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

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Abstract— **Recent years the Netherlands have been shocked by a series of earthquakes. Normally an earthquake would be considered as a natural hazard, however extracting gas induces these earthquakes. Whenever a hazard is induced, it is perceived as man-made and therefore controllable. This leads to differences in risk acceptance in relation to natural hazards. When ambiguity about risks exists, a participatory strategy should be used with involvement of the local community. In cases of induced hazards, low trust between local communities and authorities exists, leading to ineffective risk mitigation. The first step of improving mitigation measures is finding out whether differences in risk acceptance lead to differences in mitigation measure preferences. In this paper this research objective is carried out by gathering data in the earthquake area in Groningen with the Participatory Value Evaluation (PVE) method. Next the data is analysed using factor analysis and logistic regression. Based on the results is concluded that citizens with lower trust in authorities prefer measures that directly target the consequences of the induced hazard. While citizens with more trust in authorities and more belief in the benefits of the activity causing the hazard are more open for measures that target the indirect consequences of the hazard. During this research, assumptions were made to construct the context of the PVE method. To improve the validity of this research it is suggested to repeat the research with different variables.**

keywords: Community involvement, risk acceptance, induced hazards, risk mitigation, PVE methodology

I. Introduction

The Netherlands is known for its fight against water and floods. This fight has been a source for research on risk governance and safety management. In recent years the Netherlands had to deal with a different disaster [22]. Gas production in province Groningen has led to induced earthquakes. At first sight earthquakes would be considered as natural disaster and therefor be treated the same as floods. However a difference occurs; because the earthquakes are caused by gas production, the earthquakes are perceived as man-made. Since the cause is man-made, the risk is grasped as controllable [2]. As involved parties perceive risks different, controllability creates complexity. If ambiguity about the risks exists, risk governance should be adapted to deal with the ambiguity. Wielding a discourse-based strategy that involves the public in decision-making can achieve this [8]. Renn 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" [8, p.40]. This strategy is known as a participatory strategy, where risk governance should focus on the underlying factors that are causing the controversy [1].

Research into community involvement and public participation starts in the 1950s [7]. If hostility towards authorities is high and the issues are of high interest for the stakeholders, Irvin and Stansbury speak of high benefit indicators. Meaning that the situation would be suitable for public participation [9]. However if not implemented well, public participation or community involvement can backfire. The inability to influence decision-making and the feeling of pretence participation may lead to even greater dissatisfaction of the public [9].

Ambiguity of risks means that differences in perception and acceptance of risks exist. Extensive research on risk acceptance shows that risk acceptance depends on a variety of factors. Risk acceptance of natural disasters relies on the characteristics of the hazard. Exposure to and impact of the hazard shape risk acceptance [27]. Risk acceptance of man-made disasters is influenced more by social and economic factors. 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 " [36, p.1049].

To involve the public in risk governance, this research focuses on the publics preferences for mitigation. As Irvin and Stansbury mention there is often hostility between the public and the authorities [9]. If people are able to state their preferences for mitigation, people might feel heard and this may lead to reinstalled trust between the public and authorities. Research has shown that mitigation implemented with the best intentions by the government is not always effective [24]. The implementation of the mitigation measures might be wrong, but another possibility is a difference in preferred mitigation between the public and the authorities. Because risks are perceived and accepted differently, preferences for mitigation might differ. The objective of this research is to improve the effectiveness of community involvement by discovering differences in mitigation preferences. Since acceptance of risks is shaped by different factors, differences in risk acceptance may influence the preferences for risk mitigation.

Traditionally researchers use cost-benefit analysis (CBA) to determine preferences for measures. However scholars argue that CBA might not be the right method to analyse

public policy. CBA uses willingness-to-pay to discover increased welfare from public policy, which can be described as the consumer approach. As people their private choice does not reflect their public choice, preferences cannot be determined by the way people are willingly to spend their private money. The consumer-citizen duality describes that citizens take different decisions based on their role in society [14], [4]. To tackle this issue Participatory Value Evaluation (PVE) is developed. Besides tackling the issues of CBA, this method is also known as tool for community involvement, which makes the method suitable for this research.

The main goal of this research is to discover whether risk acceptance influences the preference for risk mitigation. This goal leads to the following research question:

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

As side goal of the research in the further development of the PVE method. The research approach, including the PVE method, is explained in section 2. The PVE method uses a case situation that is described in section 3. Analysis of the data and the results are displayed in section 4. Section 5 includes the conclusion of the research. The discussion is written down in section 6.

II. Research Approach

To answer the research question, a case study is conducted. A selection of risk acceptance factors and a selection of included mitigation measures is made. After this selection the PVE method is used to gather the preferences of the participants. Factor analysis and logistic regression are used to analyse the gathered data. First a literature review is conducted to make the selection of risk acceptance factors and mitigation preferences.

A. Literature review method

First literature is searched for in online databases such as Google Scholar and Scopus. A selection is made based on abstracts and conclusions. Based on articles mentioned in the chosen articles the selection of included literature is extended. Besides scientific articles, newspapers and journal articles on the case situation are used.

B. Participatory Value Evaluation method

Where CBA uses a one-euro-one-vote (OEOV) assumption, PVE uses a one-person-one-vote (OPOV) assumption. This means that every vote in the public decision-making process is weighs the same, while with CBA every euro a person is willing to spend is considered as a vote. An issue with this assumption is that people with more money are able to spend more and are therefore likely to be willingly to spend more on a measure. This means that CBA does not measure preferences but willingness to spend money for obtaining a preferred choice [4]. The PVE method uses a web tool for gathering data. Participants of the research use the tool for selecting their preferred measures within a budget constraint. In this way participants operate as co-owners of the governmental budget and can make allocation decisions. To make an educated decision, each alternative that can be selected is described in qualitative and quantitative terms [14]. The participants to compare the different measures and state their preference can use these descriptions. A mentioned benefit of the PVE method is the involvement of the public by giving an opportunity to state preferences. Apart from this benefit the participation threshold for the PVE method is low in relation to public hearings and meetings. A low participation threshold must lead to attracting a more diverse range of respondents and therefore a better representation of society [4].

In this research PVE is used to gather two lists of data. First a selection of mitigation measures is gathered. PVE provides an overview of the selected measures of every individual participant. Second information on risk acceptance is gathered using survey questions. PVE provides the answers on the risk acceptance factors of every individual participant. To analyse the survey questions and create risk acceptance scores for every acceptance factor, factor analysis is used.

C. Factor analysis

Factor analysis is used to create risk acceptance scores for every included risk acceptance factor. As risk acceptance factors are mostly latent variables, survey questions are used to try to capture the aspects of a factor. With factor analysis can be checked whether the used survey questions measure the factor that they are supposed to measure and not an unknown factor. In factor analysis the survey questions are used as indicator variables, while the factor explains the correlation between those indicator variables. If one of the indicator variables has a low communality with the factor, the indicator will be excluded. In this way only the survey questions that measure the specific acceptance factor will be included [32].

To construct a single score on each risk acceptance factor, the indicator variables are combined and a new variable is constructed. Construction can be done in three ways:

1) Using a factor score
2) Using a sum score
3) Using a surrogate variable

In this research the factor analysis is confirmatory, which means that there is little doubt about the reliability or validity of the newly constructed factor. Therefore factor or sum score can be used. Sum score is used if the created scale of indicator variables meets the following conditions:

1) Reliability tested with Cronbachs alpha and higher than 0.70
2) One-dimensional scale
3) Positive correlations
4) Equal range of variables

If one of these conditions cannot be met, factor score is used. With sum score all the indicator variables are simply added up to create one overall score. Factor score creates a weighted score with factor loading as basis. The output of

factor score is standardised with a mean of 0 and a standard deviation of 1 [12]. The factor analysis is conducted in SPSS

D. Logistic regression

After using factor analysis to create a single score on each acceptance factor, logistic regression is used to analyse the relation between the acceptance factors and the selection of mitigation measures. A mitigation measure is either selected or not selected, which means that it is a dichotomous variable. To analyse dichotomous variables as dependent variable, logistic regression is used. Logistic regression uses a curve that stays between 0 and 1, therefore the chance of selecting a measure cannot drop below 0 or exceed 1. The logistic regression is conducted in SPSS. With the chi-square test can be determined whether the risk acceptance, as predictor variables have a significant effect on the selection of mitigation measures as dependent variable. Explained variance is used to determine how much of the variance of the dependent variable is explained by the predictor variables. In SPSS this is done with different goodness of fit tests: [26]

1) MC Fadden R^2
2) Cox & Snell R^2
3) Nagelkerke R^2

III. Case description

As case study to include in the PVE method, mitigation for the earthquakes caused by gas production in Groningen is chosen. In this case ambiguity about the risks exists. Mitigation measures have been implemented, but have not been effective so far [24]. Differences in risk acceptance make the case suitable for this research. This section provides an overview of the case.

Gas production in the Netherlands started in 1947 with the foundation of the Nederlandse Aardolie Maatschappij (NAM) who is responsible for the gas extraction. In 1959 the largest gas field of Europe was discovered near Slochteren, a small town in the Province of Groningen [35]. To distribute the gas in the Netherlands, Gasunie was founded and the whole country was connected with pipelines. Gas production became important not only for own use, but also for trade as it became a significant income source for the Dutch government. For the import and export of gas, GasTerra was unbundeld from Gasunie [38]. Since 1963 the gas field has been exploited commercially. It has been generating revenues up to 265 billion euros for the Dutch State [35].

In 1986 people started to notice the downside of gas production. Earthquakes caused by the extraction of gas were monitored. The extraction of gas from the layer that holds the gas decreases the pressure inside the sandstone layer. Therefore this layer cannot support the weight of the layers above and soil subsidence occurs. The layers compress what causes the earthquakes. The sandstone layer in Groningen is close to the surface, which increases the impact of the earthquakes [11].

Until 2011 the earthquakes were not perceived as problematic, however this changed when the worst earthquake so far struck witch a force of 3.6 on the Richter scale [10]. The consequences of this event led to much concern under the local communities. The topic was included in the political agenda and public media started to pay attention. The concern was amplified by a report commissioned by the dutch Ministry of Economic affairs. This report stated that the increased gas production between 2000 and 2013 increased the frequency and magnitude of earthquakes. The report concluded that earthquakes with a force up to 5.0 on the Richter scale were possible [13], [35]. To reduce the risks a gap was put on the gas production Eventually minister Wiebes of Economic Affairs and Climate decided to completely stop the gas production by 2030 [37].

A. Mitigation Measures

To answer the research question, PVE needs data as input. In the constructed PVE webtool participants first have to select their preferred mitigation measures. Therefore a selection of mitigation measures is made. The PVE method works best if the included measures are as realistic as possible within the case limits. In this way respondents believe in the research they are participating in what leads to more reliable answers. To include realistic mitigation, the measures included are constructed based on previous research and literature on the Groningen case. Based on research by Perlaviciute et al. six measures are selected from an existing measure package [24]. Most of the measures are carried out by organisations that have implementation of the measure as main task. Information on the implementation and characteristics of the measures is mostly retrieved from the websites of the specific organisations. Based on this information one of the six measures is split up in two, which brings the total number of measures included up to seven. Following are the measures:

1) Structural reinforcement: This measure is implemented to reduce the risk of damage caused by earthquakes. Buildings are checked precautionary after which a reinforcement procedure is set up. Based on information of the National Coordinator Groningen (NCG) 2500 houses are exposed to high risk . Costs estimation for structural reinforcement of these houses is 163 million euro [20], [19], [5].

2) Damage compensation: If damage to housing is caused by earthquakes, homeowners can receive damage compensation. Temporary Commission Mining Damage Groningen (TCMG) carries out the compensation procedure [31]. Estimations of TCMG show that approximately 13.600 claims are waiting to be compensated with a value of 58 million euro [30].

3) Declining house value compensation: The earthquakes in Groningen decreased the image of the region[15]. A negative image combined with risk of damage led to a loss of house values in the region. Based on the Dutch mining law, the NAM, as operating party, is responsible for dealing with the consequences of earthquakes. Therefore a value regulation is set up by the NAM that compensates homeowners. Numbers of the NAM show that approximately 900 houses need to be compensated for. The costs estimation of this compensation amounts to 5 million euro [16], [17].

4) Buying instrument: If a house is impossible to sell due to the earthquakes, NCG has a budget of 10 million euro to buy houses. In this way homeowners are able to sell their house to the NCG [18]. Estimations show that with this budget approximately 50 houses can be bought [25].

5) Standard of living enhancement: To deal with the negative image of the region, the NAM has provided a budget of 65 million euro. This budget is managed by Economic Board Groningen. With this budget investments are made in projects like fast internet connection, public transport or sport facilities [6], [20].

6) Renewable energy investment: Even after the stop of gas production in 2030, Groningen wants to remain the leading energy providing province. Collaboration North-Netherlands (SNN) provides a budget of 10 million euro for investment in renewable energy. Homeowners can claim a share of the budget for investing in renewable energy technologies in their houses. Approximately 10.000 houses can be reached with this budget [28].

7) Local job creation: Groningen has to deal with higher unemployment compared to other provinces [33]. To fight unemployment the 1000 job plan is created. This plan focuses on creating jobs in the building and technology sector. In this way jobs are created and at the same time the newly created workers can repair the damage caused by the earthquakes [21].

B. Risk acceptance

After selecting the preferred mitigation measures, participants in the web tool have to answer questions on risk acceptance. In the end these questions are used to determine risk acceptance scores and answers the research question. As mentioned in the introduction, risk acceptance of induced earthquakes differs from natural earthquakes. Not only characteristics of the hazard play a role, but also social and economic factors. Six acceptance factors are known to have most effect on shaping risk acceptance. These factors are: perceived risk, perceived benefits, trust in authorities, direct experience, media coverage and knowledge [36]. In the context of this research media coverage and knowledge are excluded. The contribution of media coverage to risk acceptance is unsure and therefore excluded. Knowledge is hard to measure because often a participant's perception of his knowledge is measured instead of actual knowledge. The final selection of risk acceptance factors includes:

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

C. Design of the web-tool

As mentioned, the PVE method uses a web tool to gather data. For designing the web tool, Sophie Pak constructed methodological steps [23]. In this research the steps are followed as shown in figure 1. A visualisation of the design of the instruction and information pages can be found in appendix A of the thesis report.

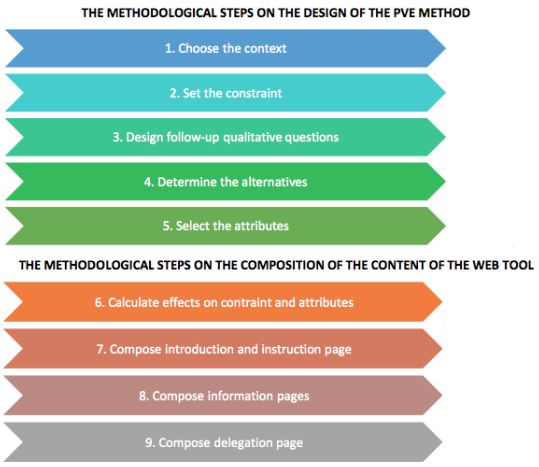

Fig. 1. Methodological steps for PVE-design[23]

First the context of the case is selected. In this research the context is the situation of earthquakes in Groningen caused by gas production as explained in the beginning of section III. In this research participants had to select mitigation measures within a budget constraint. In previous PVE research participants were able to adjust the budget, however in this research is chosen for a fixed budget. A fixed budget excludes a willingness-to-pay aspect, which would be included when the budget can be adjusted by raising tax. The budget was set to 250 million euro. In this way participants were able to select the mitigation measures they believed to be most urgent; while at the same time not all measures could be selected, forcing the participants to make a choice. Because finding enough participants was believed to be an issue, the possibility of delegating the decision was left out in this research. Participants unwillingly to participate were able to stop with the experiment at any moment.

The alternatives in this research are the mitigation measures that can be selected. The attributes are the characteristics of the measures. Both are described in section III.A. After selecting preferred measures, participants had to answer the follow-up questions. These questions include the statements used to determine the risk acceptance scores. Statements were set up using the Likert-scale. Participants had to state their level of agreement with the statements. Besides the risk acceptance statements, demographic questions were asked to determine the background of the participants and whether the sample of participants was a representative sample of society. An overview of the included statements and questions can be found in appendix A of the thesis report.

IV. Results

On April 9th 2019, the web tool was first distributed via Facebook groups related to the case. Because not many participants were gathered, 500 flyers were distributed in Groningen on April 20th 2019. Besides the distribution of flyers was decided to spread the web tool outside Groningen within the researchers network. On May 7th 2019 the

data-gathering period ended. In total 49 participants were gathered. The web-tool was opened 247 times, which means a participation rate of 19,83%

A. Demographics of respondents

Comparing the demographics of the respondents with the Dutch average shows distinct differences. The age group between 20-40 is much larger for the participants. While the group with young and elderly people is lower among the respondents [3]. This makes sense because most of the participants were gathered within the researchers network, besides the tool was distributed via social media, which are less used by elderly people.

Comparing the education shows that the sample of participants is highly educated compared to the national average. The lowest completed education of participants is secondary vocational education (MBO), while nation-wide 29% of the people is less educated. Almost half of the participants have an academic education (WO), while only 9% of the country has an academic education. Participants with higher vocational education (HBO) double the average number [3]. The number of highly educated respondents can be explained by gathering respondents within the researchers network. Of the participants 34,8% resides in Groningen.

B. Factor analysis results

To check whether the statements on the risk acceptance factors measure the same factor, factor analysis is conducted. The used extraction method is principal axis factoring. This method assumes that the statements are not perfectly constructed and that the statements leave room for unique variance. As rotation method direct oblimin is selected. Rotation simplifies the interpretation of the results. This method is used because there is believed correlation between the statements. With factor analysis, factors with eigenvalues greater than 1 are searched for. These factors can explain the communality between the different statements. When the factors with eigenvalues greater than 1 are found the factor loadings are checked. If a statement has a minimal factor loading of 0.4, the statement is included. [32], [34].

For the perceived risk statements there is one factor with an eigenvalue of 2.993. The other factors are lower than 1. This means that there is one factor that explains the communality between the statements; therefore this factor can be called perceived risk. All the statements have a factor loading higher than 0.4, which means that they can all be included. For perceived benefits the result is the same. One factor with an eigenvalue of 2.242 exists, the other factors have an eigenvalue lower than 1. All the perceived benefit statements have a factor loading higher than 0.4 and are therefore included.

To construct risk acceptance scores, the conditions as explained in section II.C have to be met. The statements are constructed in a way that only the reliability has to be checked. For both perceived risk and perceived benefit the Cronbachs alpha is higher than 0.7, which means that sum score can be used. To create a risk acceptance score, the scores of the statements are added up and averaged. Finally the different risk acceptance factors are divided into three equal categories using cut-off points. A low-, medium- and high-score group is created for perceived risk, perceived benefit, low trust in the government and low trust in the NAM. Direct experience is asked with a yes/no question and is therefore not divided into a category. An overview of all the SPSS output can be found in appendix C of the thesis report.

C. Logistic regression results

After creating the risk acceptance score categories, the effect of the risk acceptance on the selection of risk mitigation is checked using logistic regression. The selection of a mitigation measure is considered as a dependent variable. Logistic regression checks whether indicator variables have a significant effect on the selection of this dependent variable. First the chi-square test is considered. This test checks whether a model with the indicator variables included is a better predictor of the selection of the dependent variable than a model with just a constant. A p-value of 0.05 is used. To predict whether the model has a good fit with the data, the Nagelkerke R-square test is performed. To use the chi-square test the following conditions need to be met [29], [26].

1) No more than 20% of the expected counts are less than 5
2) All individual counts are 1 or greater

After conducting the chi-square and the Nagelkerke R-square test, the Wald statistics are used to check the effect of the individual risk acceptance factors. Again a p-value 0.05 is used [29], [26].

Looking at the chi-square test only models for the selection of damage compensation, value regulation and local job creation are statistically significant. For the other mitigation measures, a model with all the risk acceptance factors included has no significant effect on whether the measure is selected. Looking at the individual risk acceptance factors, some of the factors have a significant effect on the selection of a specific measure. 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, while they are less likely to select local job creation. 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. For the other risk acceptance factors trends can be noticed, but none have a statistically significant effect on the selection of risk mitigation. Results seem to show that people with higher perceived risk, lower perceived benefit and lower trust in authorities are more likely to select measures that directly target the consequences of the earthquakes such as damage compensation or structural reinforcement. While people with higher perceived benefit and higher trust in authorities seem to be more likely to select measures that target the indirect consequences of the earthquakes such as enhancement of living standards and the image of the region. This is confirmed by qualitative results of the web tool.

Figures 2 and 3 show the trends of trust in the two authorities influencing the selection of structural reinforcement, which is considered as a direct measure and the selection of standard of living enhancement, which is considered as in indirect measure. People with lower trust are less likely to select standard of living enhancement. Figure 4 shows the influence of perceived benefit on the selection of standard of living enhancement. Higher perceived benefit leads to more selection of this indirect measure. A complete overview of all the trend figures is displayed in chapter 9 of the thesis report. All the SPSS output of the logistic regression is displayed in appendix D of the thesis report.

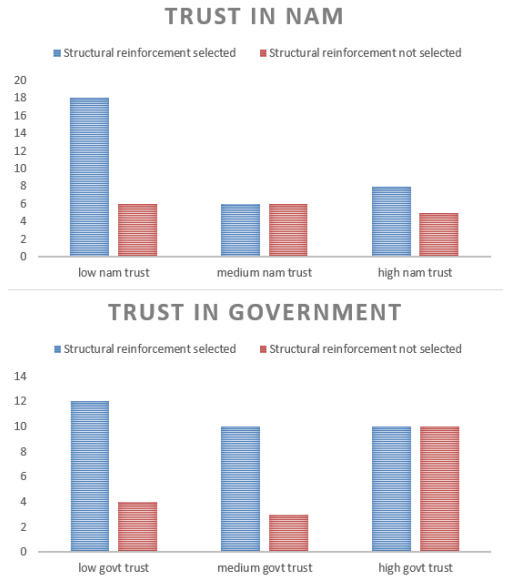

Fig. 2. Influence of trust in authorities on selection of structural reinforcement

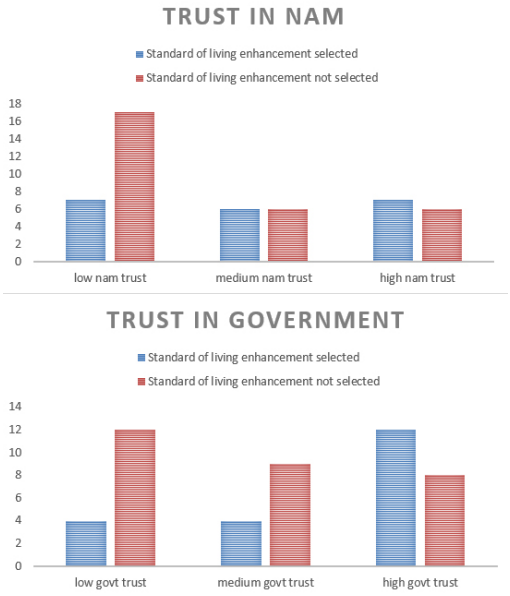

Fig. 3. Influence of trust in authorities on selection of standard of living enhancement

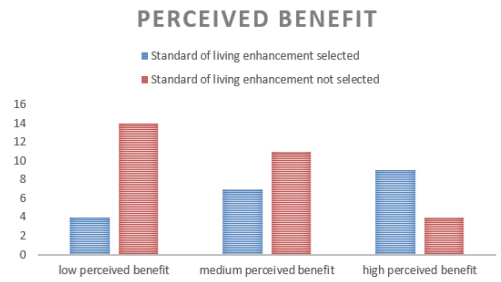

Fig. 4. Influence of perceived benefit on selection of standard of living enhancement

V. Conclusions

Conducting a literature review on risk acceptance showed that risk acceptance of natural hazard differs from induced hazards. Acceptance of natural hazard risks depends mainly on the exposure to the hazard and the size of the hazard. Induced hazards are perceived as man-made and controllable, therefore risk acceptance of induced hazards is also shaped by social and economic factors. To control the risks of induced earthquakes, the government and the NAM, as operating authorities, tried to implement mitigation measures, however the implementation has not been effective so far. To improve the effectiveness of implementation, authorities should take differences in risk acceptance into account. Conducting research using the PVE method has shown effects of risk acceptance on the selection of risk mitigation. People with lower trust in authorities and people who have higher perceived risk are more likely to prefer mitigation measures that directly target the consequences of the hazard, while people with higher trust in authorities or higher perceived benefits are more open for other mitigation measures; for example measures that enhance living standards or the image of a region. Implementing these findings means that an authority implementing mitigation measures in a community with low trust or high perceived risk is more likely to successfully implement the measures when it is directly targeting the hazard.

Another goal of this research was to further develop the PVE method. Previous research showed that the PVE method can be used for community involvement. In this research finding enough participants turned out to be difficult and some of the participants mentioned the web-tool to be unrealistic. They stated that an online-tool is a charade and cannot be used to involve the community in this topic. Based on the findings is concluded that in a sensitive topic people want to see results and are not willing to participate in PVE research. This is also shown by the fact that PVE is known for a low participation threshold, but in this loaded topic this turned out to be not the case.

VI. Discussion

Based on the conducted research, this section describes the choices and assumptions made during this research. The first step of this research was the selection of risk acceptance factors. The factors known to have most impact on the

acceptance of induced risk were selected. Media coverage and knowledge were left out because they were difficult to measure. The results of this research show that a correlation between the risk acceptance factors is possible. A high score on one of the acceptance factors may be correlated with a high score on another factor. This might have been caused by an underlying factor. For future research it would be interesting to see whether this underlying factor is one of the left out factors.

The second step of the research was the selection of the mitigation measures and their characteristics. The selection was done based on an existing mitigation package to make the research as realistic as possible. Most of the measures are yet to be implemented, therefore assumptions had to be made on the costs and reach of the measures. These assumptions led to large costs differences between the measures, which may have led to over-selection of the cheapest measures because participants had budget left. Validity of the research can be improved by repeating the same research with different characteristics. In this research a fixed budget constraint was used for the PVE method. The height of the budget may have affected the selection of mitigation measures. Future research should use different budgets to improve the validity.

While conducting the research an issue occurred with finding enough participants. In total, 49 participants were gathered. This was not enough to gather statistically significant results. Besides lacking significant results, most of the participants were gathered within the researchers network. This led to a highly educated sample, which is not diverse and not comparable with society. The lack of diversity may have affected the risk acceptance scores. Future research should focus on repeating the research with more participants to improve the validity of the results.

The low number of participants may have been caused by the sensitivity of the topic. Trust in authorities is low for the local communities and they may not be willingly to participate in more research. A downside of the PVE method was the lack of responsiveness of the web tool for mobile phone use. As the web tool was distributed via social media, this may have been a reason for the low number of participants.

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