Paper:

A Quantitative Estimate of Vulnerable People and Evaluation of Flood Evacuation Policy

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Disaster Risk Management (DRM) laws and policies ideally contain measures to reduce disaster risk to all exposed people equally, even the most vulnerable people. To investigate this, we estimate the number of potentially vulnerable people in areas exposed to flood hazard, and evaluate the laws and policies which aim to reduce vulnerability. We proposed a theoretical framework based on four recognized characteristics of vulnerability (less physically or mentally capable; fewer material and/or financial resources; less access to information, and restricted by commitments) and created indicators for six groups of potentially vulnerable people: children, older adults, minorities, people with disabilities, people living in poverty, and women. We applied the framework to the populations of Japan, the Netherlands, and the United States, and proposed a new DRM policy evaluation method; and found that measures in DRM laws and policies are not in proportion to the number of potentially vulnerable people. The most numerous indicators included children aged 0-14, women with no car, and people with pets. The top ten indicators account for 80% of all potentially vulnerable people. When addressing the needs of vulnerable people from a policy perspective, these top ten indicators may serve as a starting point in order to increase the resilience of the vulnerable population. Seven of these ten are identical across the three case study countries, meaning the countries can learn from each other's measures and possibly apply them in their own area. Policy evaluation showed that while many laws and policies do recognize various groups of potentially vulnerable people, they lack detailed support measures. Much remains to be amended in policies on all scale levels if the policies are to realize an equal disaster risk for all exposed people.

Keywords: disaster risk management, vulnerable people, social vulnerability, flood, evacuation

1. Introduction

The number of people affected by natural hazards is increasing and has already reached an average of 231 million people annually [1]. Floods are a major contributor to both losses of life and economic losses from disasters, and the expectations are that the frequency and intensity of floods will increase in the future [2]. Trends show that losses of life due to floods are decreasing while damages are increasing [3]. However, not all people are affected equally, for the extent of mortality risk may depend on intrinsic vulnerability to floods. In order to formulate effective policies and procedures to increase resilience, disaster managers must understand the natural and societal factors that influence vulnerability [4].

Managers and analysts often assume that exposure and vulnerability are either synonymous or highly related. There are many vulnerability studies that treat vulnerability as exposure and forego differentiating between people's characteristics and circumstances which are independent of exposure. For instance, the global exposure study [5] assessed vulnerability as exposure. Another example is assessment that does consider a difference between exposure and those experiencing damage, but neglects to consider why affected people experienced damage [6].

Assuming identical vulnerability across all exposed people may oversimplify the inherently variable nature of vulnerability. As vulnerability can be intrinsic to the individual, it may vary across an exposed population [7]. Definitions of vulnerability should encompass the intrinsic vulnerability of individuals, including that of non-self-reliant people, and should be distinct from exposure. Vulnerability must not only relate to exposure or the susceptibility of the exposed elements, but also to social characteristics [8]. Therefore, it is necessary to have a distinction between physical vulnerability arising from exposure, and social characteristics related to vulnerable people existing in exposed areas [9]. However, what these social characteristics are remains a subject of debate.

There are several identified individual characteristics associated with increased susceptibility to harm from nat-

ural disasters. For instance, Lindsay [10] refers to social, economic and physical characteristics; the UNISDR [11] cites the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard; and Wisner [12] describes detailed examples including gender, age, physical and mental health status, occupation, marital status, sexuality, race ethnicity, religion, and immigration status. Up till now there is no consensus on which characteristics influence vulnerability and to which extent, and therefore, who are considered to be vulnerable people. To create effective DRM policies, the population vulnerable to possible hazards has to be identified.

1.1. Definition of Vulnerable People

In this research, we define vulnerable people as those who have one or more characteristics that make them more susceptible than others in a community and who therefore require extra DRM measures in order to have the same level of risk as others [13]. Additionally, we define a group of potentially vulnerable people as a group of people who share an aspect that distinguishes the group, such as age or ethnicity, and a majority of whom have one or more characteristics of vulnerable people. The specific use of *potentially* vulnerable people is crucial. For example, using age as an indicator of vulnerability implies that all people of a certain age are vulnerable, which may not be the actual case. Many of the indicators used to measure social vulnerability are factors that only *potentially* make people vulnerable.

Within this article, we focus on measures for vulnerable people in exposed areas. We adopt the UNISDR [11] definition of vulnerability, which distinguishes vulnerability from exposure (**Fig. 1**). While part (or even all) of a given area (e.g., country, region, river basin, or community) can be exposed to a hazard, the population can be seen as consisting of vulnerable people and self-reliant people.

1.2. Causes of Vulnerability

We find a remarkable difference when we compare risk tolerance and treatment of vulnerability across different fields of study. In public health and environmental risk assessment, the goal is to prevent damage by chemical compounds to either the environment or to all humans equally. To enable this, a no-effect concentration of a compound is calculated for vulnerable populations, such as infants; and a safety factor of 10 is applied for every unknown step [14]. In this way, risk assessment addresses the needs of the most vulnerable sectors of the population.

By contrast, disaster risk studies often assume the average vulnerability of an entire population. Past disaster data shows that the convention of basing policy decisions on average vulnerability of a population may not sufficiently protect the most vulnerable and may lead to gross inequity with regard to disaster risk. For instance, data from disasters in the Netherlands, USA, and Japan (Kuijvenhoven [15]; Honkawa [16]; Statistics Bureau [17]; Brunkhard et al. [18]; United States Census Bureau [19])
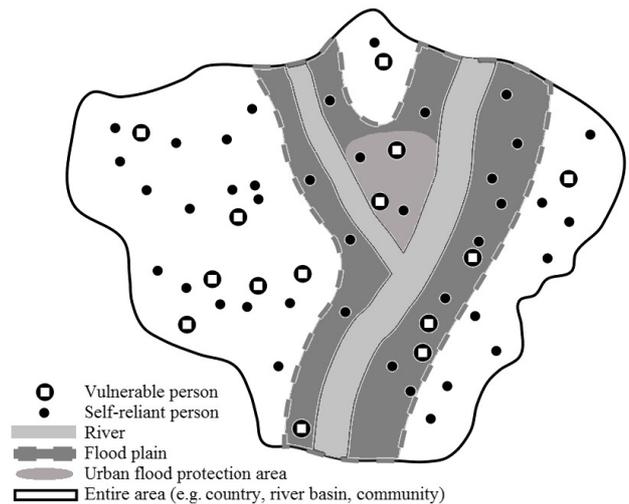

Fig. 1. Schematic visualization of vulnerable people in an area exposed to floods.

show that a certain age is associated with a higher mortality rate (**Fig. 2**). Other studies have revealed characteristics that influence mortality; including gender [20], ethnicity [18], and living in a developing country [21].

A great shortcoming of disaster risk management policies is that the social characteristics leading to vulnerability remain largely unaddressed. Evacuation plans are often based on the assumption that exposed people are physically and mentally able to evacuate themselves, and have access to certain resources and information. A survey in the USA showed that 80% of emergency managers had not adapted their plans by implementing measures for people with disabilities [22]. Japan has only recently begun to pay attention to people with different physical conditions and evacuation awareness [23]. If we truly want to realize an equal disaster risk management policy for all exposed people, the root causes of vulnerability must be addressed by investigating these social characteristics in more detail.

1.3. Problem Statement

While there are numerous vulnerability indices that take social characteristics into account when calculating the average vulnerability of a population [24–26], these indices do not use the characteristics as indicators to estimate the number of potentially vulnerable people in a population. The lack of quantitative vulnerability assessments causes great challenges to analyzing and addressing vulnerabilities [27].

Furthermore, the Hyogo Framework for Action [28] has called for the development of standards, indicators and indices for disaster risk and vulnerability. While this has prompted countries to develop laws and policies to reduce vulnerability, there is as of yet no tool to evaluate the effectiveness of these laws in reducing the vulnerability of vulnerable people.

We assume that evaluating examples from different countries might provide a variance of examples to be ap-
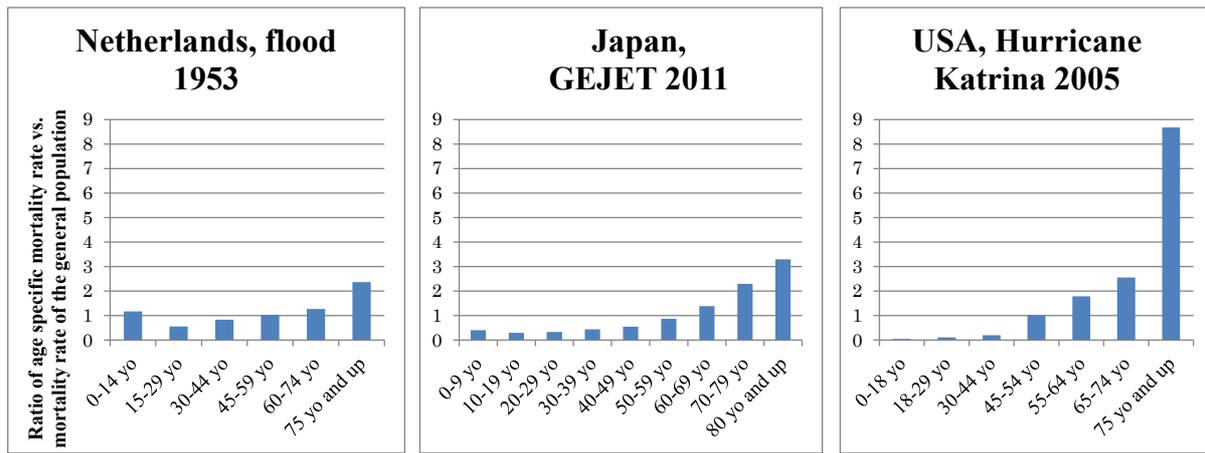
Fig. 2. Ratio of age specific mortality rate compared to mortality rate of the general population from three disasters in the Netherlands (Oude and Nieuwe Tonge) [15], Japan (Great East Japan Earthquake and Tsunami GEJET, coastal cities in the prefectures Iwate, Miyagi and Fukushima) [16, 17], and the United States (New Orleans Parish) [18, 19].

plied to areas lacking in support measures for vulnerable people.

The objectives of this research are to construct and evaluate indicators of vulnerability in order to estimate the number of potentially vulnerable people. Therefore, we compare DRM policies in three case study countries, scoring each policy according to thoroughness of measures taken to assist vulnerable people. In this research, we focus on the hazard of flooding and the response phase of disaster management, assuming an exposed population for whom evacuation has been ordered.

2. Methods

2.1. Developing a Framework of Vulnerability Indicators

Based on a thorough review of disaster data and literature, we describe the characteristics of vulnerable people as: 1) less physically or mentally capable; 2) fewer material and/or financial resources; 3) less access to information, and 4) restricted by commitments [7, 9, 12, 29–32]. While certain circumstances may lead to vulnerability, these circumstances are not necessarily the equivalent of vulnerability [7]. Thus, our proxies indicate groups of potentially vulnerable people. For example, 'older adults' (those > 65 y.o.) constitute a group with many vulnerable people as members, but not all older adults are vulnerable people. We propose indicators for six groups of *potentially* vulnerable people, attuned to the hazard type of floods and evacuation phase of flood disaster. The six groups are 1) children, 2) older adults, 3) minorities (ethnic), 4) people with disabilities, 5) people living in poverty, and 6) women. People may belong to multiple groups of potentially vulnerable people simultaneously. Such individuals may be vulnerable in multiple ways, and therefore require multiple measures on their behalf.

As risk, vulnerability, and adaptive capacity are hazard-specific [33], we choose to focus on only one hazard type.

The emphasis on defining indicators specific to different phases of disaster management is crucial to addressing the root causes of vulnerability and identifying which measures could be taken to reduce vulnerability at various stages of a disaster. We focus on the response phase, as this is the time most associated with disaster mortality.

We evaluate indicators for each of six groups of potentially vulnerable people across the four characteristics of vulnerable people (**Table 1**). We proposed the indicators following a thorough literature review covering several requirements. The chosen indicators had to be relevant to the theoretical framework, have a narrow scope and be objectively understandable. The data on indicators had to be measurable; available from reliable, valid sources; reproducible; and sensitive to dynamic aspects (changing over time). Measurability and validity significantly decreased the number of indicators as we used governmental statistics. Data availability was hampered by ambiguous data and power-related issues such as the need to provide data contributing to a positive image. We found it is particularly difficult to obtain information on disaster victim and disability information in Japan, as these are considered private and are therefore often not publically available (as encountered by [23]).

As people may simultaneously belong to multiple groups of potentially vulnerable people and experience multiple vulnerability characteristics, the indicators lead to overlap. For instance, there are the indicators 'people with disabilities and no car access,' and 'older adults over 65 years old and having multiple disabilities.' Such an overlap can only be prevented in future research by collecting data on an individual level. This study shows the limited possibilities of the currently available data and the necessity of collecting more data on an individual level.

The three case study countries where the indicators were to be evaluated further influenced the development of the indicators. Vulnerability indicators should differ by area as vulnerability represents both biophysical risks and social responses which differ by area [32]. This implies

Table 1. Framework for selecting indicators per characteristic and group of potentially vulnerable people.

Characteristic	Group of potentially vulnerable people	Indicator
Fewer material and/or financial resources	Children	Living in household without car access
	Older adults	No car ownership
	Minorities (ethnic)	No car ownership
	People with disabilities	No car ownership
	People living in poverty	No car registered to name in the lowest income category
	Women	No car ownership
Less physically or mentally capable	Children	Under certain age
	Older adults	Above 65 years old and disabilities
	Minorities (ethnic)	Restrictive clothing
	People with disabilities	People with physical and/or mental disabilities, chronic or temporary
	People living in poverty	(None)
	Women	Cultural travel restrictions, pregnancy
Less knowledge or experience	Children	No EWS at schools
	Older adults	Experiences leading to evacuation reluctance
	Minorities (ethnic)	Unfamiliar with local area/ language
	People with disabilities	No earlier warning for prolonged evacuation time at nursing homes
	People living in poverty	No access to EWS
	Women	No access to EWS
Restricted by commitments	Children	Caregivers of children
	Older adults	Caregivers of older adults
	Minorities (ethnic)	People with ties to the local area
	People with disabilities	Caregivers of people with disabilities
	People living in poverty	People unable to leave possessions
	Women	Caregivers of pregnant people
	People with animal dependents	Pet owners, livestock owners

that comparison of vulnerability between countries is only possible if the biophysical risk and social responses are comparable.

2.2. Selecting the Case Study Countries

We selected Japan, the Netherlands and the U.S. as case study countries. All developed countries with considerable flood hazards and different flood risk management approaches, these democratic societies also prioritize social rights, and have long histories of DRM laws. For all three countries it is expected that the percentage of older adults will increase sharply in the future [34–36]. Additionally, information on relevant DRM policies and reliable data sources for evaluating most indicators is available.

2.3. Differences in Using Cars for Evacuation

Regarding the focus on car ownership, in the Netherlands the natural hazard with the most severe possible consequences is flooding. The worst case scenario studies of a potential dike breach in the West of the country show 200,000 deaths and over 400 billion euro in damages. Since over 60% of the country lies below sea level and much of the land is reclaimed from the sea, evacuation is the preferred action when floods occur. More specifically, 81-94% of inhabitants expected to use their own transportation to evacuate in case of a flood [37]. While

there are many types of evacuation from floods (such as horizontal evacuation to shelters within the exposed areas or to safe areas outside the floodplain; vertical evacuation to higher levels within the residence/building), there are no shelters prepared for floods in the Netherlands.

Along this line, evacuation simulations from the Dutch Programma Nationale Veiligheid [38] assume that people will evacuate by car and they are at home when the evacuation orders are given. Given the dependence of evacuations on car availability, we viewed car ownership as an important indicator of evacuation success for the Netherlands.

Hurricane hazards in the USA often cause floods and most commonly lead to evacuations. A flood warning system and regulations for evacuation by car are in place in the USA. While there is a great difference between federal and state or municipal hazard preparedness, there is great attention in policies for potentially vulnerable people. The American National Incident Management System [39] even describes the 'special needs population' as those in need of transportation, and the 'individuals in need of additional response assistance' as including people who are transportation disadvantaged.

In Japan, evacuations by car have been strongly discouraged by the government since the Great East Japan Earthquake and Tsunami in March 2011, when many people became stuck in traffic jams while trying to evacuate, but drowned. Therefore, the indicator of car ownership is

kept for comparative purposes.

2.4. Statistics of Vulnerable People

Using the indicators from **Table 1**, we estimated the number of potentially vulnerable people per indicator in each country, using information from governmental statistic and research agencies.

Most data were obtained directly from governmental statistics (the central bureaus of statistics and governmental research agencies in the respective countries). Other sources included ministerial research reports and related research theses, national police agencies, and local research agencies contracted by the government. We estimated some data, including: 'restrictive clothing,' 'cultural travel restrictions,' and 'no access to EWS (television in household)' for women. For the characteristic 'less physically or mentally capable' and the group 'people living in poverty' we unfortunately could not identify a proper indicator. We harmonized the data according to the 2010 populations and converted the numbers of people to percentage of total population. We evaluated 26 indicators of vulnerability and estimated the percentage of population belonging to each indicator, group, and characteristic.

We did not consider religious or sexual/gender identity minorities, as well as people with service animals and rescue personnel, due to lack of data and/or smaller number of people. We did consider people with pets and livestock owners, as various literature and policy sources indicated that the number of people belonging to these groups might be significant for evacuation operations. We would like to note that we do not consider pregnancy not being in a good physical or mental condition; rather that it requires extra physical care.

2.5. DRM Policy Evaluation Method

We proposed a new DRM policy evaluation method, to determine the extent to which laws or policies include measures supporting specific groups of vulnerable people. We proposed a five-point evaluation method [40], and applied the following scoring system:

1 No mention of groups of potentially vulnerable people

2 Recognition of a group of potentially vulnerable people

3 Specific measures taken to reduce the vulnerability of potentially vulnerable people

4 Anticipation of future trends in numbers of potentially vulnerable people

5 Involvement of potentially vulnerable people in policy formulation

Scoring is cumulative, meaning that to obtain a score of 5, policies also must satisfy previous conditions (with the exception of 1) (**Table 2**). The scoring method is illustrated by three examples in section 3.

We limited our scope to DRM laws and polices focused on floods and evacuation, in relation to the six main identified groups of potentially vulnerable people and the indicators for evacuation. Though other laws related to human rights, health care, spatial planning, finances, and education also influence vulnerability; these laws do not directly influence vulnerability during evacuation, and are thus outside the scope of this research. We obtained national laws from governmental law databases [41–43]; national policies from ministerial websites; and regional policies from governmental research or consultancy agencies. We selected keywords to search databases, including 'disaster,' 'flood,' 'vulnerable people' and words relating to the six groups of potentially vulnerable people; the Japanese and Dutch equivalents were applied in the respective countries. We made equal effort to find all the relevant disaster policies in each country.

We selected two local regions in each country for the evaluation of policies; namely Rotterdam-Rijnmond (1.2 million inhabitants), western Netherlands; Twente (0.6 million inhabitants), eastern Netherlands; Sanjo city (over 100,000 inhabitants), Niigata Prefecture, western Japan; Chikusei city (over 100,000 inhabitants), Ibaraki Prefecture, eastern Japan; New Orleans (over 1 million inhabitants), Louisiana, southeastern U.S.; and Hillsborough County (over 1 million inhabitants), Florida, southeastern U.S.. The selected communities are primarily urban and located in areas of moderate to high flood risk. We deliberately chose regional areas likely to have policies focusing on vulnerable people. This served two purposes: first of all to guarantee the availability of policies with suitable measures for evaluation; secondly to find policy measures that may serve as examples for other areas where policies for vulnerable people are less well established.

3. Results

3.1. Statistics of Potentially Vulnerable People

In all three countries, we find that potentially vulnerable people comprise a considerable proportion of the population. Overall, people with the characteristics "fewer material and/or financial resources" and "restricted by commitments" are the most numerous, while fewer vulnerable people are associated with the characteristics "less access to information" and "less physically or mentally capable."

We find that in all three countries, the top ten indicators based on numbers of potentially vulnerable people describe 80% of all potentially vulnerable people (**Figs. 3-5**). Seven of these ten indicators are identical across the three case study countries, namely: women with no car access, people with pets, people with disabilities, people with low or no literacy skills, children 0-14 years old, caregivers of children, and caregivers of people with disabilities.

While many indicators in the top ten are the same

Table 2. Evaluation metric of national, regional and local disaster risk management laws and policies of the Netherlands, Japan and the United States.

Country	Scale	Law/policy title	Year	1	2	3	4	5
Netherlands	(Inter) National Laws	European Flood Directive	2007	O				
		Water Law	2009	O				
		Law Safety Regions	2010	O				
		Delta Law	2012	O				
		Law of Population Displacement (inactive)	1952			O		
	National Policies	National response plan high water and floods	2007	O				
		Guidance Information for evacuations in flood events and flooding	2008				O	
		National crisis plan high water and floods	2008			O		
		National guidance manual for high water and floods	2010		O			
	Regional Policies	Policy Plan Rotterdam Rijnmond	2012		O			
		Regional Crisis Plan Rotterdam Rijnmond	2009		O			
		Regional Risk Profile Rotterdam Rijnmond	2012		O			
		Policy Plan Twente	2012		O			
		Regional Crisis Plan Twente	2011		O			
		Regional Risk Profile Twente	2011		O			
Japan	National Laws	Disaster Countermeasures Basic Act	2013		O			
		River Law	1999		O			
		Flood Fighting Law	2005		O			
	National/ Prefectural Policies	Committee for policy planning on disaster management final report	2012			O		
		Action Policies for Supporting Evacuation Activities of Persons Needing Assistance During Forced Evacuations	2013			O		
		Niigata Prefecture regional disaster management plan (Wind & Flood)	2013				O	
		Ibaraki Prefecture regional disaster management plan (Wind & Flood)	2010			O		
	Regional Policies	Sanjo city flood disaster manual	2005				O	
		Sanjo City Area Disaster Prevention Plan	2012				O	
		Chikusei City Local Disaster Management Plan [summary version]	2013			O		
		Disaster Prevention Measures at Chikusei City	2012			O		
United States	National/ State Laws	Stafford Disaster Relief and Emergency Assistance Act	2013			O		
		Louisiana Homeland Security and Emergency Assistance and Disaster Act	2009			O		
	National/ State Policies	National Response Framework	2013			O		
		National Incident Management System	2008		O			
		Governor's Office of Homeland Security and Emergency Preparedness Strategic Plan	2013			O		
		State of Louisiana Emergency operations plan	2009			O		
		Florida State CEMP Basic Plan	2012		O			
	Regional Policies	Orleans Parish 2010 Hazard Mitigation Plan update	2010			O		
		Current Local Mitigation Strategy Document Hillsborough County	2009				O	

across the three countries, we note variability in the rankings of 'people living in poverty with no car.' In the USA, this is the top indicator, comprising 27% of the total population, while it is ranked as number 9 and 13 in the Netherlands and Japan (representing 6% and 3% of the population respectively). Another indicator which varies between nations is 'minorities (ethnic) no car,' which is 12% in the Netherlands, 5% in the USA and only 1% in Japan.

When comparing the top indicators of potentially vulnerable people, in both Japan and the Netherlands the top two results are women with no car and people with pets. By contrast, these indicators rank at number 5 (women with no car) and 9 (people with pets) in the USA.

Furthermore, in both Japan and the USA 'children aged 0-14' appear in the top three most numerous indicators whereas children are ranked number 7 in Netherlands. In all three countries two indicators were found to have 0 potentially vulnerable people; namely children at schools without EWS and women experiencing travel restrictions.

3.2. Laws and Policy Evaluation

Table 2 shows the results of the policy evaluation for vulnerability related laws in the three case study countries. The laws and policies are ordered by scale from national to regional for each country. Due to the lack of concrete measures or concrete definitions of groups of potentially vulnerable people in the laws and policies, the
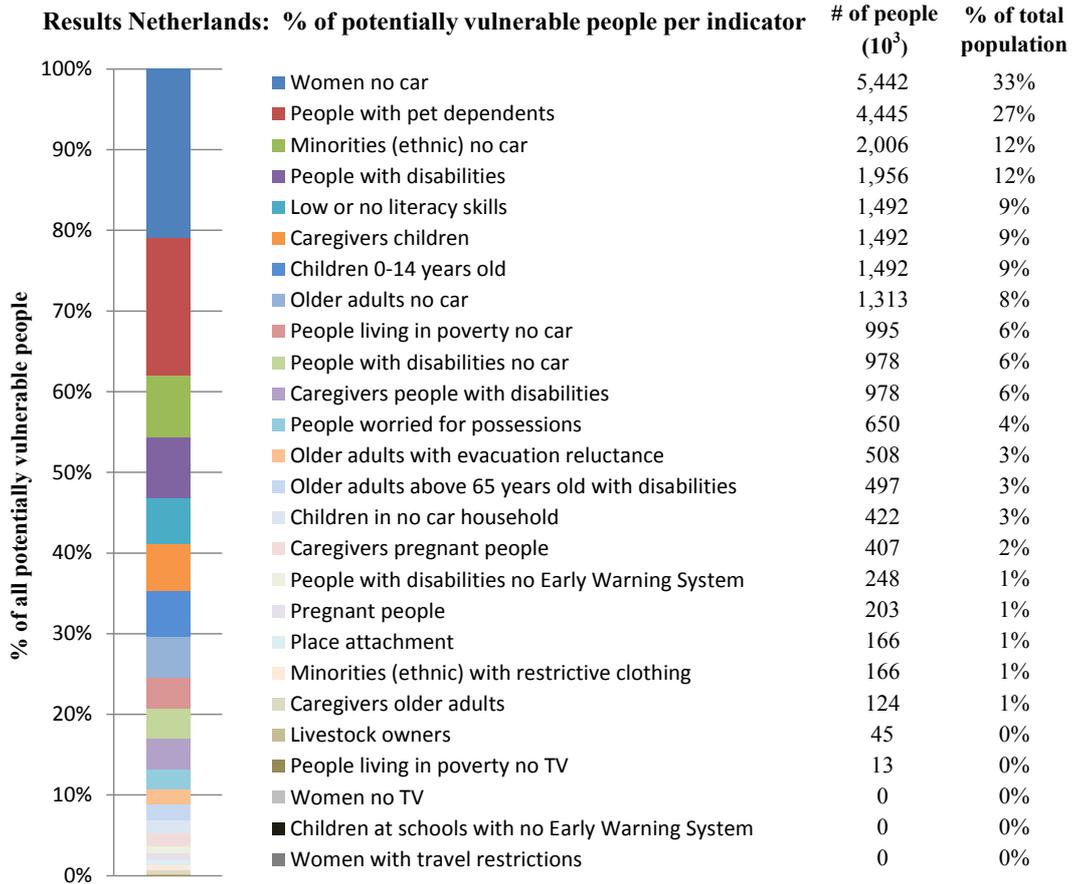
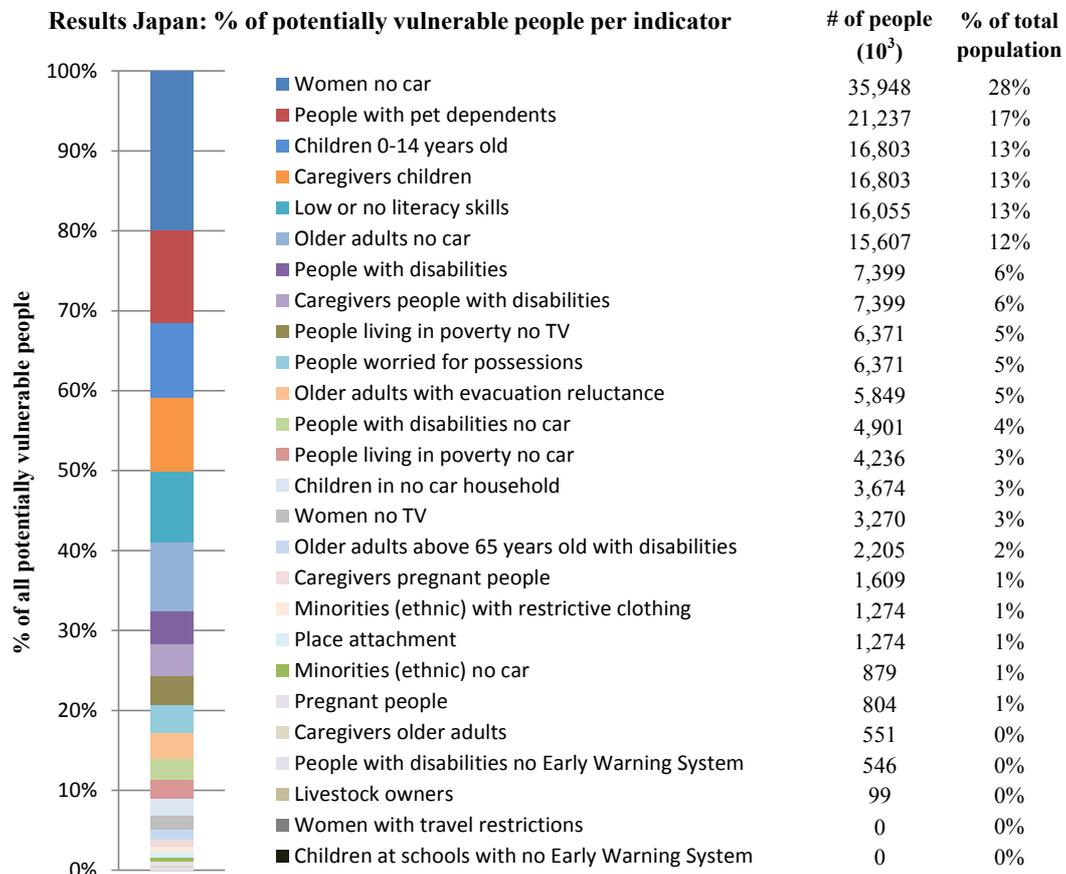**Results Netherlands: % of potentially vulnerable people per indicator**

	# of people (10³)	% of total population
Women no car	5,442	33%
People with pet dependents	4,445	27%
Minorities (ethnic) no car	2,006	12%
People with disabilities	1,956	12%
Low or no literacy skills	1,492	9%
Caregivers children	1,492	9%
Children 0-14 years old	1,492	9%
Older adults no car	1,313	8%
People living in poverty no car	995	6%
People with disabilities no car	978	6%
Caregivers people with disabilities	978	6%
People worried for possessions	650	4%
Older adults with evacuation reluctance	508	3%
Older adults above 65 years old with disabilities	497	3%
Children in no car household	422	3%
Caregivers pregnant people	407	2%
People with disabilities no Early Warning System	248	1%
Pregnant people	203	1%
Place attachment	166	1%
Minorities (ethnic) with restrictive clothing	166	1%
Caregivers older adults	124	1%
Livestock owners	45	0%
People living in poverty no TV	13	0%
Women no TV	0	0%
Children at schools with no Early Warning System	0	0%
Women with travel restrictions	0	0%

Fig. 3. Results Netherlands: % of potentially people per indicator.

Results Japan: % of potentially vulnerable people per indicator

	# of people (10³)	% of total population
Women no car	35,948	28%
People with pet dependents	21,237	17%
Children 0-14 years old	16,803	13%
Caregivers children	16,803	13%
Low or no literacy skills	16,055	13%
Older adults no car	15,607	12%
People with disabilities	7,399	6%
Caregivers people with disabilities	7,399	6%
People living in poverty no TV	6,371	5%
People worried for possessions	6,371	5%
Older adults with evacuation reluctance	5,849	5%
People with disabilities no car	4,901	4%
People living in poverty no car	4,236	3%
Children in no car household	3,674	3%
Women no TV	3,270	3%
Older adults above 65 years old with disabilities	2,205	2%
Caregivers pregnant people	1,609	1%
Minorities (ethnic) with restrictive clothing	1,274	1%
Place attachment	1,274	1%
Minorities (ethnic) no car	879	1%
Pregnant people	804	1%
Caregivers older adults	551	0%
People with disabilities no Early Warning System	546	0%
Livestock owners	99	0%
Women with travel restrictions	0	0%
Children at schools with no Early Warning System	0	0%

Fig. 4. Results Japan: % of potentially people per indicator.

Results USA: % of potentially vulnerable people per indicator

	# of people (10³)	% of total population
People living in poverty no car	82,250	27%
Children 0-14 years old	61,227	20%
Caregivers children	61,227	20%
People with disabilities	58,774	19%
Women no car	50,485	16%
Low or no literacy skills	44,768	15%
People worried for possessions	28,899	9%
Caregivers people with disabilities	19,266	6%
People with pet dependents	19,266	6%
Older adults above 65 years old with disabilities	19,234	6%
Minorities (ethnic) no car	15,395	5%
Children in no car household	15,133	5%
Older adults no car	12,942	4%
People with disabilities no car	10,374	3%
Older adults with evacuation reluctance	9,664	3%
Caregivers pregnant people	6,637	2%
Caregivers older adults	4,809	2%
Pregnant people	3,318	1%
Minorities (ethnic) with restrictive clothing	3,087	1%
People with disabilities no Early Warning System	2,102	1%
Livestock owners	1,809	1%
Place attachment	1,149	0%
People living in poverty no TV	1,072	0%
Children at schools with no Early Warning System	0	0%
Women with travel restrictions	0	0%
Women no TV	0	0%

Fig. 5. Results USA: % of potentially people per indicator.

scoring could not be differentiated by specific groups of potentially vulnerable people. However, we paid close attention to whether or not there were any measures related to the top ten indicators in each country.

Overall, our evaluation of laws and policies indicates that measures for vulnerable people are more elaborate in the USA and Japan as compared to Netherlands. DRM laws in all three countries at all administrative levels rarely anticipated future numbers of potentially vulnerable people, and none were created by involvement of potentially vulnerable people.

Due to the lack of concrete measures or definitions of groups of potentially vulnerable people in the laws and policies, we were unable to differentiate the scoring by specific groups of potentially vulnerable people.

3.2.1. (Inter-) National/State Level

In the Netherlands, we found that no active national laws mention vulnerable people. This is due to the laws focusing on prevention rather than preparedness or response, and the explicit mention that each region should define its own risks. As example of scoring, this led to the score of '1' for these laws. One law often mentioned in evacuation procedures is the Law of Population Displacement (1952), which could be used to order evacuations in case of floods. According to this law, people can receive a special designated shelter depending on their age, health, and behavior. The basic disaster law, the Law

of Safety Regions, does not explicitly mention that local plans should include measures for vulnerable people.

The Japanese Flood Fighting Law (last translated revision 2005) recognizes some groups of potentially vulnerable people, but does not contain measures on their behalf. It requires evacuation plans from the owners of underground shopping complexes and facilities used by "elderly people, people with disabilities, infant and toddlers, and other people who especially require care from the perspective of disaster prevention." The Disaster Countermeasures Basic Act (last translated revision 2013), is equally unspecific as it mentions in Art. 8 (14) "the State shall endeavor to carry out measures for the elderly, the handicapped, infants and others requiring special care."

The American Stafford Act contains extremely detailed measures for vulnerable people during evacuations. As example of scoring, this led to the score of '3' for this law, the highest of all policies on this scale.

3.2.2. National/Prefectural/State Policies

Only one Dutch policy mentions a possible future increase in the number of vulnerable people (increased aging). There is no policy that involves vulnerable people in the policy creation itself.

The Japanese Final Report (2012) from the Central Disaster Management Council is more detailed as it includes measures for elderly, people with disabilities, children, foreign nationals, expectant/nursing mothers, and others

requiring special assistance to evacuation centers; and once there, measures to ensure people's needs are equally met.

The American policies vary in detail from recognizing vulnerable people (score of '2') to measures (score of '3'), despite the national laws indicating specific measures. This shows national policy is not always transcribed into lower policy scale levels.

3.2.3. Regional Policies

The evaluated Dutch safety region policies show a great diversity in identified vulnerable people, although they are lacking in specific measures taken for these groups. The local policies also recognize certain groups of potentially vulnerable people in the form of vulnerable buildings (e.g. prisons, abbeys, asylum centers, schools, hospitals, nursing homes). A disheartening shortcoming is the vision expressed in the Regional risk profile of the region Twente, which serves as a shelter region in case of a flood in the West of the country. In this policy the initial focus lies on helping self-reliant people. Not self-reliant people are of secondary importance, alongside animals and valuable goods such as art treasures and national heritage.

The Japanese regional policies provide an accurate description of expected measures, as the Japanese local governments rely heavily on response organized by citizens. The Sanjo city flood disaster manual (2005) describes how local disaster prevention organization should provide volunteers to physically and mentally challenged people in evacuations. According to the manual, the main reason for this dependence on citizens is experiences from the Hanshin Kobe earthquake in 1995, where 60% of people were saved by neighbors and 20% by family members. Without mentioning specific measures, the manual does mention the city should be made safe for the rapidly aging population, thus leading to a score of '4.'

The regional Orleans Parish 2010 Hazard Mitigation Plan update contains an extensive vulnerability assessment; however it focuses on the vulnerability of the city itself and buildings within it, and not its inhabitants. This is in stark contrast to the Current Local Mitigation Strategy Document (2009) of Hillsborough country. Not only does it limit the construction of new facilities for people with special needs in hazardous zones, it also includes the demographics from the population census including a breakdown into ethnicity, income, age, and female headed households per jurisdiction. Most importantly, the assessment of the countywide population at risk is divided into minorities, over 65, disabled, poverty, language isolated, and single parent. It also includes a section on future land use and anticipated population growth, and the accompanied increased need for evacuation shelters, but does not recognize increased numbers of specific groups of potentially vulnerable people. Of all the examined documents, this county wide DRM policy document is the most promising in quantifying local potentially vulnerable people and arranging supporting measures on their behalf in all phases of disaster management.

4. Discussion

4.1. Numbers of Vulnerable People

In all three countries, we find that the top ten indicators based on number of potentially vulnerable people described account for 80% of potentially vulnerable people. The percentages of the total population attributed to single indicators in these top ten range from 5% to as much as 33%. Moreover, we observe that seven of the top ten indicators are identical across the three case study countries. When addressing the needs of vulnerable people from a policy or regulatory perspective, these top indicators may serve as a starting point to formulate resilience-building measures. There may be opportunity for countries to learn from each other's measures and possibly apply them in their own area, especially when similar percentages of vulnerable people exist. By directing attention and resources to ameliorate sources of vulnerability shared by large portions of the populations, a policy or regulatory framework may increase the resilience of the vulnerable population.

In all three countries, we find that women with no driver's license or no car registered to their name make up sizable portion of people with the characteristic 'fewer material and/or financial resources.' As the assumed mode of transportation people will use during an evacuation in the case study countries, car access may influence evacuation success. In practice, the amount of time available for evacuation and the time of day at which a sudden flood disaster occurs will affect the number of people who can reach a car. For instance, during the impending flood in 1995 in the Netherlands, most inhabitants decided to leave one or two days in advance of the mandatory evacuation orders and used their own transportation (cars) to reach family or friends elsewhere in the country [44]. In this case there was enough time to coordinate between family members, arrange places to stay, and to pack valuables in the car. If the worst case scenario is considered where immediate evacuation is necessary, car availability becomes more crucial. The time of day at which a disaster occurs will determine where the car is, especially if only one car is available to a household. For these reasons we view car availability as an important vulnerability indicator during flood evacuation.

The second most numerous characteristic is formed by people restricted by commitments, be those dependents or pets. In all three case study countries, the same four indicators make up most of all potentially vulnerable people having the characteristic restricted by commitments, albeit in different proportions. These are: caregivers of children, people caring for someone physically unable to leave, people with pets, and people worried possessions might be stolen.

The third most numerous characteristic is formed by people who are less physically or mentally capable. The high result for the USA can be explained by two indicators: children and people with disabilities. The number of children in the USA is about twice the number of children in Japan and the Netherlands. This same difference can

be found for people with disabilities: in the USA this is 19.0%, whereas in the Netherlands this is 11.8% and in Japan 5.8%. A possible influence affecting the high number of people with disabilities in the USA is the Americans with Disabilities Act, which enables easier access to health care after registration. Regarding people with disabilities, a consultancy agency based in the Netherlands estimates that only 1% of non-self-reliant people are staying at a location with organized care [45]. This means most people with disabilities or their caretakers at home have to take evacuation measures by themselves.

The indicators associated with the lowest number of potentially vulnerable people in every country are people with the characteristic of 'less access to information.' The indicators related to access to early warning systems (EWS) thought to influence vulnerability during this phase resulted in few or no vulnerable people. Many people in the three case study countries are likely to use the Internet to try to obtain information during unfolding disasters. For instance in the Netherlands 94% of households have internet access and over 86% use the internet daily or almost daily [46]. In practice, the Dutch legal system requires the provincial websites to function as communication sources; however their capacity is limited to 10,000 simultaneous visitors, rendering it useless during disasters [47]. If people use alternative sources to find governmental information on unfolding disasters such as television or radio, or the provincial server capacities could be legally required to provide for a more realistic number of 1-10 million simultaneous visitors, then the number of vulnerable people can indeed be one of the least numerous indicators. The most numerous indicator for this characteristic in every country is people with low or no literacy skills. Even by increasing internet alerts or other modern media, illiterate people run the risk of not fully understanding the warnings and might require extra communication measures.

4.2. Policies Supporting Vulnerable People

In comparison with USA and Japan, policies in the Netherlands provide the least support to groups of potentially vulnerable people. On the one hand, this is due to new national laws intentionally keeping general descriptions in order for policies to be attuned to the local situation. On the other, as the policies are also relatively new, they rarely go beyond describing the existence of several groups. Subsequent revisions might prove a more accurate description of the number of potentially vulnerable people as well as specific measures. Examining the DRM policies of Japan, we see that the national-level laws are more descriptive but lacking concrete measures, which are found in the national and regional policies. By contrast, this clear separation is not the case in the US, where the basic national-level disaster law (the Stafford Act) cites very specific measures for vulnerable people. National policies might help shape what happens on a more regional level.

When we consider the results from our analysis of the

number of potentially vulnerable people and our assessment of DRM policies, we observe that the DRM laws and policies rarely take into account how many potentially vulnerable people there are in a given jurisdiction, and the measures taken for identified groups are not proportional to the number of people in each group. This indicates that much room for improvement remains.

National policies are still often created and decided upon by a majority of people who do not have the characteristics of vulnerable people. The majority of lawmakers does not often consist of people living in poverty, people with disabilities, ethnic minorities, children, older adults, or women; nor are these people represented well or consulted during the drafting of national DRM laws, which must be adhered to on the regional levels. It would benefit down to the regional level if national laws already concern themselves with vulnerable people, a point which can be emphasized by pointing out just how many people this affects. It would be a great improvement if policies at the national level are formulated in consultation with vulnerable people.

To evaluate the role of regional policies, we investigated two areas per country. Not only is this a very low amount, the choice of these areas was also based on data availability, more specifically, the expectation to encounter support measures for vulnerable people. While support measures were not always found, these regional examples should not be seen as representative for the entire country. Rather the national measures can be seen as supporting the regional areas. Further research is necessary to conclude whether or not these regions can be considered as representative of all regions in the areas. We acknowledged that measures supporting vulnerable people may or may not be implemented, as well as complemented by measures not written down in any policy document.

4.3. Limitations

Three main issues arise in assessing numbers of potentially vulnerable people. The first derives from the lack of independence associated with vulnerability characteristics. As people may have multiple characteristics of vulnerability simultaneously or characteristics which change over time, considerable overlap may exist. As our indicators are not independent, people may belong to multiple groups of potentially vulnerable people at the same time, thus it is not possible to combine these numbers to a total number of potentially vulnerable people. However, given that some of our individual indicators flag large proportions of the population as potentially vulnerable, we still may conclude that DRM policies should pay close attention to establishing measures aimed at vulnerable people.

The second issue is that individual vulnerability exists along a continuum with respect to severity, which we do not account for in this study. Implicitly, we assume vulnerability is binary rather than a continuous variable. The only distinction being made is that between vulnerable people and people who are not vulnerable. By our

analysis, once a person is vulnerable by any characteristic, they are as vulnerable as any other person with any other characteristic; e.g. people without access to cars are equally vulnerable to people restricted to wheelchairs. While it may be possible to apply a gradient or weights to each of the characteristics, we judged it was difficult to remain objective and likely to vary depending on culture. We assessed it would be more informative to show the absolute numbers per characteristic without attributing a higher importance to any characteristics over others. However, we would like to emphasize that the number of vulnerable people in terms of the proportion of population and relative severity of vulnerability are both crucial considerations from the perspective of DRM policy design.

The final issue relates to the characteristic 'restricted by commitments.' While people restricted by commitments may or may not have any or a multitude of other characteristics making them vulnerable, it could be argued that being restricted by commitments does not necessarily make a person vulnerable. What is implied here is that while people with a commitment may or may not be self-reliant, they may choose not to evacuate themselves immediately in order to assist another. This could be due to a sense of duty, or the nature of the relationship to a dependent or asset they wish to protect.

An arguable flaw is that once a person who is not self-reliant is taken care of by someone else, this system would count both people as vulnerable. There are different scenarios imaginable where this either could or couldn't be the case in reality. For instance, a self-reliant person could save their neighbors who don't have access to a car by sharing their vehicle. In this case the people who got offered a ride may evacuate with the same speed as self-reliant people without dependents. But in many cases both or all people involved would become endangered. To err on the conservative side, we retain the characteristic 'restricted by commitments' as a vulnerable characteristic within our framework.

A main conceptual problem with developing indicators is that as the causes of vulnerability are highly dynamic, any change can render the proposed indicators useless [30]. Even if support is generated for the most numerous indicators of potentially vulnerable people, other groups with different needs will subsequently form the most numerous indicators over time. The question remains as to how indicators can reliably be measured over time, if the subject of measurement changes. One solution might come in future population projections. These are already prepared by various governments to cover different age categories, ethnic minorities, and occasionally factors such as religion or political preference are also taken into account. If the same projections were made for other indicators found in this research, such as car ownership, language proficiency, dependents, and disabilities, the future size of the groups of potentially vulnerable people can be estimated. This can then be combined with trends of support measures in policies, which also change over time.

One major shortcoming was the unavailability of national data on people living in poverty, who also have the characteristic 'less physically or mentally capable.' This led to no indicator being available for this group. While recording data on both income and health status may lead to privacy issues, this group of potentially vulnerable people can be both extremely vulnerable and numerous. It is vital the governments have measures in place for this group.

4.4. Implications and Future Research

Our metric and rating scales showed that, unfortunately, a wide gap remains in DRM policies between identifying groups of vulnerable people and specific measures to support them. A comparison of the scores per scale level shows that identification or lack of identification of groups of potentially vulnerable people at the national level does not necessary lead to more or less detailed support measures on their behalf. It would be worthwhile to examine if similar results are found for support measures in other phases of disaster risk management. Most importantly, it is clear that in these developed countries, policymakers are not yet paying sufficient attention to the diversity of their population, and additional support measures must be formulated depending on their circumstances. We count on our governments to make equitable policies, but this has clearly not yet been established in these countries. Given that the investigated measures were related to the hazard type flood, and that floods are a prominent hazard in many areas, developing additional measures deserves immediate attention. The existence of measures for vulnerable people related to other hazard types should also be investigated.

Future research should pay attention to factors that might lead to increased resilience or capacity. One factor that could be useful in such an approach comes from [48], who propose social connections as a main influence on resilience. Furthermore, the exact mechanisms spurring people into greater preparedness for disasters needs to be researched. Future research should also investigate to which extent measures are a result of laws and policies. Laws involved in the different aspects of vulnerability, in combination with the systems in place for organizing the actually implemented measures, can provide recommendations for best practices on a regional scale per group of potentially vulnerable people.

5. Conclusions

This study uses social vulnerability indicators to estimate estimates of the numbers of potentially vulnerable people. We propose a framework based on four characteristics of vulnerability and focused on six groups of potentially vulnerable people. We estimated corresponding statistics per indicator for the hazard type flood and response phase of disaster management for Japan, the Netherlands and the United States.

We found that the top three most numerous indicators were comprised of women with no car access, people with

pets, and children aged 0-14, in two of the three countries. In all countries, the top ten indicators account for 80% of all potentially vulnerable people. These top ten indicators can serve as a starting point in order to increase the resilience of the vulnerable population. Even more promising, seven of these ten are identical across the three case study countries, meaning the countries can learn from each other's measures and possibly apply them in their own area.

We proposed a scoring system to determine whether DRM laws and policies from national to regional level in the three countries supported the identified groups of potentially vulnerable people. We found the USA and Japan have more elaborate measures compared to the Netherlands. However, DRM policies rarely anticipated future numbers of potentially vulnerable people, and no DRM policies were created by involvement of potentially vulnerable people. Our results show the governments of these countries still have a long way to go in creating equitable DRM policies.

This procedure using a division in characteristics and disaster phases can be applied for other hazard types as well as other groups of potentially vulnerable people, if it is clear which indicators should be used and corresponding statistics are available. Our scoring system may be applied universally to all DRM related laws and policies, and can be refined to focus on measures per group of potentially vulnerable people to identify where policies might be improved.

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