RIFS DISCUSSION PAPER

Research Institute for Sustainability (RIFS)

Potsdam, February 2023

Vulnerability Analysis Made Easy

A step-by-step guide on how to conduct a vulnerability analysis

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RIFS POTSDAM

Funding Acknowledgement

Esther Schuch acknowledges funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 675997, and the project Investigating the Systemic Impacts of the Global Energy Transition (ISIGET), financed by the Federal Ministry of Education and Research (BMBF) under the "Make our Planet Great Again - German Research Initiative", grant number 57429628, implemented by the German Academic Exchange Service (DAAD).

Contents

1. Introduction

1.1 At a glance

This chapter provides a quick overview of the content of the manual and answers a number of key questions.

What is vulnerability?

Vulnerability is defined as the susceptibility of a system toward a specific hazard. The concept of vulnerability is used to describe how a system's inherent characteristics contribute to the risk which arises through the exposure of that system to a specific hazard (Chapter 2.2).

Why measure vulnerability?

The concept of vulnerability is frequently used to assess differences between various systems regarding their susceptibility to specific hazards. The results of such assessments can be used to inform decision-making, for example in the field of development work, where it is crucial to find those places or people most at risk (Chapter 2.4). With the vulnerability approach, assistance can be coordinated effectively and evaluated data can be incorporated into decision-making processes in a more targeted manner.

Who is the manual for?

The vulnerability analysis is a tool for all actors who are involved or interested in decision-making processes related to resilience development measures. The results of vulnerability analysis open up a uniform communication basis for actors from different areas since data from the social, economic, and biophysical dimensions are brought together.

What do I need to conduct a vulnerability assessment?

The data requirements of a vulnerability analysis depend on the assessment context and the desired level of detail. The more detailed the data, the more meaningful are often the results. The lack of data is one of the biggest obstacles to vulnerability assessments. How to deal with it is also described in this manual (Chapter 4.4).

What results and products does a vulnerability analysis provide?

With the help of vulnerability analyses, differences between rated systems can be displayed both in diagrams and maps. This not only facilitates access to and communication of the results but can also be used to visualize before and after comparisons (Chapter 4.5).

1.2 How is the handbook structured?

In addition to the introduction, the following manual consists of 3 sub-chapters. Depending on the question and the previous knowledge of the user, the relevant chapters can be read selectively (see Figure 1). In the second chapter, users will find an overview of the background and the theoretical foundation of vulnerability analyses. The risk concept with the vulnerability concept embedded in it is described in more detail and the relationship between vulnerability and risk is examined. The third chapter deals with the question of how vulnerability can be recorded and measured and what barriers limit the process. In the fourth chapter, step-by-step instructions are provided for users. In these instructions, the most important points to be considered in a vulnerability analysis are described and put into context with a practical example. This should help to give the user a good overview and a first feeling for the process

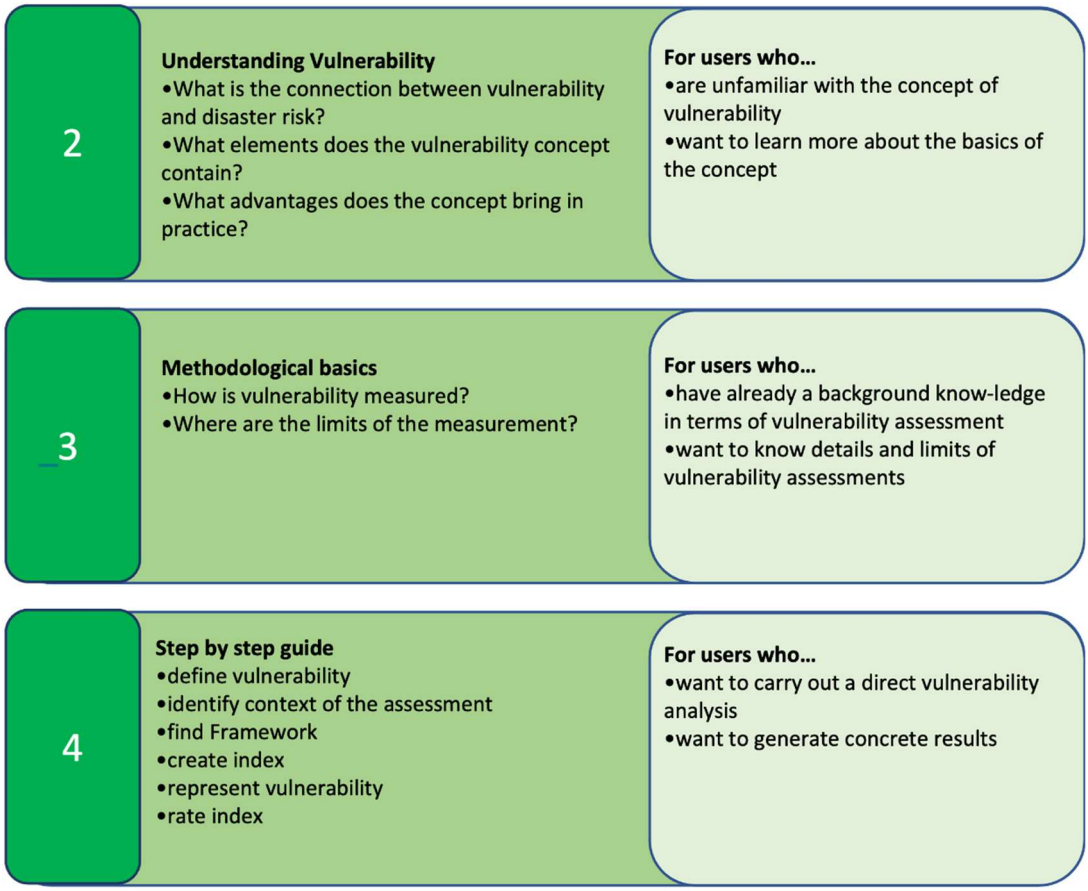
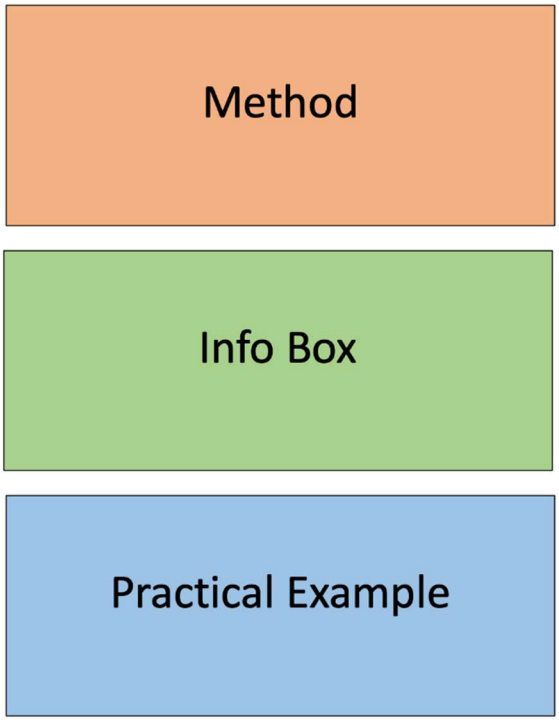


Figure 1: Overview of the chapters of the book.

1.3 Which working aids does this manual offer?

The manual uses three different coloured boxes to highlight certain content. Depending on the colour code, these boxes contain specific information tailored to the chapter. The orange box contains brief summaries about methods that can be used for a vulnerability analysis regarding data collection or indicator choice. The green box contains information about various aspects like further literature, explanations, or background knowledge. A practical example of vulnerability assessment as it is described in this manual can be found in the blue boxes.



Box 1: Colour code used in this guide.

1.4 Disclaimer

This manual is designed to provide guidance on how to conduct a vulnerability analysis for practitioners without previous experience. It is not a comprehensive review of the different ways a vulnerability analysis can be conducted. Thus, while this guide enables the reader to conduct a vulnerability analysis it does not attempt to summarize all the approaches available. Rather, the most frequently observed methods are presented with the goal of lowering the barriers towards vulnerability assessment.

2. Understanding vulnerability

Measuring vulnerability is a hands-on task but to do so it is necessary to establish a theoretical and conceptual basis upon which the assessment can be conducted. This chapter provides a concise overview of vulnerability, its relationship with disaster and risk, and highlights the context specificity of vulnerability.

2.1 Introduction

The basic approach of the concept of vulnerability is often referred to as the susceptibility of a system or entity to a specific hazard. The goal of vulnerability assessment is to make the susceptibility of similar systems comparable to each other and identify those systems which are most vulnerable. The difference between ecological vulnerability assessment and sociological vulnerability assessment is that in the former, ecosystems or species are the focus of the analysis, while in the latter, specific groups of people and how they deal with hazards are examined. The concept has been around for a long time in these basic forms, but it has been broadened to identify not only groups or ecosystems but also locations (coupled human-environmental systems) that are at increased risk of being adversely affected by a hazard. Especially in the context of development cooperation and development research, the word "vulnerability" has developed into a term that can be used to describe different forms of expression of disadvantage. What is described as vulnerable is constantly being redefined and tailored to the specific context ranging from susceptibility to natural hazards such as earthquakes and floods to famines (often caused by a combination of natural and societal factors). The versatility of the concept allows for the wide application of vulnerability analysis. However, it also complicates assessments as the context-specific elements need to be determined. The vulnerability concept has been further developed over the years and vulnerability itself has been defined and classified differently by many experts (see Box 2 for key literature). The result of this process is an immense variety of concepts and models that attempt to make vulnerability tangible. While this was intended to simplify vulnerability analyses, the number of conceptual variations of the concept often results in the opposite and makes it difficult to enter the subject area and use it in an application-oriented manner.

A good overview of the development of the concept is provided by Kim et al. (2021), who conducted a bibliometric analysis to investigate historical changes in disaster risk management's vulnerability concept and its related fields between 2000 and 2019. The aim of this manual is to introduce the vulnerability concept, provide application-oriented instructions that summarize the most important steps for a successful vulnerability analysis, and illustrate each step with a practical example.

Further Reading

In this section you find popular papers and books in the field of vulnerability research sorted by their publication date. Making yourself more familiar with different concepts and methods of vulnerability will help you to get a better picture of how the word

1976 Phil O'Keefe, Ken Westgate and Ben Wisner argue the case that disasters are more a consequence of socio-economic than natural factors:
O'Keefe, P., K. Westgate, and B. Wisner (1976). "Taking the naturalness out of natural disasters." Nature 260: 566-567.

1996 This progress report reviews the research on vulnerability in the hazards field up to this point. It proposes a new conceptual model of vulnerability (Hazard of place).
Cutter, S. L. (1996). Vulnerability to environmental hazards. Assessment, 20(4), 284–290

2003 Turner and his colleagues present in this paper a vulnerability framework for the assessment of coupled human–environment systems:
Turner, Billie L., et al. "A framework for vulnerability analysis in sustainability science." Proceedings of the national academy of sciences 100.14 (2003): 8074-8079.

2006 This paper reviews research traditions of vulnerability to environmental change and the challenges for present vulnerability research in integrating with the domains of resilience and adaptation:
Adger, W. Neil. "Vulnerability." Global environmental change 16.3 (2006): 268-281.

2006 This paper reviews the concept of adaptation of human communities to global changes, especially climate change, in the context of adaptive capacity and vulnerability: Smit, Barry, and Johanna Wandel. "Adaptation, adaptive capacity and vulnerability." Global environmental change 16.3 (2006): 282-292.

2014 This book discusses disaster not as an abnormality, but as a signal failure of mainstream 'development'.
Wisner, Ben, et al. At risk: natural hazards, people's vulnerability and disasters. Routledge, 2014.

Box 2: Recommended reading on vulnerability.

2.2 The link between vulnerability and disaster risk

Vulnerability analysis is often used where disadvantages are investigated, or preventive measures towards hazards are examined. The aim of such analyses and preventive measures is to be able to estimate and relate the risk for certain groups or places to a specific hazard. Accordingly, the field of vulnerability research is closely interwoven with that of risk research. Therefore, the most important terms (vulnerability, exposure, danger, and disaster risk) and their connections in risk research are discussed in more detail below. Figure 2 represents one of the simplest ways to illustrate disaster risk and is based on Oliver-Smith‘s (1999) definition of disaster as a consequence of external variability and internal complexity. The clear differentiation between external and internal systems, their connection, and the quality of this connection, is crucial for conceptualizing disaster risk.

Because disaster risk assessments are often developed in the context of environmental hazards, it is often the natural system, the environment, which defines the external component, and the social system, which defines the internal component. In Figure 2 (page 11), the social system is represented by the inner circle and the natural system by the external circle. Only if both systems are connected is there a risk of a disaster caused by a natural hazard. Thus, in Figure 2 (A) there is no risk of a disaster since the internal system is independent of the external system. If both systems are connected there are two possible states, the “harmony state” (B) and the “hazard state” (C). The harmony state describes a situation in which the social system is perfectly adjusted to the natural system, while the hazard state describes a situation in which the social system is not adjusted to the environmental system. If this occurs, there is a risk of a disaster and efforts must focus on bringing the two systems into a harmonious state. The figure shows that such a state can be achieved through two processes: by changing the external component and/or by changing the internal component. Often a hazardous state is generated by a change in the environment. Accordingly, the environment’s variability can pose a threat to the social system embedded in it. The level of risk that the hazard can generate depends on the one hand, on its strength or severity and, on the other hand, on the inability of the social system to adapt to the hazard or to limit the severity of the hazard (vulnerability). The difference between risk and vulnerability is that vulnerability is the potential for damage, loss, and destruction in a particular system, while risk is the combined outcome of vulnerability, exposure, and the severity of the hazard. A risk of disaster arises if there is a hazard towards which a system (or parts of it) are both exposed *and* vulnerable. Assuming that both the severity of an environmental hazard and the exposure to it are equally strong between social entities, a different risk, which represents the hazard for the social entity, results from its vulnerability to it (see Box 3). Therefore, vulnerability and disaster risk are closely related, and vulnerability assessment forms a large part of risk research.

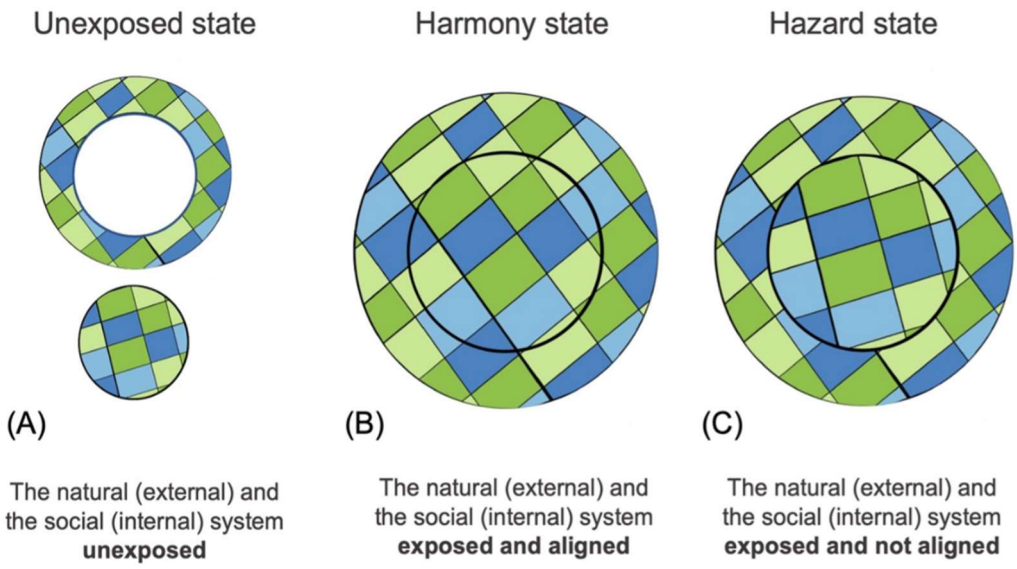


Figure 2: The three states of vulnerability (Laura Lange).

Relationship between Risk, Hazard, Exposure, and Vulnerability

The following equation explains the relationship between risk, vulnerability, exposure, and hazard:

$$R = H * V * E$$

R, is the risk of a disaster happening, E is the magnitude of exposure, H is the external hazard, and V is the vulnerability of the (social) system towards this hazard (Brooks 2003).

Box 3: The relationship between risk, hazard, exposure, and vulnerability.

2.3 Which elements does the vulnerability concept contain?

To be able to assess vulnerability, it is necessary to define more precisely what exactly the concept contains. Vulnerability can be viewed as the potential for damage, destruction, and loss of a system. Whether this potential is fully exploited depends on the intensity of the hazard and exposure. The vulnerability concept was developed to assess the potential of a specific hazard to cause damage in an element. Vulnerability depends on the internal structure, the complexity of a system. Capturing this complexity in its entirety is beyond the scope of any vulnerability analysis. For this reason, the focus of any vulnerability analysis lies on identifying the most relevant structures that determine the potential for damage in a system in relation to a hazard.

How to understand which structures are important and which are unimportant?

In recent decades, a concept has been established in vulnerability research that is intended to simplify the identification of crucial structures. The concept is based on the classification of structures into two opposing categories. The structures in the first category are declared as those that make the whole system more sensitive towards the dangers of a certain hazard (Sensitivity). The structures of the second category are those that improve the system's ability to adapt to the hazard (Adaptive Capacity) (See box 4 and 5).

The following equation describes the presented concept as follows:

$$Vulnerability = Sensitivity - Adaptive\ Capacity$$

Box 4: The relationship between adaptive capacity, sensitivity, and vulnerability.

Further Reading

Dive into the historical background of risk research and understand how one paper changed the way we look on natural hazards:

Macdonald, Neil & Chester, David & Sangster, Heather & Todd, B. & Hooke, J. (2012). The Significance of Gilbert F. White's 1945 paper 'Human Adjustment to Floods' in the Development of Risk and Hazard Management. Progress in Physical Geography. 36. 125-133.

Box 5: Recommended reading on risk research.

2.4 What are the advantages of applying the vulnerability concept in practice

Climate change, which is changing environmental patterns such as rainfall in many places on Earth, also increases the risks to social systems exposed to these changes. The vulnerability concept can be applied to examine these risks faced by people on a daily basis and the mechanisms that generate them. As late as the 1980s, methods aimed at reducing risk from environmental hazards were designed to contain the hazard itself. Through the construction of dams and irrigation systems, attempts have been made to change the environment so that it once again meets the needs of the social system exposed to it. Although these decisions were often aimed at protecting the social system, today their unintended consequences often contribute to increased risk, since they have strongly influenced the stability of nature. Man-made climate change is an example of this, but progressive soil erosion and species extinction can also be associated with it. The application of the vulnerability concept is interesting because it focuses on much more far-reaching social and economic structures that are responsible for the generation of environmental hazards and vulnerabilities. Instead of seeing risk as a problem that has not yet been solved with technical effort, the application of the vulnerability concept allows the perspective of risk as a mixture of very different social processes and structures. This reveals a much higher level of cause-and-effect relationships that, if modified, represent the potential for risk reduction. A possible illustration of the social causation of disasters is shown in Figure 3.

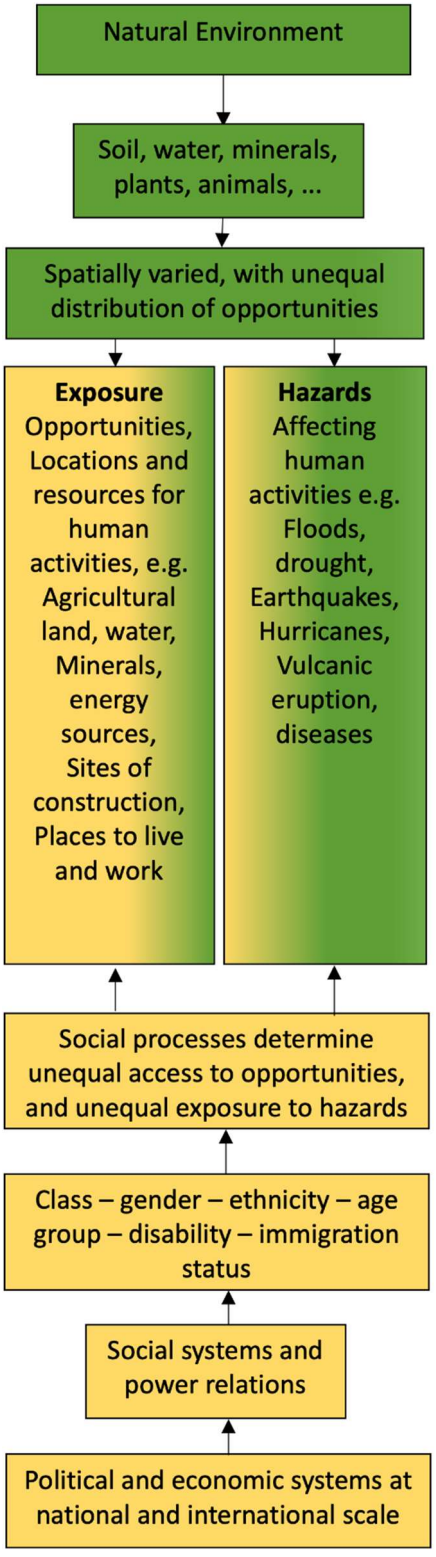


Figure 3: Social causation of disaster (based on: Blaikie 2003).

2.5 Why is vulnerability context specific?

Vulnerability is a measure of the potential of a hazard to cause harm in a system. The "social system" can be a group of people who are either united by living in a particular place or shared social factors. Examples of factors are gender, age, income level, or residence status. The potential for damage to the social system, which can arise from an (environmental) hazard, is not only dependent on the hazard itself, but also on the structures that make the system sensitive to the effects of this hazard or that provide the options for adaptation of this hazard. Structures in a system depend on the context in which they arise. It is easy to understand that, for example, women in different places in the world can use different structures and mechanism that allow them to protect themselves against or cope with danger. If one now wants to assess and compare the vulnerability of women in Ethiopia to drought, the overall context, the living conditions, influenced by social, cultural, political, and institutional norms, and the resulting opportunities for this social group must be included in the assessment. An example of such a context-specific evaluation of structures is that in vulnerability analyses conducted in the Global South, private social structures and safety nets often have a higher priority than in the Global North. This is due to the fact that people in the Global North are much more likely to rely on institutional arrangements and support than people in the Global South.

3. Methodological background

In this chapter, the methodological background of the vulnerability analysis is presented, from content assessment levels to their limits.

3.1 How can vulnerability be measured?

To measure how structures that affect vulnerability are configured, the most common approach is to develop an index. The use of an index for vulnerability analysis is somewhat intuitive as it helps to transfer the multidimensional complexity of vulnerability to a single metric. The process is characterized by different stages. Probably the most important stage is the selection of the indicators, which are used as proxies for certain structures that determine the vulnerability of the system of interest. To simplify the process of indicator selection and to prevent the risk of arbitrary decisions for certain indicators, many frameworks have been developed in recent years which help to identify important dimensions of vulnerability and the process of indicator selection can be structured.

3.2 What are the limits of vulnerability assessment?

Even with adequate use of vulnerability assessment tools, it is important to be aware that any assessment of vulnerability can only be an approximation of reality. It is a challenge to identify all relevant characteristics and indicators that influence or represent the vulnerability of a system, as they depend on many different factors (Cutter and Finch 2008). Because vulnerability is context-specific, not all indicators used in one place should be used in another. This presents challenges for researchers, whose values are likely to influence the selection (Engle 2011; Carpenter et al. 2001). For example, in many Global South countries, it is common that households rely mainly on agricultural-dependent income. It is frequently argued that income diversification through non-farm employment or the diversification of crops is a good strategy to reduce the risk of shocks and stresses and thereby reduce vulnerability (Ellis 2000). In the Global North, income diversification (i.e., working multiple jobs) is often interpreted as a sign that a householder is unable to secure full-time employment and must rely on poorly paid side jobs. For example, the US Census Bureau calculated that individuals who are not multiple jobholders earn an average of 15,750 dollars per quarter, while multiple jobholders earn less (13,550 dollars) (U.S. Census Bureau 2021). Often the selection process of indicators is based on a top-down approach that favours more structural and quantitative determinants at the expense of the more difficult quantifiable determinants of human agency (Jones and d'Errico 2019). For example, people are more likely to be asked about completed school years than about the ability to acquire knowledge and how to use it. Relying on quantitative data that has been collected without input from the ground carries a high risk of omission bias. If survey tools are designed without input from those exposed towards hazards, there is a risk that the wrong questions will be asked and important, often informal, social structures will go unidentified. Another reason why the assessment of vulnerability using an index often leads to criticism is the handling of the results or the omission of testing their validity. Despite the challenges described in measuring vulnerability adequately, vulnerability analysis is an important tool in resilience and risk research. The aim of the following part of this handbook is to provide people who want to use this tool with practice-oriented instructions that can be used to understand the most important steps in index development.

4. Step by step: Vulnerability assessment illustrated

A step-by-step approach is recommended for a quantitative assessment of vulnerability, which is presented in Figure 4.

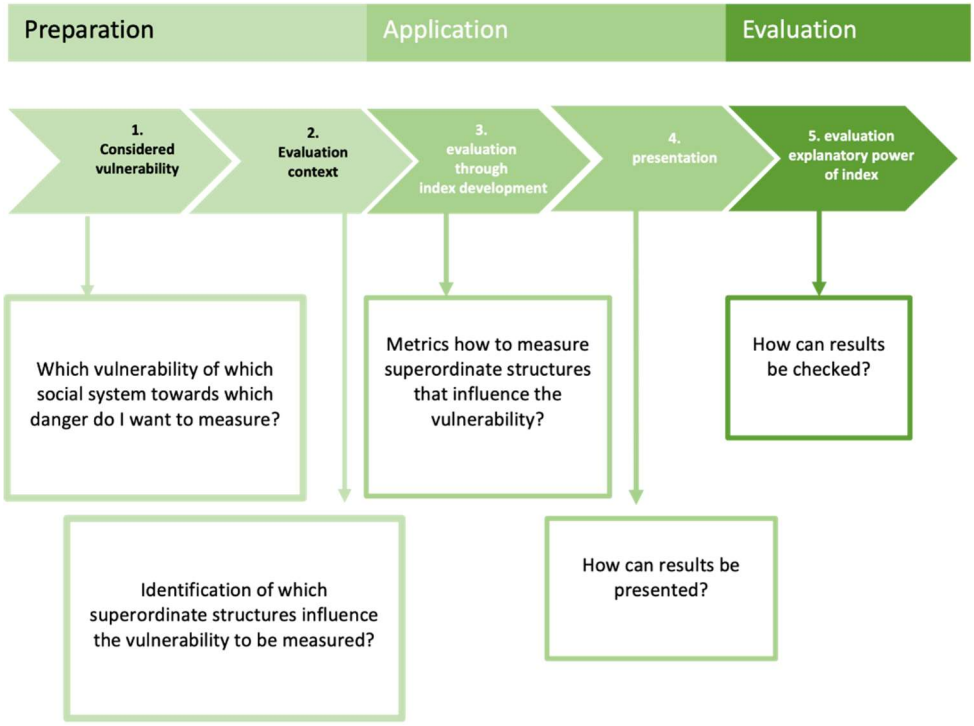


Figure 4: Schematic representation of vulnerability analysis in five steps.

4.1 Considered vulnerability

The most crucial step in a vulnerability assessment is defining whose vulnerability to which hazard is to be measured. Füssel (2007) offers robust guidance on this aspect and an overview of important factors that need to be defined in the vulnerability analysis. In the following, we consider four key factors: the system of interest, hazard, temporal reference, and the attribute of concern.

The system of interest: *Whose vulnerability do we want to assess?*

The first step in every vulnerability assessment is the definition of the system of interest. Defining what the system of interest is, is based on the distinction between what is external and what is internal to this system. Internality to the system can be based on geographical boundaries or on the "power to influence" (Füssel 2007). While geographical boundaries are self-explanatory, the "power to influence" is not. If the system of interest is the household, the factors that are considered internal are all those over which the household has the power to influence them (e.g., division of labour within the household, number of children, income sources). These factors influence the household's vulnerability and thus need to be part of the assessment. Examples of a system of interest are a population, a sector, a geographical region, or a natural system.

Hazard: *What hazard are we talking about?*

The next step is to identify and define the relevant hazard. Hazards are defined as ''a potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation'' (United Nations Office of Risk Research 2022). A hazard is normally referred to as something external to the social system such as earthquakes, droughts, or flooding. However, this distinction does not always hold. For example, conflict or war can be defined as a hazard putting social systems at risk while being generated in the social system itself.

Temporal reference: *For which time do we assess the system's vulnerability?*

Vulnerability analyses are not only used for assessing the susceptibility of a system of interest at one specific point in time but also through time. Vulnerability can change over time and especially if this change is of interest, for example when assessing the vulnerability to climate change, then it is crucial to define for which period or point in time the vulnerability is assessed.

Attribute of Concern: *In which outcome are we interested?*

One hazard usually affects different facets of the human system. Thus, it is important to clearly specify the attribute of concern. Depending on the attribute of concern, some determinants can be more or less important in the vulnerability assessment, as the following example shows: Droughts can influence the livelihood of people and communities in various ways. Droughts have impacts on food security, but also on health and general security standards. In order to assess the vulnerability of households to the impacts of droughts with respect to human health, it is necessary to identify indicators relevant to the physical health of household members as well as indicators to measure awareness of risks arising from contaminated water. In order to assess the vulnerability of households to the impacts of droughts on general security, indicators must be identified that show how households react in conflict situations and track adaptive mechanisms that decrease the risk of households becoming involved in conflicts. See box 6 for a practical example.

Practical example: vulnerability analysis

In this box, the implementation of the vulnerability analysis is illustrated by using a practical example. The description in the box always refers to the aspect that was described and explained in the chapter:

The context chosen for the exemplary vulnerability analysis is rural Cambodia. Cambodia is one of the countries whose people face frequently multiple hazards like droughts and floods. Especially droughts pose a significant risk on food security in rural regions. Food security insecurity mainly manifests itself on household level. The survey-data used to conduct the vulnerability analysis was gathered in 2019 and the questions referred to the year 2018. Accordingly, following factors were identified for the vulnerability analysis:

Hazard: Drought

System: Household

Temporal reference: Year 2018

Attribute of Concern: Food security

Box 6: Practical example of a vulnerability analysis regarding the definition of the four main factors for the assessment

4.2 Context of evaluation

It is important to realize that vulnerability is also a product of external circumstances that determine the makeup of the social system through which the potential for harm and loss from an environmental hazard arises. Vulnerability analyses must accordingly draw on different research methods to identify the structures in which social systems are embedded. Possible methods and their advantages and disadvantages are detailed in Table1. See Box 7 for a practical example.

Practical example: vulnerability analysis

Review context: Rural Cambodia

Method: Literature research

Reasoning: Literature research was chosen for this example because it is one of the most common, fastest, and cheapest techniques when it comes to gathering information.

Findings:

- Most rural households in Cambodia rely on rice farming for their living.
- Many rural Cambodians not just sell their rice but rely on it for food consumption.
- Poverty has a negative impact on the vulnerability of droughts in the rural Cambodian context.
- Households who are relying on agriculture as the only income source are more vulnerable to droughts.
- A higher education level was found to have a positive impact on the Adaptive capacity of households towards varying hazard in the rural Cambodian context.
- Landlessness is a big problem in the Cambodian society contributing to high risks of food shortages.
- Landlessness goes in hand with fewer assets and lower incomes.
- Irrigation access correlates with higher productivity of land in the Cambodian context
- Higher productivity and resulting surplus are said to decrease vulnerability

Box 7: Practical example of a vulnerability analysis regarding the definition of contextual elements.

Table 1: Overview of methods for determining context of evaluation

Method	Definition	Advantage	Disadvantage
Literature research	Overview of previously published works on a specific topic	**Costs**: Cheap **User Friendliness**: Can be done from anywhere **Time investment**: Fairly low **Methodological**: Good overview and background information	**Costs**: **User Friendliness**: Paywalls might restrict access; requires English language skills; can be overwhelming **Time investment**: **Methodological**: Might not have the exact information one needs
Expert interviews	Qualitative interview method often aimed at gaining information about or exploring a specific field of action.	**Costs:** Costlier than literature research but still usually not too expensive **User Friendliness:** **Time investment:** Somewhat time-intensive in preparation and execution **Methodological**: In-depth knowledge (very context specific); Includes knowledge of people without English language skills	**Costs:** **User Friendliness:** Logistical effort (to identify experts and to arrange how, when, where to interview them) **Time investment:** **Methodological**: Biases depending on the experts
Focus group discussion	A focus group is a group interview involving a small number of demographically similar people or participants who have other common traits/experiences	**Costs:** **User Friendliness:** **Time investment:** **Methodological**: Input from people one is interested in; Includes knowledge of people without English language skills; Very detailed information that can raise issues that might have been overlooked otherwise	**Costs:** Costlier than expert interviews **User Friendliness:** Logistical effort (to identify experts and to arrange how, when, where to bring them together and facilitate a safe environment for exchange) **Time investment:** Time-intensive in preparation, execution, and analysis **Methodological**:
(Household) surveys	Household surveys are questionnaires that are given to a sample of households in a population.	**Costs:** **User Friendliness:** **Time investment:** **Methodological**: Standardised input from the population of interest; Focuses on issues of interest; Able to cover a lot of different people	**Costs:** Costly in preparation and execution **User Friendliness:** **Time investment:** Time intensive in preparation and depending on number of staff also in execution **Methodological**: Standardised questions will not provide input on things one might have overlooked

4.3 Choose framework

Using a framework to determine vulnerabilities is advantageous because it provides instructions that can be used as a guide. To select a suitable framework, it is important to have answers to all the previously posed questions. Once it is clear whose vulnerability to which hazard at which location you wish to measure and when, a suitable framework can be identified. Frameworks translate the system to be examined into a concept or model that renders the system open to analysis. There are different models that are used in vulnerability research and on which the different frameworks for measuring vulnerability are based. A frequently used model is the access model by O'Keefe et al. (1976). This model assumes that access to information, cash, rights to the means of production, tools, equipment, and social networks to mobilize resources are key to avoiding disasters and decreasing vulnerability. Accordingly, in a vulnerability analysis based on the access model, the focus is set on the quantification of accessibilities. This basic model has been adjusted to fit specific contexts and/or hazards. When looking for an adequate framework it is useful to do literature research on which frameworks have been used in similar vulnerability assessments. It is advisable to look for a framework that a) deals with the same hazard, b) that assesses the same system, and c) that has been applied in a similar context. Ideally, a framework has already been established that ticks all the relevant boxes. If such a framework does not exist, it is advisable to look for a framework that has a significant overlap with the assessment to be conducted. If the framework analyses the same hazard and has been applied in a similar context (e.g., drought in developing countries) but the system is different (regional instead of households) it is advisable to look for a second framework that measures vulnerability towards a different hazard in a similar context within the same system (e.g., vulnerability of households in developing countries towards flooding). When combining two frameworks it is crucial to carefully evaluate which parameters are relevant in both settings and which ones only apply to one of the two.

TIP

At this point it is important to realize that any framework and definition in the context of vulnerability research should be seen as what it is designed for, as a tool for analyzing structures. Whether you accept this tool as it was designed, or change it according to your own goal, is up to you.

Since frameworks are also created to remove randomness from vulnerability analysis, adoption of definitions and analysis steps is desirable, but if this cannot be done for given reasons, changes and omissions of definitions and steps are also allowed.

Box 8: Usefulness and difficulties of framework application.

Practical example: vulnerability analysis

Framework chosen: framework for rural households' vulnerability assessment towards droughts by Zarahafari (2016)

Reasoning:

Framework was established for vulnerability assessment on household level

Framework was established to assess vulnerability towards droughts

Framework was applied in the Global South

Framework defines and categorizes sensitivity and adaptive capacity clearly

Method is used to include both biophysical and social dimension of drought vulnerability

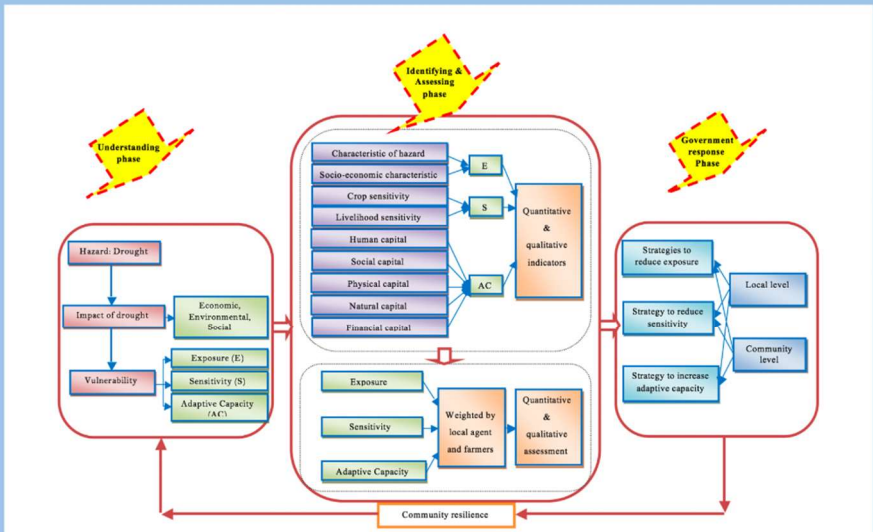


Figure 4. Conceptual framework on how to model vulnerability.

Box 9: Practical example of a vulnerability analysis regarding the choice of framework.

Social and biophysical vulnerability

In the scientific literature, a distinction is often made between biophysical and social vulnerability. There are also frameworks whose use is designed to analyze only one or the other vulnerability category.

	Social vulnerability	Biophysical vulnerability
System of interest Structures contributing to vulnerability	Social system Economic resources, social networks, cultural practice, (...)	Natural system Topography, soil moisture, land cover type, (...)

However, in many cases the distinction between social and biophysical vulnerability is unclear because social and ecological systems influence and depend on each other.

If we take **land use** as an example it is clear that the vulnerability is on the one hand biophysical (e.g. how close to a river that could cause flooding) but also social (were precautions taken by e.g. building dams).

Box 10: Social and biophysical vulnerability.

4.4 Index composition

There are different ways an index can be designed. Possible index design concepts are shown in figure 5. While in a) the index consists of six indicators, b) shows an index that consists of three main components which are each measured with three indicators, and c) has 12 indicators which are transformed into six factors that comprise the index by principal component analysis (PCA). The idea behind a) is that the most important variables are selected, normalized, and added up (weighted or not weighted). In b) a sub-index approach is used which means that either already established sub-indices are used to construct the main index, or sub-indices are constructed first and then added up (weighted or not weighted). In c) a variable reduction approach/ inductive approach is used, which collects a lot of variables that potentially have an influence. Then a PCA or factor analysis is used to identify the most influential components, which are then normalized and added up (weighted or unweighted). Ultimately, the choice of index design will depend on various factors like time and effort, the analyst's know-how, and the framework used to assess the vulnerability of interest. Some frameworks already integrate a concept of vulnerability on which the design of the index can be built. For example, the access model is a popular approach to show important livelihood dimensions that have an influence on the vulnerability towards a specific hazard. These livelihood dimensions are often defined as capitals from which a (social) system can profit. Economic capital, biophysical capital, social capital, and infrastructural capital are some examples for such a categorization. An index which is developed based on this model would be structured in a sub-index manner, where a mix of indicators would define a single capital.

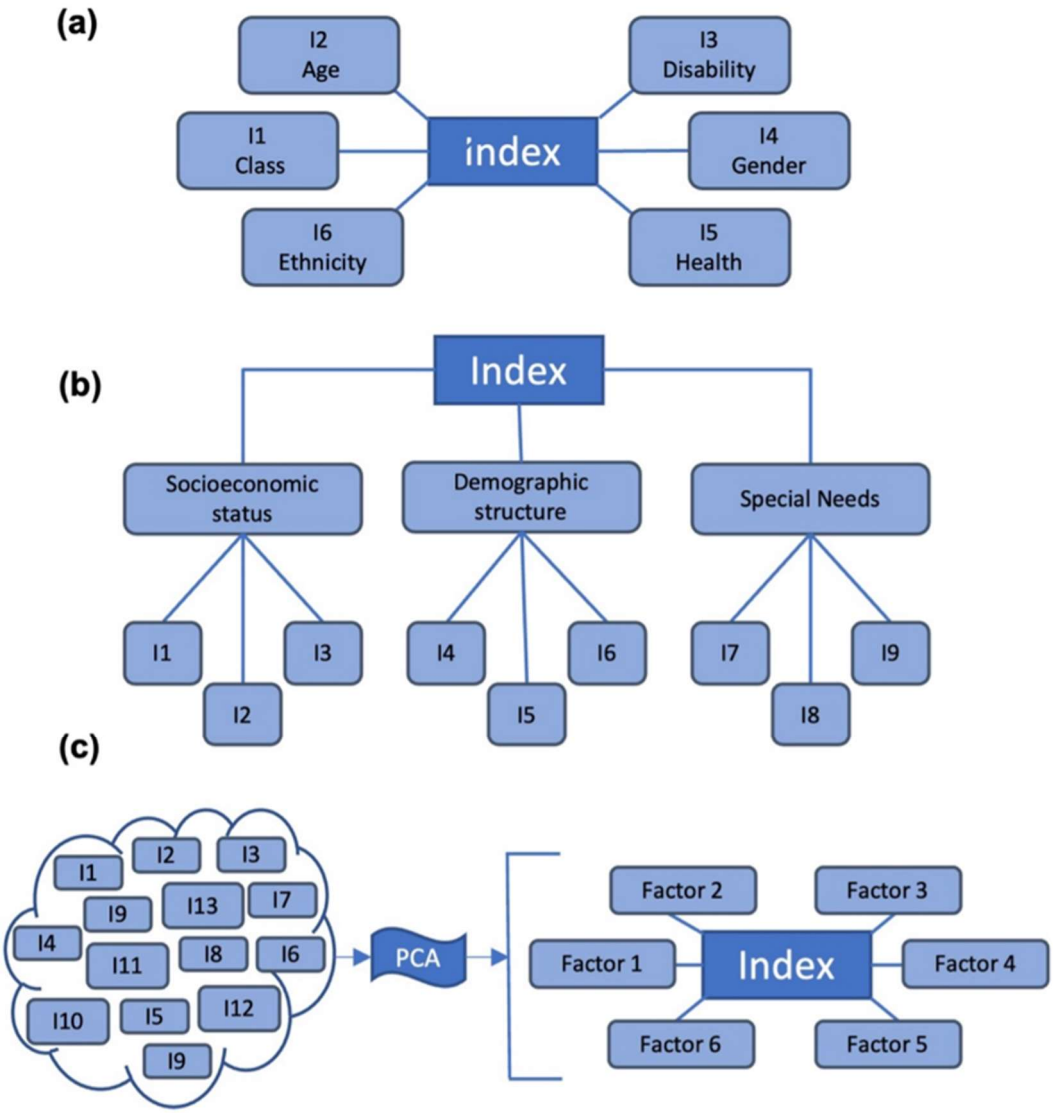


Figure 5: Examples of different index design concepts (Tate 2012).

4.4.1 Indicator choice

The identification of the right indicators is crucial. Depending on the index design the number of indicators differs but all of them need to be predetermined before the index construction can begin. Ideally, a mix of approaches is used combining indicators highlighted in the literature with more qualitative approaches such as focus groups and expert interviews to determine the local context. Table 2 provides an overview of different methods to determine indicators and box 11 a practical example. Combining the perspective of the person whose vulnerability is being analysed and the expert one (bottom-up and top-down perspectives) provides the most holistic picture. A combination of literature research, expert interviews, and focus group discussions can help to identify good indicators and offer insights into how they should be weighted.

Practical example: vulnerability analysis

Indicator choice method: literature research

Reasoning: other method would have exceeded cost and time capacities

Results:

Index component	Indicator
Crop sensitivity (CS) CS = (CS1 + CS2) / 2	Relative distance from water source to the land (CS1) No irrigation: CS1 = 0
	Relative water fee (CS2)
Non-agricultural-livelihood sensitivity (LS) LS = ((1-LS1)+LS2 +LS3) / 3	proportion of the dependent person (unemployed family member) to family size (LS1)
	debts (and difficulties in paying them back) (LS2) not repayable debts = 1 repayable debts = 0.5 no debts = 0
	proportion from annual income generated from agriculture to other income sources (LS3):
Sensitivity total (S) =	CS + LS
Index component	**Indicator**
AC Infrastructure (ACI) ACI = ((ACI1 + ACI2) / 2)	Proportion irrigated land to total owned land (ACI1) Relative maintenance state of water source (ACI2) excellent = 1 good = 0.75 average = 0.5 poor = 0.25 very poor =0
AC Economic (ACE) ACE = ACE1	Relative size of owned paddy land (ACE1)
AC Technology (ACT) ACT = ACT1	Relative numbers of cultivation per year (ACT1)
AC Social Capital (ACS) ACS = ((ACS1 + ACS2) / 2)	Number of neighbours who would come help (ACS1) FWUC-membership (ACS2) Not interested 0,6 No time/money 0,3 No FWUC 0 Other 0
AC Human Development (ACH) ACH = (ACH1 + ACH2) / 2	Relative number of working household members (ACH1)
	Relative number of schooling years that the household head (or his partner) finished (ACH2)
Adaptive Capacity total (AC) =	(ACI + ACE + ACT + ACS + ACH) / 5
Final Social Vulnerability total (SV) =	S – AC

Box 11: Practical example vulnerability analysis regarding the selection of indicators for index.

Table 2: Overview of methods for the selection of indicators.

Method	Definition	Advantage	Disadvantage
Literature research	Overview of previously published works on a specific topic	**Costs**: Cheap **User Friendliness**: Can be done from anywhere **Time investment**: Fairly low **Methodological**: Good overview of potential indicators	**Costs**: **User Friendliness**: Paywalls might restrict access; requires English language skills; can be overwhelming **Time investment**: **Methodological**: Might not fit the context on is researching
Expert interviews	Qualitative interview method often aimed at gaining information about or exploring a specific field of action.	**Costs:** Costlier than literature research but still usually not too expensive **User Friendliness:** **Time investment:** Somewhat time-intensive in preparation and execution **Methodological**: In-depth knowledge (very context specific); Includes knowledge of people without English language skills	**Costs:** **User Friendliness:** Logistical effort (to identify experts and arrange interviews) **Time investment:** **Methodological**: Biases depending on the experts
Focus group discussion	A focus group is a qualitative group interview involving a small number of demographically similar people or participants who have other common traits/experiences	**Costs:** **User Friendliness:** **Time investment:** **Methodological**: Input from people one is interested in; Includes knowledge of people without English language skills; Very detailed information that can raise issues that might have been overlooked otherwise	**Costs:** Costlier than Expert interviews **User Friendliness:** Logistical effort (to identify experts and arrange and facilitate discussion in a safe environment) **Time investment:** Time-intensive in preparation, execution, and analysis **Methodological**:
(Household) Surveys	Household surveys are quantitative questionnaires that are given to a sample of households in a population.	**Costs:** **User Friendliness:** **Time investment:** **Methodological**: Standardised input from the population of interest; Focuses on issues of interest; Able to cover a lot of different people	**Costs:** Costly in preparation and execution **User Friendliness:** **Time investment:** Time intensive in preparation and depending on number of staff also in execution **Methodological**: standardised questions will not provide input on things one might have overlooked

4.4.2 Weighting

Independent of the exact design of the index one will have to decide on how to sum up the dimensions gives structures that are particularly important or unimportant a higher or lower impact on the overall vulnerability. While weighting can clearly help to highlight vulnerabilities, the risk of incorrectly weighting vulnerabilities should not be disregarded. Thus, we often see vulnerability assessments with equal weighting.

Practical example: vulnerability analysis

Weighting

Method: literature research

Reasoning: Due to time restrictions literature research was chosen to determine the weights.

Findings: Equal weights for all indicators can be seen as the default setting for every index creation. Through the conducted literature research, it turned out that many rural households in Cambodia not only rely on their produced goods financially, but they also rely on them for own consumption. This gave reason to weight crop sensitivity slightly higher than livelihood sensitivity, because for subsidence farmers like in rural Cambodia crop sensitivity means livelihood sensitivity. Since the literature did not provide any numbers, the authors opted for a moderate difference in weighting. A weighting of 60% Crop Sensitivity and 40% Livelihood sensitivity contributing to the overall sensitivity was seen as adequate by the authors.

Result:

Sensitivity = 0.6* Crop sensitivity+ Livelihood Sensitivity* 0.4

Vulnerability = 1*Adaptive Capacity – 1*Sensitivity

Adaptive Capacity = (1*Adaptive Capacity Infrastructure + 1*Adaptive Capacity Economy + 1* Adaptive Capacity Social+1* Adaptive Capacity Human development+1*Adaptive Capacity Technology) /5

Box 12: An example of weighting in vulnerability analysis.

Table 3: Overview of methods for weighting indicators

Method	How	Advantage	Disadvantage
Principal Component Analysis (PCA)/ Factor Analysis (FA)	Statistical methods to determine weights based on collinearity	• Allows for reproduction • Little risk of biasing the weights	• Might miss local context • Can only compute weights if there is a correlation
Analytic Hierarchy Process (AHP)	Semi-quantitative method Systematic extraction of opinions by pairwise comparisons of indicators. Weights are the trade-off across indicators (willingness to forego a given variable in exchange for another).	• Captures local context and expertise	• Weights depend strongly on the experts
Budget Allocation Process	Qualitative methods. Experts are asked to allocate a budget of 100 points to the different indicators. Weights are calculated as average budgets. Could also be used with focus groups and public opinion polls.	• Local contexts are well considered	• Difficult to reproduce • Weights depend strongly on the experts

4.4.3 Normalization

The normalization of variables aims to bring indicators with different units of measure and spreads onto a common, usually dimensionless scale . While there are different ways to normalize indicators (see Joint Research Centre-European Commission (2008) for an overview) two of the most common transformations are standardization (or z-scores) and Min-Max. To calculate z-scores the average of an indicator across observations is deducted from the individual indicator and divided by the standard deviation across all observations. The Min-Max approach is even simpler and uses the following formula to normalize the value of the indicators:

$$Z_{ii} = (X_{ii} - X_i^{min})/(X_i^{max} - X_i^{min})$$

Z_{ij} = the normalized value of indicator i

X_{ij} = the original value of indicator I of the particular social system

X^{max}= the highest value among all social systems

Practical example: vulnerability analysis

Normalization

Method: Min-Max

Reasoning: Simplest way to normalize values with our data

Indicator	max	min	Equation (x = household`s own value)
Relative distance from water source to the land (CS1)	2000 m	0	CS1= (x-0)/(2000-0)
Relative water fee (CS2)	600 000 Riel	0	CS2= (x-0)/(600 000-0)
Relative numbers of cultivation per year (ACT1)	3	1	ACT1=(x-1)/(3-1)
Number of neighbours who would come help (ACS1)	10	0	ACS1= (x-0)/(10-0)
Relative number of working household members (ACH1)	6 working household members	1	ACH1= (x-1)/(6-1)
Relative number of schooling years that the household head (or his partner) finished (ACH2)	12 years	0	ACH2=(x-0)/(12-0)

Example: A household states that the distance from the next water source to its land is 1000 m. Accordingly, the calculation of the household's index value is based on the following calculation:

CS1 (household) = (1000-0)/(2000-0)= 0.5

Box 14: An example of normalization in vulnerability analysis.

4.5 Vulnerability presentation

A variety of formats can be used to present the results of vulnerability analyses. The presentation format should be chosen with consideration to the needs and specific interests of the target group(s). In the following, we present several formats and outline their use.

Tables of Summary Statistics
A table of summary statistics gives an overview of important statistical measures regarding the assessment. These enable researchers to present key information in a structured overview, which is especially convenient for target groups interested in the relevance and distribution of values. To read the table of summary statistics one needs to understand what the different statistical measures point out. In other words, tables are suitable for target groups with the necessary background knowledge and ability to interpret the results (figure 6).

TABLE 3 Summary statistics of the Social Vulnerability Index (SVI) within each district in Hong Kong

		Social Vulnerability Index (SVI)					
District	Number of constituency area	Mean	SD	Median	IQR	Min	Max
Sham Shui Po	21	7.1	1.1	7.3	1.0	4.3	8.4
Yau Tsim Mong	16	6.9	1.2	7.1	1.9	5.0	8.6
Wong Tai Sin	25	6.7	0.8	6.4	1.3	4.4	8.0
Southern	17	6.2	1.5	6.1	2.6	3.7	8.0
Kowloon City	22	6.1	1.1	6.4	1.5	3.7	7.7
Tai Po	19	6.0	1.3	6.3	2.0	3.6	8.0
North	16	5.8	1.6	5.5	2.6	3.4	8.7
Kwai Tsing	28	5.8	1.5	5.9	3.0	2.9	8.0
Kwun Tong	34	5.7	1.3	5.9	2.1	2.7	7.6
Yuen Long	29	5.4	1.7	6.1	2.4	2.3	8.4
Wan Chai	11	5.2	1.0	5.0	1.9	4.0	6.7
Tsuen Wan	17	4.9	1.4	5.1	2.1	2.4	7.9
Central and Western	15	4.8	1.0	4.7	1.4	3.1	6.9
Eastern	37	4.6	1.1	4.7	1.7	2.4	6.6
Islands	8	4.5	1.9	3.9	3.2	1.9	7.4
Tuen Mun	29	4.4	1.2	4.1	2.3	2.3	6.3
Sai Kung	20	3.8	1.0	3.9	1.5	2.3	6.0
Shatin	36	3.6	1.3	3.5	1.8	1.4	7.0

SD standard deviation, *IQR* interquartile range, *min* minimum, *max* maximum

Figure 6: A summary table (Example from: Chau et al. 2014).

Charts

While a table of summary statistics is a way to illustrate results in a very basic manner, charts make it easier to present and interpret results and draw conclusions. Viewers of this graphic representation can quickly identify the region with the highest vulnerability value and the use of colour coding facilitates comparisons (figure 7).

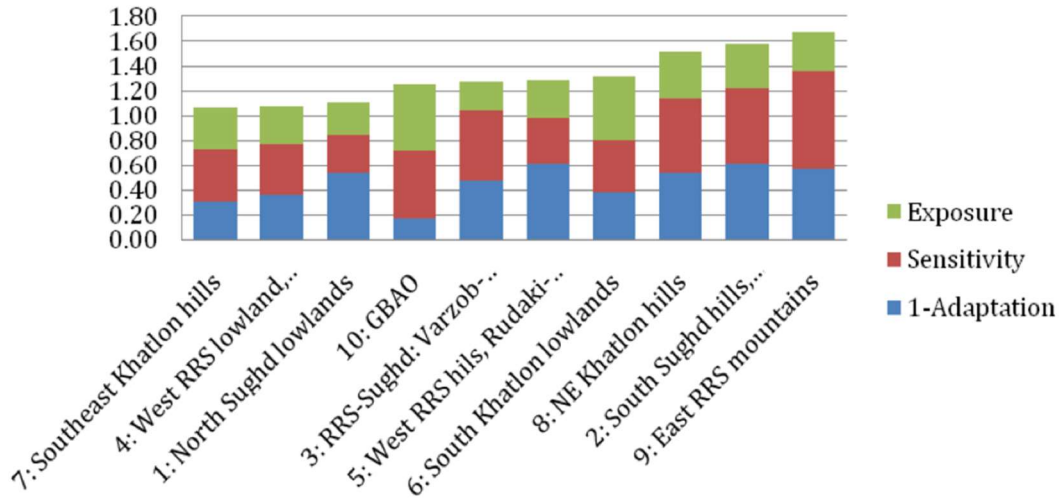


Figure 7: A chart depicting vulnerability components (Example from: Heltberg and Bonch-Osmolovskiy 2011) .

Mapping

One of the most frequently used methods in the presentation of vulnerability assessment results is vulnerability mapping. This method has the advantage that locations of high vulnerability can be detected directly by the reader. This format facilitates comparison and is highly accessible (figure 8).

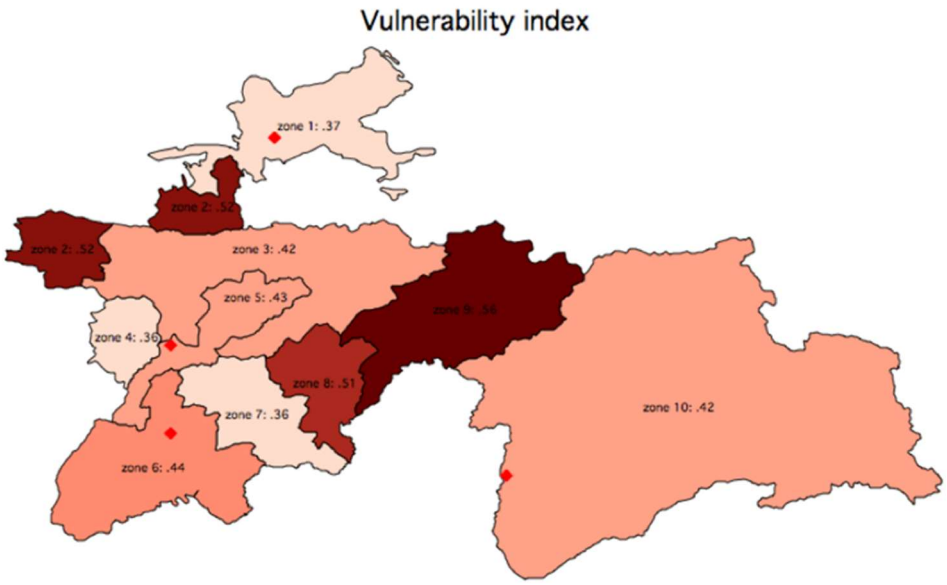


Figure 8: A vulnerability map of Tajikistan (Example from: Heltberg and Bonch-Osmolovskiy 2011)

Interactive output

Vulnerability analysis results can also be published in interactive formats. One such format is the Dynamic Interactive Vulnerability Assessment model (DIVA), which is an integrated, global model of coastal systems that assesses biophysical and socio-economic consequences of sea-level rise. It has been specifically designed and developed to support policy and decision makers in interpreting coastal vulnerability assessment and in addressing related measures. The framework can be used in conjunction with different modules and databases, enabling users to visualize and access different kinds of information (figure 9).

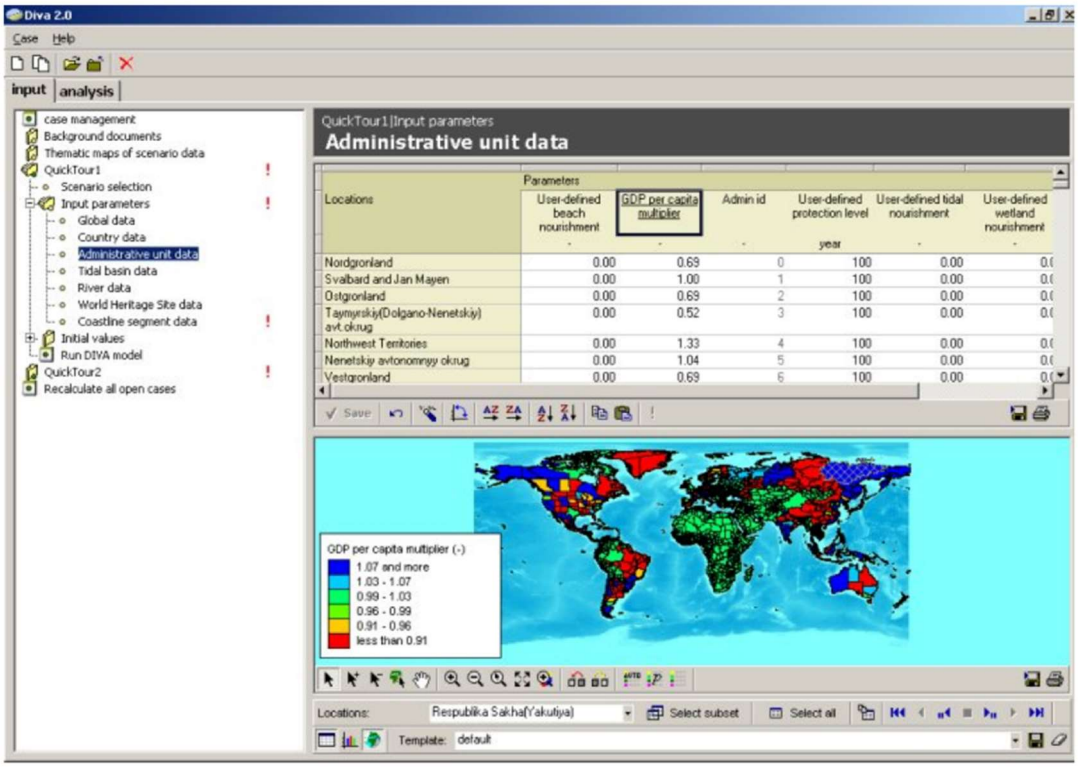


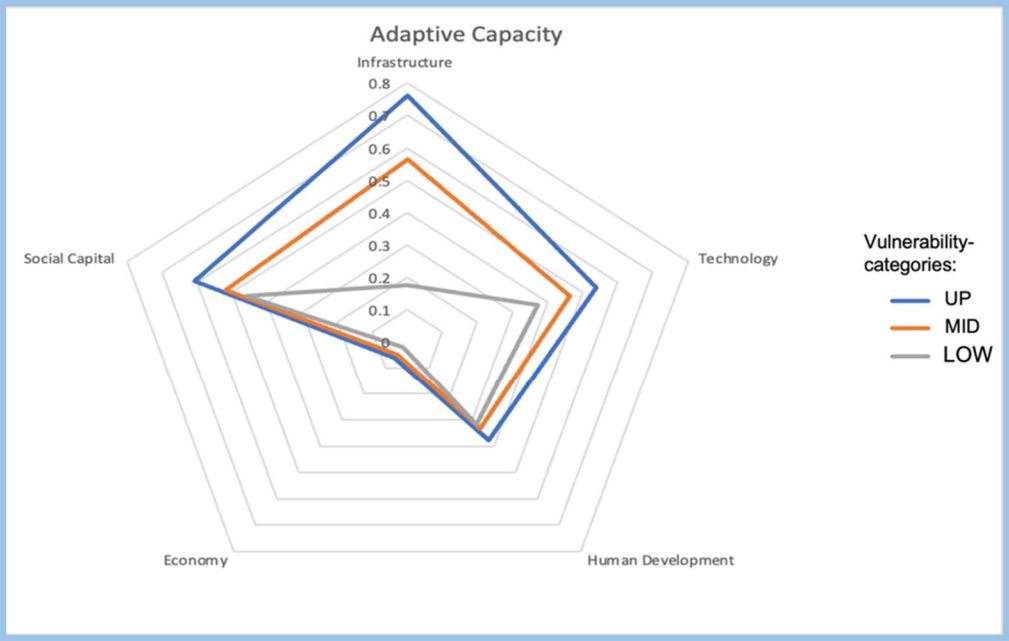
Figure 9: Interactive output, DIVA (Example from: Dinas-Coast Consortium (2009))

Practical example: vulnerability analysis

Choice of presentation: charts (pentagram)

Reasoning:

Firstly, the examined households were divided into three categories: the households with a lower vulnerability score (grey), the households with a middle vulnerability score (orange), the households with a higher vulnerability score (blue). To visualize their varying results regarding the adaptive capacity sub-components (infrastructure, technology, human development, economy, social capital) a pentagram chart was chosen. Like this, both the differences between the households regarding each subcomponent and the total adaptive capacity of each household category becomes visible.



Box 15: A pentagram chart.

4.6 Evaluation of the index (sensitivity analysis/ explanatory power analysis)

In the scientific literature, it is repeatedly pointed out that vulnerability analyses are often not sufficiently tested for their validity. To do this, different methods can be used, which are briefly presented below. Although such a procedure can be seen as an endorsement for evaluating the validity of the results, it is not a necessary condition for conducting vulnerability assessments. Existing studies that have developed indices of social vulnerability tend to follow a similar pattern. They begin with a

discussion of relevant social vulnerability theories, followed by a description of the study area and source data, a basic overview of how the index was constructed, and end with the presentation and analysis of the results using maps and tables. However, relatively little attention is paid to the reasons for index construction decisions, or, more importantly, how those decisions affect the output index. The latter is the area of sensitivity analysis, which assesses the impact of input data and parameters on output models. Sensitivity analyses generally take one of two forms: local or global. In the local analysis, the model sensitivity is evaluated with an index construction. Global analysis enables multiple construction phases to be assessed simultaneously, often through the use of Monte Carlo simulations. Both approaches provide the modeler with quantitative metrics to assess the relative importance of different modelling methods. A key benefit of sensitivity analysis is that it can help distinguish between the stages of index building that have a large impact on vulnerability output patterns and those that do not. This can allow the modeler to focus data collection and method development on the really important decisions, thus improving the robustness of the model. In addition to sensitivity analyses, other forms of index validation are also possible. Vulnerability is a hypothetical and predictive concept that can only be proven by observing the impact of the event when and if it occurs. In order to measure the quality of an index, it is possible, for example, to compare the measured vulnerability to a hazard with the consequence identified for the system from the hazard that occurs (see Box 17).

Practical example: vulnerability analysis

Analysis: Significance Index

Method: cross validation

The method used to measure the quality of the developed index was cross validation. The usage of this method was possible, because the examined households stated if they have had experienced food shortages in 2018 or not. Food shortages are an indicator for droughts impacts. Accordingly, through cross validation it could be detected how well the measured vulnerability score of the households explains if the household suffered from food shortages. The parameter results of the cross validation are shown in the down table. The specificity indicates that 46% from the households who suffered from food shortage could be detected by the index.

Results:

Parameters	
Sensitivity	0.8317
Specificity	0.4625
Accuracy	0.6685
Kappa	0.3045

Box 16: Practical example vulnerability analysis regarding the evaluation of index.

Box 16: An example of index evaluation in vulnerability analysis.

5. Conclusion

The vulnerability analysis is a valuable and versatile tool. If used correctly, it can generate insights that facilitate comparisons between people and places, describe their vulnerability towards specific hazards, and provide a foundation of knowledge for further research and assistance. Against the background of climate and societal change, vulnerability analyses can generate important insights for the present and future. Simple, clear, and comprehensible guidance is needed to increase the accessibility and implementation of vulnerability analyses. The authors of this manual are aware of the danger that comes with simplification, which carries the risk of insufficiency. This handbook is not intended as a comprehensive textbook on vulnerability assessment. Rather, it offers an introduction to the field and outlines various steps and important aspects of vulnerability analysis and enables readers to conduct their own vulnerability analysis.

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RIFS Discussion Paper

February 2023

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Editing: Damian Harrison

DOI: 10.48481/rifs.2023.004