Swedish Civil Contingencies Agency

Research/Study

FEMA's National Risk Index

Experiences and good practices to support a future Swedish implementation

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Summary: Despite the importance of National Risk Assessments, the National Risk Index developed by FEMA seems to be the only comprehensive index in the world. The aim of this study is to delve into the National Risk Index and identify the key experiences and practices that have led to its success. This is done by semi-structured interviews with representatives from FEMA and experts provided methods and data.

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1 Introduction

1.1 Motivation

Many types of risks in our society need to be assessed from an overall perspective, including everyday risks and risks that may cause great damage to our society. Such risks can have consequences for the public, the functionality of our society, and ultimately, our ability to uphold our basic values (MSB, 2011).

Under the European Union Civil Protection Mechanism (UCPM) Decision (1313/2013/EU), EU member states must periodically develop risk assessments and make the summary of their National Risk Assessment (NRA) available to the European Commission to prevent disaster risks in Europe. NRAs identify and assess the disaster risks of natural hazards that would require a response at a national level. However, despite the guidelines provided by the EU, performing an NRA is a demanding process and presents a challenge for member states in terms of resources, time, and complexity (Poljanšek at al., 2019).

According to the MSB, a national risk assessment could inform the public about risks Sweden is facing as a nation and prepare the population nationally and in collaboration with other EU member states (MSB, 2011). A national risk assessment will become an essential tool to support the establishment of preventive, preparatory, operational, and evaluating aspects of the joint European Union efforts to strengthen the security of the union.

Despite the importance of NRAs, the National Risk Index in the US developed by FEMA seems to be the only comprehensive risk index in the world (Zuzak et al. 2022).

This study seeks to delve into the National Risk Index developed by FEMA and identify the key experiences and practices that have led to its success. By exploring the roles and responsibilities of various actors involved in the process, we hope to gain a deeper understanding of what has worked well and what challenges and limitations must be addressed.

To achieve this goal, a qualitative approach was employed, and semi-structured interviews were conducted with representatives from FEMA, as well as authorities and organizations that contributed data and methodologies during the implementation phase. By gathering such insights, this study aims to establish a foundation of knowledge that can support the future implementation of a national risk assessment in Sweden.

The study is structured around three key questions. Firstly, what are the good practices and methods that have been used in the FEMA's National Risk Index? Secondly, what challenges and limitations have been encountered, and how can they be avoided? Finally, which of these approaches are most relevant for Sweden, and how can they be adapted to meet the specific needs of the Swedish context?

By addressing these questions, this report provides a valuable resource for policymakers and other stakeholders involved in risk assessment and management. It offers practical insights and recommendations that can inform the development of effective risk assessment strategies, helping to ensure the safety and well-being of citizens in Sweden and beyond.

1.2 The National Risk Index

The National Risk Index (NRI), developed by the Federal Emergency Management Agency (FEMA), provides a relative measurement of community-level natural hazard risk across 50 US states and Washington, DC. The index uses nationwide datasets and multiplies values for exposure, annualized frequency, and historic loss ratio to derive expected annual loss estimates for 18 hazard types. It then combines this metric with Social Vulnerability and Community Resilience scores to generate Risk Index scores for every Census tract and county in the United States (Zuzak et al., 2021; Zuzak et al. 2022).

The NRI is intended to help different users better understand the natural hazard risk of their communities. Intended users include emergency managers and planners at the local, regional, state, and federal levels, as well as interested members of the general public. Specifically, the tool can support decision-making to (FEMA, 2020):

- Update emergency operation plans
- Prioritize and allocate resources
- Identify the need for more refined risk assessments
- Enhance hazard mitigation plans
- Encourage community risk communication and engagement
- Support enhanced codes and standards
- Inform long-term community recovery
- Educate homeowners and renters

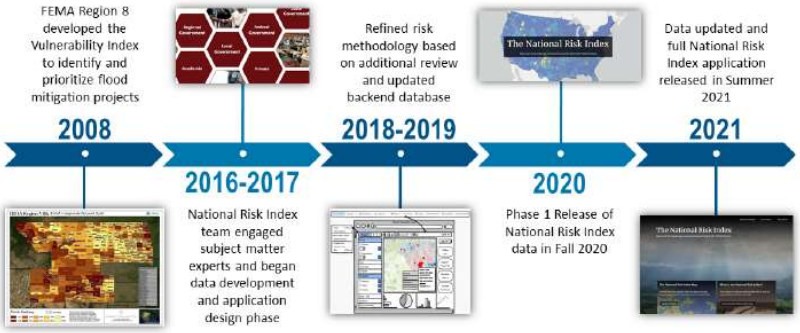
In the next sub-chapters, a detailed overview of the NRI background, data sources and processing methodologies is presented.

1.2.1 Background

In 2016, FEMA's Natural Hazards Risk Assessment Program (NHRAP) began work on the NRI, establishing a vision for a multi-hazard view of risk that combines hazard likelihoods and consequences with social vulnerability factors and resilience capacities. The main aim was to provide a broad, integrated view and to create a nationwide baseline of natural hazard risk.

To achieve this vision, the NHRAP group collaborated with various working groups to develop a methodology and procedure to create the NRI database. They also researched, designed, and developed the NRI website and application.

Figure 1. Timeline of the development of the National Risk Index (Zuzak et al., 2021)



The development team conducted multiple sessions and workshops to discuss and determine the methodologies for translating different data sources into risk parameters for input into the NRI. According to the technical manual (Zuzak at al., 2021), the key objective of these activities and exercises was to ensure that a vetted risk framework was leveraged throughout all methodological development and that different factors were not being misinterpreted across the 18 natural hazards.

1.2.2 Literature review

As a starting point, the development team conducted a broad literature review to determine approaches and strategies for data collection in the fields of hazard mitigation, emergency management, hazard risk science, and other related fields. Centering around a search for natural hazards and exposure variables, the literature review identified datasets, risk indices, reports, methods, indicator lists, and existing risk assessments at national and global scales (FEMA, 2020). According to the technical manual, the team concluded that the new system of viewing risk would involve three components:

- Natural hazard (likelihood and consequences)
- Social vulnerability
- Community resilience

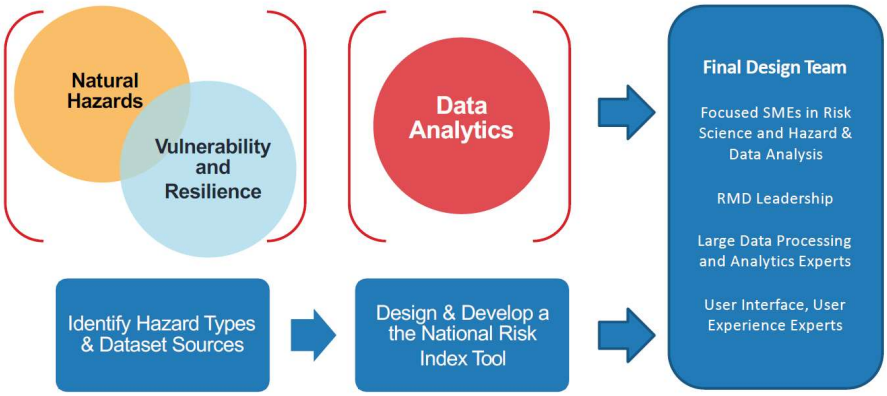
1.2.3 Working groups collaboration

Following a detailed literature review, the NRI development team convened three working groups comprising subject matter experts, potential users, stakeholders, and parties from all levels of government, the private sector, non-profits, and academia. The working groups were responsible for different aspects of the NRI's methodology and development, helping to continue the literature review and guide

the data and application development. These groups are outlined in the FEMA Technical manual as follows:

- The *Natural Hazards Group*, which assessed and recommended datasets associated with the 18 natural hazards selected for inclusion and determined the best ways to incorporate the associated data into the index.
- The *Social Vulnerability Group*, which evaluated and reviewed existing efforts to measure social vulnerability and community resilience to determine which components were most important and which indexes should be used in the NRI.
- The *Data Analytics Group*, which supervised the spatial processing, normalization, and aggregation of data to arrive at the index methodology and calculation that integrated the final dataset and was identified by the other two working groups.

Figure 2. National Risk Index working groups (Zuzak at al., 2021)



The groups collaborated and created the National Risk Index through discussions and development, including (FEMA, 2020):

- The datasets and indices to incorporate
- Definitions
- Data management strategies and metadata requirements
- Data processing
- Index creation methodologies
- Index integration
- Data visualization and exportable results
- Online mapping and data exploration tools

1.2.4 Data selection and collection

Upon conducting a comprehensive review and assessment, the development team and working groups of the National Risk Index collaborated to select datasets and indices from reliable sources across the United States. All data behind the NRI components needed to cover the US territory and be measured at the county and census tract levels. Moreover, hazard-related data had to have location and time information (Zuzak at al., 2021).

The data used to support the National Risk Index was gathered from both publicly available resources and organizational networks. A detailed list of all the contributors and a description of their contributions is available at the following link: https://miptest.msc.fema.gov/nri/contributors

1.2.5 Determining Risk

In the NRI, risk is defined as the potential for negative impacts resulting from a natural hazard. The risk equation (Equation 2) behind the index comprises three components: a natural hazards component (Expected Annual Loss), a consequence-enhancing component (Social Vulnerability), and a consequence reduction component (Community resilience) (Zuzak at al., 2021; Zuzak at al. 2022). A description of the parameters is given in the following sub-chapters.

$$Risk = \frac{Expected\ Annual\ Loss\ \times Social\ Vulnerability}{Community\ resilience}$$

1.2.6 Natural Hazards (Expected Annual Loss)

Within the NRI, Expected Annual Loss (EAL) represents the average economic loss in dollars resulting from natural hazards each year. EAL is calculated for each hazard type and quantifies loss for relevant consequence types:

- Buildings
- People
- Agriculture

Expected Annual Loss is calculated based on a multiplicative equation that includes exposure, annualised frequency and historic loss ration risk factors for 18 different natural hazards.

$$Expected\ Annual\ Loss = Exposure\ x\ Annualised\ Frequency\ x\ Historic\ Loss\ Ratio$$

Exposure is a consequence factor of natural hazards that represents the value of buildings, population, and/or agriculture that are potentially exposed to a natural hazard occurrence. Annualized Frequency refers to an incidence factor of natural hazards that represents the expected frequency or probability of a natural hazard occurrence per year. Historic Loss Ratio is a consequence factor of natural hazards that represents the estimated percentage of the exposed building value,

population, or agriculture value that is expected to be lost due to a natural hazard occurrence.

In the NRI, an Expected Annual Loss is calculated for each consequence type (buildings, population, and/or agriculture) for each community (county and census track). Building and agriculture values are measured in dollars, while the population is measured in fatalities and injuries. To ensure a common unit of measurement in the NRI, as reported by the NRI Technical Manual, the population Expected Annual Loss is monetized into a population equivalence using a value of statistical life (VSL)[1]. Based on the VSL approach, each fatality or ten injuries are treated as $7.6 million of economic loss.

To generate the relative EAL scores, the values of each of the three consequence types (buildings, population, and agriculture) are summed up to represent the total loss for each hazard type in each community, and then they are min-max normalized for every community. With respect to the composite EAL score for each community, the unnormalized total EAL values for hazards are summed and then min-max normalized. A composite EAL score measures the total Expected Annual Loss of a community considering all 18 natural hazards, while a hazard type EAL score measures the relative level of Expected Annual Loss of a community from that hazard type.

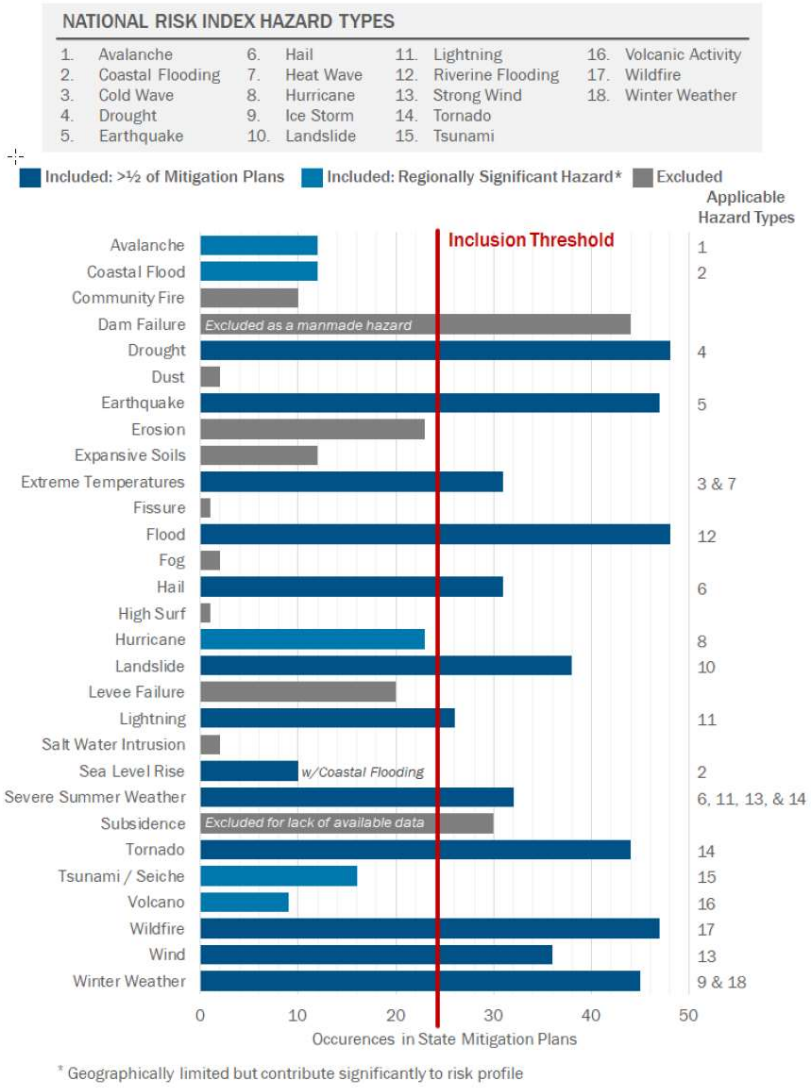
The 18 hazard types included in the National Risk Index were selected based on a comprehensive review of hazard risk profiles from State Hazard Mitigation Plans for all 50 states (Zuzak et al., 2021).

To be included in the index, a hazard type had to be profiled by at least half of the State Hazard Mitigation Plans or be considered a significant regional hazard. A significant natural hazard, as defined in the technical manual, is a hazard that is geographically limited in occurrence but contributes significantly to a region's risk profile, such as volcanic activity or hurricanes.

No man-made hazards, such as dam or levee failure, were included in the index, and the subsidence hazard was excluded due to a lack of available data (Zuzak et al., 2022). Figure 3 presents the natural hazards selected for the NRI. For a more detailed description, please refer to the NRI Technical Manual (Zuzak et al., 2021).

[1] https://aspe.hhs.gov/reports/updating-vsl-estimates

Figure 3. Determination of Hazard Inclusion based on State Hazard Mitigation Plans (FEMA, 2020; Zuzak et al. 2021)



1.2.7 Social Vulnerability

Communities are impacted differently by natural hazards. To address the inequities of disaster impacts, the National Risk Index uses social vulnerability as a community-specific factor that increases risk, and community resilience as a community-specific factor that decreases risk (Zuzak et al., 2022). Within the NRI, social vulnerability data is provided by the University of South Carolina's Hazards and Vulnerability Research Institute (HVRI) Social Vulnerability Index (SoVI).

SoVI is a location-specific assessment of social vulnerability developed by Cutter et al. (2003) that utilizes 29 socioeconomic variables deemed to contribute to a

community's reduced ability to prepare for, respond to, and recover from hazards (NRI Technical Manual, 2022).

Vulnerability scores are available for all counties, but they are not presented for 292 Census tracks where the population is zero. Risk cannot be calculated for tracks without a Social Vulnerability score, and as a result, those census tracks are classified as "Insufficient Data" (NRI Technical Manual, 2022).

1.2.8 Community Resilience

Community resilience is defined by FEMA as the ability of communities to prepare for anticipated natural hazards, adapt to changing conditions, and withstand, recover from, and reorganize after disruptions (FEMA Technical Manual, 2022). Because there was no national bottom-up community resilience index available, the Social Vulnerability and Community Resilience Working Group decided to move forward with a top-down approach (NRI Technical Manual, 2022). The group reviewed multiple top-down indices and decided to proceed with the University of South Carolina's Hazard and Vulnerability Research Institute (HVRI) Baseline Resilience Indicators for Communities (HVRI BRIC[2]) index.

The HVRI BRIC dataset includes a set of 49 variables that represent six types of resilience: social, economic, community capital, housing and infrastructure, institutional capacity, and environment (Cutter et al., 2008). HVRI BRIC scores are only available at the county level, so Community Resilience scores were inferred from county to census track level by assigning each census track the score of its parent county.

1.2.9 Access to the National Risk Index and data resources

The FEMA National Risk Index can be accessed through multiple locations, including a website (https://www.fema.gov/flood-maps/products-tools/national-risk-index), an interactive map and data exploration tool (https://hazards.fema.gov/nri/map), Community Risk Profile and Comparison Reports (please see Appendix 1 for a report sample), downloads (available in different formats: Geodatabase, shapefile and Table (CSV) formats) and Geographic Information System (GIS) web layers and services (https://hazards.fema.gov/nri/data-resources#hdrDownload).

[2] https://www.sc.edu/study/colleges_schools/artsandsciences/centers_and_institutes/hvri/data_and_resources/bric/index.php

2 Method

The data for this study was derived from semi-structured personal interviews with risk experts who were involved in the process of formulating the NRI in the US. The first interview took place in June 2021 with two officials from FEMA. Using a snowball effect by asking responders at the end of the interview for recommendations of other involved experts, four more interviews were conducted with representatives from different organizations. These representatives provided data and/or methodological approaches to the NRI development team. These interviews were conducted in November 2022.

The interviews were semi-structured, based on questions that functioned as a loose structure but not as a fixed guideline (Jennings, 2005), so that the interviews have a more spontaneous character in their narration (Albert et al., 2021). This is due to the different roles the interviewees had in the process.

For the interviews, guiding questions were developed based on insights from the NRI technical manual (Zuzak et al., 2021). These questions focused on four different topics:

i) Response to the NRI initiative by the FEMA officials and the different groups,

ii) Experiences with collaboration between FEMA and Subject Matter Expert Groups,

iii) Reflections of the three working groups responsible for the different aspects of NRI's methodology and development,

iv) Data, methodologies and contributions from agencies and organizations and

v) Questions focusing on challenges and limitations.

These main groups were supported by spontaneous questions, for example, concerning a certain step in the process and/or time and costs during development.

The interviews differed in length between 30 and 60 minutes and were video and audio recorded. Afterwards, the data was processed and analyzed in three stages (Jennings, 2005; Wilson, 2014). Stage 1 involved transcribing the data, Stage 2 involved coding the data, and Stage 3 involved data analysis.

In the first step, the transcripts were openly coded to identify the main aspects in the process of formulating the NRI - including individual views and reflections about the interviewees on their role and the role of other actors during the process. In the next step, the generated codes were clustered along with the main topics that functioned as core categories and were then interpreted and linked to each other. In the last step, the categories were associated with substantial and relational beliefs for presentation.

3 Findings

This section presents the findings based on the analysis of the interviews with the officials from FEMA (Section 3.1) and different subject matter experts (Section 3.2) that provided data and/or methodologies to the NRI.

3.1 FEMA officials

3.1.1 FEMA response to NRI initiative

In the beginning of the interviews, the responders were asked to describe how FEMA responded to the NRI initiative as an institution. The interviewees reported that when FEMA announced the NRI seven years ago, it was not necessarily responding to specific inquiries but more so as an institution that started to work towards the initiative. FEMA had a lot of open questions, such as "*how can we understand the risk i.e. from flooding but also risk from other hazards,"* but no answers. They did not have a directive or initiative by the agency, but more of a push for a solution. One official stated,

"what if we came up with the solution so that we can start dying down a larger risk to natural hazards overall approached the national risk index with cautious cautiously at the beginning, and then over time we work to build support for the national risk index."

By engaging experts from the field, they were able to build a comprehensive and acceptable product that is academically correct, correct from a hazard perspective, and answer the open questions about risk and risk reduction. The responders emphasized that this was not a quick process, as it took a long time, and many groups were hesitant at first, mainly due to the level of effort, resources, and funding needed.

3.1.2 Subject Matter Expert teams and the initial application design phase

In 2017, the NRI team engaged Subject Matter Experts and started the application design phase. The interviewees reported that they engaged up to eighty subject matter experts, many of whom are related to the hazards field and studied different natural hazards. There were also experts in social vulnerability and community resilience, as well as experts for the application user interface and user experience. Their aim was to ensure that they were generating data using the best available experts and inputs and that they understand the differences in how communities are impacted by disasters and their ability to recover after disasters. Another set of experts was focused on how to communicate this information in a way that is consumable. One responder explained that they wanted to know how anyone could take any information from the national risk index and take action from there or know what to do with the data, which was one of the key pieces in the process.

The responders commented that some problems in other projects in the past drove them to leverage subject matter experts in the NRI to ensure that they developed a product that is consumable by everyone, *"something that my grandparents or parents could use"*.

Furthermore, a responder highlighted the intended audience of the NRI – *"decision-makers, hazard experts, the general public, or all of the above"* - and how intense and challenging it was to make it scientifically credible, useful, and get support from hazard researchers, but also to communicate it to a broader audience. The same official added that it was incredibly complex information, language, and communication to tie altogether.

In terms of the strategy to engage different partners, the responders described that they tried to connect all the different partners under FEMA's umbrella and manage a lot of time and resources for the index development team. It took them three-plus years to identify datasets, make sure that they were using the right datasets, identify the right resources, and produce an outcome. As discussed, it was a very big effort in terms of time and resources on their end, the NRI development team. They also highlighted that all the subject matter experts were volunteers and none of them were paid to provide data and methods.

The interviewees commented that some subject matter experts were hesitant to join in the beginning because it was such a large initiative and *"they were kind of scared of what NRI meant to them."* To solve this problem, the responders reported that they tried to keep the minimum effort for them and *"the conversations very focused on their area of expertise"*. On the other hand, if they wanted to join other conversations, *"they were always welcome"*, but the NRI development team set the expectation that they want the different partners to provide input on their areas of expertise only. Moreover, they allowed the different partners to provide inputs as they believed in the initial stages.

After that, we asked the interviewees what the best source of motivation for the different partners was, and according to their responses, the NRI provided a way for many partners to utilize their data. Many groups are producing data, such as hazard data, but they lack the expertise or resources needed to translate it into risk assessments. The integrated approach used in the NRI provided these groups with an opportunity to take the next step with their analyses.

With respect to difficulties in engaging/dealing with the different groups, the responders highlighted that a lot of different groups had their opinions about their data. Some of the most difficult are those that were recognised flaws in their databases and mentioned "*don't use my data set because my data are not good enough*". However, in reality, as it is reported, their dataset was the best available. There was a need to use their data and worked with them to help them to understand the NRI goals and data needs. The responders mentioned, "*We had to keep telling them the story over and over again. Having a nationally available baseline risk assessment your data is important*". Furthermore, the interviewees mentioned that it was really important for them to come to a consensus with their peers on *"the methodology itself, so hazard*

identification and the best available datasets, and what datasets were available from a national perspective versus from each of the individual state or local governments in the US."

The responders were asked during the interview to comment on the voluntary efforts of different stakeholders. They mentioned that when they worked with federal partners, they tried to leverage the partnership as much as possible and engage the community. From the perspective of the subject matter expert teams, they reported that they had to incorporate state and local partners who were initially cautious about joining and did not want to invest too much effort. To solve this issue, the responders noted that they tried to keep the conversations very focused on the specific expertise of each partner. They explained, *"We want to engage you because of your expertise and how you can apply this at the state or local level, which are things we need to consider. By making a product that is beneficial for you in the long run, it reduces your long-term investment on risk assessments."* Furthermore, they highlighted the unique situation where working on the NRI project would give something back to communities: *"We want your input here so that we can provide this tool in the long run to support your costs and your needs."*

In the next step, the officials were asked how they built bridges between the different groups and teams. As reported, it was difficult to bring them together, and their target was to keep every working group focused on its task. On the other hand, they kept the working groups informed about the work done by the others and always tried to keep them updated on the different milestones.

For example, the social vulnerability and community resilience group was a huge group with many opinions on different approaches and ways to incorporate data. Hence, the conversations were often centered on how to use the data for natural hazards. Another example is the hazards working group, which was tasked with developing methodologies for 18 different natural hazards, and they had many challenges to work through. In this line, they wanted to make sure that there was some general communication between them, and FEMA officials worked hard to ensure that they were engaged with each of the working groups in their areas of expertise. Here, they commented that this type of cooperation allowed the NRI to be successful.

In the next step, they were asked about the time they decided to bring some of these groups together. They reported that this point was when they realized that all of the datasets were identified, and they had a valid methodology. As reported, they were able to step back and say: *"All right, I think we have enough information. Let's go ahead and try this out. See what we get."*

3.1.3 Data

In the following stage, the officials were questioned on the data used in the long process of index development. According to the interviewees, the main goal was to develop the national risk index by using data that covered the U.S. territory and were open and free of charge. Their aim was not to use credentials and allow every user to use the NRI without a username and password. They developed the index

in a way that allows users to download data and recreate different hazard scenarios.

Moreover, they did not want to host data that was already available from another agency/authority. They wanted different authorities to own their data (i.e. hazard identification data sets) and FEMA to take it a step further and turn it into a risk assessment information. Through the voluntary approach, they made all the data open and free. During the process, they only had to purchase a few data sets. They used social vulnerability index data as an example. Once they had to purchase the dataset, they paid the provider to ensure that the data were open and free. These data came with a user license agreement to make the final product openly available.

The responders also stated that another important issue related to data was around disaster impacts and how to quantify impacts of historic events. As reported, they had a few different databases and leverage the right data and understand where it is an impact versus cascading impacts; and where do they draw that line to understand the hazards to include. They mentioned that they settled on eighteen different natural hazards. There is more that is impactful to the United States, but they did not have data or the data was not available at the appropriate scale (*"it was not accurate, some data sets were old - as thirty years old and have not been updated since then - so they did not include those"*).

They also mentioned that in order to make sure that they had the available/right data sets to move forward with developing the NRI, they had a lot of conversations around geography and scales with the different partners. This process took them a lot of time, specific GIS capabilities, specific data management and big data techniques. They described that to be able to perform some of these large-scale impacts or assessments and especially in that scale (United States) - where hundreds of thousands of census tracks which are about six thousand people per unit and even smaller units of geography - it took a week or two just to process one data set.

Regarding data formats, the interviewees were asked if they preferred raw or processed data. As conveyed by them, they used both data formats. All the data used in the NRI were manipulated at some point to get to that standardized risk score at the end. As disclosed, raw data was better because they could manipulate it into the format they needed to work. In general, all the information they asked the contributors to provide, such as frequency, exposure, loss ratio, was manipulated backward to the census tract level data.

During the interview, we asked the interviewees if they had any problems with authorities who were afraid to be held accountable and therefore kept information secret. They reported that they did not have any of these problems. This was because they used publicly available datasets only and did not leverage protected or private data.

However, the interviewees reported that there were a few instances where one group felt that their dataset was better than the other was. To solve this problem, they worked with both groups to figure out which dataset would suit them better. Only on rare occasions did they bring two groups together and tried to reduce any conflicts that may arise. The target always was to work with the groups and understand their databases and how they could integrate them into the larger picture. By following this strategy, they were able to understand more about the available datasets and which ones were right to use and why they were the better dataset.

Next, they did receive some questions on why they did not include some hazards such as dam failure. According to the interviewees, this was because often this information is protected, and they did not have all the components for a complete analysis.

In the subsequent step, we focused on data and methodological updates in the future. As reported, FEMA is working on continually updating the NRI, but they have not specified any regular intervals for updates. For example, they have been informed that the release of the 2020 US census data will be available soon. Once this data is available, they will update the NRI's social components, voting value components, population values, and agricultural impacts.

Regarding hazard data, they are continuously trying to involve hazard data updates, as new data are available. They emphasized the importance of ensuring that all datasets are regularly updated. As noted, *"if we update it once every five to seven years, it will be perfect."* In this regard, they work closely with various authorities such as NOAA (National Oceanic and Atmospheric Administration) to update flooding data, incorporate climate change in the analyses, and consider changes in frequency.

3.1.4 Challenges

Focusing on the challenges that the officials faced in the long process, an important issue - as the responders highlight it - was how to integrate social vulnerability and community resilience to develop the equity component within the NRI. *"There is a lot of different ways to define risk and to quantify natural hazard risk. So it's coming together on a composite formula that not only meets theory and practice but also was able to be implemented."*

They noted that another challenge was not engaging big data experts early in the development process. Initially, they thought they would be able to develop everything internally using ArcGIS and the model builder suite; *"something really quick,"* as it is mentioned. Nonetheless, as they reported, they quickly found out that it was not possible. If they wanted to develop something that would be long-term maintainable, they had to go into the big data world and develop complete SQL back-end databases and coding to support all the different processes.

In the same line, another challenge they noted was not engaging user experts and user interface experts early enough. They produced a Beta application that they

thought would be functional, but it was not. As indicated, *"It was not user-friendly at all, and users did not understand how to use it or what data they were looking at."* Consequently, if they produced something super technical first, it did not work quite well.

During the interview, they were asked if it was easy to engage the group repeatedly when they realized a problem, or if they had to start the process again from the beginning. The responders commented that they kept it as an interpretive process over time and heavily engaged the working groups in the first six months to face those challenges. By doing that, they could understand the data and/or methods and the best ways to interpret it.

By realizing the problems early enough and solving them over time, they kept the large working groups focused on the individual subject matter expert discussion. For example, they worked with the U.S. Geological Society and their earthquake hazard reduction program on earthquake-specific issues, or they worked with the landslide program on landslide-specific hazards, and they had conversations with them probably once or twice every six months. By meeting two to four times a year, it was possible to check the data, understand any data updates that were coming, and present what they had found.

In the next step, we focused on challenges related to time management and resources that the development team faced in the process. As reported by the interviewees, the biggest challenge was time management. It was difficult to manage expectations of when they were rolling out the index and when the data would be released. They put a lot of effort into coordinating and ensuring they had enough time to review the data leading up to the index release.

Furthermore, they identified resources and the management as a crucial challenge in the process. *"Ownership of resources, making sure we accounted for staffing, funding, data and material development, application development, maintenance of data overall, and making sure that we put logical pauses on work when we needed to do a release or check with subject matter experts."* They estimated many resources, but they needed more.

In addition, the team reported that navigating governmental bureaucracy was a significant challenge when working with different groups and external affairs.

Furthermore, the team discussed that the project received media attention, and they had to invest extra time and resources to keep it going.

Overall, they described facing two perspectives when developing the NRI. The first was negative, "*don't do it, it's hard, no you can't get anyone to agree on anything and you know whatever you do is just it's not going to work, just don't even try*". They noted a rethinking here and said that they are not going to get this right on the first iteration - which they got it - and they want to iterate over time to make sure that they are developing something that actually matches not only risk and their perspective but risk from hazards and from a historical perspective. As a positive perspective they emphasized that the index is the first of its kind and that their goal was to involve stakeholders and develop it over time to build a better dataset

"*this index is the first of its kind - no one has ever developed anything like this across the United States for so many hazards, incorporating social equity and being able to define risk"*. Their goal was to evolve it and develop it over time to make sure that they get a good picture upright and then build a better data set over time, which is something that they have been able to do.

3.1.5 Index use/user groups

After discussing the successful release, we focused on the different groups using the index. According to the officials, the final product received very positive attention. *"Many groups are interested in using the NRI to support long-term communication of risk, understanding what risks are there so that they can plan for natural hazards over the long term, and connecting it to different programs like FEMA's medication planning program."*

They used the example of building codes. In the US, building codes are a huge initiative, and members of the structure integrity program want to leverage the NRI. Their goal is to understand where they have the highest and lowest risk to natural hazards so they can identify communities to target for code improvements or updates.

Other examples, as reported, include the National Flood Insurance program, communities supporting grant applications, and the private sector. By integrating the NRI into their activities, all of these stakeholders can make data-driven decisions. Many groups are lobbying at the higher level of the government the need to use the NRI for making data driven decisions. Index will help the communities to communicate more about hazards, rescue operations and understanding impacts. Moreover, it gives them the opportunity to incorporate climate parameters and social equity perspectives. As mentioned, *"Many actors are interested in leveraging the NRI and its data because it is an open and available tool that they do not have to invest in."*

3.1.6 Limitations

In the next part of the discussion, we focused on limitations. The interviewees reported that the limited period of data records for some hazards was an important limitation. In this line, they are working to find solutions for this limitation. For example, calculating return periods is a challenge. As mentioned, *"Exposure is defined by the hundred year floodplain, and that hundred year floodplain may not capture all of the losses related to flooding. So, by understanding what percentage of historic losses occur in the hundred year floodplain versus outside of it, they can have a better understanding of the actual exposure for flooding within the N.R.I."* Recognizing and acknowledging the limitations of the available data and methodologies was a crucial step in the development process.

Another limitation that they discussed, is that certain hazards, such as geological hazards, occur over a timescale of millions of years, and attempting to quantify them using data from the last few hundred years is not feasible. Despite this limitation, the decision was made to proceed with certain methodologies, such as

in the case of volcanic eruptions. While these methodologies may not be perfect, they were chosen after careful consideration and evaluation of the available options.

3.1.7 *"If you have to take place in the process again what you will be doing differently and why?"*

In the last part of the interview, we asked the FEMA official the question: *"If you had to go through the process again, what would you do differently and why?"*

They responded that instead of starting with the literature around individual hazards, they would look at it from a larger risk assessment perspective that includes not just natural hazards, but all hazards and all-hazard risk calculations. As commented, they learned a lot from the approach that they followed, but they were not engaging upfront because their focus was very narrow on natural hazards.

3.2 Subject Matter Experts' interviews

The section presents the findings based on the analysis of interviews with Subject Matter Experts (SMEs). Four of the interviewees are from the natural hazards community (Contributor 1 (C.1), Contributor 3 (C.3), Contributor 4.1 (C.4.1), and Contributor 4.2 (C.4.2)), while one is from the public health community (Contributor 2).

3.2.1 SMEs response to the NRI initiative

In the first part of the interviews, we asked the interviewees to describe how they responded to the NRI initiative. Two of the interviewees were approached by FEMA, one reached out to FEMA to contribute with data and methodologies to a specific hazard type (which was not presented in the NRI), and one stated that they started discussions with FEMA when the NRI was established and socialized enough (C.2: *"been open-minded to conversations around the development of it, the refinement of it as well as potential users of it."*).

The interviewees approached by FEMA represent huge organizations working with specific natural hazards. Both of them reported that they brainstormed ideas, discussed methodologies used, and available datasets with FEMA in the initial stages of the index development. They brought expertise in different problems, added value, and benefits to different aspects of the index. One contributor also stated that they were working on a similar idea when they were approached by FEMA. After some discussion, they recognized the potential of NRI and decided to join the project

The interviewee that reached out to FEMA reported that they are working with a natural hazard, which is limited in terms of economic impacts. They saw potential in the NRI as a way to move forward and shared datasets and methodologies with FEMA officials.

The contributor that started discussions with FEMA when the index was established highlighted the multidimensional information that the tool provides (C.2: *"multiple hazard information under one platform"*) as a benefit to their authority. Climate and hazards impact information provided by the index was an important aspect to collaborate with FEMA's project. The organization that they represent is interested in hazard impacts of critical infrastructures, and it was difficult for their community to access information from multiple sources. The NRI tool supported the organization's activities by providing information under one platform (C.2: *"the NRI tool makes so much different information on so many different climate hazards available under one platform. It makes it available in special units. It is very easy to use and access and it provides a way that that information is easily digested and used by the community at large."*).

3.2.2 Subject Matter Expert teams participation and collaboration with FEMA

In the subsequent process, we asked the participants if they were part of the Subject Matter Expert (SME) Team. Four out of the five participants were heavily involved in SME teams. Their organizations provided different experts, data, and information for the NRI project.

We asked the interviewees if they had to convince their organizations to participate and provide datasets or methodologies voluntarily. All of the interviewees mentioned that they are representing federal authorities and that collaboration with other organizations and authorities is encouraged. One respondent stated that if the task could be completed within a reasonable amount of time, it would be considered part of their core duties. They also reported that FEMA and their organization had undertaken projects in the past that included dedicated funding, but this was not the case for the NRI project.

Another responder highlighted that it was of paramount importance for them, as governmental scientists, to ensure that the information they produce remains accessible to different organizations and the general public (C.1: *"It is straightforward for us to ensure that our science can be used for different applications."*).

In the next step, we asked them to characterize the collaboration with FEMA. All of them characterized the collaboration as great. On the other hand, they highlighted some challenges in working with other subject matter experts. They had different meetings to engage and become familiar with the products and different data suites. Moreover, they described it as important to form sub-groups to look at specific questions and problems.

With respect to the challenges in these groups, one participant mentioned that combining different hazards in a geographic area is a challenge. There are subject matter experts who have different opinions on how the different hazards should be dealt with/analyzed. For example, some hazards are more frequent than others, and it is difficult to bring them into a single composite index approach. On the other hand, as mentioned by the same contributor, convincing the different

experts/stakeholders to think beyond their own domain/expertise was a key piece of success.

3.2.3 Data

In the next stage, we asked the interviewees whether they contributed data and, if so, what kind of data they provided. Three out of four interviewees reported contributing data to the NRI. They were from the hazard subject matter and contributed different datasets, such as hazard maps, gauge data, time-series and historical loss data. In addition to hazard data, they supported FEMA in analyzing the frequencies of different hazards and estimating the expected annual loss for counties and census tracks. Furthermore, one respondent reported updating a dataset that FEMA was already using. As previously mentioned, with regard to the data repository, they provided both raw and processed data.

Regarding data, we discussed with them if they had concerns that their data would be criticized by FEMA or other participants. All the participants agreed that they did not feel criticized. One contributor highlighted that understanding the nuances of data (C.4.1: *"understand the accuracy, the limitations, the precision, the limits basically what the data can present."*) and presenting them to the other experts/participants was the key to avoiding criticism. Another participant reported that they had some good discussions about the best way to represent the data *"but never felt any criticism or something like this"* (C.3).

3.2.4 Challenges

Next, we asked the participants what the biggest challenges they faced were. The majority of the participants did not face any challenges in the process. As mentioned, the development team created an environment to smooth the process for all the involved subject matter experts and was open to feedback and new ideas (C.4.2: *"They have been extremely receptive to our feedback, and it was really a great collaboration"*).

Another participant emphasized (C.1: *"It is always a challenge in any scientific idea when we produce an important new development, it takes time for the general public to understand and digest that information in a meaningful way, and there's always a danger of misinterpretation or misinformation floating around. I think NRI was not an exception to that. But I think that the development team did a lot of effort to communicate the benefits of the study and what it provides and what it does not provide").*

On the other hand, the same participant mentioned that they never worried that information or data would be misused by FEMA. However, they wanted to make sure what FEMA would produce does not mislead the general public.

Furthermore, it is mentioned that there are two types of challenges with this kind of tool. One is how users pursue and use the index information. Following this challenge, they highlighted that *"that needs to be tackled every cycle, every time we update in such a research study, and that challenge will not go away easily unless there is significant broader support for this"* (C.1). The other challenge is more dealing with the scientific and

technical aspect of this development. The participant added, *"There are different schools of thought on how different hazards should be perceived and tackled. Some argue that combining multiple hazards is not the right approach since they can be dealt with and mitigated individually. Putting too much investment in one hazard may not be wise. On the other hand, there are hazards that are rare and may not occur often, but have the potential for catastrophic impacts. It is important to maintain clarity in the process. Efforts should be made to communicate this to the community at large."* (C.1).

3.2.5 Milestones

In the following stage, we asked the experts about the critical milestones in their participation. According to one interviewee, the most important milestone was when the development team came up with a reasonable representation of combining hazard with social vulnerability and community resilience (C.1: *"I think when I saw that effort - leading to some useful development of an index - I was more comfortable with that development."*).

Another participant emphasized that the most critical point was the openness of the NRI development team. *"From my point of view, a significant milestone was realizing that there is room for iteration and improvement in the overall process. It is important to understand that products are evolving, and FEMA has been receptive to feedback on how things can be improved from start to end. Good communication is key, including timelines, scope, and how things fit in with the datasets in hazard areas they are looking at."* (C.4.2). A series of meetings, the same participant highlighted, was important to understand that there is room to move forward and find the data needed was the most critical milestone.

3.2.6 Limitations

In the next part of the discussion, we focused on limitations. The majority of the interviewees did not identified any limitation. One participant however, referred to the indirect damages. On the other hand, the participant also mentioned the difficulty to access this kind of damage.

3.2.7 Index use/user groups

In the next step, we discussed with the participants if they are using the index in their activities. The majority of them reported that the index is being used in their organizations. They mentioned some activities and authorities that are utilizing the index:

- Activities
    - Hazard mitigation planning
    - Contingency planning
    - Hazard impacts managing responses
- Agencies
    - Federal Grants Agency

- National Centers for Environmental Information (NCEI)
- University students
- Department of Housing and Urban Development
- Environmental protection Agency (EPA)
- Department of Energy (DOE)
- NOAA
- SIRA project

As reported by one participant, some of these authorities heavily utilize the NRI. Another responder highlighted that they are trying to bring together different data tools and resources in one portal to provide context and information for different stakeholders, and the NRI is one of the main tools.

We continued the interviews by asking the interviewees for their opinions about the benefits of the index. The responders highlighted the simplified way it communicates risk, that it is actionable, easy-to-use tool, gives access to complicated data and enhances the analytical capacity. The integrated information it provides, including hazard, social vulnerability, and resilience to quantify risk score, was also highlighted as highly important. A responder emphasized: *"There is a big focus on populations that are underserved and at higher risk. The idea is to make sure that we are focusing on all types of risks for all types of people/groups, and certainly knowing where the risk is going to be helpful for planning."* (C4.1).

In the same vein, another participant mentioned consistency. Offering mapping around the U.S. territory and being able to compare the different areas is important for management authorities.

Furthermore, a participant highlighted its usefulness in providing a qualitative description of risk, ranging from low to high. This information is easy for different users to understand and has helped their organization to communicate risk effectively.

3.2.8 *"If you have to take place in the process again what you will be doing differently and why?"*

We closed the interviews by asking the interviewees the question: *"If you had to participate in the process again, what would you do differently and why?"*

All of them reported that they would like to participate in the process again and collaborate with the NRI development team. One respondent reported that they would like to be involved in the methodology aspects of the development of the NRI. However, they found it exciting to support this effort and to see the information produced within its authority used in many different ways and applications. In the same vein, another participant highlighted that they would like to get involved in other aspects of the index.

4 Conclusions - recommendations

The National Risk Index developed by FEMA is a one-of-its-kind tool that offers a top-down approach to measuring natural hazard risk across the United States. By using nationwide datasets, the index provides a relative measurement of community-level risk in all 50 states and Washington, DC. The use of multiple variables such as exposure, frequency, and historic loss ratio to derive expected annual loss estimates for 18 hazard types ensures that the index is accurate and comprehensive. Additionally, the inclusion of social vulnerability and community resilience scores in the index provides a more holistic understanding of natural hazard risk in communities.

Based on the analysis and research questions, important conclusions are presented in the following paragraphs.

The development team's engagement with subject matter experts during the design phase was a key factor in the success of the NRI. By seeking input from various fields, the team was able to create a product that was both comprehensive and academically sound. The multidimensional information platform provided by the index has been identified as a benefit by those who have engaged with the project, making it a useful tool for decision-making, hazard assessment, and disaster management. The initiative's practice of creating different working groups and connecting them under FEMA's umbrella has been recognized as a good practice, ensuring that all aspects of the project are coordinated and aligned towards a common goal.

Despite some challenges in engaging certain groups, particularly those who had identified flaws in their databases, the development team made significant efforts to address these issues. They recognized the importance of convincing these groups that their dataset was the best available and maintained regular meetings and discussions with them. In addition, the team ensured that each working group remained focused on their task while keeping them informed about the progress made by the other groups. This approach helped to maintain a successful collaboration and ensure that everyone was working towards the same goal.

The positive feedback from the participants highlights the effectiveness of the collaboration between FEMA and the Subject Matter Expert Teams. Their feedback suggests that open communication and cooperation were integral to the success of the project. The teams were able to provide valuable input and expertise in the design and development phases of the project, ensuring that the NRI was based on the best available inputs and experts. This cross-disciplinary collaborative approach (Zuzak at al., 2022) also helped to address any limitations or challenges in the data and analysis, resulting in a more robust and accurate tool.

Some participants identify challenges in working with different experts, including the need to combine various hazards in a geographic area and reconcile differing opinions on how to handle hazards. However, the participants also recognized the importance of forming sub-groups and convincing experts to think beyond their own areas of expertise. The fact that four out of the five participants were heavily involved in SME teams suggests that these teams were critical to the success of the project. This may imply that the involvement of SMEs in similar projects could be important for achieving successful outcomes.

Overall, these conclusions suggest that collaboration (cross-disciplinary) and effective communication were key factors in the success of the NRI project, and that involving SMEs and addressing challenges in working with different experts were important steps in achieving the project goals.

The officials aimed to develop an index that would be accessible to everyone without the need of a username and password, using open and free data and avoiding hosting data that was already available from another agency or authority. Based on our analysis the majority of the interviewees contributed data and methods to the NRI, indicating a willingness to support FEMA's effort. The data provided by the interviewees included hazard maps, gauge data, and historic losses, as well as other data relevant to hazard analysis and loss estimation. Both raw and processed data formats were used, and all data used in the NRI were manipulated to obtain a standardized risk score. The interviewees had productive discussions about the best way to represent the data, which suggests a collaborative approach to data sharing and analysis within the NRI was a key element.

The responders did not feel any criticism by FEMA or other participants, indicating that effective communication and transparency about the nuances of the data helped to avoid misunderstandings and potential criticisms. Authorities who were afraid of being held accountable and kept information secret were not a problem for the officials, as they used only publicly available datasets and did not leverage protected or private data.

How to integrate social vulnerability and community resilience to develop the equity component within the NRI, reported as a critical challenge and milestone. The officials noted that they had to come up with a composite formula that met both theory, practice, and was implementable. The involvement of different stakeholders and the literature review supported efforts to solve this challenge. Developing a reasonable representation of combining hazard with social vulnerability and community resilience was a critical milestone in the development of the NRI. This was highlighted by many interviewees, who stated that they were more comfortable with the development after seeing this effort.

Another significant challenge was the lack of involvement of big data experts and user interface experts in the early stages of development, resulting in the creation of an application that was not user-friendly. Nevertheless, the team recognized the issue and took steps to integrate these teams and explore the big data realm to

support all processes effectively. This emphasizes the critical role that big data experts play in any comparable initiative, as they bring valuable knowledge and expertise in handling large and complex data sets and creating user-friendly interfaces that enhance the user experience. Therefore, involving these experts from the outset can contribute to the success of any similar initiative.

Time management and resource management were crucial challenges in the process, and navigating governmental bureaucracy was also a significant challenge when working with different groups and external affairs. The development of the NRI was a lengthy and challenging process that required significant resources and funding. Despite these challenges, the team invested extra time and resources in keeping the project going. This highlights the importance of commitment and perseverance in pursuing large-scale initiatives. Overall, the responders' comments suggest that FEMA's response to the NRI was a complex and evolving process that required careful planning, collaboration, and investment. Despite these challenges, the development of the NRI appears to have been a significant achievement for the agency in terms of understanding and reducing natural hazard risks.

The analysis identified some limitations in the available data and methodologies for assessing hazards, such as the limited period of data records for some hazards and the challenge of calculating return periods and losses. Additionally, certain hazards like geological hazards occur over a long timescale of millions of years, making it difficult to quantify those using data from the last few hundred years. Despite these obstacles, the decision was made to proceed with certain methodologies, such as in the case of volcanic eruptions, after careful consideration and evaluation of the available options. As reported by the participants, they are working to find solutions to these limitations. The interviewees acknowledged these limitations as a crucial challenge in the development process.

The openness of the tool and its user-friendly information has been positively received by various groups, including government agencies, community organizations, and the private sector. The NRI can be used to support long-term communication of risk, planning for natural hazards, and identifying communities for code improvements or updates. The NRI can be integrated into various activities, such as the National Flood Insurance Program, grant applications, and private sector decision-making, to make data-driven decisions and incorporate climate change parameters and social equity perspectives.

The majority of the interviewees highlighted the benefits of the index, particularly the simplified way to communicate risk and its easy-to-use and actionable nature. The index provides a consistent way to map and compare different areas in the US, which is important for management authorities. Many actors are interested in leveraging its data without having to invest in developing their own risk index.

From the above, it can be concluded that the NRI has been successful in providing a comprehensive and academically correct approach to understanding

natural hazard risks in the United States, and its usefulness has been recognized by various stakeholders. The NRI has many potential uses and benefits, there are also limitations and challenges that need to be addressed. However, the interviewees suggested that they are actively working to improve the index and make it more useful and relevant for decision-makers at all levels. The officials are working on continually updating the NRI, with no regular intervals specified, and are continuously seeking hazard data updates as new data becomes available. They emphasize the importance of ensuring that all datasets are regularly updated.

Focusing on Sweden and with respect to the third research question, is crucial to establish processes and methods for conducting risk assessments from a comprehensive national perspective in order to strengthen civil protection and emergency preparedness. Sweden places a high priority on this development (MSB, 2011). A national risk assessment would enable a comparison of risks from a national perspective and provide a more solid basis for effectively prioritizing resources. From the analysis and conclusions, we present a summary of the good practices of relevance from a Swedish perspective.

An integrated Risk Framework:

In Sweden, although significant ongoing work relates to various dimensions of risk, the focus remains on hazards, rather than on an all-encompassing understanding of disaster risk in all its dimensions (Aronsson-Storrier, 2021). The same report noted that the language of "risk and vulnerability" is not in line with contemporary SFDRR terminology (SFDRR, 2015; UNISDR, 2018), where vulnerability is considered a fundamental aspect of disaster risk, rather than separate from it.

Our analysis indicated that an integrated risk framework (incorporating social vulnerability and community resilience to develop the equity component) within the NRI was an important milestone. Officials noted that they had to come up with a composite formula that was in line with theory, practice, and implementable. In this regard, any future implementation must put effort into developing an integrated risk framework for the Swedish conditions.

To create an integrated risk framework and following the findings of this study, an extensive literature review and meetings with relevant stakeholders could form the basis. Guidelines provided by different authorities (European Union: Poljanšek et al., 2019; United Nations: SFDRR, 2015) could support and offer guidance in the process. The EU and UN publications provide principles, good practices and scientific support to member states in charge of the preparation of national risk assessment processes and disaster risk management planning.

A collaborative approach:

Following the experiences of the study participants, the development of the National Risk Index faced several challenges. To overcome these challenges, the development team integrated a wide variety of experts. The expert teams were able to provide valuable input and expertise in the design and development phases of

the project, ensuring that the NRI was based on the best available inputs. This cross-disciplinary collaborative approach helped to address any limitations or challenges in the data and analyses, resulting in a more robust and accurate tool.

In this regard, a participatory approach is suggested for any future implementation in Sweden. This approach would allow the integration of relevant stakeholders from the very beginning, ensuring that requirements and key value points are identified and thoroughly addressed during the development process (Sanders, 2002; Bergvall-Kåreborn & Ståhlbröst, 2008).

Big data experts:

Within the participatory approach, and following the conclusions of this study, big data experts must play an important role. As discussed, data management is a critical parameter in a national risk assessment, and these experts possess the necessary skills and knowledge to effectively manage large datasets, as well as process and store data securely. Additionally, big data experts are proficient in data visualization and other visual representations of data to help stakeholders understand complex information.

Zuzak et al. (2022) reported that a web application was designed using a multidisciplinary and collaborative approach that adopted principles and methods from user-centered design, user experience, usability, and design thinking to meet the needs of the National Risk Assessment. Therefore, based on conclusions of this study, it is crucial to integrate big data experts in any future implementation.

Data:

Focusing on data, significant amounts of data exist in Sweden, but it is clear that dissemination and communication could be further improved (Aronsson-Storrier, 2021). The amount of existing data is relatively large, and the quality is relatively high, but there is a need to further improve and harmonize data from different sources – in collaboration with a range of actors, stakeholders, and experts.

MSB described the different types of hazards that may have serious consequences in Sweden (MSB, 2011). This analysis could be a foundation for any future development with respect to consequences, available data, and methods used. For some hazards, information is available, while for others it is not. A recommendation could be to start with the available hazards but on the same time to create routines from the initial development stages for the integration of more hazards in the future.

With respect to the damage data and loss data, the report published by Johanson & Månsson (2022) provides an analytical description of the available data in Sweden. They offer relevant sources of information for meeting the minimum requirements of the SFDRR and EU. This information can support the initial stages of any future implementation.

Within the NRI, social vulnerability (SOVI) and community resilience (BRIC) indexes are used to develop the equity component. In Sweden, the social

vulnerability methodology developed by Cutter et al. (2003) was tested by Karagiorgos et al. (2021) and adapted to the Swedish conditions by Haas et al. (2022). With respect to the BRIC index, Khairallah (2020) studied how this index could be adjusted to suit Swedish conditions. The knowledge gained from these studies can be leveraged by development teams in the future to enhance their work.

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Appendix 1: National Risk Index Report sample

National Risk Index

February 13, 2023

Census tract 12031013901, Duval County, Florida

Summary

Risk Index is **Relatively High** — Score **28.26** (0 – 100)

Expected Annual Loss is **Relatively High** — Score **36.55** (0 – 100)

Social Vulnerability is **Very Low** — Score **26.82** (0 – 100)

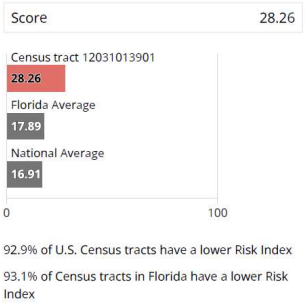
Community Resilience is **Relatively High** — Score **55.80** (0 – 100)

While reviewing this report, keep in mind that low risk is driven by lower loss due to natural hazards, lower social vulnerability, and higher community resilience.

For more information about the National Risk Index, its data, and how to interpret the information it provides, please review the **About the National Risk Index** and **How to Take Action** sections at the end of this report. Or, visit the National Risk Index website at **hazards.fema.gov/nri/learn-more** to access supporting documentation and links.

Risk Index

The Risk Index rating is Relatively High for Census tract 12031013901 when compared to the rest of the U.S.



92.9% of U.S. Census tracts have a lower Risk Index

93.1% of Census tracts in Florida have a lower Risk Index

Risk Index Legend

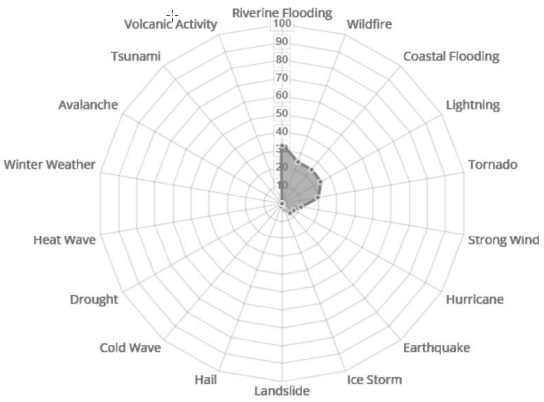
Very High | Relatively High | Relatively Moderate | Relatively Low | Very Low

No Rating | Not Applicable | Insufficient Data

Hazard Type Risk Index

Hazard type Risk Index scores are calculated using data for only a single hazard type, and reflect a community's relative risk for only that hazard type.

Hazard Type	Risk Index Rating	Risk Index Score
Avalanche	Not Applicable	--
Coastal Flooding	Relatively High	24.68
Cold Wave	No Rating	0.00
Drought	No Rating	0.00
Earthquake	Very Low	6.90
Hail	Very Low	1.70
Heat Wave	No Rating	0.00
Hurricane	Very Low	7.26
Ice Storm	Very Low	3.40
Landslide	Relatively Low	2.23
Lightning	Relatively Moderate	23.89
Riverine Flooding	Relatively High	32.60
Strong Wind	Very Low	10.50
Tornado	Relatively Low	19.67
Tsunami	Insufficient Data	--
Volcanic Activity	Not Applicable	--
Wildfire	Relatively High	24.77
Winter Weather	No Rating	0.00

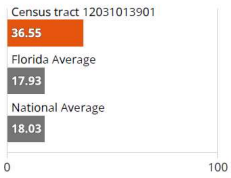


The chart above demonstrates the relative distribution of hazard type Risk Index scores for Census tract 12031013901. Risk Index scores are plotted for each hazard type included in the National Risk Index. Higher relative risk corresponds to larger colored areas inside a given hazard type chart slice.

Expected Annual Loss

In Census tract 12031013901, expected loss each year due to natural hazards is Relatively High when compared to the rest of the U.S.

Score	36.55



98.1% of U.S. Census tracts have a lower Expected Annual Loss

98.8% of Census tracts in Florida have a lower Expected Annual Loss

Expected Annual Loss Legend

Very High | Relatively High | Relatively Moderate | Relatively Low | Very Low

No Expected Annual Losses | Not Applicable | Insufficient Data

Composite Expected Annual Loss	$2,458,614.24
Building Value	$707,706.16
Population	0.23 fatalities
Population Equivalence	$1,750,908.08
Agriculture Value	$0.00

Expected Annual Loss for Hazard Types

Expected Annual Loss scores for hazard types are calculated using data for only a single hazard type, and reflect a community's relative expected annual loss for only that hazard type. 15 of 18 hazard types contribute to the expected annual loss for Census tract 12031013901.

Hazard Type	Expected Annual Loss Rating	Expected Annual Loss Score
Avalanche	Not Applicable	--
Coastal Flooding	Relatively High	31.93
Cold Wave	No Expected Annual Losses	0.00
Drought	No Expected Annual Losses	0.00
Earthquake	Relatively Low	7.91
Hail	Very Low	2.06
Heat Wave	No Expected Annual Losses	0.00
Hurricane	Relatively Low	6.92
Ice Storm	Very Low	5.33
Landslide	Relatively Low	3.32
Lightning	Relatively High	38.63
Riverine Flooding	Very High	44.89
Strong Wind	Relatively Low	11.88
Tornado	Relatively Low	21.49
Tsunami	Insufficient Data	--
Volcanic Activity	Not Applicable	--
Wildfire	Relatively High	32.45
Winter Weather	No Expected Annual Losses	0.00

Expected Annual Loss Values

Hazard Type	Total	Building Value	Population Equivalence	Population	Agriculture Value
Avalanche	--	--	--	--	--
Coastal Flooding	$908,781	$199,336	$709,444	0.09	n/a
Cold Wave	$0	$0	$0	0.00	$0
Drought	$0	n/a	n/a	n/a	$0
Earthquake	$6,975	$6,632	$343	0.00	n/a
Hail	$33	$2	$31	0.00	$0
Heat Wave	$0	$0	$0	0.00	$0
Hurricane	$4,938	$2,926	$2,012	0.00	$0
Ice Storm	$60	$31	$29	0.00	n/a
Landslide	$318	$132	$186	0.00	n/a
Lightning	$13,260	$447	$12,812	0.00	n/a
Riverine Flooding	$982,412	$15,374	$967,037	0.13	$0
Strong Wind	$1,867	$1,144	$723	0.00	$0
Tornado	$27,426	$11,934	$15,491	0.00	$0
Tsunami	n/a	n/a	n/a	n/a	n/a
Volcanic Activity	--	--	--	--	--
Wildfire	$512,545	$469,747	$42,799	0.01	$0
Winter Weather	$0	$0	$0	0.00	$0

Exposure Values

Hazard Type	Total	Building Value	Population Equivalence	Population	Agriculture Value
Avalanche	--	--	--	--	--
Coastal Flooding	$48,235,209,000	$651,609,000	$47,583,600,000	6,261.00	n/a
Cold Wave	$0	$0	$0	0.00	$0
Drought	$0	n/a	n/a	n/a	$0
Earthquake	$48,235,209,000	$651,609,000	$47,583,600,000	6,261.00	n/a
Hail	$48,235,209,000	$651,609,000	$47,583,600,000	6,261.00	$0
Heat Wave	$0	$0	$0	0.00	$0
Hurricane	$48,196,217,038	$650,908,256	$47,545,308,782	6,255.96	$0
Ice Storm	$48,235,209,000	$651,609,000	$47,583,600,000	6,261.00	n/a
Landslide	$16,228,218,159	$149,214,472	$16,079,003,686	2,115.66	n/a
Lightning	$48,235,209,000	$651,609,000	$47,583,600,000	6,261.00	n/a
Riverine Flooding	$25,817,063,699	$411,509,320	$25,405,554,379	3,342.84	$0
Strong Wind	$48,235,209,000	$651,609,000	$47,583,600,000	6,261.00	$0
Tornado	$48,235,209,000	$651,609,000	$47,583,600,000	6,261.00	$0
Tsunami	n/a	n/a	n/a	n/a	n/a
Volcanic Activity	--	--	--	--	--
Wildfire	$24,547,643,681	$380,718,259	$24,166,925,423	3,179.86	$0
Winter Weather	$0	$0	$0	0.00	$0

Annualized Frequency Values

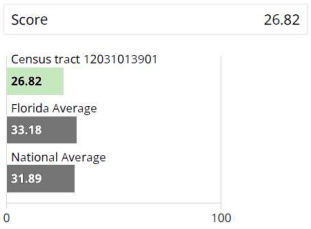
Hazard Type	Annualized Frequency	Events on Record	Period of Record
Avalanche	--	--	--
Coastal Flooding	2.7 events per year	n/a	Various (see documentation)
Cold Wave	0 events per year	0	2005-2017 (12 years)
Drought	17.1 events per year	308	2000-2017 (18 years)
Earthquake	0.036% chance per year	n/a	2017 dataset
Hail	1.7 events per year	54	1986-2017 (32 years)
Heat Wave	0 events per year	0	2005-2017 (12 years)
Hurricane	0.3 events per year	27	East 1851-2017 (167 years) / West 1949-2017 (69 years)
Ice Storm	0 events per year	0	1946-2014 (67 years)
Landslide	0 events per year	0	2010-2019 (10 years)
Lightning	108.2 events per year	2,380	1991-2012 (22 years)
Riverine Flooding	3.3 events per year	78	1996-2019 (24 years)
Strong Wind	0.9 events per year	30	1986-2017 (32 years)
Tornado	0 events per year	0	1986-2019 (34 years)
Tsunami	n/a	n/a	1800-2018 (219 years)
Volcanic Activity	--	--	--
Wildfire	0.191% chance per year	n/a	2016 dataset
Winter Weather	0 events per year	0	2005-2017 (12 years)

Historic Loss Ratios

Hazard Type	Overall Rating	Building Value	Population	Agriculture Value
Avalanche	--	--	--	--
Coastal Flooding	Very Low	$1.13 per $10K	5.51 per 1M	n/a
Cold Wave	No Rating	$5.25 per $10M	1.30 per 10M	$1.10 per $100
Drought	No Rating	n/a	n/a	$4.97 per $1M
Earthquake	Very Low	$1.68 per $100	1.40 per 10K	n/a
Hail	Very Low	$1.79 per $1B	3.86 per 10B	$4.71 per $1M
Heat Wave	No Rating	$2.77 per $10B	7.93 per 10M	$6.01 per $1M
Hurricane	Very Low	$1.79 per $100K	1.68 per 10M	$2.55 per $10K
Ice Storm	Very Low	$3.15 per $1M	4.10 per 100M	n/a
Landslide	Very Low	$8.87 per $100K	1.16 per 1M	n/a
Lightning	Very Low	$6.56 per $1B	2.56 per 1B	n/a
Riverine Flooding	Very Low	$1.15 per $100K	1.17 per 100K	$3.97 per $100K
Strong Wind	Very Low	$1.87 per $1M	1.62 per 100M	$1.50 per $1M
Tornado	Very Low	$1.12 per $100	2.00 per 10K	$1.32 per $100
Tsunami	Insufficient Data	n/a	n/a	n/a
Volcanic Activity	--	--	--	--
Wildfire	Very Low	$4.00 per $10	6.04 per 10K	$1.36 per $100
Winter Weather	No Rating	$1.87 per $1M	4.24 per 100M	$2.51 per $1M

Social Vulnerability

Social groups in Census tract 12031013901 have a Very Low susceptibility to the adverse impacts of natural hazards when compared to the rest of the U.S.

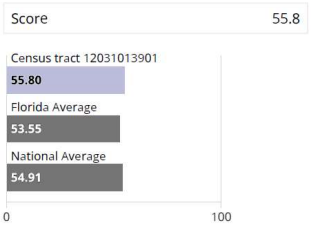


9.7% of U.S. Census tracts have a lower Social Vulnerability

6.6% of Census tracts in Florida have a lower Social Vulnerability

Community Resilience

Communities in Census tract 12031013901 have a Relatively High ability to prepare for anticipated natural hazards, adapt to changing conditions, and withstand and recover rapidly from disruptions when compared to the rest of the U.S.



35.1% of U.S. Census tracts have a higher Community Resilience

4.5% of Census tracts in Florida have a higher Community Resilience

How to Take Action

There are many ways to reduce natural hazard risk through mitigation. Communities with high National Risk Index scores can take action to reduce risk by decreasing Expected Annual Loss due to natural hazards, decreasing Social Vulnerability, and increasing Community Resilience.

For information about how to take action and reduce your risk, visit hazards.fema.gov/nri/take-action.

Disclaimer

The National Risk Index (the Risk Index or the Index) and its associated data are meant for planning purposes only. This tool was created for broad nationwide comparisons and is not a substitute for localized risk assessment analysis. Nationwide datasets used as inputs for the National Risk Index are, in many cases, not as accurate as available local data. Users with access to local data for each National Risk Index risk factor should consider substituting the Risk Index data with local data to recalculate a more accurate risk index. If you decide to download the National Risk Index data and substitute it with local data, you assume responsibility for the accuracy of the data and any resulting data index. Please visit the Contact Us page if you would like to discuss this process further.

The methodology used by the National Risk Index has been reviewed by subject matter experts in the fields of natural hazard risk research, risk analysis, mitigation planning, and emergency management. The processing methods used to create the National Risk Index have produced results similar to those from other natural hazard risk analyses conducted on a smaller scale. The breadth and combination of geographic information systems (GIS) and data processing techniques leveraged by the National Risk Index enable it to incorporate multiple hazard types and risk factors, manage its nationwide scope, and capture what might have been missed using other methods.

The National Risk Index does not consider the intricate economic and physical interdependencies that exist across geographic regions. Keep in mind that hazard impacts in surrounding counties or Census tracts can cause indirect losses in your community regardless of your community's risk profile.

Nationwide data available for some risk factors are rudimentary at this time. The National Risk Index will be continuously updated as new data become available and improved methodologies are identified.

The National Risk Index Contact Us page is available at hazards.fema.gov/nri/contact-us .

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