Using the Participatory Value Evaluation methodology to discover influences of risk acceptance on preferences for risk mitigation

A case-study on gas induced earthquakes in Groningen

R.M. de Waard

TUDelft

Using the Participatory Value Evaluation methodology to discover influences of risk acceptance on preferences for risk mitigation

A case study on gas induced earthquakes in Groningen

by

R.M. de Waard

to obtain the degree of Master of Science
in Complex Systems Engineering and Management
at the Delft University of Technology,
to be defended publicly on Thursday July 4, 2019 at 14:00.

TUDelft

Preface

When writing a preface at the end of the process, everything seems simple. My thesis is almost finished and the last weeks of wrapping up felt relatively easy. When reading this thesis, you only see the end result. A result that pleases me, although I had no idea it would end up like this.

Looking back at the entire graduation process I would definitely do things differently. The first step of finding a suitable topic was difficult. After endless talks with different people I committed myself to an existing project. After a period of trying to structure my part within this project it did not work out and I decided to slightly change the topic. This first period felt like ages and in the end it just led to a vague research proposal.

During my kick-off meeting, Maarten Kroesen, who was my second supervisor at that time, suggested to change my focus towards the PVE method to create structure in my research proposal. This turned out to be a push in the right direction. After the kick-off meeting, Niek Mouter took the role of second supervisor, but I still received help from Maarten during the data-analysis part. I appreciate all the help I received from Maarten, while not being my supervisor anymore.

As Niek is the creator of the PVE method, he was probably the most suitable second supervisor I could have. When designing the context of the method I had quite a few questions, but with the help of Niek and Perry Borst of SlicedGene, I was able to construct the web-tool the way I wanted it. With his feedback on my work, Niek helped me a lot with fine-tuning my text.

Graduation is a process filled with many first-time experiences. I came across many challenges I had not encountered before. As it was my first-time graduating, it was Simone her first time as first supervisor. Despite not having done this before, she was able to help me with all my questions not only relating to the research but also to the entire graduation process. During our meetings, many times she had already addressed my doubts before I even could raise them. I really appreciate her pro-active attitude as involved supervisor.

Finally I would like to thank Pieter van Gelder as my chair and Charles Vlek for putting me in contact with researchers in Groningen. It helped me shaping my knowledge on the topic and much of the information I received is used in this thesis.

R.M. de Waard
Delft, June 2019

Summary

This research focuses on risk mitigation for induced hazards. When a hazard is induced, people perceive the hazard as man-made and therefore as controllable. This difference in relation to natural hazards leads to a change in risk acceptance of induced risks. To manage risk mitigation in these situations, a participatory strategy must be used. Which means that the local community should be involved in the decision-making process. With natural hazards, the frequency and magnitude of the hazard play major roles in shaping the acceptance of the risks; however the man-made aspect of induced hazards means that social and economical factors are more important factors in shaping risk acceptance.

In cases of induced hazards, trust between the local communities and the operating authority is often low. People feel unheard and while authorities are trying to implement mitigation measures, implementation often turns out to be ineffective. To improve the implementation and rebuild trust, the first step is to discover whether differences in risk acceptance lead to differences in preferences for risk mitigation measures.

To evaluate mitigation measures, traditionally cost-benefit analysis (CBA) is used. However scholars argue that this method is not suitable for measuring welfare effects from public policy. CBA uses a willingness-to-pay approach that uses people their private choices to state their measure preferences. Because citizens their public choice does not reflect their private choice, a novel method called Participatory Value Evaluation (PVE) is developed that tackles this issue. Further development of this method was a side-goal of this research. The main goal of this research was to discover whether a link between risk acceptance and risk mitigation preference exists. This has led to the following research question:

What is the influence of risk acceptance on the preferences for risk mitigation measures?

Selected case

To answer this research question, a case study was conducted on the induced earthquakes in Groningen. Extracting gas by the NAM, has led to induced earthquakes causing damage to housing and unsettling the lives of the affected people. Social justice is a pressing issue in Groningen. The local community feels they have to carry the load of the gas production, while not receiving any of the benefits. Trust between the local communities and the authorities is very low and implemented mitigation measures have not been effective so far. These issues made the case suitable as case for this research.

Conducted research

After finding the case, the first step of the research was to make a selection of risk acceptance factors to include. The induced and controllable aspects of the earthquakes means that the earthquakes can be compared with energy projects such as geothermal- and CO_2 storage projects. These projects have shown that it is important to include moral values when selecting risk acceptance factors. Looking at factors that have most effect on shaping risk acceptance, four risk acceptance factors were selected:

- Perceived risk
- Perceived benefit
- Direct experience
- Trust in authorities

The second step of this research was to select the included mitigation measures. To do this, case-specific literature was studied. In January 2014, a mitigation measure package was constructed. Based on this package, measures were selected in three categories:

- Risk prevention measures
- Compensation measures
- Investment measures

Prevention must reduce the risk of the hazard. Compensation measures target the direct consequences of the hazard, while investment measures target the indirect consequences of the hazard such as deterioration of the image of the region.

To gather data, the PVE method was used. This method uses a web-tool where participants can state their preferences for the mitigation measures. Participants were able to make a decision by comparing the measures based on their costs, reach and a short description. Participants were able to select as many measures as possible within a budget constraint. The second step in the web-tool was collecting information on risk acceptance of the participants. The included risk acceptance factors were split up in statements. Participants of the research had to state their agreement with the statements.

The first step was spreading the web-tool via social-media. Since this led to only a small number of participants, flyers were distributed in province Groningen and the researcher spread the web-tool within his own network. Spreading the tool within the researcher's network led to a middle-aged and highly educated sample of respondents. In total, 49 participants were gathered.

The first step of analysing the gathered data was conducting a factor analysis. This analysis was used to combine the statements to create a single score on the risk acceptance factors. Next the scores were divided into a low, medium and high score. The second step of the analysis was conducting logistic regression to see whether different scores on the risk acceptance factors led to differences in preferences for mitigation measures. The logistic regression shows only a few statistically significant results, however non-significant trends seem to occur.

Conclusions

Based on the results is concluded that people with lower trust in the authorities, higher perceived risk and lower perceived benefits prefer mitigation measures that prevent or directly target the consequences of induced hazards. While people with higher trust in the authorities and more belief in the benefits of gas production are more open for measures that indirectly target the consequences of the induced hazard. Authorities, when designing and implementing mitigation measures can use these findings.

Using the PVE method to gather data in this research turned out to be difficult. In a controversial and embedded topic such as the induced earthquakes the local community is not willingly to participate.

Future research

Based on the conducted research, steps are suggested for future research to improve the validity of this research. It might be interesting to see whether a correlation exists between the risk acceptance factors. To construct the web-tool, assumptions were made on the costs and reach of the measures and the budget constraint. The validity of this research would improve when the research is repeated with different measure characteristics and different budgets.

In this research it was hard to gather data using the PVE methodology. The methodology better suits a less controversial topic. However if the topic is controversial, the method should be implemented as early as possible in the process and the involved communities should be able to co-design the context of the method. The case situation in Groningen seems hard to solve. The dependency on gas makes it impossible to suddenly stop the gas production. An engineering solution should focus on developing methods of gas production without earthquakes, however this unlikely to be developed soon. From a management point of view, the focus should be on a humane procedure. Research suggests completely taking out the NAM and skipping the procedures that citizens are facing when claiming for compensation.

Contents

List of Figures

List of Abbreviations

CBA	Cost-benefit Analysis
CBS	Centraal Bureau voor Statistiek
CVW	Centrum Veilig Wonen
FES	Fund for Economic Structure Reinforcement
GBB	Groninger Bodem Beweging
MIT	Massachusetts Institute of Technology
NAM	Nederlandse Aardolie Maatschappij
NCG	Nationaal Coordinator Groningen
OEOV	One Euro One Vote
OPOV	One Person One Vote
PCA	Principal Components Analysis
PVE	Participatory Value Evaluation
SNN	Samenwerking Noord-Nederland
SoDM	Staatstoezicht op de Mijnen
TCMG	Tijdelijke Commissie Mijnbouwschade Groningen

1

Introduction

The Netherlands is known as a country fighting water and floods. In this country, improving flood defences has been a major contribution to the research on risk governance and safety management [51]. After World War II, the first focus of risk research was on managing occupational safety and this lead to the introduction of safety management in 1970. Safety management was a more systematic approach with quantification, assessment and evaluation of risk [67]. The focus on risk entered the Netherlands before 1970 in cases on flood defence. Between 1970 and 1990 there was a paradigm shift to risk- based safety decision-making. Models to quantify risk were created, but the acceptability of quantified risks caused troubles [51]. Oostendorp states "making decisions on risk relates to complex societal issues, such as ethics, stakeholder perception of risks, stakeholder involvement, and politics, all of which made the decision making process far from straightforward" [51, p.205].

Recent years the country has been shocked by a series of earthquakes in Groningen, a province in the north of the Netherlands. Normally an earthquake would be considered as a natural disaster and therefore risk governance would be applicable as for floods. However the earthquakes have been induced by gas production in this part of the Netherlands. The earthquakes, which vary in strength all across the province, damage housing and other properties leading to a reduced quality of life for the local community [55]. The earthquakes are induced and therefore perceived as man-made. Hence the risk is grasped as controllable [6]. Controllability causes the involved parties to accept risks differently, which subsequently creates complexity.

Research on risk management has shown that when there is ambiguity about the risks, a discourse-based strategy should be wielded [25]. Renn describes this strategy as a participatory strategy, where the public is involved [25]. He states that "if tolerability or acceptability of the risks is disputed and if society faces major dissents and conflicts among stakeholders, direct involvement is a prerequisite for successful risk governance" [25, p.40]. A paper by Aven and Renn has shown that the risk management strategy in the case of differences in information perception, values and priorities by stakeholders, needs to address the underlying factors that are causing the controversy [3]. Renn argues for early stakeholder involvement where actors are engaged in different aspects of the process. Starting with setting the scope of the problem to making joint decisions [25].

1.1. Community involvement

Community involvement and public participation research has been a highly discussed topic for years. The first programmes for citizen participation started in the 1950s. In essence citizen participation and involvement was created to improve decision-making and therefore provide efficiency benefits for society [26]. Fung mentions in his research that public participation can achieve key democratic values such as legitimacy, justice and effectiveness in governance. To reach these values, Fung mentions three design choices that form the democracy cube [19]:

- Who participates?
- How do they communicate and make decisions?
- What influence do they have over the resulting decisions and actions?

Irvin and Stansbury mention high benefit indicators. If these indicators are applicable, the situation is suitable for community involvement [26]:

- Hostility toward government entities is high, and the agency seeks validation from community members to successfully implement policy
- The issues is of high interest to stakeholders and may even be considered at "crisis stage" if actions are not changed

At the moment, the most used methods for community involvement are still public meetings and hearings [19]. The problem with this form of involvement is that elderly and highly educated white males attend the meetings most [26]. Therefore public meetings fail to attract a good representation of society. Apart from the representation issues, public meetings in general fail to actually involve the community, as the influence on decision-making remains limited [19, 26]. It is concluded that despite extensive research, proper implementation of community involvement is often lacking. Authorities mostly use public participation for promoting and marketing their decisions; without the public being able to influence the decisions [32]. Arnstein also describes this in his ladder of participation in figure 1.1. In this ladder he calls this phenomena of non-participation, manipulation or therapy [2].
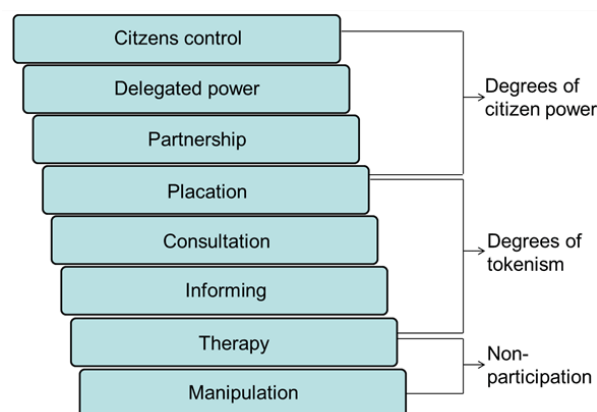
Figure 1.1: Ladder of Participation [2, p.217]

If not implemented well, public participation or community involvement can even backfire on the authorities. Most pressing issues for backfiring are the lack of representation and the inability to influence the decision-making, which may lead to even more dissatisfaction for the public [26]. For community involvement to be effective the issues of lacking representation and decision-making influence should be tackled.

1.2. Risk acceptance

As mentioned in the previous paragraph, risk governance for induced hazards differs from natural hazards. Scholars believe that risk perception and risk attitudes affect the preparedness for and response to disasters [22]. When a hazard is perceived as controllable, in general local communities have a very low level of trust towards authorities. As a division between authorities and the public can be the reason for cessation of mitigation implementation it is important to involve the community and rebuild trust between the public and authorities [66]. Stoutenborough et al. stated in their research on nuclear energy that "understanding why some within the public support nuclear energy and why others do not, is an important step toward navigating the divide between the experts and the public" [66, p.176].

Already in 1975 Otway and Cohen found out that risk acceptance forms an important input into decisions affecting the selection and deployment of technology [52]. Research into adaptation of new technologies shows that public acceptance of new technologies is influenced by psychological factors. In other words perceived risk and benefit can influence risk attitudes [23, 24]. Besides technology acceptance, Fang et al. discovered a similar result for the acceptance of mitigation against influenza viruses. A relationship exists between trust, risk acceptance and the effectiveness of mitigation implementation [16].

Extensive research has been conducted on risk perception and risk attitudes. Slovic wrote a book about risk perception in which he mentions characteristics of hazards that influence risk acceptance; voluntariness, catastrophic potential, controllability and dread [63]. Other papers name factors as familiarity, importance, confidence, controllability, likelihood, threat to life, damage to property and knowledge [4, 11, 17, 22].

Wachinger et al. state that "various factors such as knowledge, experience, values, attitudes and emotions influence the thinking and judgements of individuals about the seriousness and acceptability of risks" [75, p.1049]. The most important factor mentioned is direct experience followed by trust in authorities, experts and mitigation measures [75]. Low trust in authorities and the direct experience of the local community influencing the risk perception, make it interesting to see whether people without direct experience and more trust in authorities have different preferences for risk mitigation measures.

1.3. Issues with traditional Cost-Benefit analysis

Traditionally cost-benefit analysis (CBA) has been used to analyse governmental policy. The approach that CBA uses to discover the increased welfare effects from public policy is a willingness-to-pay approach. This approach is called the consumer approach, where preferences for public goods are based on citizens their willingness-to-pay for public goods with their own net-income. However scholars argue that willingness-to-pay is not the right way to analyse welfare gained from public policy, because people their private choices do not reflect their public choices. Research claims that citizens take different decisions based on their role in society, which can be described as the consumer-citizen duality. Participants in research have validated this stating that the government should not base their policy on choices citizens make as private persons, because the government has a different responsibility than citizens [10, 38]. Issues with CBA create a need for a new evaluation method of decision-making in the public sector.

1.4. Knowledge gap and research problem

Within the scope of this research, the findings in the technology and health sector might be applicable to a case with induced disasters. Induced disasters create ambiguity about risks and distrust between the local communities and the authorities. To overcome ambiguity a participatory and involvement approach is suggested to come up with mitigation measures. If people are able to state their preferences for mitigation they might feel heard and hostility between authorities and communities might reduce.

In the case of induced disasters implementation of mitigation is often not effective. Despite being implemented with the best intentions by the government, mitigation might fail. This has happened the first time when a compensation procedure was set-up, which was later taken away from the NAM [70]. A possibility

of failing mitigation is wrong implementation, but this research focuses on another possibility; differences in preferred mitigation between the government and the public. As mentioned in this introduction, induced disasters have a tendency of risks being accepted differently. These differences in acceptance may lead to differences in supporting certain mitigation measures. To improve the effectiveness of mitigation, the division between the authorities and the public must be reduced. However this cannot be done without understanding the link between risk acceptance and the preference for mitigation. By researching this link, governments are able to better predict whether the proposed mitigation is accepted and therefore effectively implemented. With understanding how risk acceptance influences preferred risk mitigation, mitigation strategies can be developed that tackle the risk issues perceived by the local community. Ultimately restoring trust between authorities and the public.

Another knowledge gap found is the issue with CBA. The consumer approach of CBA makes it not suitable for evaluating public policy, which is the case in a situation with induced hazards. A novel method is developed. However this method can be further developed.

To tackle the knowledge gap of improving risk mitigation in situations of induced hazards, the first step is to discover the influence of risk acceptance on preferences for risk mitigation. Therefore this research is confined to researching the link between risk acceptance and preferred risk mitigation. This scope leads to the following research question:

What is the influence of risk acceptance factors on the preferences for risk mitigation measures?

1.5. Societal and scientific relevance
In cases with ambiguity about the risks, a strategy with community involvement is favourable. From a societal point of view, involving local communities and improving their trust in the authorities would be beneficial. This research proposes the use of Participatory Value Evaluation (PVE), a novel method to support the planning and decision-making process. This method is used because it overcomes the issues with CBA. Besides, research into this new method has shown that the participants perceive the method as facilitating for the community [10]. The usage of the method is elaborated in chapter 3. The main goal of this research is to see whether differences in attitudes towards the induced disaster risks influence the preference for mitigation measures. From a scientific point of view this research must contribute towards a better understanding of risk acceptance and mitigation preferences for induced hazards. From a societal point of view, the research must contribute to improved implemented mitigation measures by authorities.

Since the PVE method is a novel method, this research will, from a scientific point of view, contribute to the further development of the method. This is considered as a secondary goal of the research.

Based on the knowledge gaps and the derived research question, four research objectives are constructed and displayed in figure 1.2.

Figure 1.2: Research objectives

1.6. Reading guide

Based on the research objectives, research questions are formulated in chapter 2. To answer these questions, the research methodology used is described in chapter 3. Part of the methodology is using a case that is described in chapter 4. Chapter 5 describes the selection of risk acceptance factors. For the described case, mitigation measures are selected and described in chapter 6. In chapter 7 is described what the characteristics and effects are of the included mitigation measures. To gather data the PVE method is used, the design of the web tool used for this method is described in chapter 8. To analysis the data, factor analysis and logistic regression is used. The results of the analysis are described in chapter 9. Based on the results, conclusions are drawn in chapter 10. Finally chapter 11 contains a discussion on the effects of the research choices and assumptions.

2

Research questions

This chapter describes the research questions. Based on the scientific knowledge gaps, four research objectives are constructed. The research objectives as described in the previous chapter lead to the following research question:

What is the influence of risk acceptance factors on the preferences for risk mitigation measures?

To find an answer to this research question, the research is split up in sub questions leading to their own sub deliverables. Combining those sub questions and deliverables leads to an answer on the main research question.

Sub question 1: Which factors have most effect on risk acceptance?

Literature provides an extensive list of risk acceptance factors. However not all can be included in the research. Based on the case situation a selection must be made with factors that have the most effect on risk acceptance. After the selection is made, the factors must be included in the research. To find out how participants accept the risks and how this influences the mitigation preferences, questions must be set up that can be asked to discover and measure how participants accept the risk based on each individual factor. The goal of this question is to come up with a list of risk acceptance factors and questions that can be asked to participants to see how they score on each factor.

Sub question 2: Which mitigation measures are most realistic for the case situation?

Literature describes multiple mitigation measures for earthquakes. However not all are suitable for the case situation. To involve the community it is best to include the most realistic mitigation measures, otherwise participants do not see the research as realistic and therefore it cannot help to rebuild trust. Based on the case situation a selection must be made with the most realistic mitigation measures.

Sub question 3: What are the characteristics of the mitigation measures?

To find out what the different preferences are for mitigation measures, people must choose based on quantitative and qualitative information on the characteristics of the mitigation measures. An example of a characteristic is the costs of a mitigation measure. The list of mitigation measures from sub question 2 will be elaborated with the characteristics of the measures. Together with the deliverable from sub question 1, the deliverable of this question will form the input for sub questions 4 and 5.

Sub question 4: What are the most preferred mitigation measures?
After constructing the list of mitigation measures with its effects, the next step of the research is to see which of the measures are most preferable. Participants will choose one or multiple mitigation measures from the list of constructed measures to find the preferred measures. The chosen measures form the input for the next sub question. That question will answer whether these preferences change in relation to the different risk acceptance factors.

Sub question 5: Does the mitigation preference vary in relation to the risk acceptance factors?
The last part of the main research is to discover whether the preferred mitigation measures vary depending on the different risk acceptance factors. If this question is answered, the main research question can be answered. This sub question uses the answers on the previous sub questions as input.

3

Research approach

To answer the research questions that are set up in the previous chapter, this chapter describes the proposed research methods. The five sub questions are split in two parts. The first three questions are preliminary questions that provide all the input needed for the last two questions. The first three questions are answered using a literature review research method. The output received from this method will be used as input for the Participatory Value Evaluation method (PVE). This method will be used to gather data for the other two sub questions. To analyse the gathered data, factor analysis and logistic regression will be used. The rest of this chapter describes how and why the methods are used. Finally the research framework is shown that displays a visualisation of the research process.

3.1. Literature review method

To provide answers to sub question 1,2 and 3 a literature review will be conducted. For this review, literature will be searched for in online databases like Google Scholar and Scopus. The first selection of articles will be based on their abstracts and conclusions, using the snowballing technique more articles will be gathered and a final selection of articles will be made. This final selection will be researched more in depth. The topic induced hazards is controversial and often hot in the public media; therefore it makes sense to base the literature review not only on scientific articles but also on the national and local newspapers. For these articles it is important to check their scientific value.

3.2. Participatory Value Evaluation method

Traditional Cost-Benefit Analysis (CBA) has trouble discovering welfare effects from public policiy. The issues as described in paragraph 1.3. ask for a new method, which led to the develoment of the Participatory Value Evaluation (PVE) method [10, 38]. This novel method works under the assumption of one-person-one-vote (OPOV) instead of one-euro-one-vote (OEOV). In CBA people with more money and who therefore are willingly to pay more, have more voting right in the public debate, while PVE treats all citizens as equal with an equal vote in the public debate [10].

In the PVE method, citizens are seen as co-owners of the governmental budget and can allocate this budget to public goods in their favour. In this method, participants use a web-tool to select a portfolio of public projects. This portfolio has to be selected within a budget constraint, however the participants are able to increase or decrease the budget by rising of lowering the taxes. The participants can base their choice on qualitative and quantitative descriptions of the effects of the public projects [38].

Besides the mentioned benefit of PVE in relation to CBA, PVE has some other benefits. PVE is a good way to involve the public in the decision-making process. Because the PVE method uses actual public projects,

people feel involved and believe their choice does actually matter. This relates to the benefit of improved communication and awareness raising factor of PVE. While using the method, citizens get an insight in the choices governments have to make and the dilemmas they are facing when having to operate within budget constraints. A last benefit of PVE is the low threshold for participating. The web-tool is easy to use, relatively quick to complete and people can participate in their own time. Since most participants of traditional public participation methods are elderly high-educated white males, these methods have trouble with being a proper representation of society. The low threshold for participating in the PVE method attracts a more diverse range of society and is therefore a better representation of society [10].

3.2.1. PVE method in this research

In this research the PVE method is beneficiary because it can answer the main research question and at the same time the participants of PVE experience, the process of using the method, as a feeling of involvement. In this way PVE adds value to both the main goal of finding mitigation preferences in relation to risk acceptance and the sub goal of public participation.

PVE is a novel method; therefore there is not much research on the use of the method. During the research, time has to be taken into account to get to know the method and to analyse the data that the method produces. An issue of this method might be finding participants. Despite the low threshold for participating, people in controversial topics have often encountered multiple surveys and questionnaires and might be tired of participating in another research. One way to overcome this is to find a research panel, however this may decrease the representation of a diverse society. Because PVE uses a web tool, social media channels might be a way to distribute the tool.

3.2.2. Data gathering with the PVE method

In this research the PVE web tool is used to gather mitigation preferences from the participants. The actual design of the web tool depends on the output from sub questions one, two and three. The final design of the web tool is described in chapter 8. With the web tool data is gathered to answer sub questions four and five. Participants have to fill in their preference for mitigation measures and have to answer survey questions on risk acceptance factors. To analyse the gathered data, factor analysis will be used to cluster the survey questions and create a score on each of the acceptance factors. This score will be used to analyse the preference for the mitigation measures. Logistic regression analysis will be used to find out whether the height of the score on a risk acceptance factor influences the preference for mitigation measures. The next paragraphs describe factor analysis and logistic regression.

3.3. Factor analysis

Risk acceptance factors are often latent variables. Latent variables are variables that cannot be observed directly. Examples are perceptions and attitudes, thoughts inside a person's head. To measure latent variables, indicator variables are used. In this research a risk acceptance factor will be split up in several survey questions that all relate to the acceptance factor. In the survey participants have to state their agreement with the statements. To create one score on the acceptance factor, the score of the indicator questions are combined. Factor analysis is used to find out if there is causality between the different indicator variables. Factor analysis is used to check whether all indicator variables measure the specific risk acceptance factor and not an unknown other factor. The factor explains the correlation between the indicators. It represents the aspect that these indicators have in common. Therefore all of the indicators can be combined into one score on the factor variable. If one of the survey questions has low communality, factor analysis is used to exclude this indicator. Only the survey questions with high factor loadings will be used to create a score on the latent variable [71]. The factor analysis will be executed using the SPSS software.

3.3.1. Constructing new variables

After selecting the indicator variables with high enough factor loading, the risk acceptance factors can be created. In general factor loading must be higher than 0.4 [71]. Using the scores on the selected indicator variables, new variables are constructed. Constructing new variables can be done in three ways.

1. Using a factor score

2. Using a sum score

3. Using a surrogate variable

If there is doubt about the reliability or validity of the new factor, a surrogate variable will be used. For this research the survey questions will be based on existing research and literature. Therefore the factor analysis will be confirmatory instead of exploratory. With a confirmatory factor analysis, great uncertainty about validity or reliability is unlikely.

If the created scale with indicator variables is reliable enough, sum score will be used. Reliability is tested with Cronbach's alpha and needs to be higher than 0.70. Other conditions for using a sum score are a one-dimensional scale, positive correlations and an equal range of variables. One-dimensional means that the selected indicator variables only represent one latent variable. Positive correlations mean that a high score on any indicator variable has the same effect on the latent variable. For example when measuring trust, high scores on indicator variables all lead to a high score for trust. If a high score on one of the indicator variables leads to distrust, this variable needs to be recoded. Finally equal range means that all indicator variables are measured on a comparable scale. If all conditions are met, sum score can be executed. With sum score the individual scores are add up to create a single score on the latent variable. To keep the same scale as has been used for the survey questions; an alternative is to take the average of the indicator scores. An advantage of sum score is its simplicity and the fact that it is unambiguously.

If the reliability is not high enough or one of the other conditions cannot be met, factor score can be used to construct the latent variable. With factor score a weighted score is created for every latent variable with the factor loading as basis. A factor score can easily be created with software such as SPSS. An advantage of factor score is a standardised output with a mean of 0 and a standard deviation of 1. However factor score is more complex than sum score and with multiple factors, the factors with lower loading are also included; meaning that indicator variables that are measuring a different variable might be included [36].

3.4. Logistic regression

For researching the effect of one or more predictor variables on a dependent variable most of the time linear regression analysis is used. However this does not work when the dependent variable is not an interval or ratio variable. The dependent variable in this research is whether a mitigation measure is selected. A measure can either be selected or not selected. This means that the dependent variable is a dichotomous variable. If linear regression analysis is used for a dichotomous dependent variable, the chance of selecting can become either negative or exceed 100%. Logically a chance can never be negative or exceed 100%. Another error of using linear regression for dichotomous variables is over- and underestimating the chance. To tackle these errors logistic regression is used. Logistic regression analysis uses a special chance curve that cannot drop down below 0 or exceed 1. This makes it a suitable analysis technique for dichotomous variables that are either selected (1) or not selected (0). The difference between a linear model and a logistic model is shown in figure 3.1. The linear line starts below 0, than overestimates the chance and subsequently underestimates the chance. Finally it exceeds 1. To get the logistic curve the mathematical constant Euler's number is used with the linear model. By using the formula in the figure, a logistic curve ranges between 0 and 1. The formula gives the chance (p) that an alternative will be selected. In this research the chance will be calculated using SPSS software.

Factor analysis, as explained in the previous paragraphs, is used to determine a single score for the every selected risk acceptance factor. With logistic regression the effect of the risk acceptance factors on the selection of mitigation measures can be analysed. In this research the selection of mitigation measures is the dependent variable and the risk acceptance factors are the predictor or independent variables.

With the Chi-square test can be determined whether the predictor variable has a significant effect on the dependent variable. SPSS uses distinct goodness of fit tests for calculating explained variance:

1. MC Fadden R^2

2. Cox & Snell R^2

3. Nagelkerk^2

Explained variance tells how much of the variance of the dependent variable can be explained by the predictor variable. In SPSS change in log likelihood shows the importance of the independent variable for the prediction of the dependent variable. The independent variable with the largest change in log likelihood has the most effect on the dependent variable [62]).
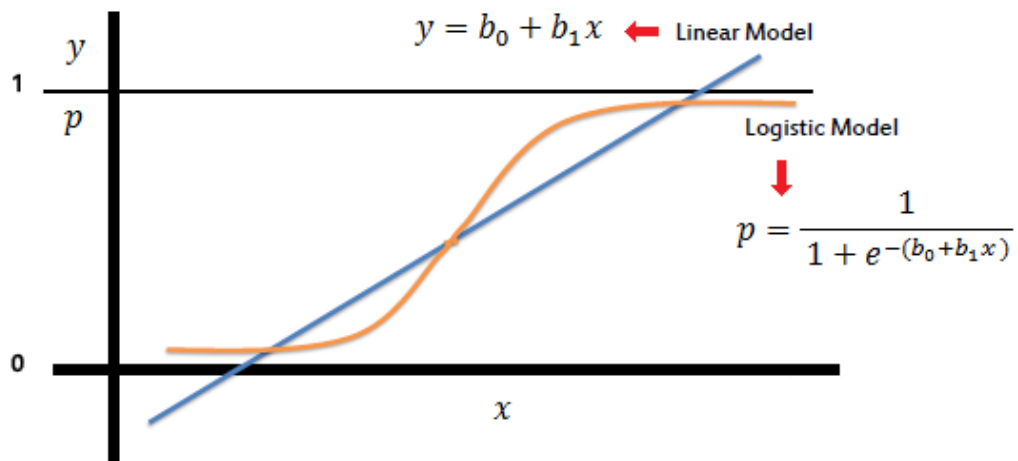
Figure 3.1: Logistic versus linear curve [61]

3.5. Research framework

In chapter 1, reviewed literature shows knowledge gaps on community involvement, risk acceptance and cost-benefit analysis. Based on these knowledge gaps, research objectives are constructed leading to a main research question. In chapter 2, the main research question is split up in five sub questions that help to find an answer on the main research question. In this chapter the different methodologies used to answer the sub questions were described. Combining these steps form the basis for the research described in the rest of this report. Figure 3.2 displays the research framework where the different steps are visualised.
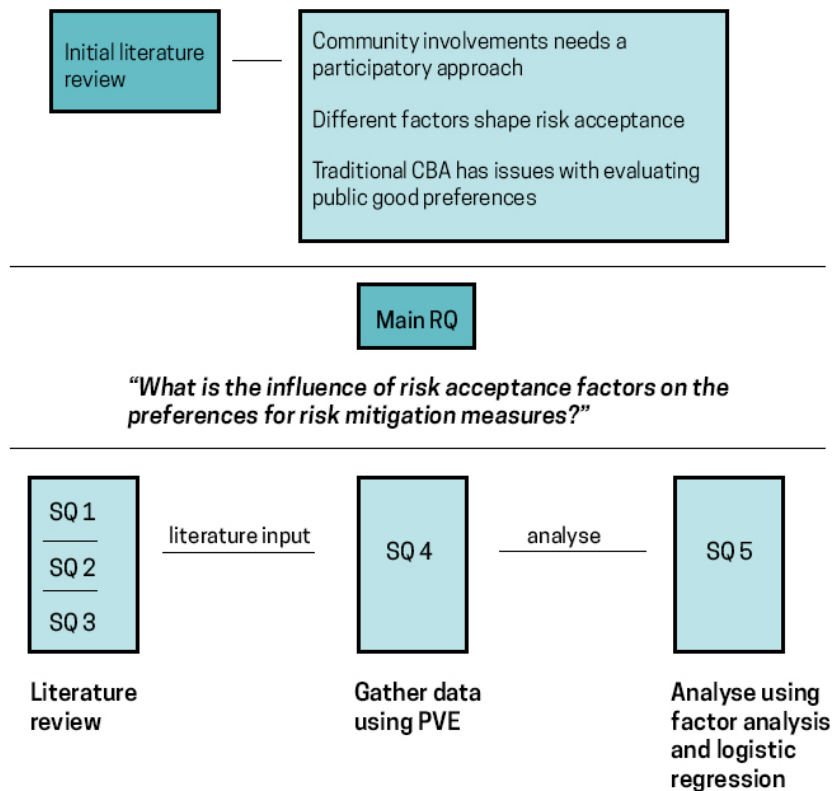
Figure 3.2: Research framework

4

Case description

This chapter describes the case used for answering the research question. A case is suitable for community involvement when hostility of local communities toward authorities is high and the issue is of high interest to the involved stakeholders [26]. Both high benefit indicators seem to be a suiting description of the Groningen case situation. Despite the known research, there is a lack of attempt to involve the people of Groningen in the decision-making. Van der Voort and Vanclay share the idea of using a participatory strategy in their paper on the Groningen situation. In their opinion the NAM has ignored this strategy by trying to improve their image instead of working on underlying values [74]. In the Groningen case, the social justice, as mentioned by Fung is a particular pressing issue. The people in Groningen feel they are shouldering the burdens of the gas extraction, without receiving any of the benefits. In order to solve this issue, community involvement can prove to be a solution. With information being digitally available for the public, the potential of community involvement has increased [19].

The induced earthquakes as man-made hazard create issues for the local community. Distrust between the public and authorities caused by the created issues. The combination of distrust and ineffective mitigation make the Groningen case suitable for this research. In the rest of this chapter the history of gas production in the Netherlands, the induced earthquakes and the issues related to the earthquakes are described.

4.1. History of gas production in the Netherlands

The history of gas production in the Netherlands starts with the foundation of the Nederlandse Aardolie Maatschappij (NAM) in 1947. A year later the NAM found the first economically feasible gas fields in the province of Drenthe. During the first years after this discovery, gas production was on a low scale. But everything changed when a major field was discovered near Slochteren in the province of Groningen in 1959. This gas field turned out to be the largest in Europe, which provided a major uptake in the gas production in the Netherlands [74]. Due to the discovery of this large gas field, the Dutch government decided to connect the whole country to natural gas. To provide this connection GasUnie was founded. Gasunie is owned by the Dutch government, which is represented by the Ministry of Finance. This company is responsible for the selling and distribution of the natural gas to all parts of the Netherlands. The NAM, which is owned by Shell and Esso, now known as ExxonMobil, for both 50%, is responsible for the production of the natural gas. In 2005, GasTerra was unbundeld from Gasunie. This public-private partnership between the State of the Netherlands for 50%, Shell for 25% and ExxonMobil for 25%, is responsible for trade with foreign countries [74, 78]. Figure 4.1 shows the organisational structure of the involved parties.
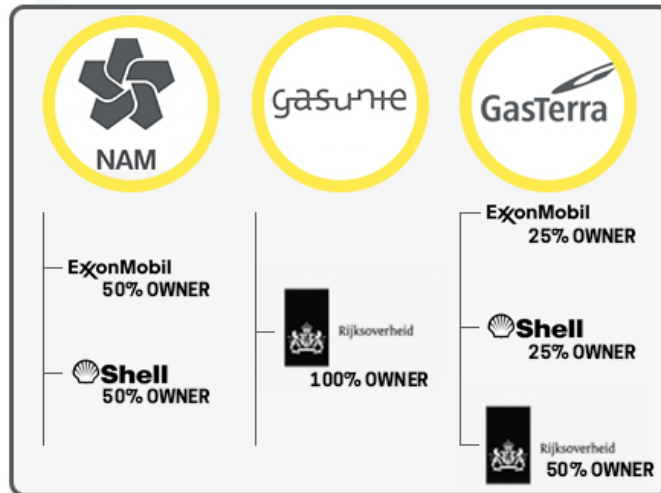
Figure 4.1: Organisational structure of involved parties in gas chain

Since 1963, the Groningen Gas field has been commercially exploited to secure the energy supply of the Netherlands and has been generating revenues up to 265 billion euros for the Dutch state. The most involved party of the Dutch government is the Ministry of Economic Affairs, since they grant the permit for production to the NAM. The approval for production depends on the production plans of the NAM and even if the permit is granted the NAM remains responsible for the consequences of its gas production activities [37, 74]. An overview of the responsibilities of parties involved in the natural gas chain is displayed in figure 4.2.
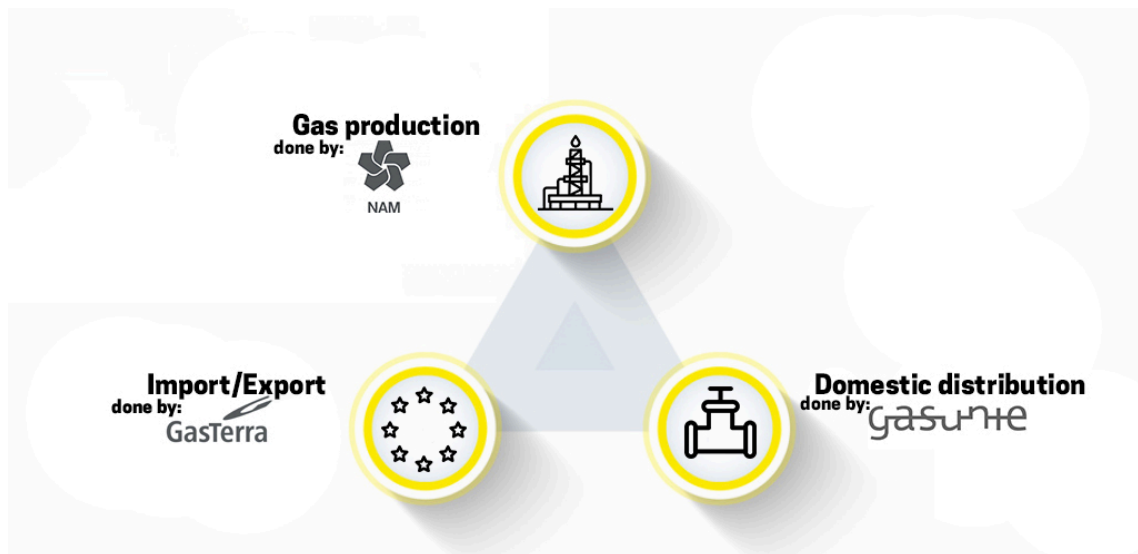
Figure 4.2: Responsible parties in gas chain.

4.2. Earthquake history

Until 1986 the discovery of the large gas field and the revenues coming from gas production caused merely positive sounds, however this changed when the first earthquake was monitored. Despite the lack of previous seismic activity, the Dutch government claimed it highly unlikely for the earthquake to be caused by gas production. After 1986, the frequency and magnitude of the earthquakes increased which led to the NAM admitting that seismic events due to gas production are possible. In 1990 MIT researchers state that the risk of significant seismic activity is low [74]. As can be seen in figure 4.3, the Groningen gas field is located in a sandstone layer three kilometres below the surface. When gas is extracted, pressure in the layers decreases. Therefore the sandstone layer cannot support the weight of the layers above and soil subsidence occurs. The layers compress and this compression can cause earthquakes. While natural earthquakes occur in layers between 10 and 20 kilometres deep, the earthquakes in Groningen happen in the sandstone layer right below the surface. This leads to a higher impact on buildings compared to natural earthquakes [31, 39].

Until 2011, the earthquakes were not perceived as problematic. Not by the NAM, the government or the local communities. This changed in 2012 when the worst earthquake so far struck Huizinge, a small-town in the province of Groningen, with a force of 3.6 on the Richter scale [30, 74].
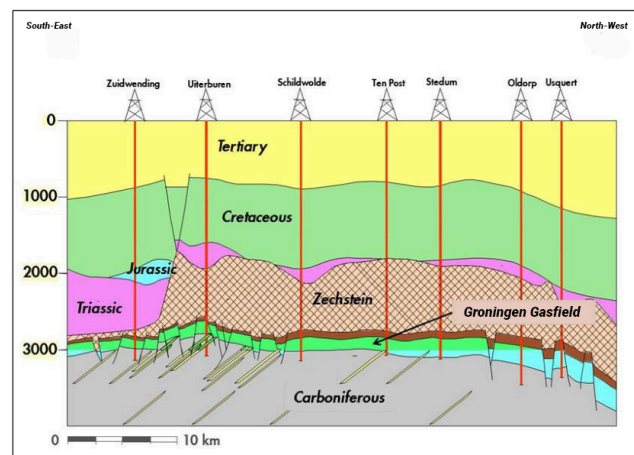
Figure 4.3: Groningen gasfield layer [49]

4.3. Consequences of earthquakes

The earthquake in Huizinge led to larger damage to the property than had been seen so far; with some of the houses becoming uninhabitable [37]. This event with larger consequences, led to much concern among the local communities. The topic became important on the political agenda and public media started to pay attention [74]. A report, commissioned by the Ministry of Economic affairs, has been published by the State Supervision of Mines (SoDM) in January 2013. This report stated that the increased gas extraction between 2000 and 2013 led to an increased frequency of induced earthquakes and concluded that earthquakes up to 5.0 on the Richter scale were possible due to the increased extraction of gas [37, 74]. Henk Kamp, the minister of economic affairs at that time, stated that reduction of gas extraction was not possible due to contractual agreements. This statement together with the SoDM report led to larger concerns for the people in Groningen [74].

After the earthquake in Huizinge, the NAM received many claims by local citizens for damage of their property due to the earthquakes. Because the NAM is, according to Dutch law, responsible for the effects resulting from its activities, they set up a compensation procedure for the affected people. However the ongoing neglecting attitude towards the risks of induced earthquakes of both the Dutch Government and the NAM, have caused serious trust issues for the local communities [37]. The compensation procedure has been

slow and the people in Groningen feel that the procedure is not objective since it is performed by the NAM itself [74]. To address this issue, a temporary committee for mining damage Groningen (TCMG) was established on March 19, 2018. This committee is responsible for the compensation procedure and is independent from both the Dutch government as the NAM. To regain trust between the local community in the earthquake prone areas and the government and the NAM, several special interest groups were established [37]. Despite increased importance and attention, the issues prove to be complicated and hard to solve. As van der Voort and Vanclay state "most pressing social impacts experienced by local residents include; damage to property, declining house prices, concerns about the chances of dykes breaking, feelings of anxiety and insecurity, health issues and anger" [74, p.1].

5

Risk acceptance factors

This chapter describes factors that are known to shape the risk acceptance of people. In the last decades societies in the US and Europe have become safer and healthier on average. More money is spend to increase these levels of safety and health even further. Despite this increased safety levels the public has become more concerned about risks [58, 63]. The world has become more polarized. Views of scientist, governments and the public are further apart. Views becoming wider together with a growing public concern cause issues for risk management and risk acceptance [58, 63].

Attitude towards risk is an important factor in motivating people to take actions to mitigate the risk or ignore the risk on the other hand. Risk acceptance depends on the type of risk and risk context, but also on the social context. Wachinger and Renn mention factors such as knowledge, experience, values, attitudes, and emotions that play a role in risk acceptance [75].

5.1. Induced earthquakes

Although research exists on risk acceptance for naturally occurring earthquakes, there is little literature published on risk acceptance for induced earthquakes. In comparison to natural earthquakes, induced earthquakes are more controllable since the hazard can be controlled to some point. This idea leads to less trust in operating parties. Research shows that human induced earthquakes are perceived more negatively than natural earthquakes, even if the consequences are the same [34]. Because induced earthquakes are more controllable and have different perception, the Groningen case should be considered as an energy case rather than a natural disaster. Therefore the Groningen case can be compared with geothermal- and CO2 storage projects.

5.2. Blocked energy projects

In Australia and Switzerland several projects are blocked due to social acceptance. Most of these projects were geothermal- or CO2 storage projects [35, 48]. Because the projects are related to energy and are also known for induced seismic activity, the projects can be compared to the gas extraction in Groningen. In the Netherlands, underground CO2 storage near Barendrecht and shale gas production near Boxtel have been aborted because inhabitants were concerned about safety [37]. Energy cases often suffer from significant social opposition. Scholars argued that low social acceptance might result from neglecting moral values. Therefore moral values should be included in the decision-making process [37].

5.3. Literature overview of risk acceptance factors

Mouter et al. applied a value-based approach to the Groningen case situation. They used relevant scientific articles to identify moral values present in the case situation. Next they checked newspapers and parliamentary debates for the identified values. Most recognized values turned out to be safety, trust and honesty. To validate the results, they interviewed respondents and found two other values; geographical equity and procedural justice. Respondents mentioned that while having to carry the load of the gas extraction, Groningen received only 1% of the benefits of the gas exploitation. They also make a comparison with the construction of a subway track in Amsterdam that was put on hold as soon as damage was noticed, while the gas extraction is an ongoing process. Respondents feel that Groningen is treated differently than the west of the country where the government and most of the population is settled. From a value point of view geographical equity and procedural justice is closely related to trust and honesty [37].

The values discovered in Groningen are comparable with the values mentioned by Wachinger and Renn [75]. Based on the values, factors can be extracted that shape risk acceptance. In literature many factors are mentioned that influence attitudes towards risks. In this research factors with the strongest effect on risk acceptance are included. Which factors have most effect depends on the context of the risk situation. Because induced earthquakes differ from natural earthquakes, social factors play a more important role [34]. Figure 5.1. shows an overview of risk acceptance factors as mentioned in extensive research by Wachinger et al. This overview is compared with literature on relatable topics to the Groningen case. Encircled in red are factors that are mentioned by either Wachinger et al themselves or studied literature. Based on the literature both risk factors are combined as perceived risk and personal experience is rewritten as direct experience. Apart from the encircled factors, perceived benefit is added. The next paragraphs describe the six factors that have most effect on shaping risk acceptance in the case of induced hazards.

Figure 5.1: Risk acceptance factors [75]

5.3.1. Perceived risk

Wang et al. conducted research on public acceptance of nuclear energy. The first factor they found was *perceived risk*. The extent to which people believe they are exposed to nuclear energy contributes to public acceptance in a way that a higher perceived exposure decreases public acceptance [76]. The other papers reviewed, prioritise other factors as more important. This might be due to the fact that the research of Wang et al. is focused on nuclear energy, which is considered a highly controversial topic. However it is still interesting to see whether there is difference in risk perception among the respondents of this research.

5.3.2. Perceived benefits

In the same paper Wang et al. mention *perceived benefits* as a factor shaping risk acceptance. Perceived benefits are associated with perceived risks. If people believe the action or hazard that produces the risks also produces benefits; people are more willingly to accept the risk [76]. McComas et al. mention benefits such as job creation or educational opportunities. They mention that induced earthquakes can be accepted as long as the perceived benefits outweigh the perceived risks [34]. McComas et al. state "previous research suggest that perceptions of fairness in the allocation of benefits will factor into acceptability of risks" [34, p.28]. Looking at the Groningen case, perceived benefit is an interesting factor to take into account. As many people claim that Groningen receives only 1% of the benefits of the gas production and they feel treated differently, there is a lack of proper benefit allocation. This factor is closely related to the values of geographical equity and procedural justice as found by Mouter et al [37].

5.3.3. Trust in authorities

One of the most mentioned factors in shaping risk acceptance is *trust*. Trust is defined as the trust local communities have in authorities. In the projects described in literature an authority is either the government or the operating party [18, 54, 63, 75]. In a complex situation where earthquakes are caused by gas extraction, people are not able to inform themselves on all the threats they face. This creates a dependency on authorities and experts. If this trust is damaged, it is less likely that risks are accepted [75]. Fessenden-Raden et al. found in their research that communities with low levels of trust in governments are more likely to dispute every decision made by the government, making policy less effective [18]. A case in Italy on public acceptance of geothermal energy showed that in complex situations where local communities lack the knowledge to decide and act, trust serves as substitute for knowledge. In this case, the view of Wachinger and Renn on public acceptance relying on the level of trust in authorities, is shared [54]. In the Groningen case situation lack of trust is a very important factor, with people in Groningen blaming both the government and the NAM as operating party [74]. In this research the factor trust must be split up in trust in the government and trust in the NAM.

5.3.4. Direct experience

Besides trust in authorities, *direct experience* is known as a factor having a high impact on risk acceptance. Direct experience is defined as experiencing the earthquakes with your own eyes [75]. Direct experience can have either a positive or a negative effect on risk acceptance. Ruin et al. showed in their research on risk perception of floods that people who experienced floods in general overestimate the dangers of floods, while people with no direct experience used to underestimate the dangers [60]. However other examples show that people who experienced hazards but escaped without damage are likely to believe that they will also escape consequences the next time [75]. Fessenden-Raden et al. show in their paper that people with a history of experiencing health issues are more likely to overestimate dangers of hazards than people without these experiences [18].

For the case situation in Groningen it is interesting to include direct experience as factor. This way can be found out whether differences exists between the people in Groningen who experienced the earthquakes at first hand and people without this experience.

5.3.5. Media coverage

The media often informs people who lack direct experience. The extent of indirect experience depends on the level of media coverage and the extent to which people use the media as their prime information source [75]. Since gas production in Groningen is currently a hot topic in the Netherlands, media coverage is high. Indirect experience through *media coverage* can shape risk acceptance. In the Groningen case it is interesting to see whether people who are close followers of media have different preferences.

5.3.6. Knowledge

Mentioned research shows that if people lack knowledge, trust in authorities can be seen as substitute. This means that knowledge is also an important factor for shaping risk acceptance. In their research on nuclear energy, Wang et al. state that a public with more knowledge on a topic is more likely to take objective and reasonable decisions. People without knowledge on energy cases are more likely to overestimate dangers of a hazard, which leads to decreased public acceptance [76]. Participants of research in Italy mentioned that knowledge is important for forming an opinion on geothermal energy. Without knowledge people are less likely to accept risks [54]. As knowledge is often mentioned as a factor shaping risk acceptance it is interesting to see whether differences exist between people with more knowledge of induced earthquakes and people without this knowledge.

5.4. Selected risk acceptance factors

In this research participants have to answer survey questions to gather their score on each of the factor. To keep the threshold for participating as low as possible the survey should be as short as possible. Therefore factors that are hard to measure or lack a thorough contribution are excluded. The link between media coverage and indirect experience is researched however its contribution is too vague to include it in the research. Since the earthquakes are a hot topic, media coverage is high. Differences between participants can be caused by the extent to which participants use media as primary information source. The PVE tool is mainly distributed via social media. It is believed that most people who use social media receive similar media coverage, therefore this research considers huge differences in media usage between participants as unlikely. However if the results show significant differences between participants from outside the region, media coverage might be an explanation.

Knowledge of a topic is hard to measure. An issue with knowledge is that often a participant's perception of his own knowledge is measured instead of the concrete knowledge level. Therefore knowledge is also excluded from the research. In research on unknown technologies such as nuclear energy, knowledge is often of influence on risk perception and risk acceptance. In the case of nuclear energy, more knowledge in general leads to higher acceptance of the technology [76]. In this research, an unknown risk like a disaster with nuclear does not exist. Earthquakes caused by gas production are already happening and this is known by most people. Therefore it is expected that knowledge does not have significant effect on the research and that leaving knowledge outside of the research will not be of high impact on the results. This leaves four included risk acceptance factors shown in figure 5.2.

Included risk acceptance factors

☑ Perceived risk

☑ Perceived benefit

☑ Direct experience

☑ Trust in authorities

Figure 5.2: Included risk acceptance factors

6

Mitigation measures

In this chapter mitigation measures for induced earthquakes are described. To make the research as realistic as possible, literature on the Groningen case has been used to make a selection of mitigation measures.

The by gas extraction induced earthquakes are different from natural earthquakes as they are man-made. Being perceived as man-made causes differences in risk acceptance in relation to natural earthquakes. Induced gas earthquakes are perceived as more controllable. Despite being more controllable, induced earthquakes are causing huge public concerns. Levels of trust in authorities are often low for induced earthquakes and there is a clear need for managing seismic activity as a result of the human activities causing the earthquakes [6, 11]. Compared to natural earthquakes, induced earthquakes are more controllable, however developed control systems have proven to be ineffective. Different projects with seismic activity, due to mining and hydraulic fracturing for shale gas, have caused earthquakes even after the production has long stopped. Given this fact, mitigation measures should not focus on controlling the seismic activity, but rather on the consequences of the earthquakes. This argues for the use of mitigation measures as used for natural earthquakes. This can however not be done before adaption due to specific characteristics of induced earthquakes and the fact that induced earthquakes are often happening in areas not used to normal seismic activity and therefore not prepared for earthquakes [6].

The most effective solution is of course to either relocate the operation causing the seismicity or the affected community. In practice this is almost never possible. Most used mitigation approach for natural earthquakes is structural strengthening of buildings. Figure 6.1 shows an overview of typical structural intervention for seismic strengthening by Sugano. He divides the intervention techniques in increasing strength, ductility or both [6].

The difference for mitigation of induced earthquakes in relation to natural earthquakes is the indispensability of transparent and open communication to the affected community. With induced earthquakes being perceived as more controllable, the local community feels that the operator can be blamed and there is in general a very low level of trust in the authorities [6]. The man-made aspect of induced earthquakes causes larger social concern than natural hazard and therefore included mitigation measures do not only focus on the hazard itself but also on the image of the affected region and improving the quality of life for the affected communities [34]. These consequences are considered as indirect consequences of an induced hazard.
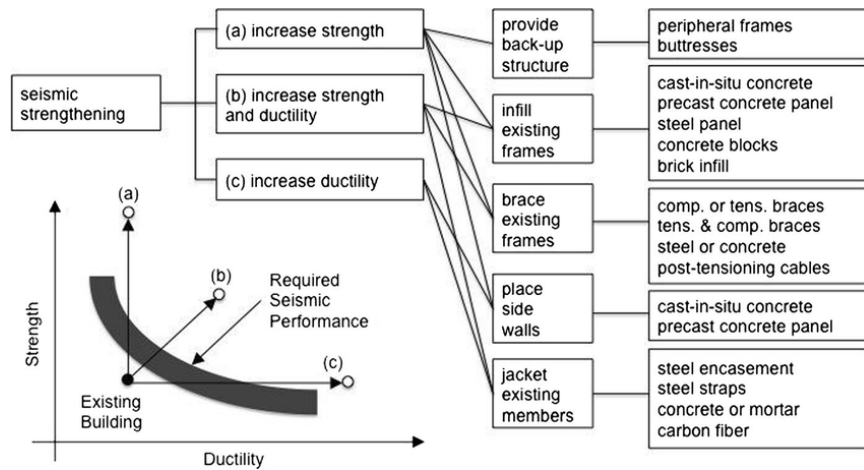
Figure 6.1: Structural intervention techniques [6, p.640]

6.1. Mitigation in Groningen

The goal of the Dutch government is to stop gas production before 2030. The state supervision of mines (SoDM) advised to reduce production to 12 billion cubic meters per year to be safe. However the Dutch government wants to go even further and after reaching this safety level by 2022, they want to stop the gas production completely by 2030 [15]. Despite the reduction, this does not guarantee a complete stop of earthquakes, which might continue for a while even after the stop of gas extraction [6]. Because the earthquakes might continue and the plans for a complete stop of gas production are already considered, gas reduction will not be included as mitigation measure. In January 2014, 9 municipalties, the Dutch government and the Province Groningen agreed upon a mitigation measure package. Some of these measures are partially implemented, others are planned for the future [29]. An overview of these measures is displayed in papers by Perlaviciute et al. and Van der Voort & Vanclay [55, 74]. The included mitigation measures can be divided into three categories. The induced earthquakes damage housing in Groningen. To prevent the risk of the damage, a prevention measure is included. Compensation measures are included to take care of the people when the damage is done. The earthquakes indirectly lead to stress for the local community and a deterioration of the image of the region. To tackle these issues, investment measures are included. This seperation is displayed in figure 6.2. In the following paragraphs the included mitigation measures are described in detail based on both papers.
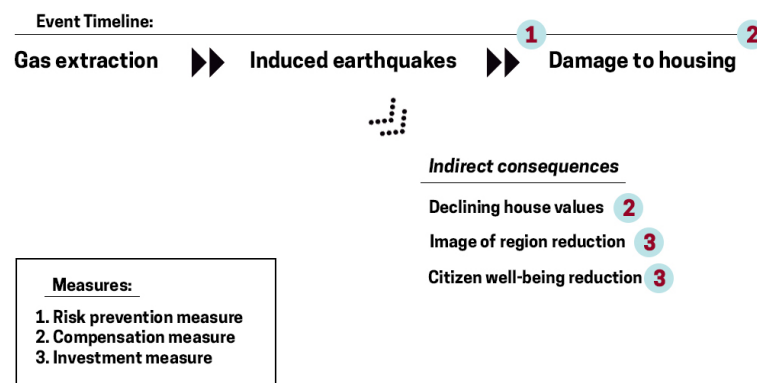
Figure 6.2: Types of included mitigation measures

6.1.1. Structural reinforcement

A mitigation measure to reduce the risk of damage caused by earthquakes is structural reinforcement. With structural reinforcement a building is checked and a reinforcement procedure is set up [6]. In the case situation the Nationaal Coordinator Groningen (NCG) is responsible for the reinforcement of housing, buildings and infrastructure. NCG is a collaboration between six municipalities in the earthquake area, the province Groningen and the national government. NCG states that people in Groningen should be able to live within the same safety limits as the rest of the Netherlands. Preventive reinforcement does not completely remove the chance of earthquake damage, but decreases the risk of severe damage. If inspection shows a need for reinforcement different options are possible. If the investment costs for reinforcement are below 150% of the market value of the building, the building should be reinforced. Investment costs higher than 150% of the building's market value call for either reinforcement, reconstruction of the building or construction of a new building When multiple options are possible the owner of the building makes the final choice. If the building is a semidetached- or terraced house the decision is made in agreement with the neighbours. Special rules are set up for monuments [44]. Reinforcement and construction follows Dutch guideline NPR 9998, which is created for the assessment of structural safety of buildings in the case of induced earthquakes [7].

6.1.2. Damage compensation

On January 31st 2018 minister Wiebes of Economic Affairs and Climate came with the resolution Mining Damage Groningen. This resolution states that the NAM should no longer be involved as handling party for the compensation of the earthquake damage. Based on this resolution compensation is handled by "*Tijdelijke Commissie Mijnbouwschade Groningen*" (TCMG) since the 19th of March 2018. This independent temporary committee is responsible for dealing with the claims of damage due to earthquakes. The procedure for damage compensation is based on four pillars following from the resolution: righteous, open-handed, independent and attention for human dimension. With every damage claim these four pillars must be taken into account [77].

The procedure follows ten steps [69]:

1. Claim damage online or via phone
2. Receive confirmation of damage claim
3. Committee chooses an independent expert
4. Person who claimed the damage has the possibility to request a different expert is case of doubt on independence
5. Damage inspection
6. Expert writes an advisory report
7. Citizen can react on the advisory report
8. Based on the report and the citizen's reaction, the committee prepares for a decision
9. The committee takes a decision on the compensation
10. Citizen is able to object against the decision

Compensation for damage less than 10.0000 euro follows the simplified procedure above. Damage for less than 10.000 euro is often straightforward. The experts of the committee have a lot of experience with these damage claims and extensive research is most of the times unnecessary. Damage above 10.000 euro often asks for multiple experts and more extensive research [70].

6.1.3. Declining house value compensation

Damage to property caused stress for the communities in Groningen. Due to increased stress more people on average want to leave the province while at the same time less people want to move towards Groningen. Damage to housing has negative effects on the wellbeing of citizens, together with media attention, uncertainty about the levels of gas extraction and the risk of new earthquakes it creates a negative image for the region [39]. Boelhouwer and van der Heijden summarise this in their paper; "In short, everywhere in the earthquake zone, earthquakes have a substantial impact on liveability and the quality of life whereby the earthquake intensity (along with a number of other determinants such as population decline) then provides a detailed spatial differentiation of the impact" [5, p.437]. A negative image has negative consequences for the performance of the housing market. A lower demand for housing causes property to be on the market for a longer time and sometimes properties are impossible to sell. Overall this leads to declining house values. A decrease in house values leads to financial issues for the homeowners, especially when they have an expensive mortgage on the house. If the value of the property declines, extra interest rates may occur or additional finance request may be refused [39].

The Dutch court ordered a resolution that states that homeowners who sold their house after the 25th of January 2013 with a demonstrable lower value due to the consequences of the earthquakes are entitled to compensation for the declining house value. This compensation is paid for by the NAM. When a compensation claim is received by the NAM, independent appraisers judge the claim and order a verdict [40]. If a house is unable to sell, Nationaal Coordinator Groningen (NCG) has a budget to buy the house. This budget is supplied by the NAM. The house has to be listed for sale for at least 12 months [43].

6.1.4. Standard of living enhancement

As mentioned in the previous paragraph, the province of Groningen, and especially the part in the northeast has to deal with a negative image. In comparison to the rest of the country this area has higher unemployment rates and lower economic growth [39, 72]. To tackle these issues and enhance the standard of living quality, the economic board is created. The goal of the board is to steer a budget for economic improvement, designated by the NAM, in the right direction [13].

One of the first projects that is being realised is faster internet for the region. Together with local contractors, Rodin Broadband is responsible for installing a network for faster internet connection [42]. Another investment is the improvement of sport facilities, which is already realised in a few municipalities. Apart from existing enhancements, there is room for local initiatives. Communities with their own initiative can use a subsidy to realise their ideas [46].

6.1.5. Renewable energy investment

In March 2018, minister Wiebes of Economic Affairs and Climate announced that the extraction of gas is scheduled for termination in 2030. The acceleration of the shut down of gas production calls for new ways of energy production [15]. Since the start of gas extraction Groningen has been the "energy province" and investment in renewable energy is necessary to keep up with this position. In 2017, 15% of the energy in Groningen came from renewable energy sources in relation to only 6,6% on average in the Netherlands. The ambition of province Groningen is to reach 60% in 2035 and 100% in 2050. To reach this goal the province Groningen supports six villages with becoming energy neutral. Besides local support, the province also researches the possibilities for wind- and solar farms [57]. A positive side effect of investment in renewable energy is job creation. While in the period between 2014 and 2017 overall employment in the region declined, the employment rate in the sustainability sector rose by 30% [56].

As mitigation measure, homeowners in the affected area are entitled to subsidy on several renewable energy technologies such as solar panels or wind energy technology. "*Samenwerking Noord-Nederland*" (SNN) provides the subsidy. The "*Waardevermeerdering*" subsidy does not only lead to more renewable energy, but also increases the value of the houses where the renewable technologies are installed [64].

6.1.6. Local job creation

Unemployment is a serious issue in the region [72]. To tackle this issue and at the same time repair the damage done by the earthquakes, a mitigation measure is to hire local contractors to repair the damage. The ministry of Social Affairs and Employment constructed the 1000-jobs plan to create permanent employment. Training in the building- and technology sector must lead to the creation of 1000 jobs between 2018 and 2021. The plan has an increased focus on people who have trouble finding a job [45].

"*Centrum Veilig Wonen*" (CVW) facilitates the reinforcement of buildings affected by the earthquakes. CVW created the "*Erkenningsregeling*", a regulation that can be seen as a certificate for companies that reinforce the affected buildings. With this regulation people can check whether their damage is repaired by an approved company. In relation to the 1000-jobs plan, CVW trains local companies to achieve this regulation [9].

7

Mitigation measure characteristics

In this chapter the characteristics of the chosen mitigation measures will be described. During a PVE research, participants have to choose the mitigation measures they prefer. To be able to make this decision, every measure is described by attributes. These attributes describe the effects of a measure when implemented.

In previous PVE research, all measures are characterized by the same all covering attributes. However in this research the measures are so diverse that it is hard to find common attributes that are affected by all the measures. Therefore only three common attributes are included. First a measure is classified by its type. In this way participants can see what the direct effects of the measure are. Second a participant can compare measures by its costs or reach. Because every measure is so specific, a short description of the measure is included, so that participants can, apart from the three common attributes, base their decision on the description of every measure. In the following paragraphs the effects of the included mitigation measures are described.

7.1. Structural reinforcement

Since 2018, Nationaal Coordinator Groningen (NCG) is responsible for the structural reinforcement of buildings in Groningen. Because this research has a focus on local communities and the PVE method puts citizens in a decision position, the scope of this mitigation measure is limited to housing. In the plan of action by the NCG is written that around 2500 houses are exposed to an increased risk, which is shown in figure 7.1.

Based on an estimation by housing corporation Lefier, the costs of reinforcement for one house vary between 45.000 and 85.000 euro. On average this would be 65.000 euro per house [12]. This brings the total costs for reinforcement of 2500 houses on: 163 million euro. The goal of structural reinforcement is to strengthen the houses in the earthquake prone area and therefore reduce the risk of damage caused by earthquakes. This mitigation measure is classified as a risk reduction measure.

Type: Risk reduction
Costs: €163 million
Reach: 2500 houses

Municipalities	Houses with increased risk profile	Houses with increased risk profile (completed)
Appingedam	714	319
Delfzijl	326	304
Groningen	48	90
Het Hogeland	8	83
Loppersum	236	136
Midden-Groningen	226	34
Oldambt	2	0
Total:	**1560**	**966**

Figure 7.1: Houses with increased risk-profiles [47, p.10]

7.2. Damage compensation

Since March 2018, the NAM is no longer responsible for the damage compensation. Tijdelijke Commisie Mijnbouwschade Groningen (TCMG) is responsible for handling the damage claims, while the NAM still has to pay for the compensation. TCMG shows numbers on their website on the amount of claims they handled so far and the total amount of money shared out for compensation. Of the 3700 claims so far, 85% is awarded, which is around 3150 claims. Until March 2019, 13.4 million euro is paid as compensation. On average this is 4250 euro per awarded claim [68].

Figure 7.2 shows that the amount of claims not yet handled fluctuates around 16.000 claims. If 85% of these claims are awarded, there are 13.600 claims left waiting for compensation. With an average compensation of 4250 euro per claim the total costs of awarding these claims is 58 million euro [68].

Damage compensation compensates citizens for the repair of damage caused by the earthquakes. Therefore this mitigation measure is classified as a compensation measure.

Type: Compensation
Costs: €58 million
Reach: 13.600 Damage claims
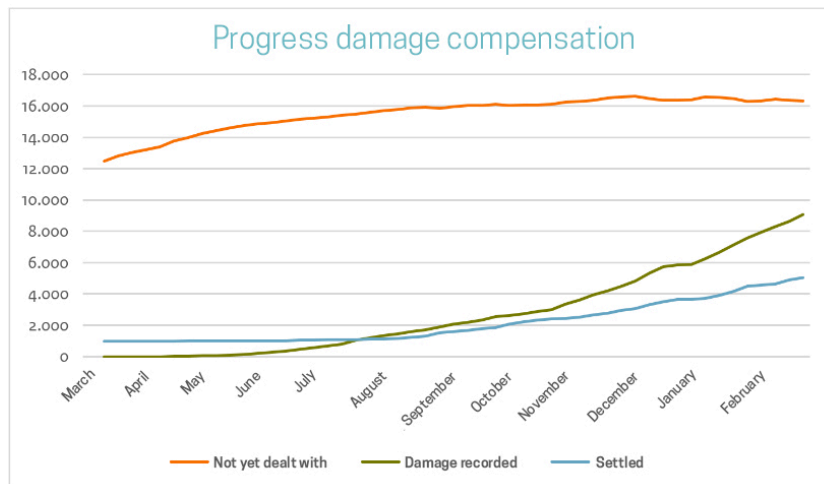
Figure 7.2: Progress damage compensation [68]

7.3. Declining house value compensation

The consequences of the earthquakes in Groningen have led to a drop in the values of houses [39]. Because the decline in house values is directly related to the gas extraction the Dutch court holds the NAM responsible for the compensation of this drop based on the Dutch mining law [14]. In practice the compensation for a decline in house value can be split up in two specific measures. If a house is sold for a demonstrable lower price, a value regulation exists called "*Waarderegeling*". If people are unable to sell their house due to the effects of earthquakes, the house can be bought by the NCG. This buying instrument is called "*Koop instrument*"

7.3.1. Value regulation

Numbers of the NAM show that 80% of the 5000 requests for compensation have been handled. This leaves 1000 claims to be handled. So far the NAM awards 90% of the claims. So it is concluded that still 900 sold houses are waiting for compensation [41]. Research shows that the NAM has spent 12 million euro on the compensation for values losses of 2.175 properties [39]. On average this is 5500 euro per building. The total costs for compensating value losses of 900 houses is 5 million euro. This measure is compensating people who have sold their house with a demonstrable loss of value. Therefore this measure is classified as compensation measure.

Type: Compensation
Costs: €5 million
Reach: 900 houses

7.3.2. Buying instrument

The NCG has a budget of 10 million euro to buy houses that are impossible to sell due to the earthquakes. This budget is supplied by the NAM, but the execution of the instrument is done by the NCG [43]. Numbers of the cadastre show that the average house price in Groningen is 201.000 euro, which is the lowest in the country [59]. This means that with a budget of 10 million euro, NCG is able to buy 50 houses. By buying houses, the NCG compensates people who are unable to sell their house. Therefore this measure is classified as a compensation measure.

Type: Compensation
Costs: €10 million
Reach: 50 houses

7.4. Standard of living enhancement

To improve the negative image of the region, the NAM has provided a budget of 65 million euro. Compared to the rest of the country, Groningen has low economic growth[39]. The Economic Board Groningen is created to manage the budget. Examples of projects realised at the moment are fast internet connection for the whole region and investment in sports facilities [13]. Because of all the different possibilities to spend the budget it is hard to specify the reach of this measure. This mitigation measure is classified as an investment measure.

Type: Investment
Costs: €65 million
Reach: Inhabitants of province Groningen

7.5. Renewable energy investment

After the stop of gas production Groningen wants to remain the "energy province" and therefore has a focus on investments in renewable energy. As a mitigation measure an organisation called Samenwerking Noord-Nedeland (SNN) provides a subsidy for people in the affected region that want to install renewable energy or sustainability technologies in their houses. The budget for this subsidy is 40 million euro and every household is entitled to a maximum amount of 4000 euro [64]. This means that the minimal number of houses reached is 10.000. With this measure homeowners can invest in renewable energy technologies and at the same time increase the value of their house. This mitigation measure is classified as an investment measure. This measure is only applicable to damaged houses.

Type: Investment
Costs: €10 million
Reach: 10.000 houses

7.6. Local job creation

Compared to the rest of the country unemployment rates in Groningen are high [72]. To tackle this issue and repair the damage caused by earthquakes at the same time, a 1000 job-plan is created. An investment of 6.2 million euro is needed to train people for jobs especially in the building- and technology sector [45]. Therefore this mitigation measure is classified as an investment measure.

Type: Investment
Costs: €6 million
Reach: 1000 jobs

8
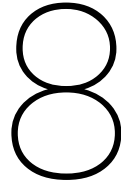
Design of the PVE method

This chapter describes the design of the PVE method. As mentioned in the methodology in chapter 3, PVE is a novel method. In 2018 Sophie Pak constructed methodological steps for the design of a PVE method for her MSc. thesis [53]. These steps, as shown in figure 8.1, are used in this research. The steps are followed in a different order in the context of this research. First all the information for the PVE method must be gathered. Second the web tool must be constructed. An overview of the web tool can be found in appendix A. This overview shows the introduction, instruction and information pages as mentioned in step 7 and 8.

THE METHODOLOGICAL STEPS ON THE DESIGN OF THE PVE METHOD

1. Choose the context
2. Set the constraint
3. Design follow-up qualitative questions
4. Determine the alternatives
5. Select the attributes

THE METHODOLOGICAL STEPS ON THE COMPOSITION OF THE CONTENT OF THE WEB TOOL

6. Calculate effects on contraint and attributes
7. Compose introduction and instruction page
8. Compose information pages
9. Compose delegation page

Figure 8.1: Methodological steps on the design of the PVE method [53])

The first step of the design is choosing a context. In this case the context is mitigation for the earthquakes in Groningen. An elaboration of the context can be found in the case description in chapter 4. The alternatives that participants can choose are mitigation measures for the earthquakes. The selection of the alternatives is described in chapter 6, while the included attributes and effects are described in chapter 7. Chapter 6 and 7 cover methodological steps 4, 5 and 6. Appendix A.1. shows the Dutch translation of the alternatives, attributes and effects as they have been used in this research.

8.1. Follow-up questions

The risk acceptance factors as described in chapter 5 are compiled using the follow-up questions in the PVE method. Most of the risk acceptance factors are feelings or attitudes of people; this makes it difficult to quantify the acceptance factors. To measure attitudes the Likert scale is used. With the Likert scale method participants are offered a set of statements. Next they have to show their agreement with the statements on a metric scale [27]. Most times either a 5-point or a 7-point scale is used. With a 7-point scale respondents have more freedom of choice and therefore less likely have to choose between two undesirable points on the scale [27]. However a 7-point scale makes the research less orderly and accessible. One of the indicated issues of this research is finding enough participants. To gather enough participants the web tool should be made as attractive as possible, within the limits of the research. Therefore this research uses a 5-point scale. In this research participants have show their agreements with the statements mentioned below. This has to be done on a scale ranging from strongly disagree to strongly agree as can be seen in figure 8.2.

Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
(1)	(2)	(3)	(4)	(5)

Figure 8.2: Likert-scale

Because feelings and attitudes cannot be directly measured, every acceptance factor is split up in multiple statements. This increases the validity of the measurement and reduces the chance of aspects of the factor being missed. All statements will follow from existing research and will be created based on literature review. Because existing questions are being used, which have been tested before, the reliability and validity of the Likert scale is improved [27].

8.1.1. Perceived risk

In 2016, Perlaviciute et al. conducted a research in Groningen on risk perception of the local community on the earthquakes. In their research they used five aspects of risk perception for measuring risk perception. In this research the same five aspects are used because these aspects show the different risks people in Groningen perceive [55]. In the research of Perlaviciute et al. participants had to rate the statements on a scale from very unlikely to very likely. To make the Likert-scale of perceived risk comparable with Likert-scale for the other acceptance factors, the statements have been revised. In this research participants have to show their agreement ranging from strongly disagree to strongly agree. Following are the included risk perception statements:

1. I consider damage to houses in Groningen because of the earthquakes as likely
2. I consider a drop of value of houses in Groningen because of the earthquakes as likely
3. I consider a reduced quality of life for the people affected by earthquakes as likely
4. I consider physical injury for the people affected by earthquakes as likely
5. I consider stress for the people affected by earthquakes as likely

8.1.2. Perceived benefits

For the case of Groningen there are no existing survey questions on perceived benefits. However research shows people in Groningen feel there is an unfair distribution of the benefits of gas extraction. Following from the article of Mouter et al. it is concluded that citizens in the affected region feel treated differently than citizens in the other parts of the country. Besides they feel that the benefits of gas extraction are unfairly distributed [37]. This is substantiated in a report by Van der Voort and Vanclay who mention a fund for economic structure reinforcement (FES). The FES is financed with money from the gas production, but the three northern provinces receive only 1% of this fund, while they account for 10% of the Dutch population [74]. Research done by Gronings Perspectief shows that after the heavy earthquake of Zeerijp in January 2018, feelings of fairness have declined even further [21]. Based on these feelings three statements are created for measuring the thoughts of participants on perceived benefits. These statements focus on the distribution of benefits and whether this distribution is in proportion with the negative effects of gas production. Research conducted by the general accounting office has shown that it is hard to trace the exact benefits of gas production. However they mention that most of the money has been used for investment in infrastructure and social services [1]. Therefore this research considers investments in social services and infrastructure as benefits of gas production. The included perceived benefit statements are:

1. I believe the benefits of the gas production are evenly distributed throughout the country
2. I believe the benefits of gas production for Groningen are in proportion with the burden of gas production
3. I believe citizens of Groningen are treated the same way as citizens in the rest of the country

8.1.3. Direct experience

To measure direct experience one simple question is asked. As can be read in chapter 5, direct experience with the hazard has a large effect on the acceptance of risks. In this research direct experience is asked directly with a yes or no question.

1. I have experienced an earthquake in Groningen

8.1.4. Trust in authorities

Trust in authorities is a known factor to shape risk acceptance. In this case authorities can be divided in two different authorities. It is important to make this distinction because research has shown significant differences in levels of trust in the different authorities. Trust in the national government and the NAM as operating party is known to be low, while trust in the local government is relatively high. Because local governments do not have a financial interest in gas production, there main goal is to secure the safety of their citizens. Therefore most citizens in the affected region trust local governments [74]. Trust in this research is limited to trust in the government and the NAM. There is overall high trust in the province Groningen. Therefore the province is not included since it is unlikely that differences appear and extra survey questions increase the participation threshold. The affected municipalities are not included because these are too small. It will be hard for participants to form opinions on the performance of municipalities.

1. I have trust in the Dutch government dealing with the earthquakes in the right way
2. I have trust in the NAM dealing with the earthquakes in the right way

8.1.5. Demographic questions

After the statements on risk acceptance, participants of this research have to answer a few demographic questions. Asking demographic questions allows the researcher to determine whether the target audience is being reached [20]. The target audience for this research is people who live in the affected area. Demographic questions can also be used to determine whether the sample of participants is a representative sample of society.

In this research is chosen for only four demographic questions because research showed that more questions are causing a significant increase in dropout rates for surveys. Because participants in general lose interest during the questionnaire, the most important questions for the research are asked first [20]. In this case the risk acceptance questions are asked first and the demographic questions come second. The first three questions are asked to determine the demographic profile of the respondents and can therefore be used to find whether the sample of participants is a good representation of society. The fourth question is asked to determine whether the targeted audience is reached. Finally a question is included to check whether the experiment was clear for the participants. This open question may lead to valuable insights.

1. What is your age?
2. What is your gender?
3. What is your highest completed education?
4. Are you a citizen of province Groningen?
5. Do you have any questions and/or comments related to this research?

8.2. Constraint

Step 2 of the methodology is setting the constraint. The constraint for this research is the budget for implementing mitigation measures. Researchers in previous PVE research have chosen for either a fixed or a flexible budget. With a flexible budget participants are able to adjust the budget. An increase of the budget would lead to tax raise while a decrease of the budget would lead to tax reduction. One of the advantages of PVE in relation to traditional CBA is the fact that CBA uses a consumer approach with the one-euro-one-vote principle, while PVE uses a citizen approach where the vote of each participant is equal [10, 38]. If a flexible budget is used and this affects the tax, the citizen approach is partly lost and a willingness-to-pay aspect is introduced. Participants anticipate a one-euro tax raise differently. To exclude the consumer aspect this research uses a fixed budget. In this way participants make a decision as government or operating party and do not have to think about their personal responsibilities.

Research by Perlaviciute et al. showed that respondents considered mitigation measures aimed at reduction of the earthquake risk and compensation the consequences as more urgent than improving the quality of life or the image of the region [55]. The costs of the most urgent measures in this research is 236 million euro, while the total costs of all measures combined is 317 million euro. For participants to be able to select the risk reduction and compensation measures and at least one extra measure the budget for this research is set to 250 million euros. In this way there is a choice left to be made by the participants

8.3. Delegates

Step 8 shows that in previous PVE research participants had the choice to delegate their decision to an expert, the average participant in the research or to someone who lives in the affected region. Participants who have ethical concerns about decision making or feel they lack the information to make a decision were able to delegate their decision [10, 38]. Because reaching enough participants is already viewed as an issue for this research, the option of delegating decisions is left out this research. To reach the goals of this research as many participants as possible must make a decision and participants delegating their decision does not contribute to the research goals. Lacking information should not be a problem because this research is intended for people without information. Participants who have concerns about decision-making can quit with the experiment at any time.

<div style="text-align: right;">

9

</div>

<div style="text-align: right;">

Results

</div>

This chapter describes the implementation process and the results of the web tool. First an overview of the data gathering process and an overview of the demographics of the respondents are displayed. Second the gathered data will be analysed with factor analysis and logistic regression as explained in the methodology in chapter 3. Based on the analysis a conclusion will be drawn in the next chapter.

9.1. Distribution of the web tool

After selection of the risk acceptance factors and the mitigation measures, the web tool was designed as explained in chapter 8. Before designing the web tool it was known that gathering enough participants might be a potential issue. To try to solve this issue, many organisations were approached as can be seen in figure 9.1. Despite finding PVE an interesting method, organisations hesitated to help with the distribution.

Organisation	Response
TCMG	Could not help
NCG	Could not help
Sociaal Plan Burea Groningen	Could not help
Gronings Perspectief	Suggested TCMG & NCG
CMO STAMM burgerpanel	No response
OIS Groningen burgerpanel	No response
Municipality Loppersum	No response
Municipality Delfzijl	No response
Dagblad van het Noorden	No response
Gasberaad	Forwarded --> no response
Provincie Groningen	Suggested GBB
Groninger Bodem Beweging	No response

Figure 9.1: Contacted organisations for web-tool distribution

Because all the contacted organisations could either not help or did not respond, it was decided to distribute the web tool via social media. An overview of the data gathering process is given:

April 9th The web tool is distributed in three local Facebook groups related to the earthquake topic. A few responses are gathered. However people mainly just comment on the post. First people are interested in the web tool, but after a few days people suddenly start to post angry comments.

Participants:

- *This experiment makes painfully clear that you have no idea what you are talking about*

- *You try to implement a method for citizen participation, however you don't know anything about the case and asking people to participant via an online-tool is ridiculous.*

- *This research is probably commissioned by Shell or the NAM*

April 18th First evaluation moment. Ten participants are gathered. The angry comments make clear that the topic is sensitive, which was expected. During this first evaluation it is decided to spread flyers in Groningen and distribute the web tool outside Groningen via Facebook and LinkedIn.

April 20th 500 Flyers are distributed in Hoogezand and Slochteren. The design of the flyer can be found in Appendix B.

April 26th Second evaluation moment. At this point about thirty responses are gathered. In terms of research planning, it is decided to try to gather responses for one more week after which the data analysis phase should start.

April 29th The researcher within his network approaches potential participants.

May 7th End result. During the data-gathering period the web tool is opened 247 times. In total 49 participants are gathered. The conversion rate of participating is 19,83%.

9.2. Demographics of the respondents

In this paragraph the demographics of the respondents will be compared with the average in the Netherlands. In the web tool participants had to answer questions about their age, education, gender and whether they lived in Province Groningen or not. The Central Bureau for Statistics (CBS) gathers the average demographics [8]. A more detailed overview of the participants, including missing cases, can be found in appendix C.1. To check whether differences between two proportions are significant, often the Z-test is used. However this could not be done because the demographics of the participants were gathered using different groups than CBS uses.

9.2.1. Age

The age groups in the web tool are different than the age groups that CBS provides. To improve the comparability, the original age groups between 25 and 65 are merged into two age groups. If the respondent group of 25 − 45 is compared with the CBS group of 20 − 40, this age group is much larger for the respondents than the average in the Netherlands. While at the same time the average of young and elderly people is lower among the respondents. These differences are expected because young people are less likely to be interested in the topic and elderly people are less likely to use social media, which was used to distribute the web tool. The distribution of the web tool within the network of the researcher creates an explanation for a larger 25 − 45 age group. An overview of the percentages is displayed in figure 9.2.
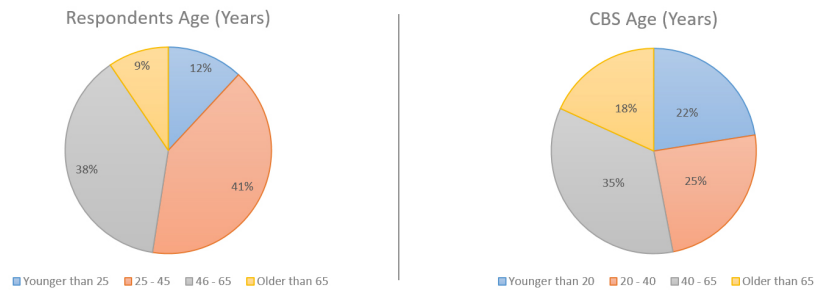
Figure 9.2: Age of the respondents versus the national average

9.2.2. Education

Respondents of the web tool are higher educated than the average in the Netherlands. As can been seen in figure 9.3, almost half of the respondents have an academic education (WO) while on average only 11 percent of the country has an academic education. Numbers of respondents with higher vocational education (HBO) also double the national average. In the Netherlands 29% of the population has completed secondary school or lower as highest education, while all of the participants at least completed secondary vocational education (MBO). This difference can be explained by the fact that most participants are gathered within the network of the researcher. For the people in Groningen, outside the researcher's network, this difference can be explained by the fact that in general participating in involvement tools and experiments is mostly done by a higher educated population.
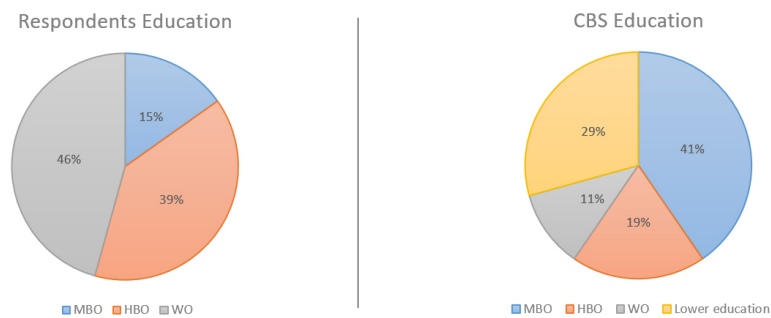
Figure 9.3: Education of the respondents versus the national average

9.2.3. Gender and residence

The ratio of male and female participants is exactly 50/50. This corresponds with the average in the Netherlands. As the distribution process shows, finding participants in Groningen with direct experience was hard. Of the participants that filled in this question, only 34.8% resides in province Groningen. An overview of the gender and residence distribution is found in figure 9.4.
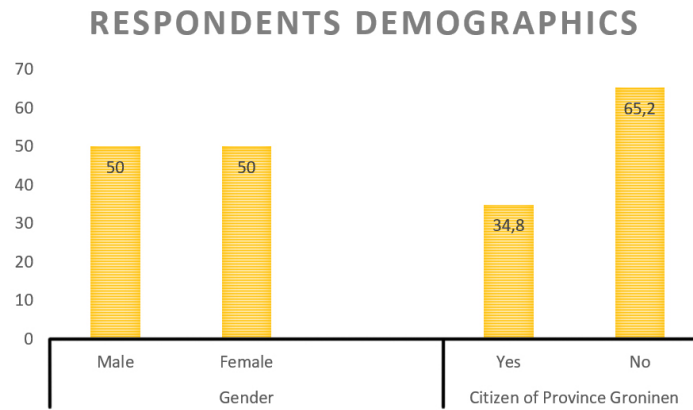
Figure 9.4: Gender and residence of the respondents

9.3. Factor analysis results

In this research participants had to answer questions on risk acceptance. Risk acceptance is divided into perceived risk, perceived benefit, direct experience and trust in authorities. Perceived risk and perceived benefit is split up in several survey questions. Factor analysis is used to combine those survey questions into one perceived risk score and one perceived benefit score for each participant. For conducting factor analysis in SPSS, a few choices have to be made.

Most used extraction methods are either principal components (PCA) or principal axis factoring. PCA works under the assumption that all questions are set up perfectly and no unique variance exists. Because this is unlikely principal axis factoring is used as extraction method. This method assumes that every survey question includes unique variance, which means that the question also displays other information than information about the common factor [71, 73].

After the extraction a choice must be made for the rotation method. Rotation simplifies the interpretation of the results. If there is believed correlation between the survey questions, which is the case in this research, direct oblimin is the most used rotation method [71, 73].

Factor analysis looks for factors with an eigenvalue greater than 1. Eigenvalue shows the common variance that can be explained by a common factor. If there is one factor with an eigenvalue greater than 1, this means that there is one factor that can explain the communality between the different survey questions [71, 73].

After finding the number of factors with an eigenvalue greater than 1, one takes a look at the factor loading of each question with the factors. In literature the minimal acceptable factor loading is mostly 0.4 [71]. A more detailed overview of the conducted factor analysis in SPSS can be found in appendix C.2.

9.3.1. Perceived risk

For perceived risk participants had to state their agreement from strongly disagree (1) to strongly agree (5) with the following five statements:

1. I consider damage to houses in Groningen because of the earthquakes as likely
2. I consider a drop of value of houses in Groningen because of the earthquakes as likely
3. I consider a reduced quality of life for the people affected by earthquakes as likely
4. I consider physical injury for the people affected by earthquakes as likely
5. I consider stress for the people affected by earthquakes as likely

Conducting factor analysis on these statements shows one factor with an eigenvalue of 2.993 explaining 59,586% of the total variance. The other four factors have a eigenvalue lower of 0.681 or lower. This means that there is one common factor that explains the correlation between the statements. In the way the statements have been set up this factor can be called "Perceived Risk". Now that perceived risk factor is found, the factor loading of the statements is checked. The lowest factor loading is 0.564, which means that all statements load above 0.4 and can be included to create a single risk perception score for all the participants. To create a single score either factor score or sum score can be used. To use sum score the conditions as explained in chapter 3 need to be met. The statements are designed in a way that only the reliability has to be checked. In SPSS this is done with Cronbach's alpha. The Cronbach alpha of the risk perception statements is 0.825 and does not improve when removing one the statements. The Cronbach alpha is higher than 0.7, which means that the reliability condition is met and all the statement can be combined to a single score. With sum score this is done by averaging the score of all the statements to a single score between 1 and 5.

Figure 9.5 displays the agreement of the participants with the risk statements. Most participants agree or strongly agree with the first two statements and the last statement. Agreement with the statements on reduction of quality of life and physical injury caused by the earthquakes is more widespread.
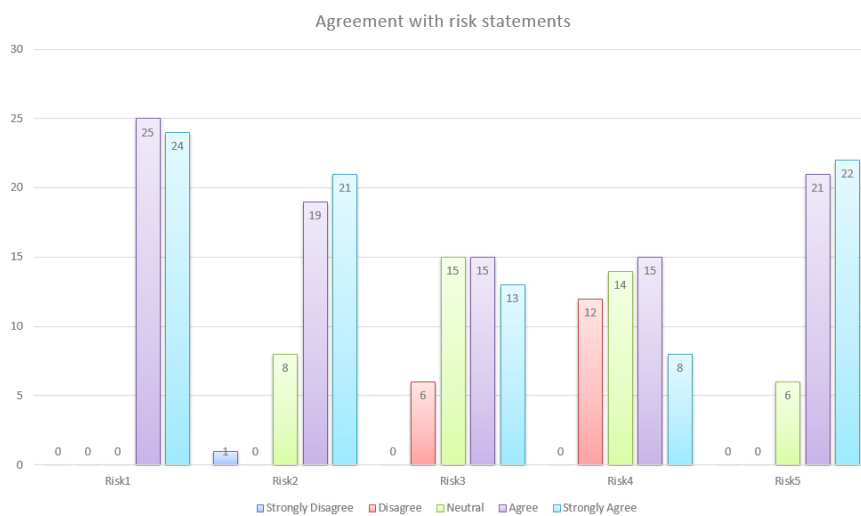
Figure 9.5: Agreement with risk statements

9.3.2. Perceived benefit

For perceived risk participants had to state their agreement from strongly disagree (1) to strongly agree (5) with the following three statements:

1. I believe the benefits of the gas production are evenly distributed throughout the country
2. I believe the benefits of gas production for Groningen are in proportion with the burden of gas production
3. I believe citizens of Groningen are treated the same way as citizens in the rest of the country

Conducting factor analysis on these statements shows one factor with an eigenvalue of 2.242 explaining 74,949% of the total variance. The other two factors have a eigenvalue lower of 0.519 or lower. This means that there is one common factor that explains the correlation between the statements. In the way the statements have been set up this factor can be called "Perceived Benefit". Now that perceived benefit factor is found, the factor loading of the statements is checked. The lowest factor loading is 0.627, which means that all statements load above 0.4 and can be included to create a single perceived benefit score for all the participants. The Cronbach alpha of the benefit perception statements is 0.829. If the first statement is deleted, the Cronbach alpha increases to 0.861. This benefit statement has a factor loading of 0.627 and is therefore not deleted. A Cronbach alpha of 0.829 is higher than 0.7 and therefore including all three benefits meets the reliability condition. With sum score averaging the three statements creates a single score for perceived risk.

Figure 9.6 displays the agreement of the participants with the benefit statements. Most participants disagree or strongly disagree with the statements. Although some participants are neutral to or agree with the benefit statements. Almost none of the participants strongly agrees with the benefit statements.
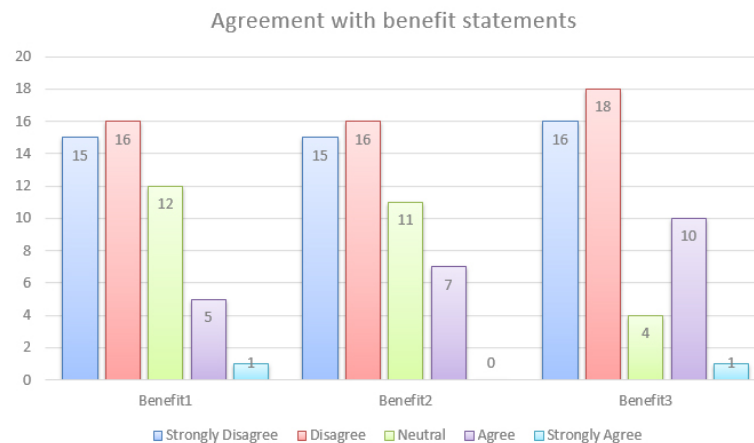
Figure 9.6: Agreement with benefit statements

9.3.3. Factor score categories

Factor analysis is used to construct a single score for risk perception and perceived benefit. For the other risk acceptance factors; direct experience, trust in the government and trust in the NAM only one question was asked, which means that they all have a single score between 1 and 5.

To use the risk acceptance factors in the logistic regression categories are created for every acceptance factor. Dividing the scores between 1 and 5 into categories does this. For every acceptance factor a low-score, medium-score and high-score category is created. The categories are created in a way that they are all approximately the same size. Finding cut-off points that divide every factor in three equal groups does this. An overview of the cut-off points can be found in appendix C.3. For the risk acceptance factor "Direct Experience" a yes/no question was asked. That is why there is no need to create categories for this factor.

9.4. Logistic regression

Logistic regression is used to find out whether risk acceptance has a significant effect on the selection of mitigation measures. This research includes seven different mitigation measures and five risk acceptance factors. The selection of a measure is the dependent variable, while the risk acceptance factors are the independent variables. For each mitigation measure a logistic regression is performed in SPSS. Binary logistic regression in SPSS produces several output, which can be found in appendix D.

First the Chi-square test is considered. This test compares the probability of a model with the risk acceptance factors with the probability of a model with just a constant. If the Chi-square is significant, the model with the acceptance factors has a better fit with the data than a model without the acceptance factor. If a model with acceptance factors has a better fit, the risk acceptance factors have a significant effect on the selection of the mitigation measure. In general a p-value of 0,05 is used to test significance [62]. To use the Chi-square test, two conditions need to be satisfied [65]:

1. No more than 20% of the expected counts are less than 5

2. All individual counts are 1 or greater

By dividing the risk acceptance factors into equal score categories, as described in the previous paragraph, both conditions are satisfied.

SPSS produces three different goodness of fit tests for calculating explained variance. Most used method for logistic regression is Nagelkerke R-square. If this test reaches a value of 1, the model has a perfect probability prediction [62]. This test is used to indicate how useful the model ,with the risk acceptance factors included, is for predicting whether a mitigation measure is selected. After predicting the fit of the model, the Wald-statistics are used to check the effect of the independent variables on the dependent variable. With this statistic can be checked which of the risk acceptance factors have a significant on the dependent variable, again a p-value of 0,05 is used [62].

Because only 49 participants were gathered, effects might not be significant. To see if the data shows a small effect, without being significant, a descriptive overview is presented for the selection of each mitigation measure. Looking at the selected measures in figure 9.7 shows that the first four measures are selected most. These measures are directly targeting the consequences of the earthquakes, the other measures targeting the indirect consequences of the earthquakes are selected less.
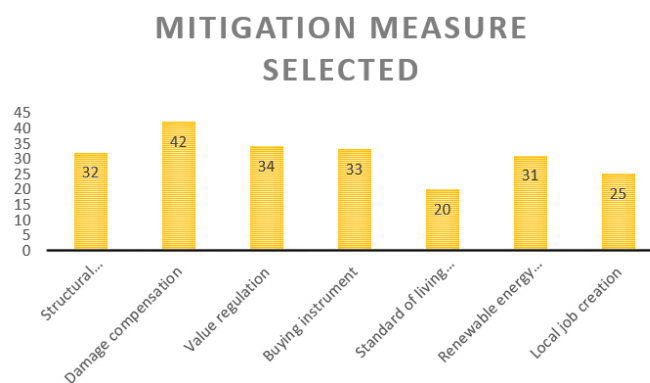
Figure 9.7: Selected mitigation measures

9.4.1. Structural reinforcement

Of the 49 participants, 32 participants selected structural reinforcement. First the probability of a model with the five risk acceptance factors is predicted. Looking at the Chi-square test, the model with five degrees of freedom has a p-value of 0,517. This value is greater than the 0.05 which means that the model with the risk acceptance factors included is not statistically significant for the selection of structural reinforcement. Conducting the Nagelkerke R-square goodness-of-fit test produces a value of 0,114. Since this value is not close to 1, the model is not an adequate probability predictor.

Looking at the Wald-statistic of the individual risk acceptance factors, all factors do not have a statistically significant effect on the selection of structural reinforcement. However looking at the descriptive statistics trends can be noticed. As can be seen in figure 9.8 different scores on all the risk acceptance factors lead to a relatively different selection of structural reinforcement. People with direct experience are less likely to not select structural reinforcement. While people with high risk perception, low perceived benefit, low trust in the NAM and the government are more likely to select structural reinforcement.

Figure 9.8: Descriptive statistics of risk acceptance on structural reinforcement selection

9.4.2. Damage compensation

Of the 49 participants, 42 participants selected damage compensation. This is 85,7% of the participants. So most of the participants selected this mitigation measure. Looking at the Chi-square test, the model with five degrees of freedom has a p-value of 0,016. This value is lower than 0.05, which means that the model with the risk acceptance factors included has a significant on the selection of damage compensation. Conducting the Nagelkerke R-square goodness-of-fit test produces a value of 0,441. In general models with this value are considered as acceptable probability predictors.

Looking at the Wald-statistic of the individual risk acceptance factors, the factors do not have a statistically significant effect on the selection of damage compensation. However looking at the descriptive statistics trends can be noticed. As can be seen in figure 9.9 different scores on the risk acceptance factors lead to a relatively different selection of damage compensation. People with high risk perception, low perceived benefit, low trust in the NAM and the government are more likely to select damage compensation.

Figure 9.9: Descriptive statistics of risk acceptance on damage compensation selection

9.4.3. Value regulation

Of the 49 participants, 34 participants selected value regulation. The Chi-square test shows a p-value of 0.012, so the model is statistically significant. The Nagelkerke R-square is 0.365 and therefore this model is a moderate probability predictor for the selection of value regulation.

Looking at the Wald-statistic of the individual risk acceptance factors, perceived risk has a p-value of 0,033 and therefore has statistically significant effect on the selection of value regulation. A Beta-value of 1,486 means that higher perceived risk leads to an increased preference for value regulation as mitigation measure. all other factors do not have a statistically significant effect on the selection of value regulation. Looking at the descriptive statistics trends can be noticed. As can be seen in figure 9.10 different scores on the risk acceptance factors lead to relatively different selection of value regulation. People without direct experience are more likely to select value regulation. While people with low trust in the NAM are more likely to select value regulation. Differences in scores on perceived benefit and trust in the government do not show clear trends.
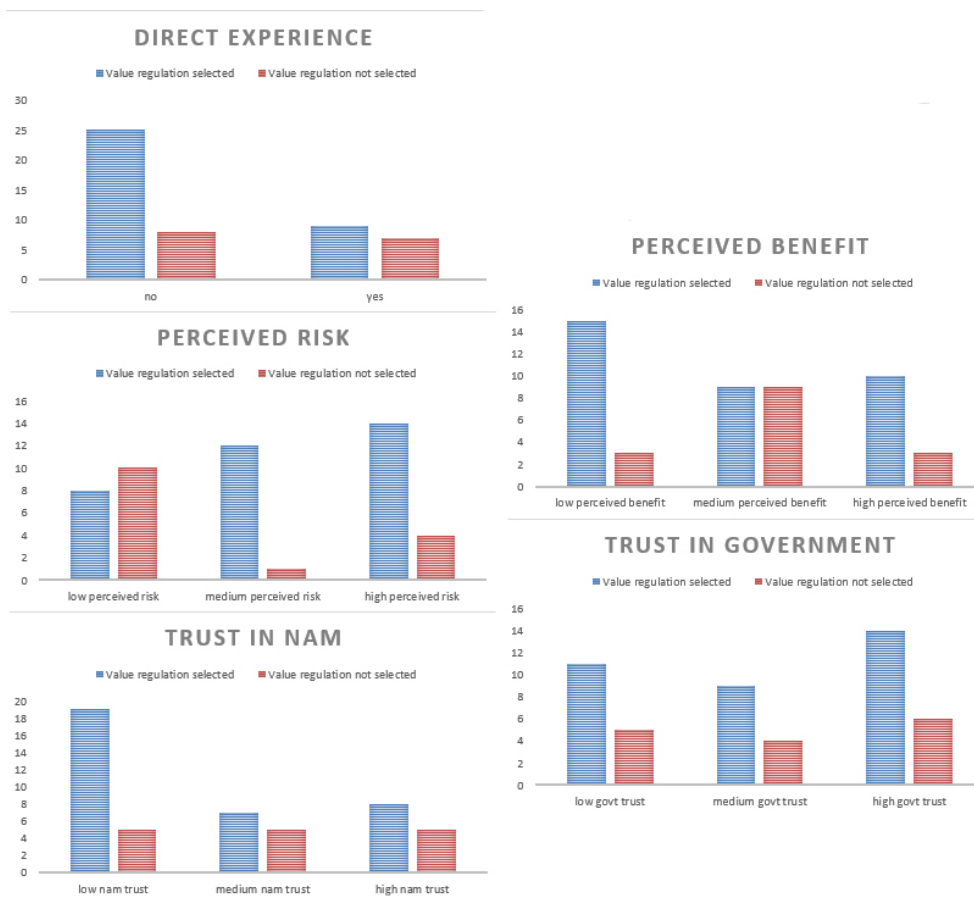
Figure 9.10: Descriptive statistics of risk acceptance on value regulation selection

9.4.4. Buying instrument

Of the 49 participants, 33 participants selected buying instrument. The Chi-square test of the model with the risk acceptance factors for the selection of this mitigation measure has a p-value 0,503. This model is not statistically significant. The Nagelkerke R-square of 0,118 shows that model is not an adequate probability predictor.

As expected based on the model's Chi square none of the individual risk acceptance factors is statistically significant. Based on the descriptive charts, as displayed in figure 9.11, people without direct experience seem to be more likely to select buying instrument. The same goes for people with low trust in the NAM. The other three risk acceptance factors do not show distinct trends.

Figure 9.11: Descriptive statistics of risk acceptance on buying instrument selection

9.4.5. Standard of living enhancement

Of the 49 participants, 20 selected standard of living enhancement. The p-value of the Chi-square test for the model of selecting this measure is 0,141, which is not significant. The Nagelkerke R-square is 0,210. This shows that probability of the model predicting the effect correctly is low. The Wald-statistics of all the risk acceptance factors are not significant. Figure 9.12 shows the descriptive charts of the risk acceptance factors. Overall more than half of the participants did not select this measure. Looking at the charts, it seems that people with direct experience, high perceived risk, low perceived benefit or low trust in the NAM are less likely to select standard of living enhancement. People with high trust in the government are more likely to standard of living enhancement.

Figure 9.12: Descriptive statistics of risk acceptance on standard of living enhancement selection

9.4.6. Renewable energy investment

Of the 49 participants, 31 selected renewable energy investment. The Chi-square test of this model has a p-value of 0,240. Therefore this model is not significant. The Nagelkerke R-square of 0,176 shows that the model is not an adequate probability predictor.

The Wald-statistics show that only perceived benefit has a significant effect on the selection of renewable energy investment. This risk acceptance factor has a Beta of 1,682. This means that people with higher perceived benefit are more likely to select this mitigation measure. Figure 9.13 displays the descriptive charts of the risk acceptance factors for selecting renewable energy investment. Besides perceived benefit, people with lower trust in the NAM seem to be more likely to select renewable energy investment. People with higher trust in the government seem to be more likely to not select renewable energy investment. Direct experience and perceived risk do not show obvious trends.

Figure 9.13: Descriptive statistics of risk acceptance on renewable energy investment selection

9.4.7. Local job creation

Of the 49 participants, 25 selected local job creation. This is almost exactly 50% of the participants. The model with the risk acceptance factors has a Chi-square p-value of 0,030. This means that the model has a significant effect on the selection of local job creation. The Nagelkerke R-square value is 0,297. This is not very high, which means that the model is a moderate selection probability predictor.

Of the five risk acceptance factors, perceived risk has a p-value of 0,034. With a Beta of -0,946 people with higher perceived risk are statistically significant less likely to select local job creation. The other risk acceptance factors are not significant. Based on the descriptive charts, as displayed in figure 9.14, people with higher perceived benefit and higher trust in the government seem to be more likely to select local job creation. Direct experience and trust in the NAM do not show distinct trends.

Figure 9.14: Descriptive statistics of risk acceptance on local job creation selection

9.5. Qualitative results

At the end of the web tool participants had the possibility to add questions or comments in relation to the web tool or the content of the experiment. For the web tool some of the participants stated that it should be made responsive. At the moment it does not work properly on mobile phones. Participants also mentioned that they appreciate the PVE method. Compared with traditional questionnaires, participating in a PVE method is considered as more fun to do. One of the participants suggested that you should be able to change the budget for a specific measure. For example the costs of the buying instrument is 10 million, because this is the budget the NAM made available, however this participant believes that you should be able to increase this budget in the web tool.

Participants mention finding compensating for damage and repairing damage important measures. Believed is that other measures such as buying instruments or image enhancement are ways of saying sorry. Budget should be allocated to finding ways of producing gas without the earthquakes instead of accepting damage and saying sorry. One of the participants mentioned that he believed the experiment to be unrealistic; the cost of repairing damage is hard to estimate. Future damage is hard to predict. This participant suggests a generous buying instrument that allows everyone, wanting to leave, to be able to sell their house.

10

Conclusions

The goal of this thesis was to discover whether differences in risk acceptance lead to differences in preference for risk mitigation. To reach this goal the Participatory Value Evaluation (PVE) method was used. Based on the reviewed literature, four research objectives were constructed.

- Research factors that shape risk acceptance

- Research the PVE method and adapt for thesis goal

- Use PVE method for researching risk mitigation preferences

- Research the relation between risk acceptance and mitigation preferences

To tackle the knowledge gaps, a case-study has been conducted on the situation of gas induced earthquakes in Groningen, a province in the north of the Netherlands. Using the PVE method on this case, the following main research question is addressed: What is the influence of risk acceptance factors on the preferences for risk mitigation measures?

10.1. Sub questions
In this research the research question is split up in five sub questions. By answering the sub questions and combining their output, the main question can be answered.

10.1.1. Sub question 1
The first sub question was chosen to select the risk acceptance factors that were to be included in the research. Literature describes multiple risk acceptance factors, however not all can be included. Therefore the first sub question reads: Which factors have most effect on risk acceptance? Before being able to answer this question, the case must be described and categorised. Since the earthquakes are induced by gas production, the hazard can been seen as man-made. From this point of view the case looks more like energy projects such as geothermal or CO2 storage rather than a natural disaster case. This approach has an effect on which risk acceptance factors to select. Conducting a literature review led to the selection of four risk acceptance factors. Where **perceived risk** and **direct experience** also have impact on shaping risk acceptance in natural hazard cases, **trust in authorities** and **perceived benefit** are related to the induced aspect of the energy cases. The fact that earthquakes are perceived as controllable means that the authorities are seen as operating parties. Trust in these authorities is an important reason for the risk of the activity being accepted. The earthquakes are caused by gas production, the perception of benefits originating from the gas production has a significant effect on whether risks are accepted.

10.1.2. Sub question 2

After the selection of the risk acceptance factors, the mitigation measures had to be selected. Participants had to state their preference for mitigation measures. To involve the community and use the outcomes of this research to rebuild trust between the local community and the authorities, the mitigation measures had to be as realistic as possible. To do this, again a literature review was conducted. Based on research specifically on the Groningen case, seven mitigation measures were selected. Not all mitigation measures were directly related to the earthquakes. While one of the measures was selected to reduce the risks of earthquakes, others were to compensate for the damage or to improve the image of the region. The seven selected mitigation measures could be divided into three types: risk reduction, compensation or investment.

10.1.3. Sub question 3

To include the mitigation measures in the web tool, information was needed on the characteristics of the measures. Based on this information participants were able to make a choice between the measures. Most information was gathered from the organisations that are responsible for carrying out the measures. Based on this information every measure had his own qualitative description, an overview of the costs and the reach of the measure.

10.1.4. Sub question 4

All the gathered information for the first three sub questions is used to design the PVE web tool. With the web tool, participants were able to state their mitigation measure preferences. The most selected measures are structural reinforcement, damage compensation, value regulation and buying instrument. These mitigation measures were all directly related to the earthquakes. Renewable energy investment followed closely. In this research this measure was described as an investment type to keep up with the energy goals of the province. However this measure was specifically targeting the damaged houses. By implementing this measure, homeowners are able to increase the value of their houses. In this way this measure can also be seen as a compensating measure and that is why it makes sense that this measure is also preferred. Standard of living enhancement and local job creation are not directly related to the earthquakes and therefore less preferred. This result is underlined by the qualitative results gathered from the web tool. Participants state that measures directly targeting the earthquakes are preferred over other measures because they feel the problem should be tackled and other measures are just a way of saying sorry for the caused trouble. Based on both qualitative and quantitative results is concluded that in general mitigation measures targeting the earthquake issues are preferred over measures targeting issues indirectly related to the earthquake issues. These findings are in line with the conclusions of Perlaviciute et al [55].

10.1.5. Sub question 5

For the fifth sub question, all the previous gathered information is used. After selecting the preferred mitigation measures as researched in sub question 4, participants had to fill in their agreement with statements on the five risk acceptance factors. Using factor analysis, the statements on each of the factors were combined to create single scores on the acceptance factors. Next the participants were divided for each risk acceptance factor into equal groups; a low, medium and a high-scoring group for each of the factors. Finally logistic regression was used to discover whether different scores on the risk acceptance factors influence the selection of mitigation measures. Of the risk acceptance factors, **perceived risk** turned out to have a significant effect on the selection of the value regulation and the local job creation measures. **Perceived benefit** had a significant effect on renewable energy investment. Despite having no statistical significant effect, the other risk acceptance factors showed trends that suggest an influence. In the next paragraph the main question will be answered by describing the noticed trends of all risk acceptance factors.

10.2. Main research question

After researching all sub questions, an answer is formulated on the main research question. The constructed main research question was:

What is the influence of risk acceptance factors on the preferences for risk mitigation measures?

Below the influence of all risk acceptance factors is described.

10.2.1. Perceived risk

Perceived risk has a significant effect on the selection of value regulation and local job creation. People with higher perceived risk are more likely to select value regulation and less likely to select local job creation. Despite not being significant, people with higher perceived risk seem to be more likely to select structural reinforcement and damage compensation, while these people seem less likely to select standard of living enhancement. Renewable energy investment and buying instrument show no distinct trends. Looking at the different measure types, people with high risk are more likely to select either risk reduction or compensation measures while at the same time are less likely to select investment measures. Taking into account that not all results are significant, a conclusion is drawn that people with higher perceived risk prefer measures that directly target the consequences of the earthquakes over measures that target the indirect consequences.

10.2.2. Perceived benefit

Perceived benefit has a significant effect on the selection of renewable energy investment. People with higher perceived benefit are more likely to select this measure. Without being significant, trends show that people with higher benefit are also more likely to select local job creation. People with lower perceived benefit are more likely to select structural reinforcement and damage compensation, while these people are less likely to select standard of living. Perceived benefit shows no obvious trends on the selection of value regulation or buying instrument. It seems that people with higher perceived benefit prefer investment measures, while people with lower perceived benefit prefer risk reduction or damage compensation. Based on these trends a conclusion is drawn that suggests people believing in the benefits of gas production are more likely to select other measures that do not directly target the earthquakes than people who have less belief in the benefits.

10.2.3. Direct experience

Direct experience has no significant effect on the selection of risk mitigation measures. Looking at the trends, people without direct experience are more likely to select value regulation and buying instrument. People with direct experience are less likely to select standard of living and more likely to select structural reinforcement. The selection of local job creation, renewable energy investment and damage compensation shows no clear trends. Because there are no significant effects and three of the seven risk acceptance factors show no obvious trends it is hard to draw clear conclusions on the influence of direct experience on preferences for risk mitigation measures.

10.2.4. Trust in the government

Trust in the government has no significant effect on the selection of risk mitigation measures. Looking at the trends, people with lower trust in the government are more likely to select structural reinforcement and damage compensation. People with higher trust in the government are more likely to select standard of living enhancement and local job creation. While they are more likely to not select renewable energy. Value regulation and buying instrument do not show distinct trends. Taking into account that none of the results is significant, it seems that people with lower trust in the government are more likely to select measures that directly target the consequences of the earthquakes. People with higher trust in the government are more likely to select investment measures that enhance the image of the region. However this is contradicted by the trend of renewable energy selection.

10.2.5. Trust in the NAM

Trust in the NAM has no significant effect on the selection of risk mitigation. Looking at the trends, people with lower trust in the NAM are more likely to select structural reinforcement, damage compensation, value regulation, buying instrument and renewable energy investment. These people are less likely to select standard of living enhancement. The selection of local job creation does not show a clear trend. Despite being not significant a conclusion is drawn that suggest that people with lower trust in the NAM are more likely to select mitigation that directly targets the consequences of the earthquakes. This conclusion agrees with the conclusion of trust in the government, which seems logically as they both are considered as authorities.

10.3. Scientific and societal implications of findings

Literature shows that acceptance of induced risks differs from acceptance of natural hazard risks. Induced hazards are perceived as man-made and therefore controllable. Trust in authorities is an important factor for the acceptance of risks. The perceived risk of an induced hazard is compared with the perceived benefit of the hazard. Literature has shown that an induced hazard with the same consequences as a natural hazard has a relative lower risk acceptance. In cases with induced hazards, local communities often have low trust in the authorities. To tackle the issues caused by the induced earthquakes, authorities are trying to implement mitigation measures. However implementation of the measures often turns out to be ineffective. To improve the effectiveness of the measures, the authorities must make sure they are implementing the measures that are preferred by the affected community. This research focused on discovering whether people with different risk acceptance had different preferences for mitigation measures. In this way authorities are able to implement measures that are preferred, which must improve the effectiveness of implementation and eventually restore trust between the authorities and the local communities.

This research shows that risk acceptance presumes to have effect on the preference for risk mitigation. In general is concluded that people with lower trust in the authorities seem to be more likely to prefer mitigation measures that directly target the consequences of the induced hazard or mitigation measures that reduce the risks of the hazard in the first place. In this case for example structural reinforcement of buildings or compensation for the damage caused by the earthquakes. On the other hand people with more trust in authorities or higher perceived benefits are more open for other mitigation measures. Mitigation measures that indirectly target the consequences of an induced hazard. In this case for example investments to enhance the standard of living or the creation of local employment. For governments and/or operating parties this is an important finding. In cases were the relation between the authorities and the local community is weak it is important to come up with clear mitigation measures that target the hazard. Other mitigation measures are seen as a way of saying sorry, which is not appreciated and is likely to only deteriorate the relationship and the level of trust.

10.3.1. Conclusions on using the PVE method

In this research data was gathered using the Participatory Value Evaluation method (PVE). This method uses a web tool where participants could select their preferred mitigation measures within a budget constraint. After selecting measures, participants had to answer a few demographic questions and had to state their agreement with risk acceptance statements.

In earlier research on the PVE method was found that the method can be used for community involvement. By showing the dilemmas the government is facing and giving the public an opportunity to make a choice, the public should feel more involved. In this research the relationship between the authorities and the local communities was so weak, that the community was not open for involvement. Some local people mentioned that the web tool was a charade. In a topic as loaded as the earthquakes in Groningen, communities want to see action and are not willingly to participate in any more research. This research suggests that PVE is not useful for involving the community when the topic is too sensitive for the potential participants. However some of the participants from outside the region mentioned that the method is more fun to use

than traditional questionnaires. Based on the positive reactions the conclusion can be drawn that PVE has potential in future less controversial topics.

Previous research suggested that PVE, compared to public hearings and other participation meetings, has a low participation threshold and attracts a more diverse range of participants. In this research however this was not true. People and organisations highly involved in the topic refused to participate, while people not directly involved where not very keen on participating. In the end most participants were approached within researcher's network, leading to many high-educated participants and not a diverse range of participants.

11

Discussion

During the research several choices and assumptions have been made. This chapter describes how these choices are believed to have affected the outcomes of the research. Based on the discussion, suggestions for future research related to this research are constructed. Based on the findings in this research, a potential solution for the case and potential use of the PVE method are discussed. Finally this chapter describes how this thesis fits within the CoSEM curriculum.

11.1. Influence of the risk acceptance factors selection

The first step of this research was the selection of risk acceptance factors. Based on literature, four factors were selected that suited the case. Besides the four selected factors, media coverage and knowledge were mentioned in literature as factors shaping risk acceptance, in this research they were left out as described in paragraph 5.4. The results show that people with differences in trust, perceived risk or perceived benefit have different preferences for mitigation measures. Knowledge was left out because it is hard to measure, however knowledge might be an underlying factor for the differences in the risk acceptance factors. A correlation between different risk acceptance factors might exist; people with a high score on one of the factors might also score high on another risk acceptance factor. Because all risk acceptance factors are determined using their own survey questions, a potential correlation does not affect the results of this research. However it would have been interesting to see whether knowledge of the topic was an underlying factor explaining the correlation.

The conducted literature review mentioned direct experience as most important factor shaping risk acceptance, however is this research direct experience was the only included factor that did not show a distinct effect on risk mitigation selection. A possibility for this difference might be the low number of participants. However the other risk acceptance factors showed trends despite the low number of participants. Induced earthquakes is a hot topic in the Dutch media, this might reduce the differences between people with and without direct experience.

11.2. Assumptions on risk mitigation characteristics

To make the research as realistic as possible, an existing package of mitigation measures was used. At this point some of the measures are partly implemented while other measures are planned for future implementation. Because most of the measures are not yet implemented, estimating the effects and characteristics of the measures was hard. The costs and reach of most of the measures are based on assumptions as described in chapter 7. Some of the potential participants mentioned the measures to be unrealistic. Having to use this many assumptions may have affected the number of respondents. People in Groningen might have refused

to participate because they felt the research was too unrealistic.

Besides fewer participants, the assumptions might also have affected the selection of mitigation measures. Based on the assumptions the costs for the mitigation measures ranged from 5 million to 163 million euro. This large difference in costs might have affected the selection. Structural reinforcement, which was the most expensive measure, is selected more than local job creation, which was only six million euro. However the difference in selection might have been even larger. Because participants used a budget supplied by the NAM, they might have tried to spend as much of the budget as possible. Therefore relatively cheap measures might be selected just because participants had some of the budget left after selecting their preferred measures. Large differences in costs of the measures might encourage over-selection of the cheapest measures, while these measures might not actually be preferred.

11.3. Effects of data gathering process

During this research 49 participants were gathered. This has affected the research in a way that trends were noticed on risk acceptance influencing the selection of mitigation measures, but most of the trends were not statistically significant. In order to be significant the required number of participants would have to be around 400. Many organisations were approached, but none of them were willingly to participate probably due to the sensitivity of the topic. The loading of the topic was shown by angry comments of the local community. It would be interesting to repeat the research with a less loaded topic.

The trouble of finding participants also affected the diversity of the participants. In the end most participants were gathered within the researcher's network, leading to a highly educated sample of participants. A sample this monotonous may have affected the results. As mentioned in paragraph 11.1, knowledge might have been an underlying factor influencing the other risk acceptance factors. Assuming that the highly educated sample in this research has on average more knowledge, the lack of diversity may have affected the risk acceptance scores. High scores on trust in authorities or perceived benefit may have been overestimated.

11.4. Implementation effects of PVE method

In this research a budget constraint was used in the PVE web tool. Participants had a budget of 250 million euro to select their preferred measures. To force participants to make a choice, the budget was not high enough to select all the measures. However the height of the budget may have affected the selection of mitigation measures. For example after choosing the most expensive measures, participants may have selected other measures just because they fitted in their remaining budget. For future research it would be wise to repeat the same research with different budgets. Another possibility is to use a flexible budget instead of a fixed budget. This has been done in previous PVE research, however in this research is chosen for a fixed budget as is argued for in paragraph 8.2.

A downside of using the PVE web tool was its lack of responsiveness for mobile phone use. The web tool was mainly distributed using social media, however the web tool was not working properly on mobile phones, while most people use social media via their phone. This is believed to be one of the reasons for the low number of participants. Making the web tool responsive would be an improvement of the method.

11.5. Future research related to this research

For future research it might be interesting to see whether people who score high on a specific risk factor also score high on another risk factor. For example do people with more trust in authorities also belief more in the benefits of gas production. It would be wise to research whether a correlation exists. Knowledge might be a potential underlying factor that could explain this correlation.

Despite the low number of participants, this research shows some interesting trends on risk acceptance factors influencing risk mitigation preference. Since the sensitivity of the topic may have affected the results, it would be interesting for future research to repeat the same research with a less loaded topic.

At last it would also be interesting to repeat the same research with a different budget constraint and different characteristics. The choices and assumptions made may have affected the outcomes of this research. Therefore the validity of the conclusions would improve if future research would repeat the research with different assumptions.

11.6. Designing a case-specific solution

The conclusion of this research shows that in the future governments should implement measures targeting the direct consequences of the induced hazard in a situation where the relation between the authorities and the local community is weak. However in the short run this does not solve the issues in the case situation. This paragraph describes a potential design of a specific solution for the Groningen case.

Taking a closer look at the topic during this research has shown that the topic covers several values. As the research has shown, trust is low between the government, the NAM and the local communities. But other values also play a role. As the recent earthquake of may 22th 2019 showed, safety is a serious issue. An earthquake with a force of 3.4 led to significant damage. Despite a cap on the gas production, this earthquake was the second-strongest earthquake monitored. Research has shown that people increasingly feel unsafe [39]. Besides feeling unsafe, people feel treated unfairly. Politicians and the NAM are seen as dishonest, which is leading to more distrust. From a value point-of-view ethics is an important value in Groningen. People in Groningen mention that projects in the rest of the country are immediately aborted when issues occur, while gas production keeps ongoing. Based on the issues of the earthquakes it would make sense to immediately stop with the gas production. However many people in the country depend on the gas and contracts exist, making it impossible to suddenly stop. The Dutch government faces a difficult ethical choice. As the recent earthquake has shown, the situation in Groningen is deteriorating and a solution must be found, however immediately quitting with the gas production is not an option.

As mentioned in the introduction, when having to make ethical decisions, community involvement is advised. However as turned out in this research, a long-term controversial issue completely embedded in national policy and budget cannot be changed by more community involvement. Giving citizens control, as mentioned by Arnstein's ladder of participation would maybe stop the gas production and the earthquakes, but would create new issues in the rest of the country [2].

As one of the participants in the research mentioned, future research should focus on finding a solution where gas can be produced without the earthquakes. From a system engineering point of view this is a difficult task and not likely to succeed in short-term, however to completely solve the issue this seems to be a necessary step to take. Managing the process, a participatory strategy should still be executed. While experts should probably execute the design and operation of such an engineering solution, the local community has the right to be well informed during the entire process. Arnstein considers "informing" as the first step in participating; to increase the participatory aspect the next step is consulting the community [2]. In this way values such as trust, honesty and ethics, which are violated in the current situation, will be secured. The proposed solution is hypothetical and might never be reached, but future research more into a civil engineering or earth science field might be beneficial for the Groningen situation.

As this proposed solution is a technological solution on the longer run, is it possible to improve the situation in the short run? Looking at the involved actors, most friction is between the national government, the NAM and the citizens in the affected areas. Is collaboration between those parties possible on short-term. Citizens see the government and the NAM as the culprit. To restore the relation, the government and the NAM should act as one body. However the relation has deteriorated so far that restoring the relation seems impossible. As long as the earthquakes do not stop, local citizens will feel unsafe, betrayed and angry. A report by the Dutch research council states that the current policy and procedures are too bureaucratic [28]. To improve the relation, the government should be honest about the size and the effects of the issues. When compensating damage and finding solutions, the focus should no longer be on procedural justice, but on a humane procedure. According to the research council this means that the NAM should no longer be involved

in any of the decisions. When designing solutions, from a process management point-of-view multiple departments of the government should be involved. At the moment the ministry of Economic Affairs has to deal with conflicting interest of securing the gas benefits, but also securing the safety of the people in Groningen. Future research on process management should focus on involving other governmental bodies to tackle this conflict of interest

11.7. Designing a suitable situation for using the PVE method

This research shows that the situation in Groningen is not very suitable to use as case in the PVE method. As previous research showed, PVE is a suitable method for less controversial topics than the earthquake topic. Gas production in Groningen has been an ongoing process for decades. The process is embedded in society and the country has become dependent on the benefits of gas production and the gas itself. These facts make it difficult to create change. The relation between the authorities and the local community has reached a point where only concrete actions can help to solve the issues. More research in the form using the PVE method will therefore not help. However does this mean that PVE cannot be used at all for controversial topics?

In Harlingen, a small city in the northwest of the Netherlands, plans exist for the extraction of salt close to the coast. Research by the state supervision on mining activities (SoDM) has shown that the extraction of salt may, just like gas extraction, cause soil subsidence. Warned by the Groningen situation, the local community was triggered and started a foundation to fight for their rights and protect the buildings in the city from subsidence. Supported by the ministry of Economic Affairs and Climate, the foundation negotiated with the company responsible for the salt extraction. After a year a deal was made to install a network of measuring instruments throughout the city. If the soil subsidence exceeds the limit of two centimetres, the extraction of salt will be stopped immediately. The entire negotiating process took place before the extraction of salt started [33, 50].

This example shows that public participation and involving the community when designing mitigation measures can also be successful in a controversial topic. The difference with Groningen is however that the community was involved before the activities started. Using the PVE method in controversial topics can be beneficial, however it depends on the moment of implementation. Believed is that using the PVE method as early as possible in the process will increase the chance of being successful.

The example of salt extraction is not only successful because the community was involved in an early stage; the public also had the possibility to negotiate over the mitigation measures. Leading to the installation of measuring instruments and a deal on the subsidence limit. As a participant of this researched mentioned, being able to adapt some of the characteristics of the measures would have been appreciated. Taking this into account, implementation of the PVE method would improve when it is not only used in early stages, but also co-designed with help of the people that are affected by the outcomes of the research.

11.8. Relation to the CoSEM curriculum

This research was conducted as thesis for the Complex Systems Engineering and Management (CoSEM) master at TU Delft. This paragraph describes how the conducted research fits in with the master program. The description of the program is designing in complex socio-technical environments. Gas production itself is a technological process where gas is extracted from the ground to be used as fuel for other technological processes. However extraction of gas cannot happen without a social component. First the government gives out a permit to the operating party. Second other parties are getting involved for distribution and trade of the gas. While at the same time the community living near the production site has to deal with the consequences of the gas production. This makes gas production a multi-actor process where has to be dealt with complex economic, governance and legal issues. This socio-technical environment creates a good fit with the master program.

This research uses the PVE method to find out which mitigation measures are preferred and how these preferences are affected by differences in risk acceptance. Finally the outcomes of this research can be used

to design improved mitigation measures. Measures as a combination of agreements and laws, are a good example of designed interventions in a socio-technological environment. Besides mitigation measures, this research contributes to improving the design of the PVE method. Since the PVE method is a novel method suitable for research in socio-technical environments, contributions by this research can help the further development of the method.

As this research focuses on finding differences in risk mitigation selection and risk acceptance it falls within the Safety and Security Science department of the TPM faculty. While at the same time this research tries to further develop the PVE method, which takes place within the Engineering Systems and Services department of the faculty. As this research touches multiple topics, it is multidisciplinary in nature.

Bibliography

[1] Algemene Rekenkamer. Besteding van aardgasbaten : feiten , cijfers en scenario's. 2014.

[2] Sherry R. Arnstein. A Ladder Of Citizen Participation. *Journal of the American Institute of Planners*, 35(4): 216–224, jul 1969. ISSN 0002-8991. doi: 10.1080/01944366908977225. URL http://www.tandfonline. com/doi/abs/10.1080/01944366908977225.

[3] Terje Aven and Ortwin Renn. Risk Management. In *Risk Management and Governance*, pages 121–158. Springer Berlin Heidelberg, Berlin, Heidelberg, 2010. doi: 10.1007/978-3-642-13926-0_8. URL http: //link.springer.com/10.1007/978-3-642-13926-0{_}8.

[4] James R. Bettman. Perceived Risk and Its Components: A Model and Empirical Test. *Journal of Marketing Research*, 10(2):184–190, may 1973. ISSN 0022-2437. doi: 10.1177/002224377301000209. URL http: //journals.sagepub.com/doi/10.1177/002224377301000209.

[5] Peter Boelhouwer and Harry Van Der Heijden. The effect of earthquakes on the housing market and the quality of life in the province of Groningen, the Netherlands. 2018. doi: 10.1007/s10901-018-9600-y. URL https://doi.org/10.1007/s10901-018-9600-y.

[6] Julian J. Bommer, Helen Crowley, and Rui Pinho. A risk-mitigation approach to the management of induced seismicity. *Journal of Seismology*, 19(2):623–646, apr 2015. ISSN 1383-4649. doi: 10.1007/ s10950-015-9478-z. URL http://link.springer.com/10.1007/s10950-015-9478-z.

[7] Bouwend Nederland. Wetgeving en beleidsafspraken. URL https://www.bouwendnederland.nl/ aardbevingen/bouwen-met-een-andere-opdrachtgever/wetgeving-en-beleidsafspraken.

[8] CBS. Bevolking; kerncijfers, 2018. URL https://opendata.cbs.nl/statline/{#}/CBS/nl/ dataset/37296ned/table?ts=1558009456322.

[9] CVW. Erkenningsregeling. URL https://www.centrumveiligwonen.nl/versterken/ erkenningsregeling-2.

[10] Thijs Dekker, Paul Koster, and Niek Mouter. The Economics of Participatory Value Evaluation. *SSRN Electronic Journal*, jan 2019. ISSN 1556-5068. doi: 10.2139/ssrn.3323645. URL https://www.ssrn. com/abstract=3323645.

[11] Michalis Diakakis, Georgios Priskos, and Michalis Skordoulis. Public perception of flood risk in flash flood prone areas of Eastern Mediterranean: The case of Attica Region in Greece. *International Journal of Disaster Risk Reduction*, 28:404–413, jun 2018. ISSN 2212-4209. doi: 10.1016/J.IJDRR.2018.03.018. URL https://www.sciencedirect.com/science/article/pii/S221242091730345X.

[12] DvhN. Studie: versterking huizen kost miljarden, 2017. URL https://www.dvhn.nl/groningen/ Studie-versterking-huizen-kost-miljarden-22087955.html.

[13] Economic Board Groningen. ROUTE VOOR HET VERSTERKEN VAN DE ECONOMIE IN NOORDOOST GRONINGEN. Technical report, 2014. URL https://www.provinciegroningen.nl/fileadmin/ user{_}upload/Documenten/Downloads/Programma{_}Economic{_}Board{_}Groningen.pdf.

[14] EZK. Wijziging van de Gaswet en van de Mijnbouwwet betreffende het minimaliseren van de gaswinning uit het Groningenveld. (3):1–38, 2018. URL https://zoek.officielebekendmakingen.nl/kst-34957-3.html.

[15] EZK. Kamerbrief over gaswinning Groningen. *Letter to Parliament*, pages 1–23, 2018.

[16] David Fang, Chen-Ling Fang, Bi-Kun Tsai, Li-Chi Lan, Wen-Shan Hsu, David Fang, Chen-Ling Fang, Bi-Kun Tsai, Li-Chi Lan, and Wen-Shan Hsu. Relationships among Trust in Messages, Risk Perception, and Risk Reduction Preferences Based upon Avian Influenza in Taiwan. *International Journal of Environmental Research and Public Health*, 9(8):2742–2757, aug 2012. ISSN 1660-4601. doi: 10.3390/ijerph9082742. URL http://www.mdpi.com/1660-4601/9/8/2742.

[17] Glenn Fernandez, Aye Min Tun, Kenji Okazaki, Saw Htwe Zaw, and Kyaw Kyaw. Factors influencing fire, earthquake, and cyclone risk perception in Yangon, Myanmar. *International Journal of Disaster Risk Reduction*, 28:140–149, jun 2018. ISSN 2212-4209. doi: 10.1016/J.IJDRR.2018.02.028. URL https://www.sciencedirect.com/science/article/pii/S2212420918302280.

[18] June Fessenden-Raden, Janet M Fitchen, and Jenifer S Heath. /4, Special Issue on the Technical and Ethical Aspects of Risk Communication. Technical Report 3, 1987. URL https://about.jstor.org/terms.

[19] Archon Fung. Putting the Public Back into Governance: The Challenges of Citizen Participation and Its Future. *Public Administration Review*, 75(4):513–522, jul 2015. ISSN 00333352. doi: 10.1111/puar.12361. URL http://doi.wiley.com/10.1111/puar.12361.

[20] Thomas Gilovich, Dacher Keltner, Serena Chen, and Richard E. Nisbett. *Social psychology*. 2016. ISBN 9780393938968. URL http://www.academia.edu/35424441/Social{_}Psychology{_}4th{_}Edition{_}Tom{_}Gilovich{_}Richard{_}E{_}Nisbett.

[21] Gronings Perspectief. De maatschappelijke impact van de beving van Zeerijp Ervaren veiligheid, gezondheid en toekomstperspectief. Technical report, 2018. URL https://www.groningsperspectief.nl/wp-content/uploads/2018/06/Zeerijprapport{_}definitief.pdf.

[22] Ming-Chou Ho, Daigee Shaw, Shuyeu Lin, and Yao-Chu Chiu. How Do Disaster Characteristics Influence Risk Perception? *Risk Analysis*, 28(3):635–643, jun 2008. ISSN 02724332. doi: 10.1111/j.1539-6924.2008.01040.x. URL http://doi.wiley.com/10.1111/j.1539-6924.2008.01040.x.

[23] N.M.A. Huijts, E.J.E. Molin, and L. Steg. Psychological factors influencing sustainable energy technology acceptance: A review-based comprehensive framework. *Renewable and Sustainable Energy Reviews*, 16(1):525–531, jan 2012. ISSN 1364-0321. doi: 10.1016/J.RSER.2011.08.018. URL https://www.sciencedirect.com/science/article/pii/S136403211100428X.

[24] Il Im, Yongbeom Kim, and Hyo-Joo Han. The effects of perceived risk and technology type on users' acceptance of technologies. *Information & Management*, 45(1):1–9, jan 2008. ISSN 0378-7206. doi: 10.1016/J.IM.2007.03.005. URL https://www.sciencedirect.com/science/article/pii/S0378720607000468.

[25] IRGC. RISK GOVERNANCE TOWA R D S A N INTEGRATIVE A P P ROAC H white paper on. Technical report, 2005. URL http://www.irgc.org/wp-content/uploads/2012/04/IRGC{_}WP{_}No{_}1{_}Risk{_}Governance{_}{_}reprinted{_}version{_}3.pdf.

[26] Renee A. Irvin and John Stansbury. Citizen Participation in Decision Making: Is It Worth the Effort? *Public Administration Review*, 64(1):55–65, jan 2004. ISSN 0033-3352. doi: 10.1111/j.1540-6210.2004.00346.x. URL http://doi.wiley.com/10.1111/j.1540-6210.2004.00346.x.

[27] Ankur Joshi, Saket Kale, Satish Chandel, and D K Pal. Likert Scale: Exlored and Explained. *British Journal of Applied Science & Technology*, 7(4), 2015. doi: 10.9734/BJAST/2015/14975. URL `https://www.researchgate.net/profile/Ankur{_}Joshi3/publication/276394797{_}Likert{_}Scale{_}Explored{_}and{_}Explained/links/55ec7d9708aeb6516268c9f4.pdf`.

[28] Jurre van den Berg. Onderzoeksraad concludeert: aanpak Groningse problemen 'traag en moeizaam' | De Volkskrant, 2017. URL `https://www.volkskrant.nl/nieuws-achtergrond/onderzoeksraad-concludeert-aanpak-groningse-problemen-traag-en-moeizaam{~}b20cba21/`.

[29] Henk Kamp. Gaswinning in Groningen [Kamerbrief]. (1):1–25, 2014. doi: 10.1007/s00244-010-9510-9.-. URL `https://www.rijksoverheid.nl/onderwerpen/gaswinning-in-groningen/documenten/kamerstukken/2014/01/17/gaswinning-in-groningen`.

[30] Johannes Kester. Energy security and human security in a Dutch gasquake context: A case of localized performative politics. *Energy Research & Social Science*, 24:12–20, feb 2017. ISSN 2214-6296. doi: 10.1016/J.ERSS.2016.12.019. URL `https://www.sciencedirect.com/science/article/pii/S2214629616303231`.

[31] Hans R.A. Koster and Jos van Ommeren. A shaky business: Natural gas extraction, earthquakes and house prices. *European Economic Review*, 80:120–139, nov 2015. ISSN 0014-2921. doi: 10.1016/J.EUROECOREV.2015.08.011. URL `https://www.sciencedirect.com/science/article/pii/S0014292115001282`.

[32] Marcus B. Lane. Public Participation in Planning: an intellectual history. *Australian Geographer*, 36(3):283–299, nov 2005. ISSN 0004-9182. doi: 10.1080/00049180500325694. URL `http://www.tandfonline.com/doi/abs/10.1080/00049180500325694`.

[33] Leeuwarder Courant. Partijen tekenen overeenkomst zoutwinning bij Harlingen - Friesland - LC.nl, 2019. URL `https://www.lc.nl/friesland/Partijen-tekenen-overeenkomst-zoutwinning-bij-Harlingen-24261278.html?harvest{_}referrer=https{%}3A{%}2F{%}2Fwww.google.com{%}2F`.

[34] Katherine A. McComas, Hang Lu, Katie M. Keranen, Maria A. Furtney, and Hwansuck Song. Public perceptions and acceptance of induced earthquakes related to energy development. *Energy Policy*, 99:27–32, dec 2016. ISSN 0301-4215. doi: 10.1016/J.ENPOL.2016.09.026. URL `https://www.sciencedirect.com/science/article/pii/S030142151630492X`.

[35] A. Mignan, D. Landtwing, P. Kästli, B. Mena, and S. Wiemer. Induced seismicity risk analysis of the 2006 Basel, Switzerland, Enhanced Geothermal System project: Influence of uncertainties on risk mitigation. *Geothermics*, 53:133–146, jan 2015. ISSN 0375-6505. doi: 10.1016/J.GEOTHERMICS.2014.05.007. URL `https://www.sciencedirect.com/science/article/pii/S0375650514000613`.

[36] Eric Molin. Construeren latente variabelen [lecture slides], 2018. URL `https://brightspace.tudelft.nl/d2l/le/content/148558/viewContent/1129946/View`.

[37] Niek Mouter, Auke de Geest, and Neelke Doorn. A values-based approach to energy controversies: Value-sensitive design applied to the Groningen gas controversy in the Netherlands. *Energy Policy*, 122:639–648, nov 2018. ISSN 0301-4215. doi: 10.1016/J.ENPOL.2018.08.020. URL `https://www.sciencedirect.com/science/article/pii/S0301421518305275`.

[38] Niek Mouter, Paul Koster, Thijs Dekker, and Perry Borst. Een Participatieve Waarde Evaluatie voor de Lange Termijn Ambitie Rivieren definitief. pages 1–72, 2018.

[39] Machiel Mulder and Peter Perey.   Gas production and earthquakes in Groningen reflec-
     tion on economic and social consequences.   Technical report, Centre for Energy Eco-
     nomics Research, University Groningen, 2018.   URL https://www.rug.nl/feb/news/2018/
     180605-gas-production-and-earthquakes.pdf.

[40] NAM.   Waarderegeling: compensatie bij verkoop.   URL https://www.nam.
     nl/nam-en-de-samenleving/groningen-gasveld-specifieke-regelingen/
     waarderegeling-compensatie-bij-verkoop.html{#}iframe=L2VtYmVkL2NvbXBvbmVudC8{_}aWQ9Q2hhcnRzL3

[41] NAM.   Voortgang   waarderegeling   (Gr.),   2019.   URL   https://www.
     nam.nl/feiten-en-cijfers/voortgang-waarderegeling.html{#}iframe=
     L2VtYmVkL2NvbXBvbmVudC8{_}aWQ9d2FhcmRlcmVnZWxpbmc.

[42] NCG.   Snel   Internet   Groningen   levert   werk   op,   .   URL   https://
     www.nationaalcoordinatorgroningen.nl/actueel/nieuws/2019/02/21/
     snel-internet-groningen-levert-werk-op.

[43] NCG.   Budget | Koopinstrument, .   URL https://www.nationaalcoordinatorgroningen.nl/
     onderwerpen/koopinstrument/budget.

[44] NCG.   Versterkingsmogelijkheden, .   URL https://www.nationaalcoordinatorgroningen.nl/
     onderwerpen/versterkingsmogelijkheden.

[45] NCG.   Ruim 6 miljoen voor 1000-banenplan in aardbevingsgebied, 2017.   URL https:
     //www.nationaalcoordinatorgroningen.nl/actueel/nieuws/2017/september/25/
     ruim-6-miljoen-voor-1000-banenplan-in-aardbevingsgebied.

[46] NCG. Meerjarenprogramma Aardbevingsbestendig en Kansrijk Groningen 2017-2021. Technical report,
     2017.

[47] NCG. Veiligheid voorop en de bewoner centraal. 2018.

[48] Andy Nicol, Matt Gerstenberger, Chris Bromley, Rachel Carne, Lauriane Chardot, Susan Ellis, Charles
     Jenkins, Tony Siggins, and Paul Viskovic.   Induced Seismicity; Observations, Risks and Mitigation
     Measures at CO2 Storage Sites.   *Energy Procedia*, 37:4749–4756, jan 2013.   ISSN 1876-6102.   doi:
     10.1016/J.EGYPRO.2013.06.384.   URL https://www.sciencedirect.com/science/article/pii/
     S1876610213006279.

[49] NLOG. Groningen gasfield | NLOG. URL https://www.nlog.nl/en/groningen-gasfield.

[50] NOS. Inwoners Harlingen dwongen inspraak af bij zoutwinning | NOS, 2019. URL https://nos.nl/
     artikel/2277434-inwoners-harlingen-dwongen-inspraak-af-bij-zoutwinning.html.

[51] Yvette Oostendorp, Saul Lemkowitz, Walter Zwaard, Coen van Gulijk, and Paul Swuste. Introduction of
     the concept of risk within safety science in The Netherlands focussing on the years 1970–1990. *Safety
     Science*, 85:205–219, jun 2016. ISSN 0925-7535. doi: 10.1016/J.SSCI.2016.01.013. URL https://www.
     sciencedirect.com/science/article/pii/S0925753516000266.

[52] H.J. Otway and J.J. Cohen.   Revealed Preferences: Comments on the Starr Benefit-Risk Relationships.
     1975. URL http://pure.iiasa.ac.at/id/eprint/511/.

[53] Sophie Pak. The Participatory Value Evaluation method : an application to the transition towards zero
     natural gas use at the local level of the neighborhood Hengstdal in Nijmegen in Engineering Policy Anal-
     ysis by. 2018.

[54] Anna Pellizzone, Agnes Allansdottir, Roberto De Franco, Giovanni Muttoni, and Adele Manzella. Exploring public engagement with geothermal energy in southern Italy: A case study. *Energy Policy*, 85:1–11, oct 2015. ISSN 0301-4215. doi: 10.1016/J.ENPOL.2015.05.002. URL `https://www.sciencedirect.com/science/article/pii/S0301421515001871`.

[55] Goda Perlaviciute, Linda Steg, Elisabeth J. Hoekstra, and Leonie Vrieling. Perceived risks, emotions, and policy preferences: A longitudinal survey among the local population on gas quakes in the Netherlands. *Energy Research & Social Science*, 29:1–11, jul 2017. ISSN 22146296. doi: 10.1016/j.erss.2017.04.012. URL `https://linkinghub.elsevier.com/retrieve/pii/S2214629617301068`.

[56] Provincie Groningen. Energiemonitor provincie Groningen. URL `https://energiemonitor.provincie-groningen.nl/`.

[57] Provincie Groningen. Vol ambitie op weg naar transitie. Technical report, 2018. URL `https://www.provinciegroningen.nl/fileadmin/user{_}upload/Documenten/Beleid{_}en{_}documenten/Documentenzoeker/Klimaat{_}en{_}energie/Energie{_}transitie/Tussenstand{_}programma{_}Energietransitie{_}2016{_}2019{_}mei{_}2018.pdf`.

[58] Ortwin. Renn. *Risk governance : coping with uncertainty in a complex world*. Earthscan, 2008. ISBN 1844072916. URL `https://books.google.nl/books/about/Risk{_}Governance.html?id=K3{_}P8YBcZtcC{&}redir{_}esc=y`.

[59] RTV Noord. Grootste verschil in huizenprijzen tussen Groningen en rest van het land sinds 2005, 2018. URL `https://www.rtvnoord.nl/nieuws/197578/Grootste-verschil-in-huizenprijzen-tussen-Groningen-en-rest-van-het-land-sinds-2005`.

[60] I Ruin, J Gaillard, and C Lutoff. How to get there? Assessing motorists' flash flood risk perception on daily itineraries. *Environmental Hazards*, 7(3):235–244, 2007. ISSN 17477891. doi: 10.1016/j.envhaz.2007.07.005. URL `http://www.tandfonline.com/doi/abs/10.1016/j.envhaz.2007.07.005`.

[61] Saedsayad.com. Logistic Regression. URL `https://www.saedsayad.com/logistic{_}regression.htm`.

[62] Inge Sieben and Liesbeth Linssen. Logistische regressie analyse : een handleiding. 0:1–19, 2008.

[63] Paul Slovic. Perception of Risk. pages 258–269, oct 2016. doi: 10.4324/9781315661773-23. URL `https://www.taylorfrancis.com/books/e/9781317341123/chapters/10.4324/9781315661773-23`.

[64] SNN. Subsidie Waardevermeerdering. URL `https://www.snn.nl/alle-subsidies/subsidie-waardevermeerdering`.

[65] Daren S. Starnes, Daniel S. Yates, David S. Moore, and Daniel S. Yates. *The practice of statistics*. W.H. Freeman, 2012. ISBN 142924559X. URL `https://books.google.nl/books/about/The{_}Practice{_}of{_}Statistics.html?id=rOZ-AN{_}T2hIC{&}redir{_}esc=y`.

[66] James W. Stoutenborough, Shelbi G. Sturgess, and Arnold Vedlitz. Knowledge, risk, and policy support: Public perceptions of nuclear power. *Energy Policy*, 62:176–184, nov 2013. ISSN 0301-4215. doi: 10.1016/J.ENPOL.2013.06.098. URL `https://www.sciencedirect.com/science/article/pii/S0301421513006058`.

[67] Paul Swuste, Coen van Gulijk, Walter Zwaard, Saul Lemkowitz, Yvette Oostendorp, and Jop Groeneweg. Developments in the safety science domain, in the fields of general and safety management between 1970 and 1979, the year of the near disaster on Three Mile Island, a literature review. *Safety Science*, 86:10–26, jul 2016. ISSN 0925-7535. doi: 10.1016/J.SSCI.2016.01.022. URL `https://www.sciencedirect.com/science/article/pii/S0925753516000400`.

[68] TCMG. Cijfers, . URL https://www.schadedoormijnbouw.nl/cijfers.

[69] TCMG. Hoe werkt het? Schade-afhandeling in 10 stappen, . URL https://www.schadedoormijnbouw.nl/thema/hoe-werkt-het.

[70] TCMG. Voorlopige werkwijze van de Tijdelijke Commissie Mijnbouwschade Groningen, 2018. URL https://schadedoormijnbouw.nl/officiele-documenten/voorlopige-werkwijze-van-de-tijdelijke-commissie-mijnbouwschade-groningen.

[71] Bruce Thompson. Factor Analysis. In *The Blackwell Encyclopedia of Sociology*. John Wiley & Sons, Ltd, Oxford, UK, feb 2007. doi: 10.1002/9781405165518.wbeosf003. URL http://doi.wiley.com/10.1002/9781405165518.wbeosf003.

[72] Trouw. Hoogste werkloosheid in Groningen, laagste werkloosheid in Zeeland, 2018. URL https://www.trouw.nl/home/hoogste-werkloosheid-in-groningen-laagste-werkloosheid-in-zeeland-{~}a7952698/

[73] UCLA. A Practical Introduction to Factor Analysis: Exploratory Factor Analysis, 2019. URL https://stats.idre.ucla.edu/spss/seminars/introduction-to-factor-analysis/a-practical-introduction-to-factor-analysis/.

[74] Nick van der Voort and Frank Vanclay. Social impacts of earthquakes caused by gas extraction in the Province of Groningen, The Netherlands. *Environmental Impact Assessment Review*, 50:1–15, jan 2015. ISSN 0195-9255. doi: 10.1016/J.EIAR.2014.08.008. URL https://www.sciencedirect.com/science/article/pii/S0195925514000766.

[75] Gisela Wachinger, Ortwin Renn, Chloe Begg, and Christian Kuhlicke. The Risk Perception Paradox-Implications for Governance and Communication of Natural Hazards. *Risk Analysis*, 33(6):1049–1065, jun 2013. ISSN 02724332. doi: 10.1111/j.1539-6924.2012.01942.x. URL http://doi.wiley.com/10.1111/j.1539-6924.2012.01942.x.

[76] Shanyong Wang, Jing Wang, Shoufu Lin, and Jun Li. Public perceptions and acceptance of nuclear energy in China: The role of public knowledge, perceived benefit, perceived risk and public engagement. *Energy Policy*, 126:352–360, mar 2019. ISSN 0301-4215. doi: 10.1016/J.ENPOL.2018.11.040. URL https://www.sciencedirect.com/science/article/pii/S0301421518307699.

[77] E.D. Wiebes. Protocol mijnbouwschade Groningen. *Staatcourant*, (6398):1–16, 2018. URL https://www.rijksoverheid.nl/documenten/besluiten/2018/01/31/besluit-mijnbouwschade-groningen{%}0Ahttps://www.rijksoverheid.nl/actueel/nieuws/2018/01/31/overeenstemming-over-nieuw-schadeprotocol-groningen.

[78] Edwin Woerdman and Minne Dulleman. Tradable earthquake certificates. *Energy Policy*, 117:370–376, jun 2018. ISSN 0301-4215. doi: 10.1016/J.ENPOL.2018.03.020. URL https://www.sciencedirect.com/science/article/pii/S0301421518301514.

A

Web tool text

This appendix shows an overview of the web tool. The web tool is set up in Dutch. When opening the web tool, participants encounter the introduction page shown in figure A.1. The introduction page explains the reasons for conducting this research, the time it takes to complete the research and the treatment of gathered data.

Figure A.1: Introduction page web tool

After the introduction participants encounter two instruction pages. The first instruction page, shown in figure A.2, shows a situation overview. It explains how gas is produced in the Netherlands, how gas production leads to earthquakes and negative consequences related to the earthquakes. The second instruction page, shown in figure A.3, explains that participants have to make a mitigation measure selection within a budget. It also explains that participants have to answer a short survey after selecting their preferred mitigation measures.

Figure A.2: Situation page web tool

Figure A.3: Instruction page web tool

Before starting with the experiment, an instruction video is shown that explains how to use the web-tool. After the instruction video the experiment is started. On the overview page, as shown in figure A.4, people can select the mitigation measure within the budget. The total budget, the budget spent and the remaining budget are shown in the upper right. The circle in front of each mitigation measure shows the costs of that specific measure. By clicking on a measure participants can view extra information of the measure as shown in figure A.5.

Figure A.4: Overview page web tool

Figure A.5: Mitigation measure information page web tool

A.1. Mitigation measure characteristics

The next paragraphs show the information of each measure in Dutch as included in the web-tool.

A.1.1. Structurele versteviging

Bij structurele versteviging worden gebouwen met een verhoogd risico op schade door de aardbevingen preventief onderzocht. Op basis van dit onderzoek wordt een advies rapport opgesteld waarna de aanbevolen verstevigingen uitgevoerd worden. De verstevigingen moeten er voor zorgen dat de kans op schade bij aardbevingen wordt verkleind. Volgens een rapport van de Nationaal Coördinator Groningen zijn er 2500 huizen met een verhoogd risico. De geschatte kosten voor het verstevigen van deze huizen bedragen 163 miljoen euro.

Type: Risico reductie
Kosten: €163 miljoen
Bereik: 2500 huizen

A.1.2. Schade compensatie

Indien een huis beschadigd is door een aardbeving kan een huiseigenaar een claim indienen bij de Tijdelijke Commissie Mijnbouwschade Groningen (TCMG). Deze commissie maakt gebruik van onafhankelijke experts om de claim te beoordelen. Uit cijfers van de commissie blijkt dat er nog 13.600 claims wachten om beoordeeld te worden. De totale geschatte compensatiewaarde van deze claims bedraagt 58 miljoen euro.

Type: Compensatie
Kosten: €58 miljoen
Bereik: 13.600 schadeclaims

A.1.3. Waarderegeling

De waarderegeling is een maatregel die in het leven is geroepen om huiseigenaren te compenseren voor de waardedaling van hun huis door de aardbevingen. Huiseigenaren die hun huis hebben verkocht na 25 januari 2013 kunnen aanspraak maken op de regeling. Indien huiseigenaren een claim indienen wordt deze beoordeeld door onafhankelijke experts. Op dit moment zijn er nog 900 claims die wachten om beoordeeld te worden. De totale geschatte compensatiewaarde van deze claims bedraagt 5 miljoen euro.

Type: Compensatie
Kosten: €5 miljoen
Bereik: 900 huizen

A.1.4. Koopinstrument

Indien een huis langer dan 12 maanden te koop staat en het huis door de aardbevingen niet verkocht wordt kan de Nationaal Coördinator Groningen (NCG) besluiten om het huis op te kopen. Het budget dat de NCG hiervoor ter beschikking heeft bedraagt 10 miljoen euro. Dit budget is beschikbaar gesteld door de NAM. Het geschatte aantal huizen dat opgekocht kan worden met dit budget is 50. Claims op aansprak voor het koopinstrument worden beoordeeld door onafhankelijke experts.

Type: Compensatie
Kosten: €10 miljoen
Bereik: 50 huizen

A.1.5. Leefbaarheid verbeteringen

Om het imago van de provincie Groningen en de leefbaarheid te verbeteren heeft de NAM een budget van 65 miljoen euro beschikbaar gesteld. Dit budget wordt beheerd door Economic Board Groningen. Van dit budget kunnen verschillende specifieke maatregelen worden geïmplementeerd. Denk hierbij aan investeringen in sneller internet, openbaar vervoer of sport faciliteiten. Het bereik van deze investeringen is lastig te schatten vanwege de diversiteit van de maatregelen.

Type: Investering
Kosten: €65 miljoen
Bereik: Inwoners provincie Groningen

A.1.6. Investeringen in duurzame energie

Om het gebruik van duurzame energie te stimuleren is de waardevermeerdering regeling in het leven geroepen. Huiseigenaren in de getroffen gebieden maken aanspraak op deze regeling. Vanuit het beschikbare budget van 10 miljoen euro kunnen huiseigenaren een subsidie krijgen voor het investeren in duurzame energie technologie zoals bijvoorbeeld zonnepanelen of betere isolatie. Dit zorgt ervoor dat duurzame energie gestimuleerd wordt en tegelijkertijd verhoogt de investering de waarde van de huizen. Het geschatte aantal huiseigenaren dat gebruik kan maken van de subsidie bedraagt 10.000.

Type: Investering
Kosten: €10 miljoen
Bereik: 10.000 huizen

A.1.7. Lokale werkgelegenheid creatie

Om de werkgelegenheid te verbeteren in regio Groningen is er een bedrag van 6 miljoen euro beschikbaar gesteld voor training en omscholing. Met dit bedrag kunnen er 1.000 nieuwe banen worden gecreëerd. Deze banen bevinden zich vooral in de bouwsector. De training en omscholing richt zich op reparatie van de schade door aardbevingen. Hierdoor worden er niet alleen nieuwe banen gecreëerd, maar kan schade ontstaan door aardbevingen sneller gerepareerd worden.

Type: Investering
Kosten: €6 miljoen
Bereik: 1000 banen

A.2. Survey questions

After confirmation of the selected mitigation measures, participants are shown two pages with survey questions. The first survey page is shown in figure A.6. The first survey page shows statements on risk acceptance. Participants have to fill in their agreements with these statements. The second survey page shows demographic questions. All the statements and questions as included in Dutch are displayed in the next paragraphs.

Figure A.6: Survey question page

A.2.1. Risk acceptance statements

Direct ervaring

1. Ik heb zelf een aardbeving ervaren in Groningen

Ervaren risico

1. Ik beschouw de schade aan huizen door aardbevingen als waarschijnlijk

2. Ik beschouw de waardedaling van huizen door aardbevingen als waarschijnlijk

3. Ik beschouw een verminderde leefbaarheid voor mensen getroffen door de aardbevingen als waarschijnlijk

4. Ik beschouw fysieke ongevallen voor de mensen getroffen door aardbevingen als waarschijnlijk

5. Ik beschouw stress voor de mensen getroffen door aardbevingen als waarschijnlijk

Ervaren opbrengsten

1. Ik vind dat de opbrengsten van de gaswinning opwegen tegen de nadelen van de aardbevingen

2. Ik vind dat de opbrengsten van de gaswinning evenredig over het land verdeeld worden

3. Ik vind dat de inwoners van de provincie Groningen gelijk worden behandeld als de inwoners van de rest van het land.

Vertrouwen

1. Ik heb vertrouwen in het handelen van de Nederlandse overheid omtrent de aardbevingen

2. Ik heb vertrouwen in het handelen van de NAM omtrent de aardbevingen

A.2.2. Demographic questions

1. Wat is uw leeftijd?

   - Jonger dan 25 jaar
   - 25 jaar - 35 jaar
   - 36 jaar - 45 jaar
   - 46 jaar - 55 jaar
   - 56 jaar - 65 jaar
   - Ouder dan 65 jaar

2. Wat is uw geslacht?

3. Wat is uw hoogst genoten opleiding?

   - Basis onderwijs
   - Voortgezet onderwijs
   - MBO
   - HBO
   - WO

4. Bent u een inwoner van de provincie Groningen?

5. Heeft u nog verdere vragen en/of opmerkingen naar aanleiding van dit onderzoek?

B

Flyer

To gather more respondents in Groningen, 500 flyers are distributed in Hoogezand and Slochteren. Slochteren is chosen because this village is where the gas field was originally found and is in the middle of the earthquake prone area. Hoogezand is a larger town near Slochteren, which makes it easy to distribute the flyers.

The flyer is designed in Dutch and can be seen in figure B.1. First a QR code was added to the flyer. Unfortunately did had no use, because the web-tool does not work on mobile phones. The flyer asks people to think along about government policy and asks if people want to participant in an experiment where they have to make an allocation decision about the NAM budget for mitigation measures.

TUDelft

Meedenken over beleid?

Aardbevingsmaatregel voorkeur onderzoek

Doe mee met een onderzoek naar participatiebegroting.
Aan welke maatregelen moet volgens jou het NAM budget besteed moet worden?

🕐 **10 min**

🔗 **http://tinyurl.com/y332yjrq**
    (Werkt alleen op pc)

Figure B.1: Flyer design

Demographic and factor analysis SPSS output

This appendix provides the demographic overview of the respondents and the output of the analysis conducted in SPSS.

C.1. Demographic frequencies

Figures C.1 up to C.4 show the frequency of the included demographic questions. Some of the participants did not fill in the demographic questions. Most missing cases are seen in the age question as is displayed in figure C.5.

Age

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Younger than 25	5	10,2	11,9	11,9
	25 - 35	10	20,4	23,8	35,7
	36 - 45	7	14,3	16,7	52,4
	46 - 55	8	16,3	19,0	71,4
	56 / 65	8	16,3	19,0	90,5
	Older than 65	4	8,2	9,5	100,0
	Total	42	85,7	100,0	
Missing	System	7	14,3		
Total		49	100,0		

Figure C.1: Participants age frequency

C.2. Factor anaysis output

The factor analysis conducted for perceived risk and perceived benefit is done with the following settings:

Method: Principal Axis Factoring

Rotation: Direct Oblimin

The eigenvalues, total explained variance and factor loading extracted with factor analysis can be found in figure C.6 for the perceived risk and in figure C.7 for the perceived benefit.

Education

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	MBO	7	14,3	15,2	15,2
	HBO	18	36,7	39,1	54,3
	WO	21	42,9	45,7	100,0
	Total	46	93,9	100,0	
Missing	System	3	6,1		
Total		49	100,0		

Figure C.2: Participants education frequency

Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Female	23	46,9	50,0	50,0
	Male	23	46,9	50,0	100,0
	Total	46	93,9	100,0	
Missing	System	3	6,1		
Total		49	100,0		

Figure C.3: Participants gender frequency

After checking the factor loading it is concluded that all statements can be included to create single scores for risk perception and perceived benefit. This can be done because all statements have a loading above 0.4. To construct the single scores, sum score is used. This can be done because the four conditions of sum score are met. These conditions are:

1. Reliability tested with Cronbach's alpha and is higher than 0.70

2. One-dimensional scale

3. Positive correlations

4. Equal range of variables

The statements are set up in a way that satisfies conditions 2,3 and 4. The reliability is tested in SPSS and this shows a reliability higher than 0.70 for both risk perception and perceived benefit. An overview of both Cronbach alphas is shown in figure C.8 and C.9.

C.3. Score category creation

Finding cut-off points that divide the risk acceptance factors into three equal groups creates the low, medium and high-score categories for the risk acceptance factor. Based on the cut-off points as displayed in figure C.10, the score categories are created by computing a variable with a low score that includes all scores below the first cut-off point, a medium score that includes all score in between the cut-off points and a high-score that includes all scores above the cut-off point.

Citizen Groningen

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	30	61,2	65,2	65,2
	Yes	16	32,7	34,8	100,0
	Total	46	93,9	100,0	
Missing	System	3	6,1		
Total		49	100,0		

Figure C.4: Participants residence frequency

Frequencies

Statistics

		Age	Gender	Education	Citizen Groningen
N	Valid	42	46	46	46
	Missing	7	3	3	3

Figure C.5: Missing cases

Total Variance Explained

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2,993	59,856	59,856	2,541	50,830	50,830
2	,681	13,619	73,476			
3	,636	12,724	86,200			
4	,427	8,543	94,743			
5	,263	5,257	100,000			

Extraction Method: Principal Axis Factoring.

Factor Matrix[a]

	Factor 1
Risk 1	,564
Risk 2	,652
Risk 3	,853
Risk 4	,818
Risk 5	,634

Extraction Method: Principal Axis Factoring.

a. 1 factors extracted. 7 iterations required.

Figure C.6: Factor analysis for risk perception

Total Variance Explained

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2,242	74,749	74,749	1,914	63,809	63,809
2	,519	17,291	92,040			
3	,239	7,960	100,000			

Extraction Method: Principal Axis Factoring.

Factor Matrix[a]

	Factor
	1
Benefit 1	,627
Benefit 2	,872
Benefit 3	,872

Extraction Method:
Principal Axis
Factoring.

a. 1 factors
extracted. 8
iterations
required.

Figure C.7: Factor analysis for perceived benefit

Reliability Statistics

Cronbach's Alpha	N of Items
,825	5

Item Statistics

	Mean	Std. Deviation	N
Risk 1	4,49	,505	49
Risk 2	4,20	,866	49
Risk 3	3,71	1,000	49
Risk 4	3,39	1,037	49
Risk 5	4,33	,689	49

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Risk 1	15,63	8,654	,516	,825
Risk 2	15,92	6,952	,601	,795
Risk 3	16,41	5,830	,748	,749
Risk 4	16,73	5,699	,741	,753
Risk 5	15,80	7,749	,579	,803

Figure C.8: Cronbach alpha risk perception

Reliability Statistics

Cronbach's Alpha	N of Items
,829	3

Item Statistics

	Mean	Std. Deviation	N
Benefit 1	2,20	1,060	49
Benefit 2	2,20	1,040	49
Benefit 3	2,22	1,177	49

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Benefit 1	4,43	4,333	,583	,861
Benefit 2	4,43	3,875	,750	,704
Benefit 3	4,41	3,413	,742	,707

Figure C.9: Cronbach alpha perceived benefit

Frequencies

Statistics

		Govt trust	NAM trust	PerceivedRisk	PerceivedBenefit
N	Valid	49	49	49	49
	Missing	0	0	0	0
Percentiles	33,33333333	1,67	1,00	3,6000	1,6667
	66,66666667	3,00	2,00	4,4000	2,6667

Figure C.10: Cut-off points

D
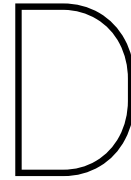
Logistic regression SPSS output

This appendix provides the model fit for all the models that predict the selection of a mitigation measure. For every mitigation measure a model including the risk acceptance factors is tested with the Chi-square test. If the p-value is below 0.05, the model has a significant effect on the selection of the mitigation measure. This appendix provides an overview of the Chi-square tests for all the models. To check whether the individual risk acceptance factors have a significant effect on the selection of a mitigation measure, the Wald-statistics are included. Again a p-value 0.05 is used. A larger Beta value of a risk acceptance factor means that the effect is larger. The sign of the Beta shows whether the effect is positive or negative.

D.1. Structural reinforcement logistic SPSS output

Figure D.1 provides the model fit of risk acceptance factors on structural reinforcement selection. Figure D.2 provides the Wald-statistic for the effect of individual risk acceptance factors on structural reinforcement selection.

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	4,232	5	,517
	Block	4,232	5	,517
	Model	4,232	5	,517

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	59,030ᵃ	,083	,114

a. Estimation terminated at iteration number 4 because parameter estimates changed by less than ,001.

Figure D.1: Model fit structural reinforcement selection

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	RiskCategory	,030	,440	,005	1	,946	1,030
	BeneftiCategory	-,480	,618	,603	1	,437	,619
	GovTrustCat	-,018	,671	,001	1	,978	,982
	NamTrustCat	-,007	,489	,000	1	,988	,993
	Direct experience	,749	,916	,669	1	,413	2,116
	Constant	1,360	1,904	,510	1	,475	3,896

a. Variable(s) entered on step 1: RiskCategory, BeneftiCategory, GovTrustCat, NamTrustCat,
Direct experience.

Figure D.2: Wald statistic structural reinforcement selection

D.2. Damage compensation logistic SPSS output

Figure D.3 provides the model fit of risk acceptance factors on damage compensation selection. Figure D.4 provides the Wald-statistic for the effect of individual risk acceptance factors on damage compensation selection.

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	13,884	5	,016
	Block	13,884	5	,016
	Model	13,884	5	,016

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	26,308[a]	,247	,441

a. Estimation terminated at iteration number 20
because maximum iterations has been reached.
Final solution cannot be found.

Figure D.3: Model fit damage compensation selection

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	RiskCategory	1,067	,883	1,461	1	,227	2,908
	BeneftiCategory	,072	,926	,006	1	,938	1,074
	GovTrustCat	,504	1,710	,087	1	,768	1,656
	NamTrustCat	-1,438	1,200	1,436	1	,231	,237
	Direct experience	18,836	9192,005	,000	1	,998	151445309,4
	Constant	1,487	3,802	,153	1	,696	4,424

a. Variable(s) entered on step 1: RiskCategory, BeneftiCategory, GovTrustCat, NamTrustCat, Direct
experience.

Figure D.4: Wald statistic damage compensation selection

D.3. Value regulation logistic SPSS output

Figure D.5 provides the model fit of risk acceptance factors on value regulation selection. Figure D.6 provides the Wald-statistic for the effect of individual risk acceptance factors on value regulation selection.

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	14,679	5	,012
	Block	14,679	5	,012
	Model	14,679	5	,012

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	45,685[a]	,259	,365

a. Estimation terminated at iteration number 6 because parameter estimates changed by less than ,001.

Figure D.5: Model fit value regulation selection

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	RiskCategory	1,486	,697	4,553	1	,033	4,421
	BeneftiCategory	,289	,744	,151	1	,697	1,335
	GovTrustCat	1,343	1,064	1,593	1	,207	3,832
	NamTrustCat	-1,621	,870	3,472	1	,062	,198
	Direct experience	-1,933	1,131	2,918	1	,088	,145
	Constant	-1,664	2,821	,348	1	,555	,189

a. Variable(s) entered on step 1: RiskCategory, BeneftiCategory, GovTrustCat, NamTrustCat, Direct experience.

Figure D.6: Wald statistic value regulation selection

D.4. Buying instrument logistic SPSS output

Figure D.7 provides the model fit of risk acceptance factors on buying instrument selection. Figure D.8 provides the Wald-statistic for the effect of individual risk acceptance factors on buying instrument selection.

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	4,331	5	,503
	Block	4,331	5	,503
	Model	4,331	5	,503

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	57,575[a]	,085	,118

a. Estimation terminated at iteration number 4 because parameter estimates changed by less than ,001.

Figure D.7: Model fit buying instrument selection

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	RiskCategory	-,062	,449	,019	1	,890	,940
	BeneftiCategory	-,367	,660	,309	1	,578	,693
	GovTrustCat	,535	,747	,512	1	,474	1,707
	NamTrustCat	-,933	,694	1,805	1	,179	,393
	Direct experience	-,855	,937	,833	1	,361	,425
	Constant	2,447	2,114	1,340	1	,247	11,551

a. Variable(s) entered on step 1: RiskCategory, BeneftiCategory, GovTrustCat, NamTrustCat, Direct experience.

Figure D.8: Wald statistic buying instrument selection

D.5. Standard of living enhancement logistic SPSS output

Figure D.9 provides the model fit of risk acceptance factors on standard of living enhancement selection. Figure D.10 provides the Wald-statistic for the effect of individual risk acceptance factors on standard of living enhancement selection.

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	8,287	5	,141
	Block	8,287	5	,141
	Model	8,287	5	,141

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	57,979[a]	,156	,210

a. Estimation terminated at iteration number 4 because parameter estimates changed by less than ,001.

Figure D.9: Model fit standard of living enhancement selection

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	RiskCategory	-,170	,430	,156	1	,693	,844
	BeneftiCategory	1,022	,644	2,519	1	,112	2,780
	GovTrustCat	,440	,681	,417	1	,518	1,553
	NamTrustCat	-,590	,636	,860	1	,354	,554
	Direct experience	-,217	,897	,059	1	,809	,805
	Constant	-1,837	1,919	,917	1	,338	,159

a. Variable(s) entered on step 1: RiskCategory, BeneftiCategory, GovTrustCat, NamTrustCat, Direct experience.

Figure D.10: Wald statistic standard of living enhancement selection

D.6. Renewable energy investment logistic SPSS output

Figure D.11 provides the model fit of risk acceptance factors on renewable energy investment selection. Figure D.12 provides the Wald-statistic for the effect of individual risk acceptance factors on renewable energy investment selection.

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	6,744	5	,240
	Block	6,744	5	,240
	Model	6,744	5	,240

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	57,694[a]	,129	,176

a. Estimation terminated at iteration number 4 because parameter estimates changed by less than ,001.

Figure D.11: Model fit renewable energy investment selection

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	Direct experience	-,016	,889	,000	1	,986	,984
	RiskCategory	,167	,443	,142	1	,706	1,182
	BenefitCategory	1,682	,768	4,800	1	,028	5,379
	GovTrustCat	-,759	,711	1,138	1	,286	,468
	NamTrustCat	-,806	,723	1,241	1	,265	,447
	Constant	,124	1,961	,004	1	,950	1,132

a. Variable(s) entered on step 1: Direct experience, RiskCategory, BenefitCategory, GovTrustCat, NamTrustCat.

Figure D.12: Wald statistic renewable energy investment selection

D.7. Local job creation logistic SPSS output

Figure D.13 provides the model fit of risk acceptance factors on local job creation selection. Figure D.14 provides the Wald-statistic for the effect of individual risk acceptance factors on local job creation selection.

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	12,342	5	,030
	Block	12,342	5	,030
	Model	12,342	5	,030

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	55,566[a]	,223	,297

a. Estimation terminated at iteration number 4 because parameter estimates changed by less than ,001.

Figure D.13: Model fit local job creation selection

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	Direct experience	-,138	,884	,024	1	,876	,871
	RiskCategory	-,946	,447	4,471	1	,034	,388
	BeneftiCategory	,896	,680	1,737	1	,188	2,451
	GovTrustCat	,354	,682	,270	1	,604	1,425
	NamTrustCat	-,912	,711	1,647	1	,199	,402
	Constant	1,187	1,911	,386	1	,535	3,276

a. Variable(s) entered on step 1: Direct experience, RiskCategory, BeneftiCategory, GovTrustCat, NamTrustCat.

Figure D.14: Wald statistic local job creation selection