“But practice shows that money is the most important aspect in a project.”* In the project Arce Novum they try to improve their processes every day; however these learning processes are not central for them. Their experiments do not go further than necessary to meet the requirements and meet the clients’ wishes. This shows that the results are more important than the learning processes in this project: *“We try to improve our processes every day. But it is not the case that we try to be the best related to sustainability. We meet the requirements and the wishes of the client.”* Therefore, the experimenting related to sustainability in this project is second- base. In the project Lindenkruis the contractor mentioned that they do not focus specifically on learning processes. The results were more important in this project than the learning processes. The contractor gave as reason that a main focus on sustainability was not asked from the client: *“When sustainability is a demand from the client, then you take that into account as contractor.”* Since this was not the case there was no money or room available in the project to put learning processes first: *“If sustainability is taken into account then we will agree to this as contractor. Then there is also budget and room available to pay attention to these aspects. But in this project that demand was not there from the client therefore we did not have the budget and means for it.”* However, the contractor did mention that they are always looking for innovations to build faster and more efficient. But sustainability is not always the reason to do this: *“We are always looking for faster and more efficient ways to build in order to lower our costs, increase quality and build faster. But that is not always related to sustainability. But sometimes sustainability is a part of the result.”*

#### *Evaluation*

In the project De Groene Loper the project developer mentioned that they evaluate their experiments based on the current law and regulations. They see this as the minimum and strive for more: *“Everything we do needs to meet the legal requirements, also to make everything verifiable and measurable.”* At the moment that the real estate is delivered they give guarantees to the private party or investor based on these minimum requirements. The projects Lage Heide and Arce Novum could not give an answer on this indicator. In the project Lindenkruis the contractor mentioned that they evaluated on two aspects: quality and costs. The quality has been evaluated during the construction phase and after the construction has been completed: *“During the construction phase we have assessments which we document in an app. . . . We also ask our subcontractors to check their own products. Sometimes we have independent parties who assess parts which have been build. . . . And then at delivery it is evaluated whether we made some mistakes or if everything has been done according to the plan.”* The costs are evaluated before, during and after completion of the building: *“Before we start with the project we make estimations and then we start buying things and hire subcontractors. There we try to achieve some result and during construction we try to be as fast as possible and use less than was estimated. Then we can achieve results related to the costs. At the end of the project we know if we earned money, lost money or played even.”*

#### 5.4.1 Discussion

Experimenting causes a lot of uncertainty in a development process. Learning is therefore an important aspect in order to provide stability (Kemp et al., 1998). For learning processes to contribute more to successful niche development it is important to not only focus on first- order learning but also on second- order learning (Schot & Geels, 2008). All projects that were researched value learning process; nevertheless they put more emphasis on the results than on the learning processes. In the project De Groene Loper learning is very important, but the results are more important in the end. This means that learning is subordinate to results and they focus mainly on first- order learning. The results were achieved through experimenting in cooperation with the Brightland Campus. This cooperation also shows that stakeholders from outside the social network

got interested, which means the project has broadened. By searching for possibilities and limitations within these experiments and bundle knowledge with the Brightland Campus they were able to find points of improvement. This was not only based on facts and data, but also on frames and assumptions. Any adjustments were evaluated based on the current law and regulation. If the experiments proved to have higher standards than the law and regulation and certain standards in society, it was successful. Therefore, this project focuses both on first- order learning and second- order learning. In the project Lage Heide the results are more important than learning. A concrete product they developed is the nitrogen restrictor for machines. In order to develop this product they needed to search for possibilities and limitations and bundle their knowledge with experts in the social network to find points of improvement. Despite that this experiment was very important in the project and they would have liked to share this knowledge with other projects; learning was not the main focus in the project since their budget was not adequate enough to create room for innovation and thus second- order learning. In the project Arce Novum they try to improve their processes every day, which means they are willing to learn. However, the results are more important than the learning processes. In this project their level of innovation is based on meeting the legal requirements and the clients' wishes. So when the level of sustainability according to those two aspects is met, the innovative level of the project is satisfied. Therefore, in this project the market and society are seen as obstacle in becoming more sustainable and invest more in second- order learning. Because the client did not want to invest more in innovation, the project treated results as more important instead of learning, experimenting and innovating. In the project Lindenkruis the results are seen as more important than the learning processes. Main reason is that they develop according to the clients' wishes. In this project the client did not want to focus more on sustainability than needed, this leads to no budget or room to put emphasis on learning processes or second- order learning. Of course they do try to be innovative in order to build faster and become more efficient, but this is not always related to sustainability. The results are evaluated based on the costs and quality at multiple moments during the building process. Briefly, all the projects focus completely on first- order learning, which is one step in the right direction towards successful niche development. But the project De Groene Loper is the only project that tends to come closer to second- order learning because they try to experiment, be innovative and progressive in order to become more sustainable and transcend the legal requirements. Therefore, they are the only project that contributes to successful niche development through their learning processes. The other projects, Lage Heide, Arce Novum, and Lindenkruis, only focus on achieving those legal requirements. These projects also mentioned some limitations which withhold them from implementing more sustainability: their budget, the market and society.

The project De Groene Loper and the project Lage Heide are large projects and the projects Arce Novum and Lindenkruis are medium projects based on figure 7. In the project De Groene Loper they focus on both first- order learning and on second- order learning because they want to implement more sustainability than needed according to the legal requirements. Therefore, they do not only research facts and data but also frames, visions and assumptions present in the society. But in the project Lage Heide there is a lack of focus on second- order learning which makes them deviant from the project De Groene Loper. The difference between these large projects can be explained by their difference in goal. The project De Groene Loper focuses on going beyond the legal requirements, which makes learning processes a very relevant aspect. The project Lage Heide is satisfied with less; meeting the legal requirements. This makes the learning processes less relevant.

The medium projects, Arce Novum and Lindenkruis, both do not contribute to niche development according to their focus on learning processes. Both projects do have a focus on first- order learning, but do not go any further than that. Reason is that their goal does not go beyond meeting the legal requirements, which puts less focus on the learning processes. Because the large projects differ from each other there is no relation between the size of the project and the formation of strategies and expectations.



## 5.5 Sub question 5

### **How does deepen, broaden and scaling affect the contribution of these innovative aspects to a transition?**

When the above three internal processes are optimized the niches develop well. This means that the innovative aspects can develop in a protected space and get the highest chance to develop successful (Schot & Geels, 2008). It is demonstrated that practices within niches are difficult to translate to the dominant regime (Smith, 2007). This means that the innovative aspects that are developed within a niche struggle to be implemented on a larger scale. Niches can improve this struggle by providing a contribution to a transition. The way for niches to contribute maximum to a transition is described by the three mechanisms explained by Kemp and Van den Bosch (2006). They refer to deepen, broaden and scaling. Deepen is the process where there is learned about the possibilities and obstacles of an innovation within a certain context. Broaden refers to the expansion from one niche to other contexts. The innovation is tested and repeated within other contexts which results in new learning experiences. Scaling refers to the development of new structures and ideas within a niche, which get implemented and established on a higher level (Kemp & Van den Bosch, 2006).

#### 5.5.1 Deepen

##### *Learning about the innovation only within the given context*

In the project De Groene Loper the project developer mentioned that their unconscious learning processes bring them further and further and provide a base to keep developing their innovations: *“Because those learning processes bring us further and further and make sure that we can keep . . . developing. That is a process that is present unconsciously.”* The project manager Area development from the project De Groene Loper mentioned that they learned from the nitrogen obstacles: *“There we learned that as you handle nitrogen problems more conscious and smarter, that you become more conscious of nitrogen problems and that will become more obligated with building applications in the future.”* In the project Lage Heide both the project developer and the advisor mentioned that learning is an important aspect, but results stay most important: *“Learning is definitely an important aspect within this project, but in practice . . . posting results is most important.”* The advisor argued that money is the more important aspect: *“Learning is an important aspect within this project, but in practice money is most important.”* According to the contractor the same applies to the project Arce Novum: *“We try to improve our processes every day. But it is not the case that we try to become the best related to sustainability. We meet the requirements and the wishes from the client.”* The contractor in the project Lindenkruis mentioned that the results are more important than learning about certain innovations. However, in order to keep improving their processes they do try to learn about certain innovations within their project: *“. . . we keep looking if their might be done something better to raise the quality, the sustainability or to make it more interesting related to the costs.”*

##### *Improving the innovation and adapt it within the given context*

This indicator is a sort of successor on the previous indicator. The project developer in the project De Groene loper mentioned that they try to improve their innovations and replicate it within its project when it is adjusted to a better structure. The example he provided is not related to the construction phase, however it still gives a view on how they handled this indicator within the project: *“An example is mobility where we started experimenting with in the first phase. . . . and we are now working. . . on a second pilot in the project. . . . Then the learning processes from that smaller pilot rise up and then you can consider on how to improve and adapt that.”* According to the project manager Area development from the project De Groene Loper they tried to improve the plan during the building process, especially since the need was there to lower the nitrogen emission: *“During the building time it is relevant to think about what is smart to do or yet focus on in the building plan. . . . And it was actually a matter of arranging the building process differently to make sure you are not*

*dependent on that type of crane anymore.” In order to improve and adapt two factors were important: “First, do I have a clear image of what the problem is and how it can be solved. And second, how do the municipal processes work and can I get in touch with the right people. Those are two conditions to map the nitrogen problem and come to a solution.” In the project Lage Heide the project developer mentioned that they always try to improve and adapt innovation within the given context: “We always try to improve aspects in a next phase or the nearby future.” The advisor from this project mentioned that they are forced to keep developing and improving their material since law and regulation keeps changing: “Related to law and regulation they are forced to keep developing and improving their material.” However, again they mention their budget for this smaller project as limiting obstacle. As already mentioned by the contractor of the project Arce Novum about the previous indicator and the dimension learning processes the project Arce Novum does try to improve their processes, but does not put a lot of effort in it because they see their results as more important: “We try to improve our processes every day. But it is not the case that we try to become the best related to sustainability. We meet the requirements and the wishes from the client.” The contractor in the project Lindenkruijs mentioned that they keep looking for aspects to improve during construction: “Most plans are already in process during the construction phase, but there are always small details to implement smart and innovative aspects, like products and parties.”*

### 5.5.2 Broaden

*Replicating the innovation within the given but also in other contexts*

In the project De Groene Loper the project developer mentioned that they do implement their innovations also in other projects: *“What is discovered in project A is always shared with others to implement it in other projects. Like the filter system; we started with that in Maastricht and are now implementing it in three to four other projects throughout the countries.”* In the project Lage Heide the project developer mentioned that they try to implement their innovations in other projects: *“The measurements we need to apply for nitrogen, if we can do it without them or apply them again. That is on a small scale; but still in other projects.”* But the advisor mentioned that if they had a larger budget they would have a bigger share in this: *“I do think that those other projects where those developments are deepened and that those innovations eventually flow to other projects.”* This shows that the project would like to be more progressive on sustainable innovation, but as already said before sees budget as limitation. In the project Arce Novum the contractor said that they do try to replicate the innovations they have in other projects: *“Yes, we do try to do that.”* In the project Lindenkruijs the contractor mentioned that they replicate their innovations in other projects, they do this through sharing their knowledge with other colleagues: *“If we notice that the innovation can deliver us something in the form of time, money or quality then we do try to replicate it. We have a platform within Hurks called the Kennisbank. In this platform those innovations are shared so other colleagues can implement them on other projects.”*

### 5.5.3 Scaling

*New structures and ideas anchored at higher level, and support of the key figure on regime level*

In the project De Groene Loper the project developer mentioned that they start at a smaller scale and after that it gets implemented on larger scale: *“Learning processes come forward out of the first small pilot which can be used to implement it on a larger scale. After that we look with the municipality to implement it in a whole area.”* Their goal is to try if their innovations can become the new standard in the building process: *“Some will become the new standard. That is the goal. At the moment it gets accepted as new standard then it becomes the base for future developments.”* This shows their progressive character but it is also dependent on the support they get of the key figures on regime level. In the project Lage Heide the advisor mentions that their budget is a limiting aspect in this indicator: *“Projects with a larger budget, there the innovation and exposure is more attractive and that is taken to other projects”.* They mentioned that the projects with a larger budget, often

the bigger projects with more support from the key figures on regime level, have more room for innovation. And that their innovations get applied to the more standard and smaller projects with smaller budgets, like the project Lage Heide. This is paradoxical looking at the definition of scaling. In the project Arce Novum the contractor mentioned that they do try to scale up their limited amount of innovation. But they consider the market and society as obstacle: *“The market likes it, but does not want to invest in it. . . . in the end it is all about money.”* This also refers to the limited support they get from the key figures on regime level. In the project Lindenkruis the contractor mentioned that they are hesitant in sharing their knowledge about materials. They prefer to keep important information for themselves so they can distinguish themselves from other contractors: *“In choice of material we do not do that yet because we try to distinguish ourselves with that. But related to BIM implementation, . . . , we try to expand it beyond the business by meeting other groups to share knowledge.”*

### 5.5.1 Discussion

Deepening, broadening and scaling refer to how much a niche contributes to a transition (Kemp & Van den Bosch, 2006). According to Sandanayake et al., (2016ab) innovations that develop in a niche struggle to be implemented on a larger scale. Within the project De Groene Loper broadening took place. Their nitrogen problem led to becoming more innovative and they also needed to gain more knowledge about the relation between nitrogen and the construction phase. This has continued to develop and has been applied within different contexts; this corresponds with the definition of broadening according to Kemp and Van den Bosch (2006). Their goal is also to implement the results from the project on a higher scale level. According to Kemp and Van den Bosch (2006) scaling is the translation from experiments and innovation in niches to their embeddedness in the existing regime. But the knowledge and experiments in this project did not receive a lot of imitation on higher scale levels, which means that scaling has not taken place yet. In the other projects, Lage Heide, Arce Novum, and Lindenkruis, only deepening took place. According to Van den Bosch and Taanman (2006) deepening is a learning process about the possibilities and obstacles of an experiment within a certain context. Within the project Lage Heide they have learned about the relation between nitrogen and the construction phase to become more sustainable. Their goal is also to implement the results from the project in other contexts. But they had not received a lot of imitation in other projects which means that broadening has not taken place yet. Neither did the results from the project Lage Heide receive any imitation on a higher scale level; therefore there is no sign of scaling. Within the project Arce Novum they would have liked to implement the results from the project in other contexts and on higher scale levels, but this happened on such small scale that it cannot be considered as broadening or scaling. The same applies to the project Lindenkruis; they would have liked to implement the results from the project in other contexts, but this happened on such small scale that it cannot be considered as broadening. Briefly, the projects Lage Heide, Arce Novum and Lindenkruis contributed to a transition through the process of deepening and the project De Groene Loper contributed to a transition through the process of broadening. This means that the project De Groene Loper had the largest contribution. However, none of the projects achieved scaling.

The project De Groene Loper and the project Lage Heide are large projects and the projects Arce Novum and Lindenkruis are medium projects based on figure 7. The large projects De Groene Loper and Lage Heide differ in their contribution to a transition. The project De Groene Loper contributed through the process of broadening and the project Lage Heide contributed through the process of deepening. The medium projects both contribute to a transition through the process of deepening. Thus, because the large projects, De Groene Loper and Lage Heide, differ from each other it can be mentioned that there is no relation between the size of the projects and their contribution to a transition.

## 7. Conclusion and recommendations

### 7.1 Conclusion

In this research the aim was to develop an answer to the following main question: How can innovative aspects within the construction phase of residential area development contribute to a transition to diminish the nitrogen emission in the Netherlands?

In order to formulate an answer to this main question the focus in this research has been on transitions and the role of niches within a transition. Based on the theory there is supposed to be a link between the quality of the internal processes within a niche (the formation and stabilization of a social network, the formation and stabilization of strategies and expectations and the learning processes) and the contribution of this niche to a transition (in terms of deepen, broaden, and scaling). To research these assumptions and formulate an answer to the main question a multiple case study has been conducted. The projects De Groene Loper, Lage Heide, Arce Novum and Lindenkruis are considered as niches in this research. For all of these cases the findings on which aspects contribute most to nitrogen emission, the quality of the internal processes within a niche, and the contribution of this niche to a transition are visually represented in figure 14.

According to Sandanayake et al. (2016ab) the aspects that contribute most to nitrogen emission during the construction phase are the machines, the transport and building time. However, based on the results it became clear that the aspects machines and transport are seen as most contributing polluters in the construction phase. Thus, these are the aspects that need to innovate and therefore need to develop within a niche. For each case this is represented in figure 14. The building time is also valued as an important aspect in the construction phase, but this is more related to costs instead of sustainability. This is not in line with the theory from Sandanayake et al. (2016ab). To optimize innovation on the aspects machines and transport they need to develop within a niche. For a niche to develop successfully it is important to determine the quality of the internal processes, this also determines their contribution to a possible transition. In figure 14 the contribution of the cases to a transition is visualized.

	Machines			Transport			Time	Social Network			Strategies and Expectations		Learning processes		Deepen		Broaden	Scaling		
De Groene Loper																				
Lage Heide																				
Arce Novum																				
Lindenkruis																				
	Age	Hours of use	Energy source	Amount	Distance	Type	Energy source	Total building time	Composition of the social network	Shared problem definition	Support base	Innovative and sustainable expectations	Clear final image	Experimenting	Evaluation	Learning about the innovation only within the given context	Improving the innovation and adapt it within the given context	Replicating the innovation within the given but also in other contexts	New structures and ideas anchored at higher level	Support of the key figures on regime level

Figure 14. [The findings on the different dimensions in every case]

The first thing that stands out is that none of the projects contribute to a transition through the process of scaling, which is the highest level of contributing to a transition. The second interesting aspect is that the project De Groene Loper has the largest contribution to a transition through the process of broadening. The projects Lage Heide, Arce Novum and Lindenkruis share the same contribution to a transition through the process of deepening. The difference in the contribution to a transition between these projects can be seen as the success of a project on the one hand and the degree of impact of a project on the other hand. Their amount of contribution is determined by the quality of their internal processes. By comparing the results of the four cases with each other several important aspects get visible which seem to be crucial for the functioning and contribution of a niche to a transition. The first three aspects are in line with the theory from Kemp et al. (1998). The findings in each case on these dimensions are visually represented in figure 14; social network, strategies and expectations, learning processes. The first aspect is that *the composition of the social network is crucial*. This aspect is also named by Kemp et al. (1998). The composition of the social network is connected to the focus on certain results that determine the development of a niche. Within the social network it is important that stakeholders work towards the same goal and are able to set aside their own individual goals for the common good. Because when the stakeholders have a certain level of commitment they are more willing to invest and it increases the support base. The second aspect is that *a clear final image based on transcending the legal requirements is important*. A clear final image is an indicator from the dimension formation and stabilization of strategies and expectations. This aspect is also named by Kemp et al. (1998). To develop certain innovations within a niche it is important to have higher goals than necessary according to the legal requirements. When the final image is based on transcending the legal requirements the social network is more willing to invest in innovation. The third aspect also corresponds with Kemp et al. (1998); *learning is important, but getting results is leading*. A niche is a place where innovations can develop which creates a lot of uncertainty. Therefore, it is important that the possibilities and obstacles of an innovation are explored to be able to learn from it. But the stakeholders in a social network are more willing to invest when there is a result. This means that the social network is only willing to learn when they know a result will be achieved. But the quality of the internal processes is not the only important aspect; *the obstacles located outside of the niche* should also be considered. This aspect does not come back in the theory from Kemp et al. (1998), but can be added. The budget, market and society are repeatedly mentioned as limiting aspects or obstacles to invest more in sustainability. This means that as long as the market and society do not want a transition the lack of budget will persist. Then the projects will not be able to create more room to innovate towards a more sustainable transition.

Since the projects are selected based on their size, this is also a criteria that should be considered. The two large projects, De Groene Loper and Lage Heide, differ from each other on every aspect that has been analyzed in this research; the innovative aspects, the quality of the internal processes, and their contribution to a transition. Therefore, it can be concluded that there is no link between the size of the project when they can be considered large and those aspects. The differences between the large projects can mainly be explained by their difference in main goal. The project De Groene Loper want to transcend the legal requirements related to sustainability, while the project Lage Heide is satisfied when they have reached the level of sustainability related to those legal requirements. But also the clients' wish can have an influence. This missing link means that the large projects do not have all the same characteristics. This does not correspond with Burgan and Burgan (2014) stating that only different sized projects are different of nature and characteristics. Since these large projects are not similar they also differ in need and thus in project approach and management. However, this does not apply to the two medium projects, Arce Novum and Lindenkruis. They only differ from each other on one dimension related to the quality of the internal processes; the social network. Therefore, it can be concluded that there is a link between the size of the project when they can be considered as medium projects and the aspects innovative aspects,

quality of the internal processes and their contribution to a transition. This corresponds with Burgan and Burgan (2014) and means that these projects share the same needs and thus project approach and management.

One important side note should be mentioned. Despite that all projects have more or less an impact on a transition in terms of deepen, broaden, and scaling, this transition does not focus on actually making the construction phase more sustainable. The cases do consider sustainability but only up to a certain height and not always with the intention to be innovative and progressive on sustainability. Their end goals do not focus on a vision related to sustainability. This shows that the cases score low on the aspect sustainability which means that their contribution to a transition in the terms of deepen, broaden and scaling cannot be considered as a transition to become more sustainable in the construction phase. Content related the results from these niches will not influence the sustainability of the current construction phase. The contribution of these cases to a transition does provide information about how new methods effect the construction system. Thus, the transitions that the niches imply are more related to the process based aspects and less to the context related aspects.

Despite that the contribution of a transition from the niches is related to process based aspects it can be concluded that the supposed link between the quality of the internal processes within a niche and the contribution of this niche to a transition can be confirmed. The more the internal processes are valued, the bigger the contribution to a transition in terms of deepen, broaden, and scaling is. So for the innovative aspects machines and transport to contribute to a transition to diminish the nitrogen emission in the construction phase multiple important aspects are relevant: 1. the composition of the social network, 2. a clear final image based on transcending the legal requirements, 3. main focus on results, 4. considering obstacles outside of the niche.

## 7.2 Recommendations

In the previous paragraph the conclusions on this research are formulated. Considering the conclusion of this research there is a link between the quality of the internal processes within a niche and the contribution of this niche to a transition. Based on this there are some recommendations that can be done. A part of the recommendations is for the involved stakeholders and another part is meant for policy makers.

The goal from a niche is to carry out an innovating project that contributes to a transition. The internal processes are of great importance for the development of this niche. When these processes are of high quality a niche functions well and the contribution to a transition will be higher. If the goal of a project is to be innovative it is important that these principles are considered while developing a niche. A diverse composition of the social network appears to be crucial for the development of a niche. It is also important that these stakeholders want the same and show a level of commitment to reach the overarching goal. In order to be innovative the goal should be based on implementing more sustainability than necessary related to the legal requirements. Otherwise the willingness to invest and learn is not present, causing a lack of innovation and experiments. This learning aspect is of great importance, but experimenting also brings a lot of uncertainty. In order to stimulate the stakeholders and provide more stability a clear end result should be given. These recommendations are for all stakeholders who have a connection to the project. This applies to stakeholders more present at the background but also stakeholders who have a more leading role; project developer, contractor, municipalities, provinces and neighborhood network.

These are all recommendations based on the internal processes of a niche. However, the external factors also play an important role. The amount of sustainability is based on the clients' wish and therefore linked to the market and society. Sustainability in general and in the user phase is increasing in popularity, but the construction phase is left behind. Therefore it is important to generate more knowledge and create more awareness of sustainability in the construction phase in the market and society. When the society is eager to learn more and strives for more sustainability, the market will respond which will lead to more room and budget for sustainability in the clients' wish towards projects. This recommendation is for policy makers who can steer these steps. Since this research did not focus on external factors influencing the development of a niche the recommendation is to elaborate further on this aspect.

A theoretical recommendation is to continue with this research and involve more projects to increase knowledge and deepen this research. Further research should also be conducted considering the obstacles towards innovation. Some obstacles were mentioned in this research, therefore it is interesting to go further in this topic and be able to provide more detailed solutions.

### 7.3 Critical reflection

During this research process multiple steps and decisions have been made. Reflecting on this there is room for improvement to increase validity and reliability.

The theory and conceptual model turned out to be very useful during the research. It was structured logically to create an interview guide and provide a foundation. The contribution of a niche to a transition was determined in this research based on the terms deepen, broaden, and scaling. During research it appeared that these terms refer more to the success and effect of a niche. In order to clearly determine the contribution to a transition the focus should be on a long-term final image related to sustainability. This aspect was missing or was not present enough in the cases causing difficulties to determine the contribution to a transition. The results in terms of deepen, broaden, and scaling do represent how innovations from a niche effect a change in the behavior and mentality of the stakeholders.

Gathering the data in this research has been an obstacle. There are some aspects that could increase the external validity. First the amount of projects is relevant; this depends on the willingness of stakeholders to cooperate. The choice for four cases is enough to make a relevant comparison, but finding stakeholders willing to cooperate related to these cases turned out to be very difficult. A lot of stakeholders mentioned a lack of time because of the hectic period due to COVID-19. Also there are some interviews from other projects that ended up not being used. This happened because the interviewed stakeholders could not give all relevant information, and the stakeholders who could give additional information were not willing to cooperate. Reflecting on this situation I could have planned the interviews better or wait until all stakeholders agreed. But because of the short time frame and the dependency of the reaction of others it is very difficult to plan interviews in the most efficient way. This qualitative approach turned out to be not enough. A step towards quantitative research in the form of surveys could have increased the gathered knowledge from different stakeholders since this takes less time. Secondly, the amount of stakeholders from the used projects is relevant. In the end I did find some stakeholders from projects that were able to give me some relevant information. However, it would have been better if there were multiple stakeholders from the same project willing to cooperate in order to deepen the analysis. In order to increase the multiple stakeholders I tried to reach more stakeholders through contacting the stakeholders I already interviewed. This is also called the snowball-effect.

The research initially focused on sustainability in the construction phase and niches that contribute to that. Most projects nowadays do focus on sustainability in their project. This is mainly because they are forced towards this direction to meet the legal requirements. Only few projects strive for more and can be considered as innovative. This made it very difficult to select relevant projects which had an innovating view implementing more sustainability than necessary relating to the legal requirements. The study showed that almost none of the projects had or adopted a vision of sustainability striving past those legal requirements. Therefore the projects do contribute to a transition, but this remains very indirect.

Despite these points of improvement this research does provide a general view on the situation and it provides an indication of the intended objective.



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