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Resilience and Vulnerability: Conceptual revolution(s) or only revolving around words?

A collection of essays, working papers and think pieces from the period 2008-2018

Edited by Alexander Fekete and Janos J. Bogardi

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Introduction

This volume is a collection of thoughts and ideas encapsulated in the following six chapters. Each of these chapters can be classified as an essay, a working paper, or simply as a think piece. Irrespective of different contexts and themes they are united as they represent efforts to grasp the elusive concepts of vulnerability, resilience, exposure, risk in context of natural hazards or willful destruction and the potential disasters these may cause. One further common feature of these pieces put together in this volume is that they were never really became known and acknowledged. Most of these writings, or versions thereof have never been published in printed media. Some were, for a while, accessible on various websites. They all originate from the period between 2008 and 2018. Some ideas which had been hatched then and formulated in these writings have been followed up and became subject of a peer reviewed publication. But most of these writings remained hidden in computer files as silent documentaries of thoughts set aside as not being considered opportune to be pursued and published. Among scientific self-criticism, academic supervisors, “dogmatic” journal editors or abandonment of a book project might be “blamed” for these fates.

Some of these “early thoughts” might have been premature then. We speculate however, that in light of the present state of the international scientific discourse in the respective area and the ever flourishing conceptual debates around vulnerability and resilience some of the ideas found in these “hidden essays” may trigger second thoughts and hence could enliven the present debates. Thus next to be the historical documentation of what has been pondered on a decade ago, some scientific follow up may occur. This chance, we believe, justifies the publication of this retrospective volume.

With all essays in this volume, we intended to preserve them as they were written. The year of writing is given to indicate the mind-set and scientific jargon prevailing then. Only typos, wordings that limit understanding and in a few cases, publication dates of then yet unpublished sources have been modified. After each essay the respective chapter includes a short summary referring to the afterlife of the think piece up to present days. Where appropriate the main academic issues and positions held then (and may be even today) are highlighted. By refraining from actualizing and expanding the essays we admit that some pieces in this volume may look somehow unfinished. But “restoration” may destroy historical authenticity. We have chosen to document the sometimes timid steps as having been taken into terra incognita of vulnerability, resilience and Co. We are convinced that for an academic debate and advancement on vulnerability and resilience concepts these thoughts, in their original form and limitations notwithstanding, contain important information and incentives for those ready to continue the intellectual struggle and scientific inquiry. One’s failure or unfinished thought may help someone else who takes up the challenge of identifying solutions.

June 2019 Alexander Fekete and Janos J. Bogardi

Inhaltsverzeichnis

The Interrelation of Social Vulnerability and Demographic Change in Germany

Alexander Fekete

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Fekete, A. (2009): The Interrelation of Social Vulnerability and Demographic Change in Germany , IHDP Open Meeting 2009, the 7th International Science Conference on the Human Dimensions of Global Environmental Change, Bonn. Fekete 2009 IHDP OpenMeeting.

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Abstract:

Social vulnerability in a developed country like Germany has a distinct profile that is significantly shaped by dynamic demographic changes. In-migration from other countries and the ageing of the population reform the fabric of society. New vulnerabilities arise not only through marginalisation or disturbances in the social welfare system, but also in context to natural perils. This social-environment interaction has implications on different scales, ranging from the household to the national level. Each level has its distinct vulnerability profile regarding exposure, susceptibility and adaptive capacities, which is transformed over the years by dynamic demographic modifications. River flood risk is constructed at the intersection of the hazard and the social patterns. This coupled system is in constant transformation which is a challenge for both scientific analyses and resulting policy recommendations. While scientific studies elaborate already extensively on demographic changes, hazard modelling, ecological stability, risk and vulnerability conceptualisation and integrative applications are still scarce. Whether this is due to lack of conceptual clarity or due to methodological limitations alone has to be clarified. The purpose of this study is thus to first apply a conceptual framework to identify social vulnerability and to integrate demographic dynamics and second, to reveal the implications of demographic change for social vulnerability assessment in Germany. Within this assessment indicators and maps are constructed to enable integration of statistical data and household interviews. These tools allow for a regional comparison that may help to track changes in vulnerability dynamics.

1. Background of social vulnerability root causes in Germany

The scope of research on social root causes of vulnerability is subject to political orientations and intensive disciplinary debate (Wisner et al. 2004). With no aim of engaging into this debate, this paper will capture only certain social peculiarities using the structure of a widely accepted standard literature source on social vulnerability (Wisner et al. 2004, Blaikie et al. 1994). Applying their model and terminology, the political and economic processes and structures underlying German society are 'root causes' and 'dynamic pressures' of a baseline social vulnerability. Social vulnerability cannot be reduced to poverty, but poverty is certainly a major topic in vulnerability research (Wisner et al. 2004: 12). A review of social strategies of the German government reveals that the scope of 'poverty' reduction has undergone major transformations (Bartelheimer et al. 2005). In the 1970s reporting of social conditions in Germany aimed at welfare development and 'quality of life' indicators (Zapf 1979). This social monitoring aimed at measuring welfare by social status and economic conditions. Mainly focused on economic conditions, this approach was augmented in later social reporting by topics like participation, exclusion, or precarious job-situation. Unemployment and integration problems are in the centre of the European 'Lisbon Strategy' and steer social cohesion and development agendas in Germany (Bartelheimer et al. 2005).

Social cohesion and inequality is defined by more facets than just absolute poverty in Germany. Poverty in Germany is often termed 'relative poverty', based on an average standard of living. Relative poverty is multi-dimensional, i.e. not restricted to financial resources (Strohmeier and Kersting 2003). Still, poverty in Germany is mainly tied to conditions of the national economy. The 'angst' of unemployment is a major driver of a new social reporting focus on 'precariousness'. Unemployment has even been stated as a risk in a global questionnaire survey of comparing different risks (Eisler et al. 2006: 113). Low income interns and students were described as 'generation precariousness' (Bonstein and Theile 2006) because of an uncertain job-situation. Even a new class debate started, instigated by a report that detected a new poverty and precarious underclass in Germany (Neugebauer 2007). Although the class debate seemed outdated in political science by individualistic perspectives (Gillies 2005, Lawler 2005), especially market research uses social milieus (Sinus Sociovision 2007). Like class, certain milieus designate persons with a certain profile to lower class or upper class. This is done regarding the status of the persons in the political system of social democracy and capitalism in (social market economy) Germany. The downward mobility of the middle-class and a rising poverty gap are topics that dominate recent media coverage (Dougherty 2008, Tagesschau 2007) and economy (DIW 2008).

The demographic composition of German society undergoes major transformations. The age pyramid changed its shape dramatically in the past 50 years. The reproduction rate is so low that the population in Germany declines (BBR 2006: 19). This is partly compensated by a strong increase of immigration, which is more the case for western Germany (EEA 2006: 11). There are two 'macro-forces' or 'dynamic pressures' (Wisner et al. 2004); German society is ageing, and second, social integration is a major issue (Strohmeier and Alic 2006: 7). The ageing of the German society has severe consequences for maintaining the social welfare system of pensions and taxes. More and more old people live in Germany and the ratio is still on the increase (BBR 2006: 30). This imposes a strain for both the working population and the dependent elderly. It drags on economic growth, health and long-term care systems, and household resources (United Nations 2007). The second demographic change is led by immigration but also by a relative higher fertility of the population with migration background (Strohmeier and Kersting 2003). This is a benefit for the ratio of young people in Germany and partly buffers the problems posed by the ageing of the population. However, education and job qualification is often lower among youths with migration background (BMI 2007, Baumert et al. 2003). While this is not generally the case, it allows for identifying certain social groups that might lack certain capacities like language proficiencies for understanding flood warnings, for example.

Social segregation and marginalisation can be observed for ethnical groups, but also for income and age groups. Social problems or 'unsafe conditions' are often related to urbanisation and population density (EEA 2006: 17) that create social focal points (Strohmeier and Alic 2006). Some city quarters are typified by integration problems of ethnical background, in combination with unemployment rates, social welfare recipients and pending poverty (Sturm 2007: 388). Older building structure, lack of access to public transportation and low education are further attributes of social focal points (Aehnelt et al. 2004: 63). Problems in some city quarters are the selective migration of affluent population into outer-urban areas, localised polarisation of special needs and social insecurity, erosion of traditional family- and neighbourhood-networks, integration problems, criminality, poverty and unemployment (Strohmeier and Alic 2006: 7). However, there are also some positive aspects like active networks and initiatives (Aehnelt et al. 2004: 76). Sub-urbanisation processes have replaced the favourite living areas from the city centres to the urban rims. While young and more affluent (double-income) families prefer the less densely populated suburbs, the elderly often remain in the city centre (Sturm 2007: 383). The prices of real estate and rent steer the location choice of specific age and income groups like young low income people or elderly citizens with low pension.

The spatial population distribution is not driven by economic aspects only. Housing structure is also a result of values and tradition. The life-style of the one family detached house is one predominant goal for many Germans and Europeans (EEA 2006: 20). Houses in Germany are a prime investment to be made in a lifetime and often connectivity to one location lasts for several years or even generations. This rooting manifests itself in the mindset and the persistence behaviour of many traditional Germans. Life-styles of cultural tradition and political tradition often imbue certain spatial regions.

Baseline social problems and specifications of the social fabric of Germany are summarised in the following table (Table 1). These problems can be structured into the Pressure-And-Release (PAR) model (Wisner et al. 2004). It highlights the backdrop upon which people are rendered generally vulnerable against stressors and natural hazards.

Table 1. Modification of the PAR model for the German context after Wisner et al. 2004: 51

Root causes	Dynamic pressures	Unsafe conditions
Social welfare system Federal system Social market economy Culture	Unemployment Social status – lifestyle Ageing of the population Integration Lack of or access to education Persistence of tradition (Globalisation)	Poverty Precariousness Underclass Social segregation Urban density related problems

2. Who are the vulnerable to flooding?

"We are not an endangered species ourselves yet, but this is not for lack of trying."
Douglas Noel Adams

When looking at humans they are not determined by a single factor like poverty only. Human profiles are composed of several characteristics and conditions. With a limited set of characteristics, certain 'typical' social groups can be identified. Of course, such a typology necessarily comes too short to explain the complexity of human facets. But they are helpful to identify patterns of vulnerable groups. Studies on social milieus or class describe disadvantaged people. For example, the political milieu of the *precarious* group is characterised by low social status, downward social mobility, low to middle level of education, the highest ratio of unemployment, blue-collar working class, predominantly male, living in Eastern Germany and in rural areas (Neugebauer 2007: 82). Eight percent of the population belong to this political milieu. This group is much related to social welfare and unemployment, especially long-time unemployment. Social milieus and class are constantly shifting. End of the 1980s, German poor were elderly women, in the 2000s the poor are the young children and young mothers (Strohmeier and Kersting 2003). Children of single-mothers are especially hit by poverty, as are children of immigrants and recipients of social welfare (UNICEF 2008). The education opportunities of children are linked to family structure and social class, however less in Eastern Germany (Baumert et al. 2003). All here presented typified groups are rendered disadvantaged concerning general social standards. They struggle mostly for economic equality but also for status recognition.
But are those groups 'the vulnerable' to natural disasters, or more precisely to river floods? This is a very difficult question to answer for at least three reasons: First, there are yet too few studies on this issue in Germany to have clear criteria what makes a person vulnerable to natural hazards. Second, those who are most social disadvantaged must not be the same that are exposed or get most severely affected by floods. The affluent, one may argue, have more values to lose and can afford to live more exposed along attractive river-side location. Third, who is vulnerable is very much dependent on interpretation and definition. If vulnerability is a function of economic loss, then start-up entrepreneurs who bear a high financial risk would be the most vulnerable group, not the poor.
Few studies have established a relationship between flood impact and social groups in Germany (Table 2). The studies are typically of a very local focus and the findings cannot easily be generalised. In Beuel, a city quarter in Bonn, new and inexperienced residents had been more affected by the floods of the Rhine in 1993 and 1995 than the old population (Pfeil 2000). The new residents were not yet integrated and familiarised with flood protection and emergency behaviour. Conversely, in Eilenburg and surrounding towns at the flood of 2006 of the river Elbe, the elderly and long time residents were especially hit. Reasons were they believed the flood would not rise above previous flood level. They were sceptical about preparedness measures and evacuation, whereas young working people were more mobile, flexible and better informed (Kuhlicke, pers. com. 2006, Steinführer and Kuhlicke 2007: 64). The study of Eilenburg seems especially support that old age and tenure played a key role (Steinführer and Kuhlicke 2007: 114). The following table reviews typical characteristics of social vulnerability as found in studies in Germany.

Table 2. Review of vulnerability characteristics of humans to flooding in Germany

Demographic characteristics	**Characteristics of higher vulnerability**	**Characteristics of higher capacities**
Old people	Suffering physical/health consequences Received less support (Steinführer and Kuhlicke 2007: 113, 114) Less capable of performing emergency measures effectively (Thieken et al. 2007: 1031) Forced to seek shelter in emergency accommodations (Birkmann et al. 2008: 134-6)	Holding insurance (Steinführer and Kuhlicke 2007: 113)
Very young people	Need more time to evacuate (Birkmann et al. 2008: 134-8)	Suffering less physical/health consequences Suffering lower general impact on household (Steinführer and Kuhlicke 2007: 113)
Gender		Female gender: Higher risk perception and preparedness for action (Martens and Ramm 2007, for city of Bremen)
Income	Lower income: Lesser degree of insurance (special case of Easter Germany) (Steinführer and Kuhlicke 2007: 113)	Higher Income: Insurance more common (Steinführer and Kuhlicke 2007: 114, Birkmann et al. 2008: 134-7) Capable of performing emergency measures effectively (Thieken et al. 2007: 1031)
Education	Lower education: Received less support (Steinführer and Kuhlicke 2007: 114)	Higher education: Capable of performing emergency measures effectively (Thieken et al. 2007: 1031)
Home owners	Properties are more affected Suffering general high impact on household (Steinführer and Kuhlicke 2007: 113)	Applying precautionary measures (Steinführer and Kuhlicke 2007: 113) (Thieken et al. 2007: 1034, Reusswig and Grothmann 2004: 99 for the city of Cologne)
People without local networks	Experiencing lack of information (Steinführer and Kuhlicke 2007: 113)	
Household size	One person households: A majority considers itself dependent on others in case of an evacuation (Birkmann et al. 2008: 134-6) They spend the least amount of money for flood protection (Kreibich et al. 2005a: 122)	Younger families seem to invest in insurance and retrofitting Household size correlated with taking effective emergency measures (Thieken et al. 2007: 1031, 1034) 3-5 person households are more ready to take action and take more responsibility (Martens and Ramm 2007, for city of Bremen)
Long term residents		Better informed than new residents (Pfeil 2000: 57, for city quarter of Beuel, for certain aspects Wöst 1992: 60 for community Irlbach at the Danube)
Students		Less damage and loss (Plapp 2004: 396, for city of Passau)

The social vulnerability characteristics have to be regarded in the context of international vulnerability studies for the theoretical framing. Lists and reviews of social vulnerability parameters are provided by several authors (Morrow 1999: 10, Tapsell et al. 2002: 1520, Cutter et al. 2003: 246, Schneiderbauer and Ehrlich 2006: 88, Simpson and Katirai 2006: 14, Masozera et al. 2007: 301) summarise social vulnerability characteristics found in other countries for comparison. This comparison is therefore valid, since some characteristics like old age are generally due to cause higher degrees of mortality to floods. Eight of nine persons killed within buildings by a flash flood in Southern France in 1999 were of pensioners' age (IKSR 2002: 14). A study in the UK (Tapsell et al. 2002: 1522) states that age of 75+ has been shown in epidemiological research to display a sharp increase in health problems. Experiments revealed thresholds up to which people of average age and constitution could withstand loss of stability or manoeuvrability due to water height and velocity (RESCDAM 2000: 44). The findings concluded that people with reduced physical strength would have lower thresholds to withstand and this would typically include the elderly, disabled or persons with additional loads like women caring for children.

On the characteristic of income deficiencies, the financially deprived are less likely to be insured and therefore have more difficulties in recovery (Tapsell et al. 2002). But there are also special groups severely affected by floods which are often forgotten in standard vulnerability assessments. One of them are the transient or homeless who typically are not recorded in standard statistics (Wisner 1998, Masozera et al. 2007). Campers are often highly exposed as camp sites are often in flood plains. 23 campers died in Savoy 1983 when camping in a flood plain (IKSR 2002: 15). 10 of 24 persons during a flash flood in Southern France in 1999 were killed inside their cars (IKSR 2002: 14). Evacuation assistance needs are identified as a major indicator of social vulnerability (Chakraborty et al. 2005). Certain variables have been analysed for the construction of a social vulnerability for evacuation assistance index. They include the population up to 5 years of age and population over 85 years (Chakraborty et al. 2005: 26). Similar observations on evacuation needs of special needs groups like children, the handicapped or persons in need of special medical care have been made for Germany and neighbouring countries (IKSR 2002: 16).

3. The Social Vulnerability Index (SVI)

At the county level, the SVI is a pilot approach as to how to identify and compare social vulnerability along river-channels in Germany. A procedure is conceptualised as how to incorporate social vulnerability within a coupled human-environment system's perspective with disaster risk assessment: the theoretical concept of the BBC framework (Birkmann 2006 and applied in: Fekete 2009) which combines hazard and vulnerability in a risk reduction perspective. The BBC framework also incorporates different spheres, the social, economic and ecological and thus provides an entry point for the integration of coupled social-ecological systems analyses. It also permits the inclusion of more social-perspective-driven research to identify the root causes of vulnerability (see first section of this paper). The framework furthermore enables later cross-validation with data and studies from other sources and other spatial levels (Fekete et al. submitted, Fekete 2008). The theoretical foundation of this vulnerability assessment is the base-line for the methodological development of the vulnerability indicators which capture the exposure, sensitivities or capacities of social groups concerning river-floods.

The SVI is an index that is aggregated by equal weighting and simple summation from three main indicators of social vulnerability:

- Fragility: elderly persons above 65 years per total population
- Socio-economic condition: unemployed persons and graduates with only basic education per total population; apartment living space per person
- Region: degree of urbanity or rural area, measured by population density lower / higher than 150 persons per km² and the number of apartments with 1-2 rooms per total number of apartments

Indicator creation: the 6 input variables are normalised to values from 0 to 1 and by simple summation the three indicators are created. The SVI contains value ranges from 1,8 to -1,8 and is displayed in defined equal intervals in 0,2 steps. The indicators contain value ranges from -1 to 1 and are displayed in defined equal colour intervals in 0,1 steps.

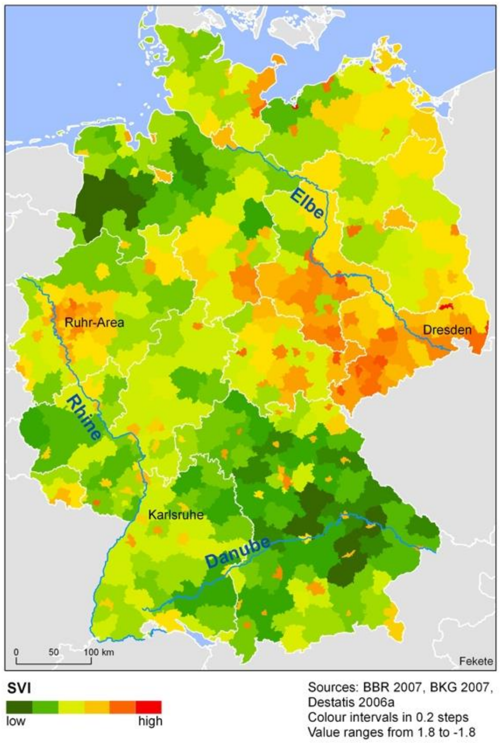

Figure 1. The Social Vulnerability Index (SVI) per county

Data Sources: BBR 2007: INKAR 2006, Statistisches Bundesamt Deutschland (Destatis 2006a): Statistik regional, BKG 2007: county shape files

The main outcome is a social vulnerability map of population characteristics towards river-floods covering all counties in Germany (Figure 1). This map is based on a composite index of three main indicators for social vulnerability in Germany - *fragility, socio-economic condition* and *region*. These indicators have been identified by a factor analysis of selected demographic variables obtained from the federal statistical office. Therefore, these indicators can be updated annually based on a reliable data source. The data selection for these indicators has been conducted after the general patterns of baseline root causes of vulnerability in Germany (see section 1) but also after the indications of impact on different social characteristics by floods in Germany (section 2).

Low SVI counties are characterised by strengths towards river-floods. These strengths are prevailing capacities for river-flood mitigation, for example, financial capacities for private preparedness measures and recovery from floods by high income sources. These counties lack indications for potential exposure to floods like high population density. Sensitivity like physical fragility of elderly citizens is also typically low. Counties with high SVI are characterised by predominating weaknesses towards river-floods. These weaknesses are lack of capacities, high degrees of sensitivity and indications for exposure potential. The SVI allow for displaying the root causes of social vulnerability and the spatial identification of vulnerable regions in Germany.

4. Social vulnerability and demographic change

Demographic change is one key driver transforming the pattern of social vulnerability in Germany. From the two main drivers of demographic change in Germany (first section of this paper) the ageing of the population is of major concern for aggravating the quota of fragile people in Germany. The distribution of a projected increase of ageing population is not uniquely dispersed over Germany (Figure 2). Regions with less economic prosperity especially in the East of Germany are especially prone to this change. The whole population and social system is affected by lesser and lesser working age people to provide for taxes and medical care of the elderly. Since the elderly are those most dependent on assistance for example in the case of evacuation (Chakraborty et al. 2005, Fekete 2009), these areas with a higher ratio of population increase are priority areas for disaster mitigation planning.

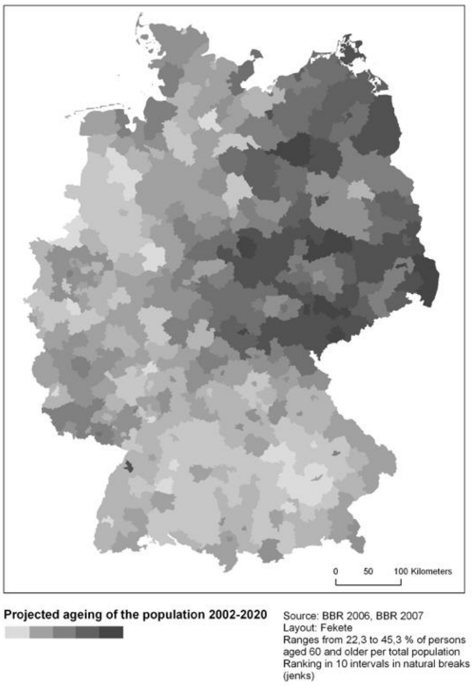

Figure 2. Projection of the ageing of the population in Germany from 2002 to 2020

Source: after BBR 2006 and BBR 2007

Ageing of the population is only one driver of demographic change. The Federal Office for Building and Regional Planning (BBR) regards the low birth rate since the 1970s, the growing internationalisation by in-migration and the individualisation of the population with more and more single households as key drivers of demographic change (BBR 2008 and www.bbr.bund.de, accessed 25 March 2009). Since demographic change affects different regions in Germany, social vulnerability patterns will also change, independently of the hazard development e.g. by climate change, urbanisation, global change, etc. This is an important future field of research. The SVI is one tool for monitoring and projecting static as well as dynamic compositions of society in relation to various hazard and demographic change scenarios. It is capable of integrating demographic change indicators and recalculating the social vulnerability part that is not directly linked to the hazard. Social vulnerability is therefore an important topic for cross-cutting planning like spatial planning or civil protection. It is thus also an important cross-cutting topic for capturing specific human facets of global environmental change by focusing on demographic and human dimensions rather than on the hazards only. This includes climate change in terms of developing necessary adaptation strategies but is at the same time not limited to it. Demographic monitoring and natural hazards mitigation will continue to receive attention in the future. The integration of demographic scenarios is just one area for further exploration of the versatility of the SVI. Scientists and decision makers will need to explain complex risks and developments to the public. The social vulnerability and the disaster risk maps that can be derived by combining the SVI with hazard scenarios like extreme floods (Fekete 2009) are contributions to the generation of long-term monitoring and comprehensive illustration of complex risk developments.

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Vulnerability to river floods: measuring a key element of water-related risk

Janos J. Bogardi, Marion Damm, Alexander Fekete

Introduction

Risk is defined as a function of hazard and vulnerability. Risk can be reduced by both, mitigating the hazard or/and the vulnerability. The hazard-specific vulnerability is determined by the exposure to the hazard, the predisposition to be hurt (susceptibility) and specific mitigation or transformation and adaptation capacities.

While hazard estimation and reduction have long hydrological and engineering traditions, vulnerability concepts and related quantitative assessments constitute a rather recent, still developing scientific area. Two approaches to estimate river flood related vulnerabilities along major rivers in Germany will be presented. The methodology is site independent, but the results are context-specific. Especially for this quantitative and transregional approach, a good data base is a pre-requisite of reliable estimations. The two methods presented here illustrate the manifold directions the emerging vulnerability research may follow. Critical evaluations of the techniques applied as well as the analysis of available data are also presented in (Damm, 2010 and Fekete, 2010).

The social and infrastructure vulnerability index highlights regions which may potentially experience higher losses and need more assistance. The index of social-ecological vulnerability assesses regions how strongly they may be affected by floods in terms of their ecosystem service ability.

The research leading to the results presented here has been carried out in the interdisciplinary project DISFLOOD, that developed a Disaster Information System for Large-Scale Flood Events Using Remote Sensing as a joint project of the United Nations University Institute for Environment and Human Security (UNU-EHS) Bonn, the German Aerospace Centre (DLR) Oberpfaffenhofen and the GeoResearchCentre (GFZ) in Potsdam (Damm et al. 2006, Damm et al. 2009). DISFLOOD was realised at the Natural Disaster Networking Platform (NaDiNe).[1] Two of the dissertations developed within this project had been defended in 2010 at the Faculty of Agriculture of the University of Bonn (Damm 2010, Fekete 2010).

The concept of vulnerability

River floods can be devastating hazard events. The consequences of floods, once they affect people, their settlements, infrastructure, industries and farmlands could turn into disasters. The hazard of the occurrence of a flood is a co-determinant of the risk of a flood, and the expected (multidimensional) losses of people and their assets. A hazard is the flood event itself, which may or may not result in a disaster, depending on whether people, their structures, assets or resources are affected. Risk is the situation before the disaster, with a yet unknown, combined potential of hazard and vulnerability parameters. Hazard parameters describe the flood itself, while vulnerability parameters characterise the subjects and objects, that are impacted by the flood, as well as their setting and context.

Flood losses as well as the impacts of climate change cannot be addressed by hazard analyses alone but must be amended by using vulnerability estimates (Bogardi 2009, IPCC 2012).

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[1] Website of DISFLOOD at NaDiNe (last access 18.Dec.2012, not online anymore) a) the web-GIS: http://nadine-ws.gfz-potsdam.de:8080/disflood/DisfloodMapClient.jsp and b) the project description: http://nadine.helmholtz-eos.de/projects/disflood/disflood_de.html

Intensive use of flood prone areas, accumulating wealth, building infrastructures along rivers, but also the lack of knowledge and experience with extreme floods and changes in the social, economic and environmental fabric contribute to the increase of vulnerability of those potentially affected. Vulnerability in the broadest sense is defined as the predisposition to be hurt by hazard(s) (UN/ISDR, 2004, IPCC 2012). Flood risks are defined as the function of hazard and vulnerability whereby vulnerability is the least known component of an equation which may express risk *(R)* as a function of the hazard *(H)* and vulnerability *(V)*:

$$R=f(H,V) \tag{1}$$

Thus forecasting the hazard may not tell the whole story about flood risk, which ultimately matters more than the natural phenomenon itself. Forecasting risk must imply the prediction (or at least an estimate prior to the occurrence of flood) of vulnerability *(V)*.

On its own turn vulnerability is also multidimensional. It is usually characterized by its social, economic, environmental, physical (infrastructure) and institutional dimensions (Birkmann, 2006; Cardona et al. 2012). Vulnerability implies the question "vulnerable to what?", hence without being exposed to this particular "what" – a hazard – people may not seem to be vulnerable. However, there is an internal core of vulnerability which does exist irrespective whether the individual is exposed to a hazard or not. This inherent pre-disposition to be hurt is suggested to be defined as the hazard-independent susceptibility. This could also be measured in different dimensions. Susceptibility may turn into hazard specific vulnerability once people were exposed to it (like living in a floodplain). Thus vulnerability *(V)* is the function of susceptibility *(S)* and exposure *(E):*

$$V=g(S,E) \tag{2}$$

Vulnerabilities of all kinds – of society, of a building or the environment - can be mitigated through certain capacities *(C)*. These capacities can be both structural and non-structural. Structural capacities are, for instance, housing and infrastructure conditions. Non-structural capacities are abilities and skills people might have acquired and might deploy prior, during or after the occurrence of a hazard event. Capacities such as knowledge of the hazard, savings, insurance or applying solid building codes for houses can directly offset vulnerabilities. Hence the "residual" vulnerability which remains to contribute to risk would be:

$$V=h((S,E)-C) \tag{3}$$

where *(C)* represents capacities to resist, to respond, to bounce back (being resilient) and to adapt. It includes also coping or even the ability to suffer or to absorb harm in any other way. Resilience is increasingly used as an all encompassing term describing all positive features and attributes mitigating vulnerability (Cutter et al. 2008, Manyena et al. 2011) or even beyond, like the recent report of the UN Secretary General's Global Sustainability Panel "Resilient People Resilient Planet: a Future Worth Choosing" (www.un.org/gsp 2012). The authors argue that this "extensive and extended" use of this term is false both linguistically (resiliere in Latin means: jumping back, cf. Manyena et al. 2011) and theoretically. While the term "resilience" is also used in ecology yet in another context (Holling, 1973, Gunderson & Holling 2002) the true meaning of the word is to describe the phenomenon to bounce back into the original state after having been exposed to the impact of a stressor (Hashimoto et al, 1982, Duckstein et al, 1987, Manyena et al. 2011). Meanwhile, the adoption of the term resilience is increasingly questioned (Levine et al. 2012). The authors opt for the name "capacities" to cover the vulnerability mitigating options, of which resilience (bouncing back) is one. Given the multitude of

their dimensions and their nature as a potential inclination to be hurt and/or suffer losses, vulnerabilities can only be approximated prior to their manifestation during a disaster with the help of proxy variables. As a tool for planning or flood risk forecasting, the selected vulnerability estimates refer to administrative entities. This is often a compromise driven by data availability that typically lacks the precision offered by assessments of individual persons, households, or objects. However, administrative units offer the advantage of being directly linked to units used by decision-makers at various local, regional, national and international levels (Fekete, Damm, and Birkmann 2010). For the purpose of this project the county scale has been identified as the most appropriate compromise between spatial precision and policy relevant information.
While the susceptibility assessment covers whole Germany (well over 400 counties) the flood related vulnerabilities are estimated and shown for counties along the Rhine and Elbe rivers.

Indicators and indices: a word of caution towards THE ASSESSMENT of vulnerabilities

„Science may be described as the art of systematic oversimplification."
Karl Popper

Analyzing complex systems involves reducing complexity to a certain degree. Simplification is an accepted part of the scientific research process and is associated with choices about how much to simplify and how to do it without misrepresenting reality? Are indicators and indices useful for accurately encapsulating a complex reality in simple metrics?
Aggregating indicators creates even more opportunities for subjectivity and thus must be even more critically appraised. By their very nature, the role of indicators is to capture an intangible process so it is not really possible to "ground truth" them. The index as an aggregate measure of several indicators is contingent upon the choice of indicators. There is a real possibility that uninformed choices are included and survive several (statistical) filters and even expert validations and can ultimately lead to an invalid index.
A critical evaluation of the limitations of indices is an imperative given the fact that they link science and policy. By summarizing and simplifying reality they are useful to policy-makers, but the absolute certainties of information expected by decision makers are often incompatible with the uncertainties of the considered hazard event(s), vulnerability of society and the epistemological uncertainties of science itself.
Indicators facilitate the task of mapping and comparing vulnerability across regions and simplify the communication between profession, public and politics. At the same time, numerous opportunities for conceptual and methodological errors, false communication signals and misinterpretation by and between those stakeholders may emerge (Fekete, 2012, Kuhlicke et al. 2011, Steinführer & Kuhlicke, 2012).
Adger et al. (2004) identify two different procedures for indicator selection, the deductive approach and the inductive approach. The deductive approach involves proposing relationships derived from theory or conceptual framework and selecting indicators on the basis of these relationships. When conducting a deductive approach, it is important to first create an understanding of the investigated phenomenon and the processes involved, second to identify the main processes to be included in the study, and third to select the best possible indicators for these factors and processes. Inductive approaches involve statistical procedures to relate a large number of variables to vulnerability in order to identify the factors that are statistically significant. Hence, potentially relevant indicators are incorporated in a certain statistical model and indicators are selected on the basis of significant statistical relationships. Expert judgment or/and principal component analysis are common methods to select the final indicators respectively.

In this study the social-ecological vulnerability (using the so called "Turner Model" (Turner et al, 2003) was assessed by indicators defined by the deductive approach, while the social and infrastructure vulnerability index based on the BBC Model (Birkmann, 2006) was partly the result of an inductive procedure.

The BBC model and its use to estimate social vulnerability

The BBC framework (Fig. 1) explicitly links vulnerability to the three spheres of sustainability; society, economy and environment. This framework is based on theoretical considerations, how social, economical and environmental dimensions of human security can be integrated with existing hazard and risk concepts. In the BBC framework, vulnerability is put into a chain starting from a natural phenomenon that can evolve to a hazard event and hits an exposed, susceptible population. This group may be equipped with certain capacities to encounter the hazard. Thus its vulnerability is reduced. Vulnerability and hazard together define risk. There are two entry points for risk mitigation: during the pending risk and after the hazard event has started to affect the people. The BBC framework puts the main analytical components of vulnerability into focus for an assessment. These three components, exposure, susceptibility and capacities, provide the main entry and structuring points for the development of vulnerability indicators (see Fig. 1).

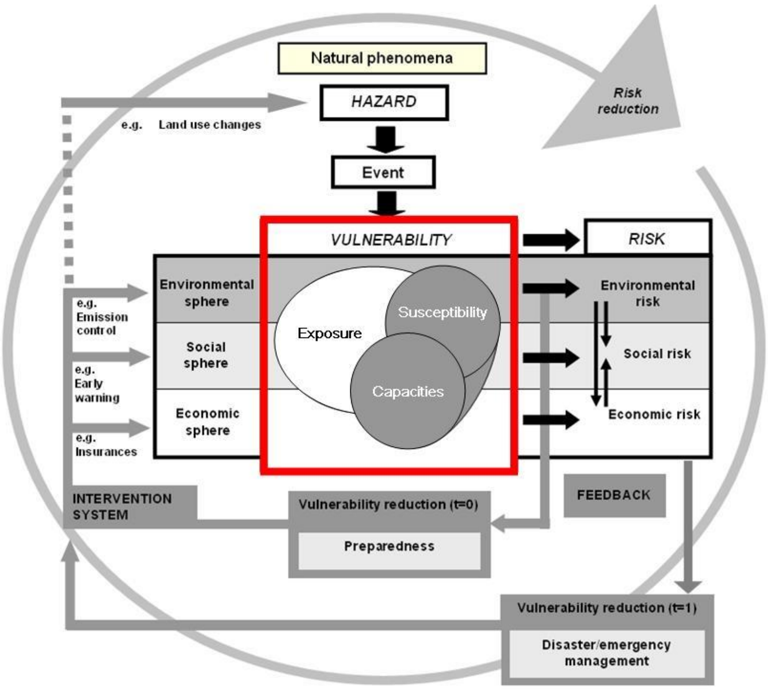

Fig. 1 BBC framework

The social vulnerability assessment focuses on aspects of potential weaknesses and also capacities of the population. Thus it stands for the vulnerability(ies) of the society of the whole research area rather than being a representation of vulnerabilities exclusively within the social fabric of the referent group of people. This means that indicators for social vulnerability have to be selected to be relevant to a hazard context. On the other hand, the BBC model shows the distinction of hazard analysis as being a different field from vulnerability analysis.

The 'social vulnerability' component will be assessed by combining a Social Susceptibility Index, including a measure of capacities to reduce this susceptibility, with exposure information.

Fig.2 presents the Social Susceptibility Index for Germany. It is based on indicators capturing (personal) fragility, socioeconomic conditions and regional aspects. All data used here are available from the standard census data of the Federal Statistical Office of Germany.[2] None of these variables seem to be related (directly) to floods, but all capture certain components of relevant susceptibilities which matter also in case of a flood. The indicators used have been obtained by using a deductive conceptual approach informed by an inductive statistical approach (see below). Two aspects were of major interest; first, can social vulnerability be assessed, even semi-quantatively be 'measured', in a country like Germany. Second, are indications of vulnerability significant for a given hazard, or do they simply reflect disparities in a society, that could also be labelled 'poverty' or else. In the deductive part, the overall conceptual framework and theoretical discussion at the time had a major impact on the mindset and conception. The BBC framework and the debates on definitions of vulnerability guided the conceptual set-up of the indicators by the break-down of vulnerability into its subcomponents. Also, the primary selection of data sets and variables was guided by the view and definitions of vulnerability. Within the development from the variables to the construction of the indicators however, an inductive approach was selected. Using factor analysis in the first step, variables were grouped and labelled with no previous preset and relation to the conceptual subcomponents 'susceptibility' or 'capacity'. One resulting variable group was labelled 'fragility', for instance, as the main variables in this statistical group related to old age. The resulting variable groups, or indicators, are capable of indicating both higher than average susceptibilities, or, capacities for any county in Germany. In the second step, exposure to river floods were calculated only for those counties along the rivers Rhine and Elbe where data was available. Settlement areas and population numbers derived by statistical and remote sensing data are proxies to describe the degree of exposure. Combining exposure with the susceptibility / capacities indicators resulted in an aggregated vulnerability index. This index was calculated for social / demographical aspects and infrastructure. In the last step, this index was tested against results from a telephone-based survey of over 1.600 river flood affected households (Fekete 2010). Using regression and bootstrapping analysis, statistically significant correlations between elderly citizens and the group of people seeking public emergency shelters were identified. However, the development of social vulnerability indicators and especially the identification of validation benchmarks are based on several assumptions and demand for further research (Fekete 2010, Fekete 2012).

The results clearly indicate that forty years of separation and diverging development paths are still visible and determine to a great degree the different susceptibility and hence vulnerability of the population in the eastern and western part of the country. It is interesting to note that the Ruhr area, irrespective of its economic strength, is among the most susceptible parts of Germany.

[2] The data is annually updated at: https://www.regionalstatistik.de/genesis/online/logon (last access: 18.Dec.2012)

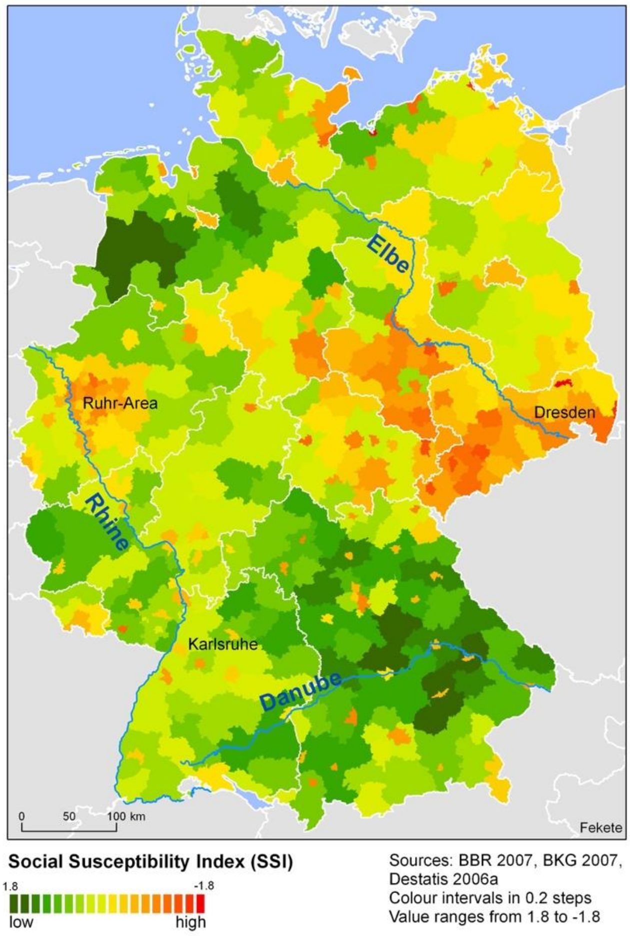

Fig. 2 Aggregated Social Susceptibility Index (SSI) for Germany using age, housing type, employment, education and population density

Flood exposure is estimated for the riparian districts along the rivers Rhine and Elbe. The inundation maps prepared are based on the available statistics of floods of at least 200 years of recurrence period. Within a Geographic Information System (GIS) framework the affected counties were classified according to the portion of the inundated area and respective population.

Social and Infrastructure Flood Vulnerability Index (SIFVI) (see Fekete, 2010) is calculated for river floods by the simple formula:

SIFVI= f (social susceptibility index, exposed area of the district, (4)
infrastructure density in the district)

Fig. 3 shows the social-infrastructure vulnerability index for the counties located along the two great rivers. Parts of the Elbe are missing due to data gaps.

Flood risk and its distribution could be predicted by superposing the SSI map with statistical inundation scenarios (hazard forecasting). This risk assessment yields relative, comparable results enabling a ranking of the affected counties without determining the absolute value of risk.

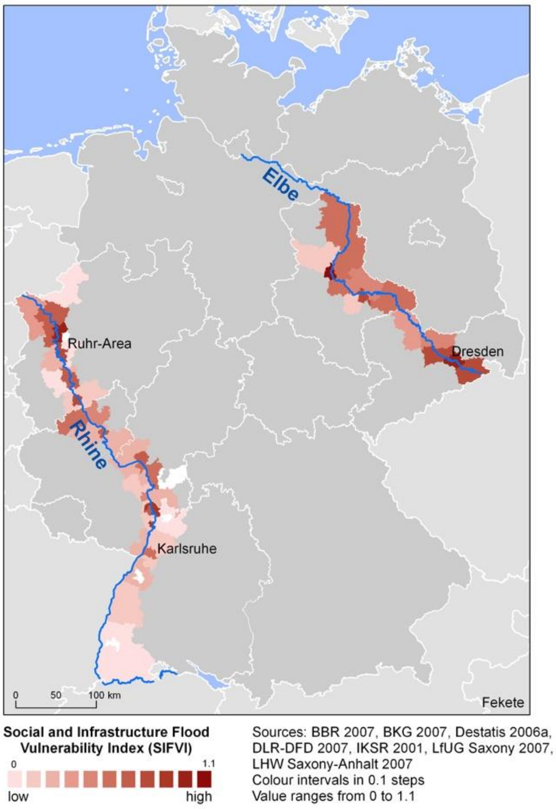

Fig. 3 Social and Infrastructure Flood Vulnerability Index along the Rivers Rhine and Elbe, based on flood exposure, susceptibility and infrastructure index

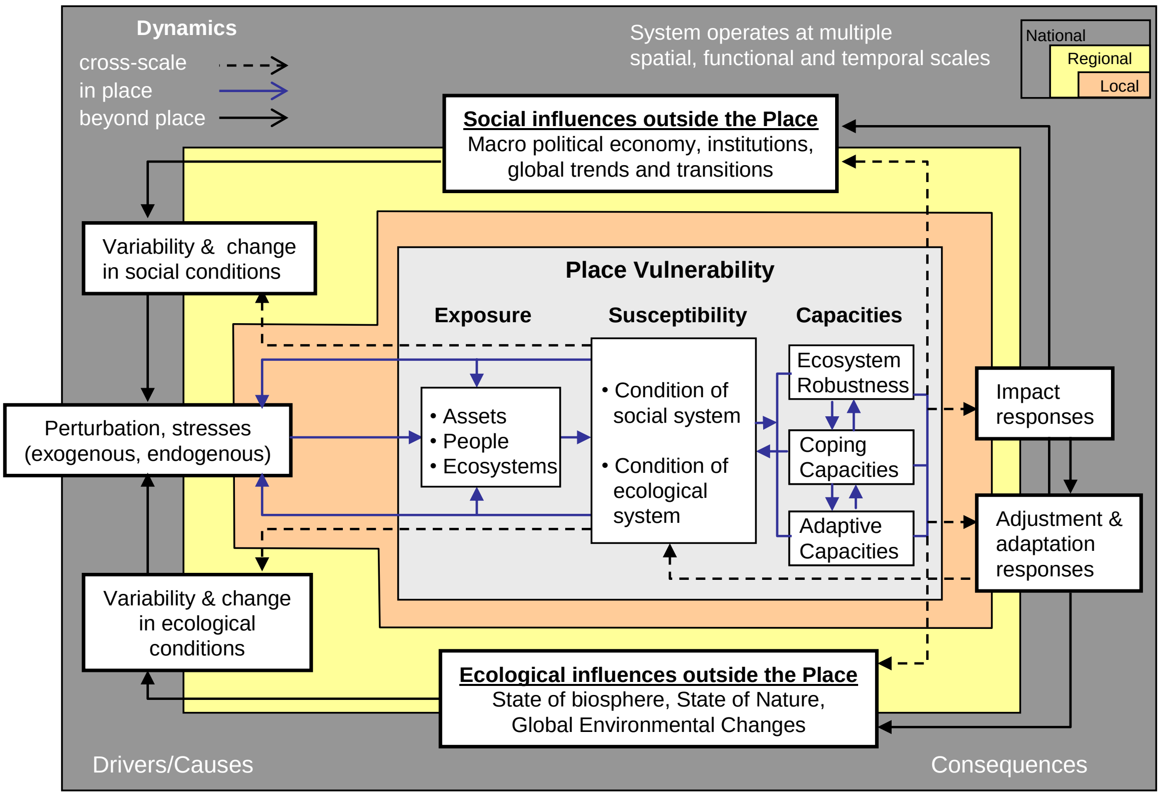

Fig. 4 Vulnerability framework used in this study. Modified from Turner et al. (2003)

The "Turner Model" of vulnerability and its application to assess social-ecological vulnerability for river floods

The "Turner Model" identifies the social-ecological system (SES) as subject of analysis. A social-ecological system is defined as "a system that includes societal (human) and ecological (biophysical) subsystems in mutual interaction" (Gallopin 2006: 294). Our society is strongly interlinked with ecological systems through the provisioning, regulating and cultural services that these ecosystems provide. Therefore, any vulnerability analysis of a SES needs to consider the processes and dynamics within each subsystem as well between the ecological and social sphere. Furthermore, SESs are subject to influences that operate and interact spatially, functionally and temporally across a range of nested or overlapping scales and levels. The dynamic behavior of vulnerability in SES is indicated by integrating feedback loops and interlinkages between the system components.

The vulnerability framework which is used here (see Fig.4) is adapted from a framework published by Turner et al. (2003).

Vulnerability is composed of three main components: exposure, susceptibility and capacities. Elements exposed to a hazard can be human-beings, assets, ecosystems etc. Susceptibility indicates the condition or rate of response of the SES with regard to all perturbations and stresses within the system. Capacities define the ability of a system to resist, cope and adapt to a certain hazard. It is important to distinguish conceptually between internal perturbations that determine the current condition in SESs and thus the vulnerability at a particular place and time, and external perturbations, like a hazard events that strike a system provoking disturbance and damage.

Althouth some modifications were made in this framework to adapt the model to the practical needs of operationalization (e.g. substituting "impact response" with "ecosystem robustness") the proposed model is still quite complex for practical use. So far few attempts have been made to implement the framework. A further constraint of the framework is the missing notion of risk. The concepts of risk and vulnerability are very often strongly interlinked in disaster research, see e.g. BBC Model. The Turner Model does not outline how risk is conceptualized. This feature was likely the main reason why this model was considered more a conceptual one. Using it for practical vulnerability assessment implied here not only the need of modifications but also to define exposure in an innovative way.

The social-ecological vulnerability is estimated through the respective assessments of the agricultural and forestry sectors. The vulnerability component 'exposure' determines the degree to which a SES is exposed to a specific threat or perturbation. This can be forested or agricultural sites as well as people whose livelihood is dependent on the respective sectors. Exposure is seen as the starting point in a vulnerability analysis. Without having any exposed elements, no hazard specific vulnerability can be detected ($E = 0 \Rightarrow V = 0$).

Susceptibility is the vulnerability component that describes the current state of the SES's elements. In other words, susceptibility is a measure to determine the expected rate of deterioration. Susceptibility is a dynamic element and is changing continuously over time.

Capacities stand for the combination of all strengths and resources available in the social-ecological system. They reduce the overall level of vulnerability and thus the effects of a striking hazard. The vulnerability component 'capacities' is composed of the three sub-components 'ecosystem robustness', 'coping capacity' and 'adaptive capacity'.

Ecosystem robustness addresses the capacity of the ecological system to absorb and resist disturbance while re-organizing and undergoing change. The concept of robustness is well developed in engineering science where it refers to the maintenance of system performance (Anderies et al. 2004),

Coping capacities stand for the means by which people or organizations use available resources and abilities to face adverse consequences that could lead to a disaster. Adaptive capacities refer to a longer time frame and reflect the learning aspects of system behavior in response to disturbances (Gunderson, 2000).

Table 1 summarizes the different indicators selected by the above mentioned deductive approach. The weighted sums technique was applied to create the composite vulnerability index CI_d which aggregates the exposure, susceptibility and capacities of the forestry and agricultural sectors as proxies for the social-ecological system. Indicators were normalized, weighted and subsequently summed up (see Damm 2010).

$$CI_d = \sum_{q=1}^{Q} w_q I_{qd} \tag{5}$$

CI = Composite Indicator, *d* = district, *q* = sub-indicator, *Q* = number of indicators,
w = weight, *I* = normalized indicator

It is important to note that in this assessment, based on the "Turner Model" exposure is not related directly to the spatial extent of the hazard like in the previously described application of the BBC Model. In this social-ecological vulnerability assessment exposure is estimated by the number of people employed in the respective sector and the percentage of the farmland or forest areas within the respective district. Thus it is a pre-determined proxy, being independent of the magnitude of the hazard which might affect the district. The inundated area (as consequence of an extreme flood) which was used as a measure of exposure in the BBC Model serves here as the proxy measure of the magnitude of the hazard instead. This approximation allows to go a step further and assess the flood risk, as a composite measure based on the vulnerability index CI_d and hazard (flood maps) estimates for the agricultural and forestry sectors. Fig. 5 illustrates for the agricultural sector the vulnerability map of Germany. Similar to the SIFVI index (see Fig. 3) the former border between the then Federal Republic of Germany and the part of the country which used to be the German Democratic Republic is still detectable.

Table 1 Selected primary indicators for the forestry and agricultural sectors

Forest Sector		
Component	**Sub-component**	**Indicator**
Exposure	Ecological system	% of forested area
	Social system	% of people employed in forest sector
		% of gross value added forest sector
Susceptibility	Human condition	Unemployment rate of the district
	Ecological condition	% of damaged forest
		Water quality index
Capacities	Ecosystem robustness	Forest size
		Forest fragmentation
		Forest type
	Coping capacities	GDP per capita of the federal state
		GDP per capita of district
		Mean income of private households
	Adaptive capacities	Reforestation rate
		% of protected areas
Agricultural Sector		
Component	**Sub-component**	**Indicator**
Exposure	Ecological system	% of farmland
	Social system	% of people employed in agricultural sector
		% of gross value added agricultural sector
Susceptibility	Human condition	Unemployment rate of the district
	Ecological condition	Soil erosion potential
		Water quality index
		Potential contaminating sites
Capacities	Ecosystem robustness	Water retaining capacity
		Filter and buffer capacity
		Dominating land use
	Coping capacities	GDP per capita of the federal state
		GDP per capita of district
		% of farmers with side income
	Adaptive capacities	% of organic farming
		% of protected areas

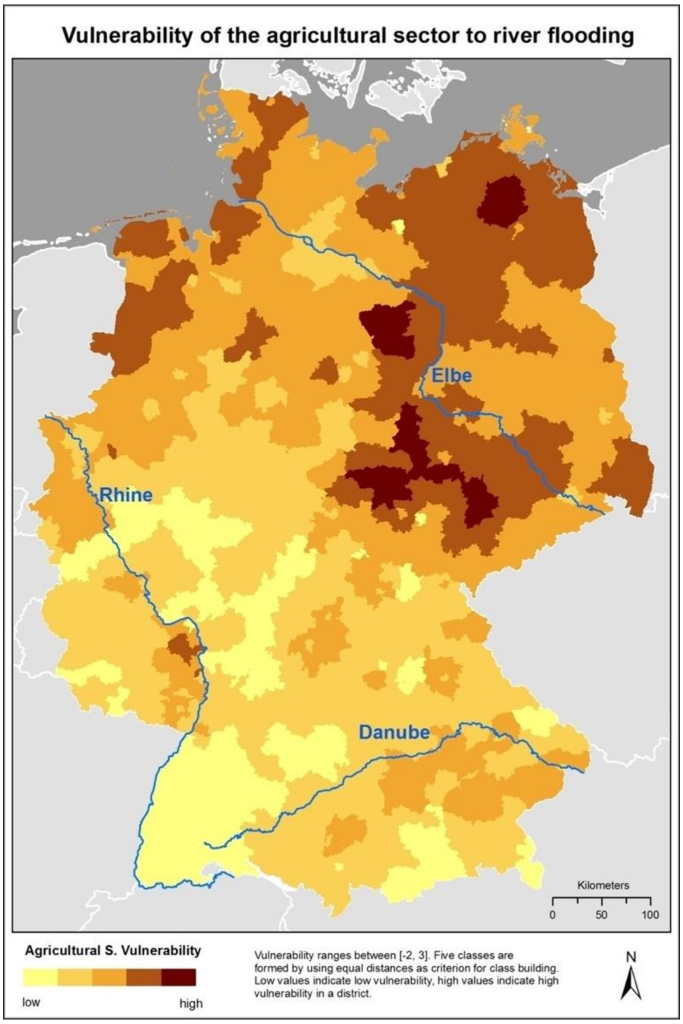

Fig. 5 Vulnerability map for the agricultural sector on district level

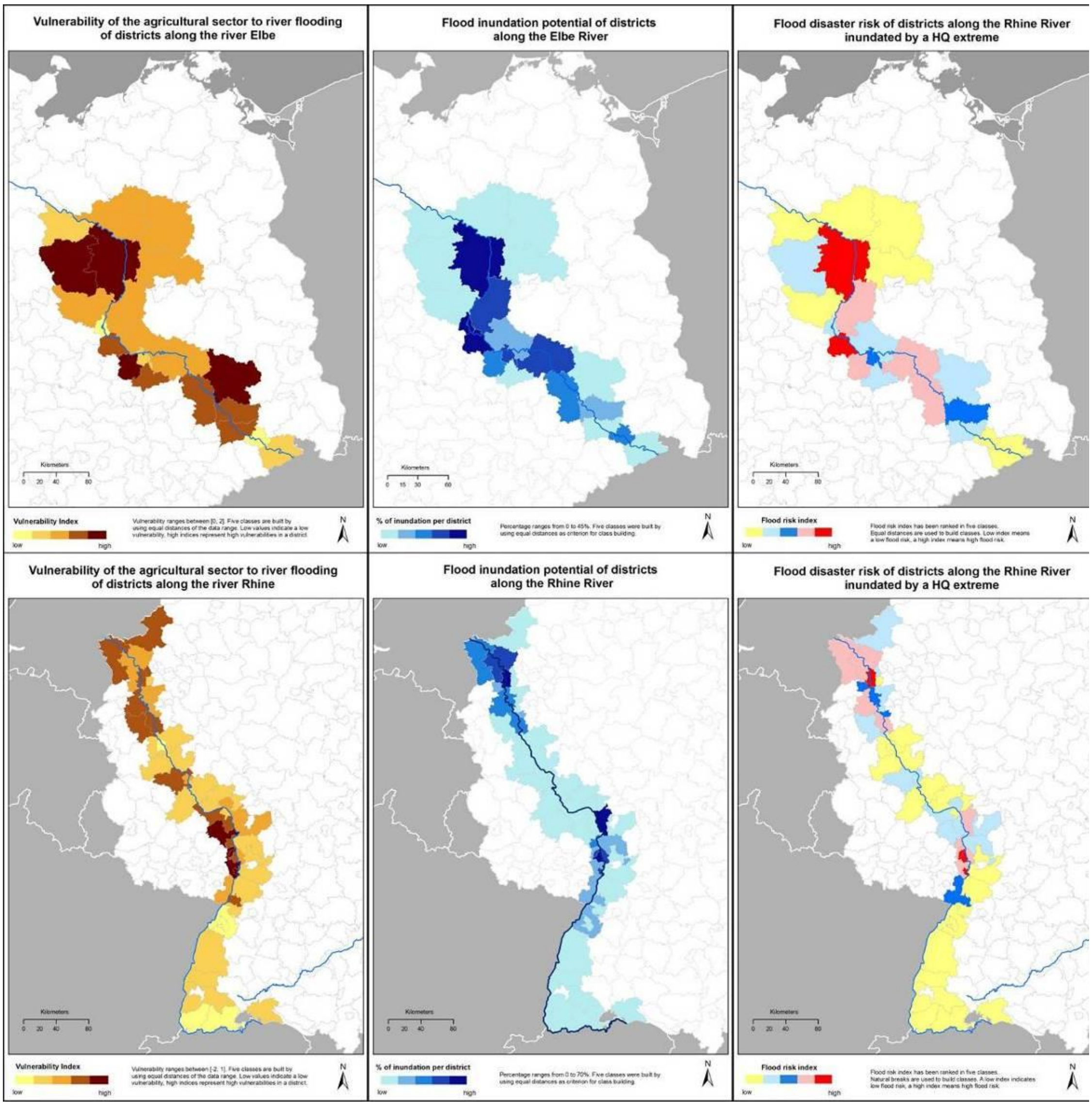

Fig. 6 Presentation of vulnerability, hazard and risk maps for the rivers Elbe and Rhine for the agricultural sector

Figs. 6 and 7 summarize the flood vulnerability, hazard and risk distributions for agriculture and forestry respectively. In the lower part of Fig. 6 vulnerability, hazard and risk are mapped for all districts along the Rhine River that can be affected by a HQ of at least 200 years of recurrence period. It is to be noted that the reach of the Elbe river under tidal influence is not assessed due to lack of data.

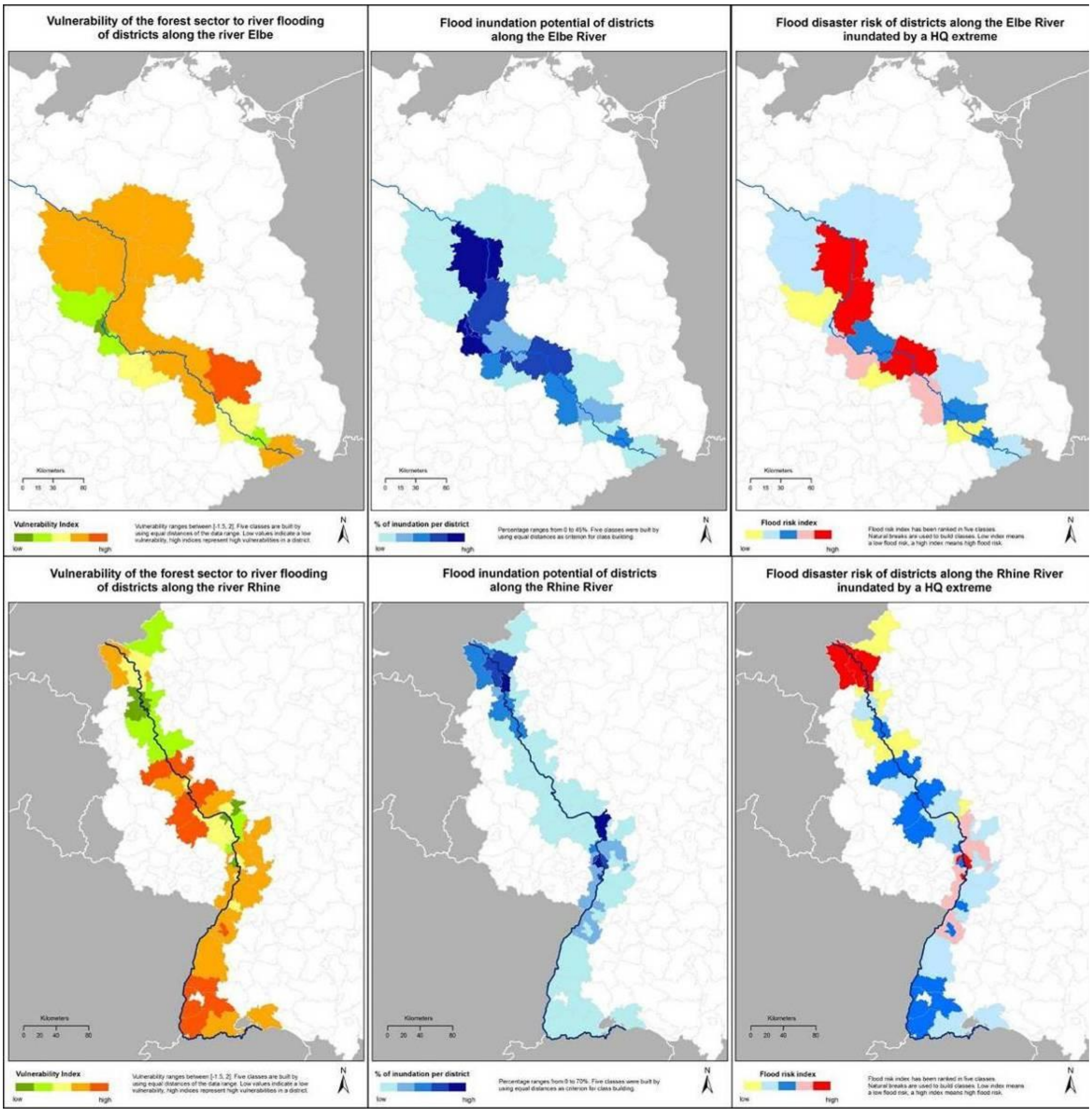

Fig. 7 Presentation of vulnerability, hazard and risk maps for the rivers Elbe and Rhine for the forestry sector

Vulnerability and Resilience Indicators: is there a difference?

The difference between vulnerability and resilience is one of the biggest looming conundrums – conceptually as well as regarding application. Indicators are one standard method for semi-quantitative assessments of both vulnerability and resilience in many areas; disaster risk reduction, climate change, critical infrastructures, amongst others. Developing indicators links the conceptual with the application part, since many indicators are based on semi-theoretical frameworks.

Many applications and 'measurements' are rather pragmatic and are not too much afraid about renaming former vulnerability, or capacity indicators into resilience indicators. The main problem lies on the conceptual side that remains open, vague and pluralistic and therefore does not provide a clear basis. Neither pragmatism nor pluralism are necessarily negative approaches, especially in the disaster and climate change areas, that often prompt for simple, pragmatic, feasible and conceivable solutions for complex, multi-disciplinary and not standard problems.

The first problem in differentiating vulnerability and resilience rests in each of the two terms and concepts that are themselves not being uniformly defined nor conceptualised. This is probably not, as often stated, a problem of lack of precise definition. Both vulnerability and resilience, as well as sustainability, are meta-concepts. They cover multiple impacts spheres, actors and characteristics and must be generally useful to many disciplines and applications. Meta-definitions and other generalisations are always vague, by design. Such meta-definitions (e.g. Thywissen, 2006) must be developed and operationalized for each case study and application accordingly to context and goal.

In the operationalization of these meta-definitions the practical problems emerge. In the case presented in this paper, the BBC framework is a breakdown of a meta-definition of vulnerability and risk, partly based on sustainability spheres and feedback-loops from ecology. In the operationalization of the BBC model, the differentiation between susceptibility and capacity indicators was difficult, as was the allocation of exposure to either the hazard or the susceptibility side (Fekete, 2010, Fekete, 2012). Anderson & Woodrow (1998) already termed it a vulnerability and capacity assessment (VCA). To this day, studies inherit this ambiguity and problem of allocating indicators to hazard, susceptibility or capacities (BEW & UNU-EHS 2012). The same type of discussion is observed by cases that adopt the term resilience as a flip-side or counterpart of vulnerability, or susceptibility (Folke et al., 2002). A classic example is the vulnerability model for sustainability (Turner et al., 2003), its later adoptions (Damm, 2010, Kienberger et al., 2011) or transformations of former vulnerability into resilience frameworks (Cutter et al., 2008).

The term 'capacity' is used in various combinations, such as adaptive capacity, coping capacity, mitigation capacity, etc. Interestingly, this combination of terms is hardly observed for the term resilience. And given the linguistic root of resilience of simply meaning 'bouncing back', it is questionable, whether it really can or should represent the same variety of aspects as 'capacities' do. Moreover, bouncing back to the same state as before is also regarded a not necessarily positive recovery characteristic.

Is there a fundamental difference between vulnerability and resilience indicators? In the notion as covered above, this is not easy to answer. This can also be stated for other approaches to operationalize resilience that partly try to integrate formerly used criteria under the umbrella of resilience. For instance, Tierney & Bruneau (2007) name the "4R's" of resilience: redundancy, robustness, rapidity (or repair) and resourcefulness. This is a very useful approach, as it is pragmatic, and captures important aspects especially for applications in engineering, critical infrastructures, but also beyond. Still, all four criteria have been in usage for a long time already, in critical infrastructure analyses, for instance. Another example, the "4E's" of resilience (Edwards,

2009) describe engagement, education, empowerment, encouragement. These are key criteria especially in what are termed ‘community resilience’ approaches that are often bottom-up and focus on the abilities and skills of the people. But again, these criteria have been in use, for instance in the Pressure-and Release Model (PAR: Wisner et al., 2004), the livelihood approach (DFID, 2000), or capitals approach (Sen, 2005). Both the 4R and 4E are included in the term capacities in a vulnerability assessment. What is the difference then? Maybe this question is less important than the question, which new lenses the new term provides us with. And undeniably, resilience prompts to focus differently, not just on the capacity side of vulnerability, but also on certain recovery, risk and change handling mindsets.

But actually, this is just half of the story on what makes resilience different from vulnerability. A distinct feature of resilience is the stability and dynamic trajectory of a system observed. While this again can be traced back to system theory and earlier roots (Bertalanffy, 2006), we leave this terminological discussion aside and focus on what is specific about resilience. There lies a real chance to add value to vulnerability by the emphasis on temporal aspects, observation of multiple stability states (Gunderson & Holling, 2002), development states and futures. Vulnerability assessments such as vulnerability indicators are still mostly static snap shots of one-time slice, though time series are possible. Some vulnerability models such as the PAR model are inherently backward-looking in collecting factors that all contributed to (negative) conditions of people. While future scenarios such as demographic or climate change can be included in vulnerability assessments (Kienberger, 2012), the bulk on vulnerability studies is based on historical information. Vulnerability by trend might look more into how conditions emerged to explain the current status quo. Resilience is sometimes regarded as a forward-looking model, including the ability to “bounce forward” (Manyena et al., 2011), despite the missing linguistic basis for this attribution. But linguistics also teaches there is a daily-use component to words we use that is equally, if not more important than it’s Latin, Greek or else, root (de Saussure, 2006). Resilience teaches us to be flexible, and this linguistc pragmatism could be an important feature we could adopt. However, it is interesting to revisit Holling and colleagues, (Gunderson & Holling, 2002) who had quite an impact in introducing the resilience concept into disaster risk and climate change research. In their seminal book “Panarchy” they provide several stability and development models for systems (Gunderson & Holling, 2002). While they argue that resilience is more than just the bouncing back notion (Holling, 1973), they offer a more precise terminology themselves for those type of stability states that are of increasing interest. What is sometimes termed “complex adaptive systems” for example, is named a “nature evolving” system (Gunderson & Holling, 2002). This model best reflects the notion of not bouncing back, but evolving to new states of existence. So maybe in the future, we should outdate and replace ‘resilient’ with ‘evolving’ when we speak of dynamic development indicators. This could be more precise and avoiding that too many attributes are summarized under the term resilience.

Concluding, there exist differences between vulnerability and resilience. The first is rather subtle, when resilience is regarded as an alternative (encompassing) term for capacities. In this deployment, resilience indicators should stress and integrate variables and components that would be overlooked uder traditional conceptions of coping capacities, for example. Resilience might benefit from more precise combinations with other terms, such as ‘restoration resilience’, adaptive resilience’ etc. At the same time, mal-resilience as well as mal-adaptation, restoring vulnerabilities or rebuilding houses and infrastructure after destruction in the same hazard exposed areas (as apparently happened after the 2002 Elbe flood in Saxony) must be critically observed as well.

The second difference between vulnerability and resilience is bound to transformation and dynamic development states. Herein, resilience may stress temporal aspects even better than vulnerability, as well as different future states and learning from system collapses. However, one must be aware that alternative terms might be even more precise, such as evolution or development. And again, not just positive aspects must be considered but also mal-resilience must be observed such as downsides of changes and transformations, flexibility and dimensions of rapid as well as slow trends.

Critical evaluation and conclusions

So far, key elements, structures and underlying theoretical concepts could be tested and operationalized for both vulnerability frameworks, the BBC and the "Turner Model". However, some analytical constraints and differences still exist which cannot be neglected.

The vulnerability reducing component 'capacities' encompasses the capacities to bounce back, resist, cope with and adapt to hazardous events. These properties, and specially their respective levels could depend on the condition of a system which is represented by the susceptibility component. The findings showed that, for instance, healthy and vital ecosystems and societies exhibit high robustness; or economically advantaged regions have stronger capacities to cope with flood events. Both components are interrelated, since stronger capacities compensate susceptibilities, or even are the flip side.

Another important aspect which is not uniformly solved in the presented models is the exposure component. The vulnerability research community has not agreed on a common interpretation of this component yet. Visually, both conceptual models place exposure within the vulnerability frameworks. In this study exposure was treated both as a hazard-independent component in the social/ecological vulnerability assessment with the Turner model but also as the estimate related to the spatial extent of the hazard phenomenon (BBC model) By using a hazard dependent exposure estimator, the risk assessment can be improved by using additional proxies for the hazard and its magnitude, such as the depth or/and duration of the inundation.

The potential hazard extent was characterized by the flood, having at least 200 years of recurrence period. At county level, the percentage of inundated land area can be derived from flood maps. The combination of hazard and vulnerability scores produced maps showing flood disaster risk potential of districts along the Elbe and Rhine Risk mapping based on detailed vulnerability assessment is still far from becoming a routine exercise. The present study has shown the potential and feasibility of applying vulnerability concepts. They could be used in strategical planning, identifying priority areas of interventions for better preparedness.

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Comment

This essay is a book chapter of a book that was never published in the end due to the death of the editor, Prof. Jürgen Pohl. Most of the chapter content has been published elsewhere in the meantime[3], however, it is the discussion chapter at the end, that deals with the real nitty gritty of academic research that kept us busy back then and over the course of a decade or more on the conundrum on how to define, delineate and operationalise vulnerability in context to different hazards. And it is also always circling around the sometime unspoken, in other publications outspoken range of open unanswered questions, such as; is there a hazard-independent form of vulnerability? Since this discussion can be understood best by reading it in context, we kept the text body around the discussion chapter, as it was when we wrote it.

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[3] Bogardi Janos J., Damm, Marion, Fekete, Alexander (2011): Multidimensional Indices to Capture Vulnerability to River Floods. In : Eriberto Eulisse (Ed.) 2011. Challenges in Water Resources Management. Vulnerability, Risk and Water Resources Preservation. Proceedings of the Marie Curie Training Course held in Venice (Venezia) 7-11 September 2010.Water Civilisations International Centre. Universitá Ca'Foscari Venezia, Civiltá dell'Acqua. ISBN Number: 978-88-88997-57-5. pp 49-63.

Research Conceptualisation for Analysing Social Vulnerability by Indicators

Alexander Fekete

"*Problem formulation is more difficult than problem solution*"
Murray Gell-Mann

Theory is a difficult term with disagreement about its definition between different scientific disciplines. Especially natural and social sciences have different comprehensions of theory, meta-theories, hypotheses and models of reality. In this chapter, 'theory' signifies generalisable observations. They describe properties of 'reality' that can be abbreviated to expressions and frameworks that can be applied for other studies as well.

3.1 Vulnerability terminology

Researchers dealing with the term vulnerability encounter a variety of definitions. While this is often stated as a major problem that hinders the applicability (Cannon, 2006: 41, Füssel, 2007: 155), uncertainty in definitions is a common course in science (Feynman, 2007). For example, similar terms like 'risk', 'disaster', 'uncertainty', 'sustainability' or even terms like 'system', 'probability' or 'flood' are subject to controversy (Rothman et al., 2008, Quarantelli, 1998). By etymology, the term 'vulnerability' stems from Latin 'vulnus', the wound and 'vulnerabilis' – being wounded (Kelly and Adger, 2000): 328[4]).

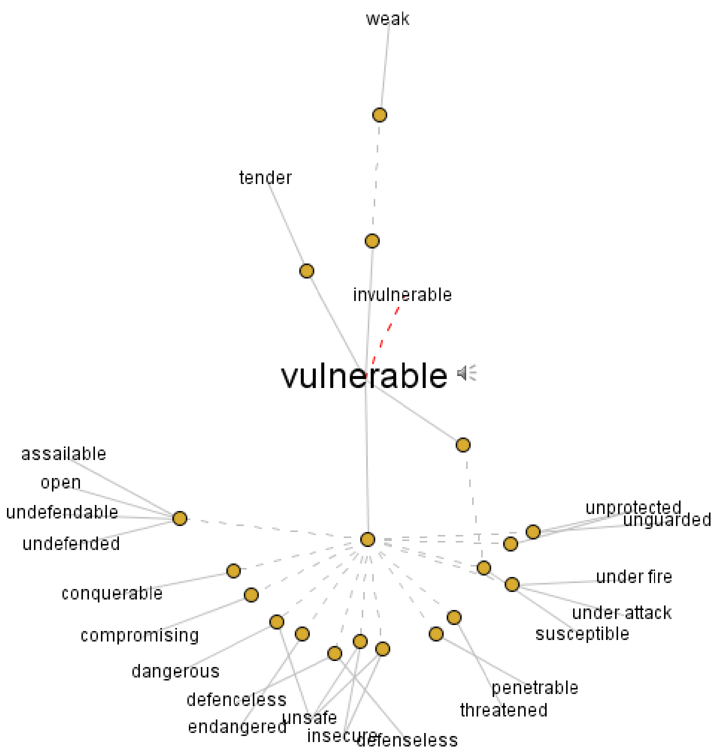

Figure 4. Diagram showing the relations of the term vulnerability to similar expressions
Source: www.visualthesaurus.com, accessed 21 May 2008

[4] "Vulnerabilis was the term used by the Romans to describe the state of a soldier lying wounded on the battlefield, i.e., already injured therefore at risk from further attack." (Kelly & Adger 2000: 328)

The confusion around the different interpretations of vulnerability arises from the differing meanings and normative attributions assigned to it. Adding new definitions to the already long list is no aim of this study. However, in the research community it is demanded to provide a working definition to enable an understanding of the research stance. Prior to this, it is necessary to highlight some important points of discussion in vulnerability terminology.

3.1.1 Important points of discussion in vulnerability terminology

Vulnerability is by etymology a negative expression, but there is a trend to attach a positive side to it. The chart of the term vulnerability illustrates its relation to similar expressions and denotes its closeness to negative attributions in common language (Figure 4). The attachment of a positive side of the coin is driven by developments of relief organisations and some disciplinary schools (Anderson and Woodrow, 1998: 11, Twigg, 2004: 19, Wisner et al., 2004: 112). They stress to view humans not only as victims but to shed light on their capacities as well (Wisner et al., 2004). In this respect it is instructive to know the disciplinary discourse of different schools of vulnerability that have been extensively reviewed (Hewitt, 1983, Cutter, 1996, White et al., 2001, Weichselgartner, 2001, Brooks, 2003, Few, 2003, Adger, 2006, Birkmann, 2006). On the backdrop of different disciplines and fields of application – from food security to climate change, the variety of definitions (Cutter, 1996, Weichselgartner, 2001, Thywissen, 2006) can be understood. The range of definitions is given by normative views of disciplines but also by the fundamental difference in science philosophy between reductionist and holistic views.

Reductionist versus holistic viewpoints are two ends to a spectrum of vulnerability definitions. The first analyses vulnerability in a single dimension of real existing objects, for example the porosity of a wall. The holistic view synthesises a wide range of facets. Often, heterogeneous facets are in this basket and thus comprise an analytical construct. An example for a holistic approach is the research not only of one human individual, but of a social system. There are many transitions in between the two extreme ends of a spectrum of strictly reductionist and holistic views. This division of definitions is helpful to understand the diverging mind-sets and analytical structures behind vulnerability assessments.

Vulnerability is often regarded as connected to a specific context. This context can be the type of external stressor, for example natural hazards or civil conflict. Also important is the spatial and temporal context as it is stressed in place-based approaches (Cutter, 1996, Research and Assessment Systems for Sustainability Program, 2001: 4, Steinführer and Kuhlicke, 2007: 115). The vulnerability TO a certain hazard IN the spatial and temporal context further demands clarification OF who or what is vulnerable. But there are also standpoints of a general vulnerability that is more or less prevailing as a general condition (Wisner et al., 2004, Bohle, 2007b: 808) or is even hazard-independent (Schneiderbauer, 2007: 27). The term ‘overall-vulnerability’ (Kleinosky et al., 2007) signifies different vulnerabilities that can be individually researched and then aggregated. There is a range of spheres for which vulnerability can be assessed (cf. Figure 5).

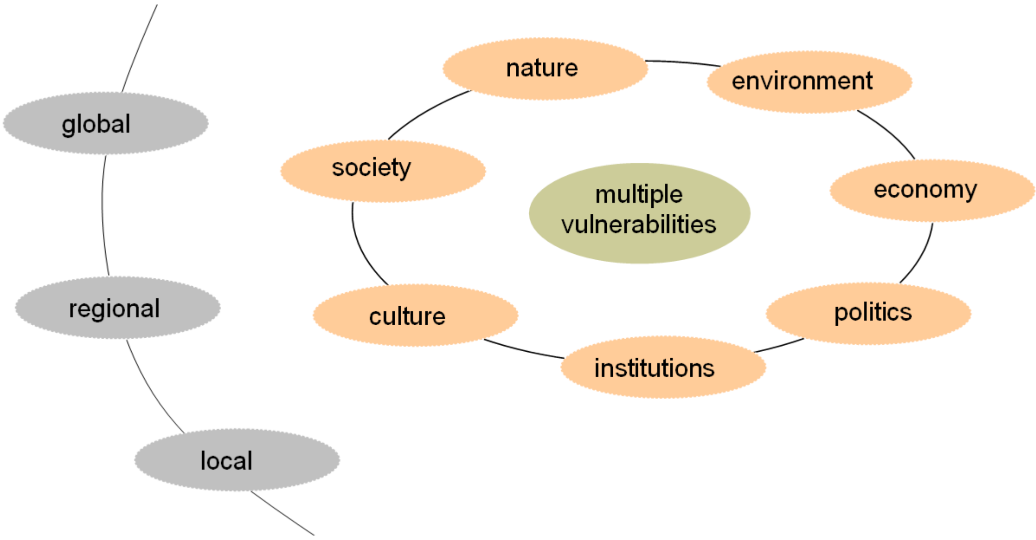

Figure 5. Diagram of the multiple fields of vulnerability that are interlinked and that can be observed at different levels

There are considerable overlaps of vulnerability with terms like damage potential or loss. The lack of concise separation of these terms hampers common understanding. A new term should not be introduced when it can be substituted by one already existing. One example is the common definition of vulnerability as loss or damage potential. This conveys economic assessments which reduce vulnerability to a single dimension view of monetary damage. For reductionist' vulnerability assessments this provides a very precise definition, but it is less useful for holistic vulnerability assessments. Damage can be thought to be subdivided into direct and indirect, tangible and intangible damage (Smith and Ward, 1998: 35). Still, this bears resemblance to measurable units like money or body counts and to economic measurements like damage functions. Normative views of anthropologists and social scientists stress human capabilities that seem hardly congruent with this perspective (Wisner et al., 2004, Bohle, 2007a). The composition of the vulnerability definition is dependent on who or what is the object of interest. When humans are in the centre of interest, non-structural aspects like social networks and human behaviour have to be included into risk assessments.

3.1.2 Working definitions

Disaster is the unwanted or unexpected realisation of risk. It is the adverse outcome of a hazard event that exceeds the capacities of people, infrastructure and environment and that results in harm not tolerated by society. Disaster impact describes all elements or processes that result from a given disaster.

Risk is the state prior to a disaster. Risk is perceived here as encompassing aspects of the hazard and the vulnerability of the human-environmental system towards extreme river floods. Risk = f(vulnerability, hazard). It comprises the probability of frequency and magnitude of the hazard as well as the inherent weaknesses and strengths of humans. This is therefore an integrated and constructed notion of risk, combining technical and social risk conceptions.

The *hazard* is in the case of river-floods a natural event that is perceived as a threat and not as a resource by humans. It can be thought of as a natural process that exceeds a certain threshold of a 'negotiated balance' between human and environmental system. When a certain criticality level is exceeded, the resource, for example, the river, becomes a threat. When this threat transgresses certain spatial and temporal boundaries of human safety spheres, the hazard realises as an impact. The hazard is revealed in the state of exposure, when the natural event actually hits the vulnerable elements.

Vulnerability captures the conditions of a phenomenon of observation – that characterise its disadvantages in the face of natural hazards (i.e. to a given stressor). Vulnerability encompasses exposure, sensitivity (Adger 2006) and capacities of the unit of research and is related to a specific hazard or stress context (Figure 6).

Vulnerability is integrated with hazard components in the risk formula; risk = f(vulnerability, hazard). Vulnerability changes in time and space and aims at identifying and explaining why the object of research is at risk and how risk can be mitigated (Figure 6). Vulnerability is both state and degree: everyone is vulnerable in the state of exposure to a hazard and is vulnerable to a certain degree. Vulnerability is a constructed analysis concept since the content and research scope is selected after arbitrary decisions of the researcher or target group.

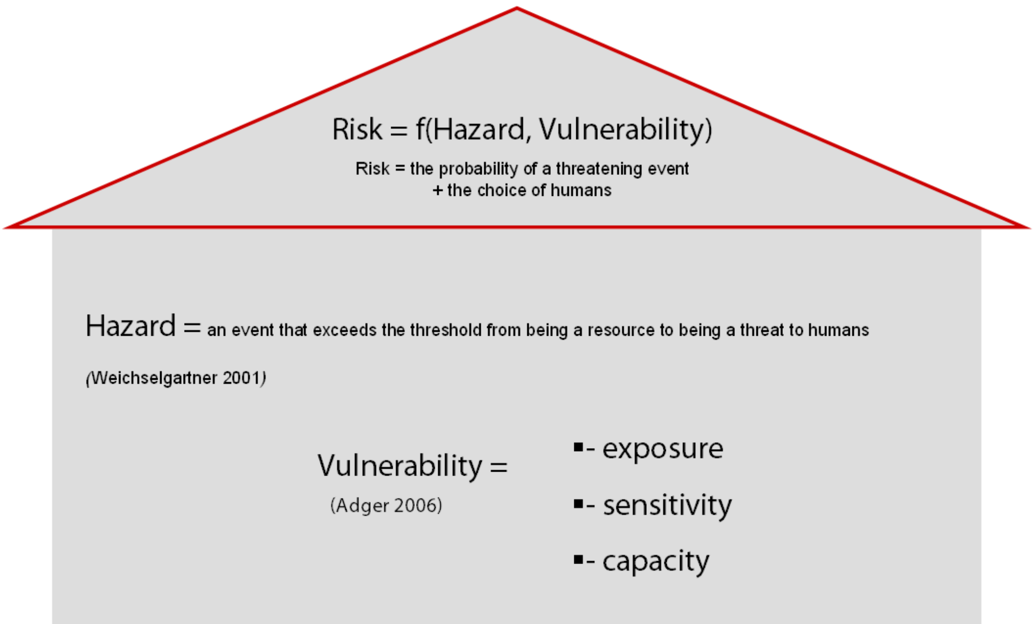

Figure 6. Conceptual diagram of risk encompassing hazard and vulnerability (the 'house of risk assessment')

Source: modified after Weichselgartner 2001, Adger 2006

Vulnerability can be subdivided into analytical *components*.

Exposure is the measure of susceptible elements within a region threatened by a hazard. The *exposure potential* is the predisposition of a region due to the portfolio of its physical assets.

Susceptibilities describe the characteristics that render persons in a region being at risk, weak or negatively constituted against a potential hazard.

Capacities are positive characteristics, skills and abilities of persons in a region that comprise all phases of the disaster cycle, from preparedness, response or coping during the disaster, and recovery and adaptation after the disaster (Figure 7).

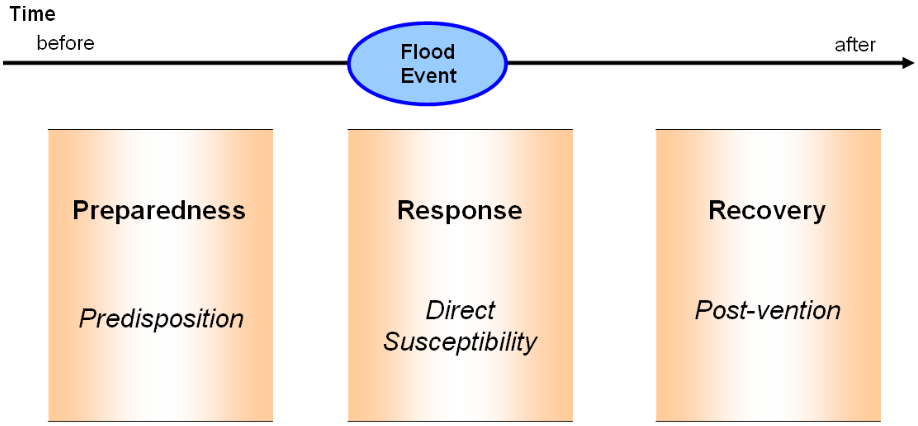

Figure 7. Time phases of disaster mitigation (capacities) before, during and after the flood event

Source: modified after Weichselgartner 2001 and Villagrán de Leon 2006

Social vulnerability is the predisposition of society and individuals towards a stressor or hazard. It is the potential to be wounded or to continue to be wounded. Social vulnerability is bound to human beings; all constituting factors are solely relevant in their function to humans (cf. Wisner et al., 2004). Social vulnerability is understood as the vulnerability of the society. Society is regarded as a social system. The social system consists of elements, humans, who interact with other humans and the environment. Within system boundaries, elements and internal processes take place that are qualitatively different to the system environment outside the spatial and cognitive boundaries of this system. A social system can be for example a county. This is therefore a place-based vulnerability view (Cutter, 1996). The environment is on the one side nature as transformed by human action. On the other side there is a system environment which is an artificial distinction between the internal and external realm of the social system level of interest, here counties. The human system as object of interest is vulnerable due to its own properties and stressors from nature, but also due to stressors from the human system itself (Figure 8).

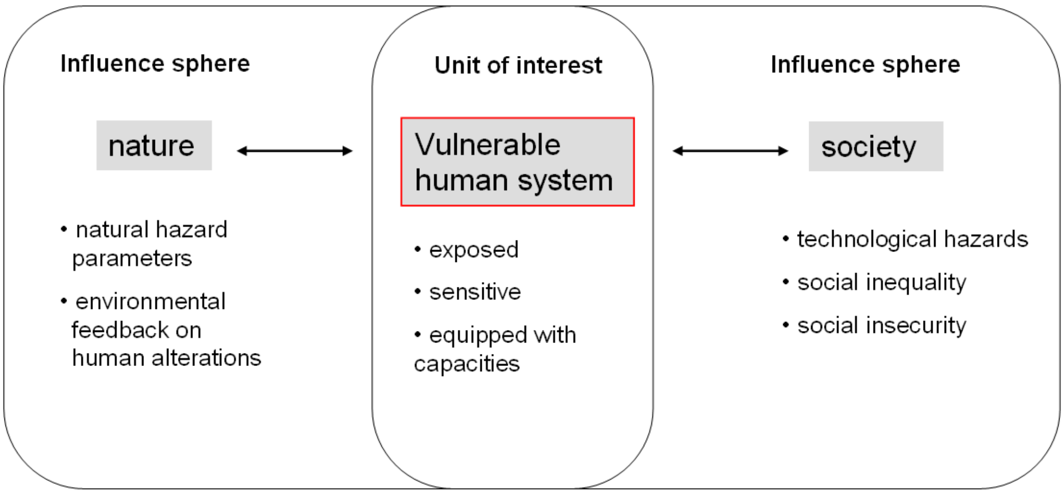

Figure 8. Diagram of the vulnerable human system as influenced by nature but also by society itself

3.2 Vulnerability concept

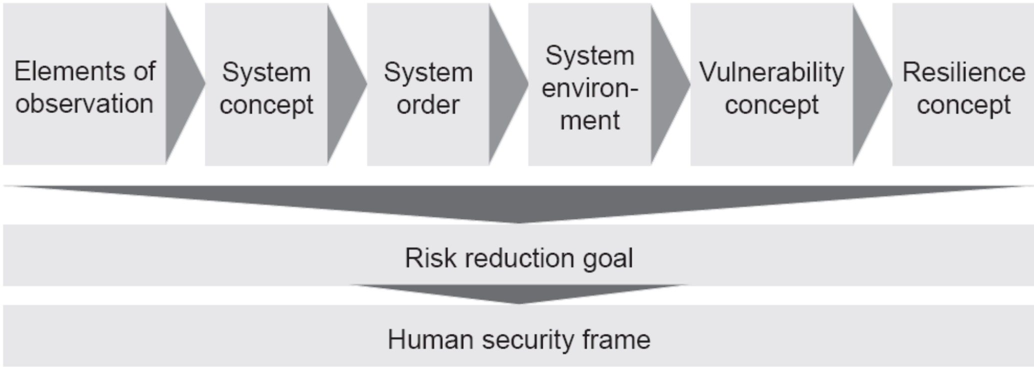

Figure 9. Structure of Chapter 3.2

The following chapter illustrates the concept of social vulnerability in the context to flooding. In the consecutive steps of this chapter the theoretical frame is outlined (Figure 9 and Table 5). The focus expands gradually from humans to social systems to a coupled human-environment perspective and to the trajectories and future states of such systems. The adjacent research perspectives and theories are framed at each step. The analytical scope expands likewise from measurable vulnerability characteristics to processes and interlinkages of a vulnerable system. Vulnerability and resilience are portrayed as analytical constructs with the goal of disaster risk reduction that is contained in the umbrella frame of a human security concept. In order to understand the current state of the art of vulnerability and resilience theory it seems advisable to review some of its theoretical progenitors more extensively, which will be conducted on the following pages.

Table 5. The progression from the element of interest to the abstract goal of analysis per sub-chapter of this study

Steps of procedure	Structure of what the theories are to explain	Theoretical considerations	Sub- chapters in this study	Own figures / considerations
1	Humans as **elements** of interest Human actions, values Processes, connections and interrelations between humans Human **characteristics** (age, skills, resources?) Fragility, dependency, marginalisation, poverty	Review of empirical findings PAR model, unsafe conditions Agency perspective	3.2.1 Humans as elements of interest *and:* 2.4 Social challenges in Germany 2.5 Who are the vulnerable to flooding in Germany?	Table 4:. Review of vulnerability characteristics of humans to flooding in Germany
2	Society as a **system** Emergence of social organisation and capacities	General system theory, Complexity theory,	3.2.2 Components and their interconnection	Figure 10:. Simplified diagram of disaster risk in a coupled human-natural system.
3	Analytical **order** of the system components	Complexity theory, Hierarchy theory	3.2.3 Order behind systems – the influence of the observer	Table 6:. The hierarchy theory model
4	**System environment** / context / setting. Time and space Place-based approach	BBC model Turner model	3.2.4 System environment – spatial and temporal scales	Figure 11:. Dynamic states of vulnerability.
5	**Analytical categories**: exposure, susceptibility, capacities	Review of literature BBC model Turner model	3.2.5 Categories for assessing vulnerability *and:* 3.1 Defining vulnerability	Figure 14:. Schematic taxonomy of the components of vulnerability and the parts which they explain.
6	**Trajectory** of the system	Adaptation, resilience	3.2.6 Resilience as trajectory of the system	Figure 18:. Trajectory of the social system.
7	Goal of **disaster risk** reduction	Disaster cycle BBC model	3.2.7 Embedding vulnerability in disaster risk assessment	Figure 14. Table 7. Social vulnerability to floods per disaster phase Figure 23. Disaster risk working framework of this study
8	Frame of **human security**	'Hierarchy of needs' Human Security	3.2.8 Disaster risk as part of human security	Table 8:. Comparison of Maslow's hierarchy of needs with the human security concept Figure 21:. Activation model of social vulnerability

Before attempting to measure vulnerability it is important to provide a clear structure what is measured, how, why, where and when. The following sub-chapters are aligned according to these questions (Table 5 provides an overview on the sequence).

3.2.1 Humans in the centre of interest

It is important to denote the human actor as the central element of interest (Table 5, point 1). Humans are not only victims, but also architects of the disaster themselves. Human agency and choice are paramount to portray the construction of disaster risk. Human behaviour, attitudes and values (White, 1945, Tobin and Montz, 1997) and risk perception (Slovic, 1987, Plapp, 2004, Amman et al., 2006) are central fields of risk assessment. 'Agency' as the active role of humans is regarded as a major explanation for the fabric of society (Giddens, 1984, Werlen, 2000) and is a central perspective of recent vulnerability research (Bohle, 2007a). Entitlement, marginalisation and access models similarly regard humans as agents that are constrained by political factors (Hewitt, 1983, Watts and Bohle, 1993, DFID, 2000, Sen, 2005, Bohle, 2007a). Risk theories of society have progressed to the paradigm of risks as constructed by humans (Beck, 1986). This notion is being followed in this study for two reasons. First, social conditions form a baseline social vulnerability as described in section 2.4. Secondly, humans are architects of the disaster risk but also of risk mitigation themselves, as outlined in sections 2.1 and 2.4. This wide range of human characteristics has to be captured by an integrated disaster risk concept.

3.2.2 System concept

System theory (Bertalanffy, 2006, Boulding, 1956) is the foundation to structuring the aspects of human characteristics in context to a hazard (Table 5, point 2). System theory has gained recognition in a range of fields related to this study, from physical and human geography (Chorley and Kennedy, 1971, Chapman, 1977, White et al., 1992) to social science (Luhmann, 1984). Major advancements have been made since Bertalanffy but still the same type of thoughts can be found in human ecology (Marten, 2001), earth system science (Jäger, 2007) or social ecology (Fischer-Kowalski et al., 1997, Becker, 2003). System theory is underlying the rather arbitrary (Adger 2006) separation of social and hazard system. System theory helps to isolate certain elements of interest (here: humans) and their core interactions into a unit. This system or unit can be assigned boundaries to separate this phenomenon from its system environments. In the system environment, other social systems or ecosystems or else exist (see Figure 10 below). The overall conceptual frame consists therefore of a relative space concept (Meentemeyer, 1989). Within the relative space concept the units of analysis and the research area are "defined by the spatial elements and processes under consideration" (Meentemeyer, 1989: 164).

The social system is a container for characteristics and dynamics of humans that are similar within a certain unit. In the language of system theory, the social system can be subdivided into a population system of physical human properties and a cultural system of non-physical properties (Sieferle, 1997: 39). The physical properties can be directly harmed by output of the natural system and are easily observed by physical exposure. Non-physical properties include culture, cognition, perception, language, attitudes and values (Tobin and Montz, 1997). These aspects are more difficult to assess. The artificial distinction of symbolic communication and physical properties of humans is useful to understand direct and indirect mutual interactions with nature (Luhmann, 1984). Still, it is less helpful to reduce society to language, as some cultural properties of society emerge outside language (Sieferle, 1997) and, physical body and buildings are the main object of direct flooding impact. The social or human system is a unity of perception, action, physical and non-physical abilities concerning vulnerability and resilience. System theory helps to discern this social system unity from other objects of interest, in this case river-floods (Figure 10).

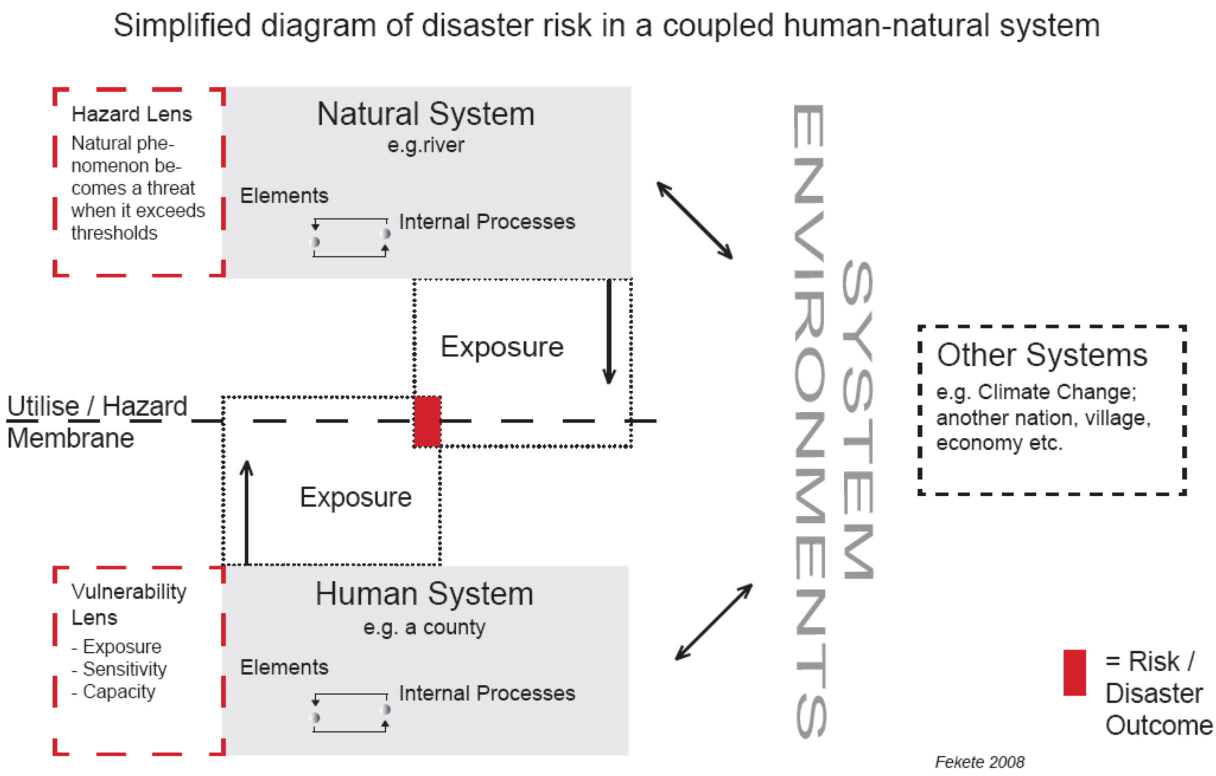

Figure 10. Schematic diagram of disaster risk in a coupled human-natural system

Figure 10 illustrates the utilisation of system theory for delineating the two systems of interest and how they interact. A system consists of an element of interest, humans, and the interactions between the humans (internal processes). The system is defined by the purpose of observation, which is detecting the vulnerability of the human system. The system boundaries delineate the system of interest from its system environment. The system environment contains other systems of interest, for example the hazard-system of a river. Common terms for coupled systems are social-ecological system (Folke, 2006) and human-environment system (Turner et al., 2003). The natural system becomes a hazard system by the perception of the exposed people or by the researcher. Whether the hazard is positive or negative to the human system is dependent on the perception of the humans actually. In the coupled human-natural system of Figure 10, risk of disaster outcome exists where both systems overlap by exposure of their systems. The exposure is not a major problem, as long as both systems are not negatively impacted by the other system. As soon as the exposure turns into a real extreme event, damage or even disaster can occur.

"The whole is more than the sum of its parts."

Aristotle

Complexity theory describes a system as being more than the sum of its parts due to (non-linear) interlinkages and emergence (Lewin 1992, (Waldrop, 1992, Cilliers, 1998). The social system in interrelation to the hazard system is a complex adaptive system. Processes are not only linear processes; there is emergence of structures and patterns not observable by looking at the reductionist components only (Lewin, 1992, Waldrop, 1992). Complexity theory is not to be confused with complicatedness. Complexity theory aims at explaining complex phenomena by a reduced set of rules.

However, the reduction of explaining anthropological or economic phenomena to a set of (natural science) rules has been criticised (Cilliers, 1998, Deuchars, 2004). Still, complexity theory is widely applied in resilience (Holling et al., 2002), coupled human and environmental systems (Research and Assessment Systems for Sustainability Program, 2001, Liu et al., 2007) and risk research theory (Pearce and Merletti, 2006). It is especially apt to tackle messy real-world problems like social vulnerability that contain non-linear relationships.

Complexity theory helps explaining the emergence of human organisation on a more abstract level. In this respect in can be applied on society which bears new forms of organisation emerging on a higher level than the human individual. It starts with social relations of family and progresses to society. Some properties of human vulnerability are on a societal level still connected to human features like age or health. Some capacities like personal skills are also connected to the human individual while other capacities, skills and resources are more allocated to society and the social environment in which the humans live. The vulnerability of society is more than the sum of its individuals as it develops dynamics, institutions and regulations. And as another feature of complexity, human interrelations and societal processes consist of patterns of linearity and non-linearity. Vulnerability, as well as adaptation is in this perspective an emergent property of human individuals and their interrelations on the higher level of society. While system theory and complexity provide the basic structure of human-environment elements and processes, there is a need for a closer look at the order in such a structure.

3.2.3 System order

Hierarchy theory provides seminal thoughts for order in the system environment and how the single systems are allocated and structured (Allen and Starr, 1982, O'Neill, 1988). Hierarchy theory recognises different kinds of scales in which the observation is embedded. Hierarchy theory has found application foremost in the fields of ecology and climate change so far (Peterson and Parker, 1998, Gibson et al., 2000, Peterson, 2000, MEA, 2003). It interlinks macro and local dynamics and is fundamental to understand the order behind systems. There is criticism to hierarchy theory for perpetuating a normative view of vertical hierarchy and top-down thinking, especially from the social sciences (Marston, 2000, Leitner and Miller, 2007). However, many social scientists in the field of vulnerability argue for a bottom-up approach (Wisner et al., 2004) which also implicitly exerts a vertical hierarchical worldview, starting from the bottom.

Table 6. The hierarchy theory model modified for the sub-national perspective on vulnerability of the social system

	Hazard System	Social system
Macro-level dynamics	Precipitation patterns Climate Change	Ageing of the population National and global economic prosperity, Globalisation
Level of observation (here: counties)	River flooding of major streams	Fragility, marginalisation, dependency, welfare, economic prosperity as a profile of the average of all residents within a county
Micro-level components	Surface sealing Groundwater rise	Human behaviour Risk perception Social networks, skills, resources and physical fitness as a profile of a person

Source: Modified after (O'Neill, 1988) and Fekete et al. (2010).

Hierarchy theory provides the structure that enables the ranking of the system to discrete levels (Table 6). It guides the identification of the vulnerability parameters and the spatial level of measurement. The hierarchical model allows for either starting with a bottom-up or a top-down approach. For the bottom-up approach it is difficult to capture enough variables with enough cases to scale up for whole Germany. Furthermore, the variability of previous observations in literature are too great on variables like risk perception and human behaviour to allow propositions for whole Germany. On a higher level of observation, spatial entities and temporal fluctuations are observable as patterns (Wiens, 1989). Within the hierarchy theory structure an intermediate stance is useful for this study. The level of observation is embedded between a macro scale of constraints and a micro level of components (Koestler, 1967). On the micro-level or 'reductionist level' the entire phenomena take place on a very local level (Table 6). On the macro-level or 'constraints level' long term effects govern people's livelihoods or the state of the hazard.

3.2.4 System environment

The spatial setting is integrated into this vulnerability assessment in a so-called place-based approach (Cutter, 1996, Research and Assessment Systems for Sustainability Program, 2001). It recognises regional hazard specifics and environmental but also social settings that allow for profiling regions as differentially vulnerable to natural hazards. The spatial setting can be analysed at different types of spatial scale (Cash et al., 2006, Fekete et al., 2010). An example is the spatial scale where the different phenomena take place. These phenomena have different spatial extents, for example the range of action of an individual in comparison to the spatial range of laws and regulations. Another type of scale is the scale of measurement, which covers units or administrative boundaries of interest. Here it is useful to differentiate between Germany as the *research area* and the regions like counties as *unit of interest.* A clear identification of scale of the phenomenon and scale of measurement is expedient for later comparison and validation of the results. The choice of scale and level of observation has a severe impact on conceptualisation, implementation and results of vulnerability assessments (Fekete et al. 2010, Fekete 2008).

Besides spatial, also cultural and temporal contexts are important for the analysis of vulnerability and disaster risk. A human system incorporates physical, cognitive and situational factors (Tobin and Montz, 1997: 135). The setting is the interface, where cognitive and situational factors have to be analysed in unison regarding natural hazards (Tobin and Montz, 1997: 136). Cultural and also, spatial contexts provide tipping points for sudden changes (Gladwell, 2000). When the 'negotiated balance' of an accepted risk level is perturbed by an extreme hazard event or societal failure, a disaster can happen. Therefore, it is essential to observe the vulnerable system as a dynamic one where all components – hazard, negotiated risk and vulnerability – may change.

The temporal dimension is emphasised in vulnerability theory (Brooks, 2003) but often neglected in vulnerability assessments. Temporal implications on vulnerability assessment are multiple; flood duration, demographic change, flood frequency; the time span of the observation, its intervals; and the point in time of the observation in relation to the process of the phenomenon (disaster phase). Vulnerability is not only different regarding various spatial scales or contexts, but also varies with time. The social system itself is not stable, but constantly co-evolves parallel to the environment, economy or hazards (see Figure 11). This notion of social conditions leading to risk is the progression of 'root causes' and 'dynamic pressures' to resulting 'unsafe conditions' (Wisner et al. 2004). Like the vulnerable system, the hazard evolves not only linearly and varies in duration, frequency and magnitude (Figure 11). Temporal aspects are only occasionally part of vulnerability assessments (e.g. frequency analyses of hazards in (Cutter et al., 2000). A focus on temporal aspects (e.g. trajectories of systems) is more commonplace in resilience studies (Gallopín, 2006; Holling et al., 2002).

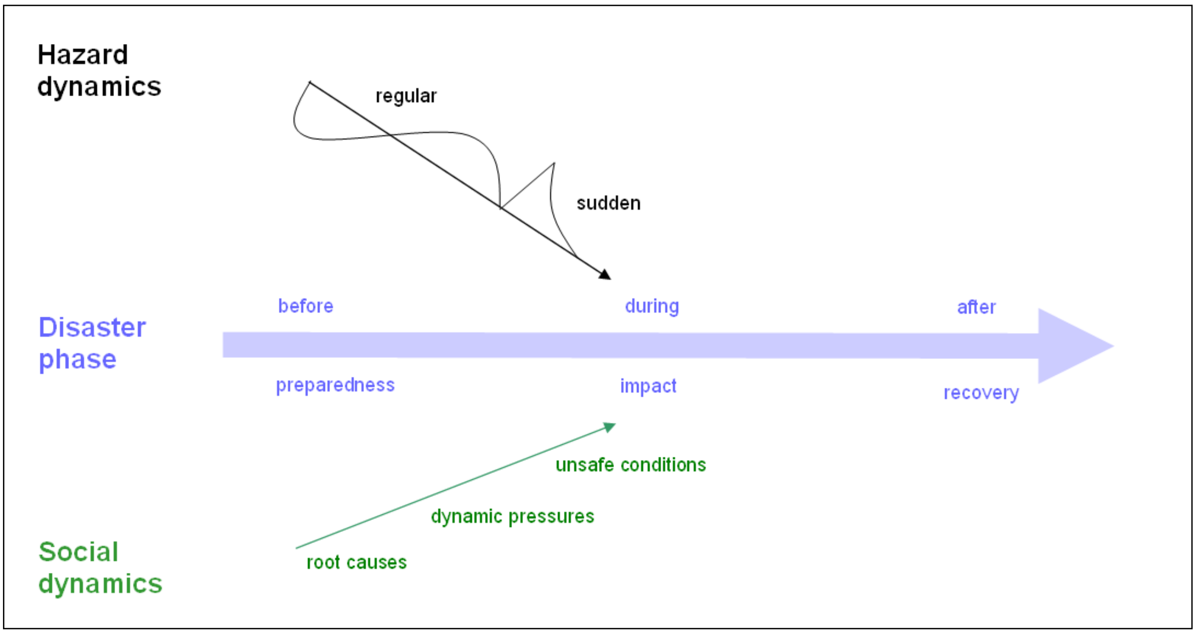

Figure 11. Dynamic states of vulnerability as given by the hazard dynamic, the temporal disaster phase and the social dynamics

Source: the progression of the social dynamics is taken from Wisner et al. 2004

3.2.5 Categories of vulnerability

Vulnerability terminology is not uniform, sometimes susceptibility is used instead of sensitivity, and resilience is used for coping or adaptive capacities (Figure 12). Among the plethora of viewpoints on the definition of vulnerability, the core description centres on the terms sensitivity / susceptibility. This characteristic of an inherent and often internal weakness is then expanded on the positive aspects of coping or adaptive capacities, depending on the viewpoint. For some authors exposure is intrinsically tied to susceptibility, while for others such a place-based characteristic has to be analysed separately. Resilience is for some authors another expression for coping or adaptive capacities. For other authors resilience refers to another quality, to the system stability. Occasionally, hazard and risk are terms subsumed or used equal to vulnerability (see Thywissen 2006).

This study takes a certain stance at terminology regarding three aspects of vulnerability.

1. Vulnerability is not just a single negative characteristic, equal to the term susceptibility. Therefore, the term sensitivity is used instead of susceptibility in order to stress that sensitivity is just one characteristic among others.

2. Vulnerability is more than just a negative characteristic; it captures positive features as well as place-based characteristics. Therefore, the separation of vulnerability into three main characteristics commonly used in most vulnerability studies is most convincing: exposure – sensitivity – and capacities (Adger, 2006: 270).

3. Resilience is not just another expression for coping capacities and a sub-component of vulnerability. Resilience refers to the system stability and trajectory.

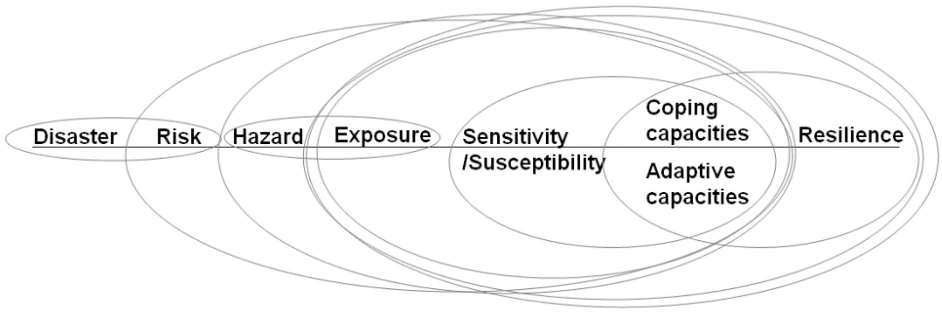

Figure 12. Overlaps of key terms in vulnerability research

The three components exposure, sensitivity and capacities are found in a number of state-of-the art vulnerability frameworks, though under differing terminology. For example, in the 'Turner model' (also named SUST framework or Airlie House vulnerability framework, cf. Research and Assessment Systems for Sustainability Program, 2001: 25, Turner et al., 2003) is the outcome of an interdisciplinary debate of a wide range of experts (see (Birkmann, 2006) for a review of vulnerability frameworks). Its main hallmark is the combination of the human and the environment system. The framework shows up interrelations, internal and external in- and outputs and the place-based nesting of coupled systems at various spatial scales. It delivers therefore important spheres and interrelations to analyse in a vulnerability assessment. Especially the interrelations between vulnerability components are starting points for embedding the argumentation for the selection of data. These multiple interrelations are also visible in the 'BBC framework' (see (Birkmann, 2006): 34, see Figure 13). The BBC framework explicitly links vulnerability to the three spheres of sustainability; society, economy and ecology. Vulnerability is put into a succession chain starting from a natural phenomenon that evolves to a hazard event and hits an exposed, susceptible population that is however equipped with coping capacities. By combination of vulnerability and hazard, risk is created. This risk is dynamic, and there are two entry points for risk mitigation provided by the framework: during the pending risk and after the hazard event has started to affect the people. The BBC framework therefore is an interface of vulnerability and disaster risk management.

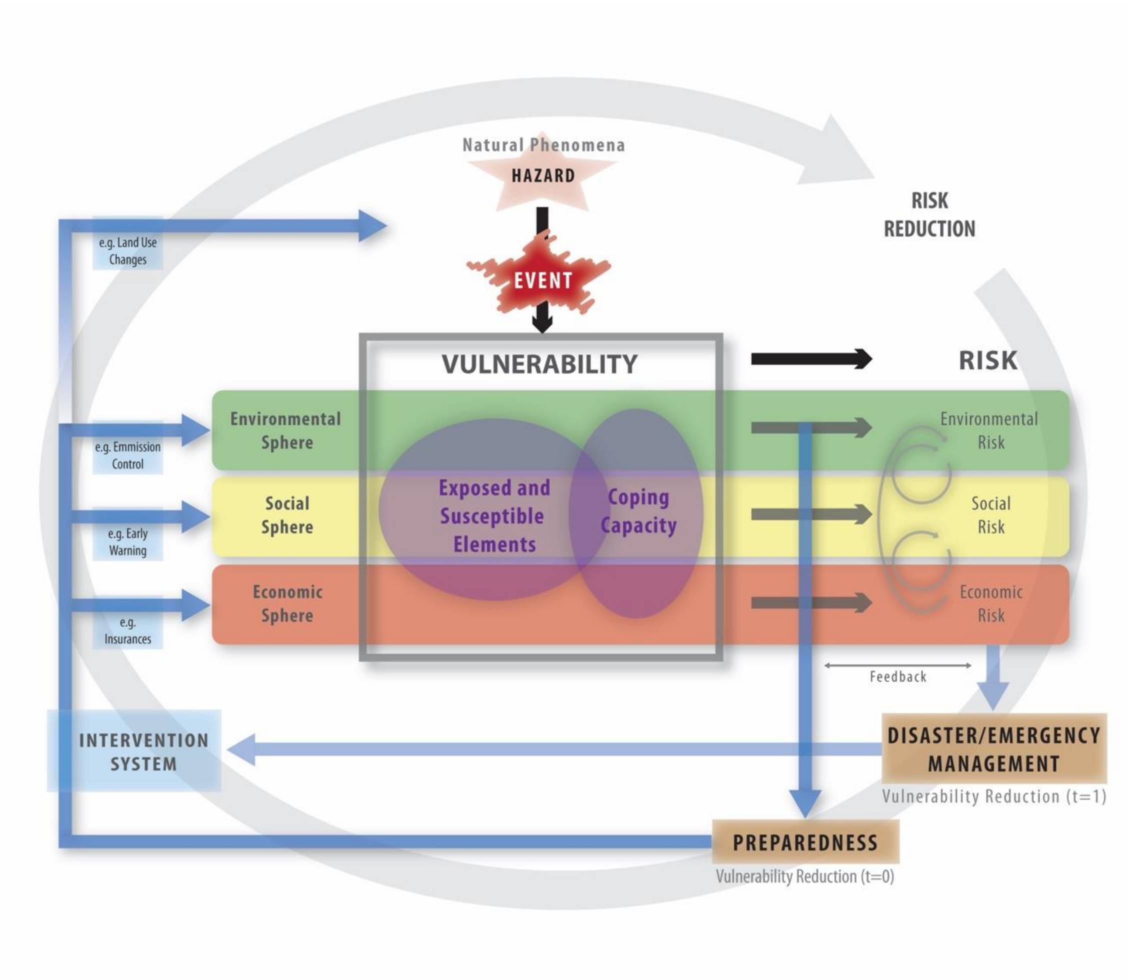

Figure 13. BBC framework

Source: Bogardi / Birkmann 2004 and Cardona 1999/2001, as cited in Birkmann 2006, layout Kienberger 2008

The BBC framework puts the main analytical components of vulnerability into focus for an assessment. These three components, exposure, susceptibility and coping capacity, can be further sub-divided and linked to key explanations of human properties and conditions (Figure 14). *Exposure*, for example not only encompasses physical exposure bound to a *location* like *population density*. Exposure of people is also determined by their *choice* to settle at a certain locality. Choice might be an active decision based on a *cost-benefit* consideration, but could also be a non-cognitive result of *traditions* (Figure 14).

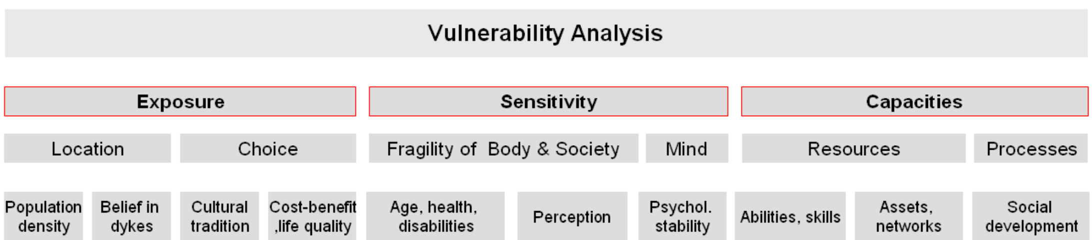

Figure 14. Schematic taxonomy of the vulnerability components exposure, sensitivity and capacities

The findings of Figure 14 can also be structured to micro and macro constraints using the hierarchy theory model once more. The following figures display the tree of interrelations of the analytical observation constructs “sensitivity”, “capacities” and “exposure” (Figures 15-17). The figures show how the macro forces and the reductionist components of measurement are related to the measured phenomenon. The measured phenomena on the meso level are those which will be analysed later on whether they display spatial patterns on county level in Germany. The reasons for selecting county level are given in Chapter 4 when it comes to the case study. The meso level as an intermediate stance of observation is grounded on the hierarchy theory model as used here in Figures 15 to 17 and as described in section 3.2.3.

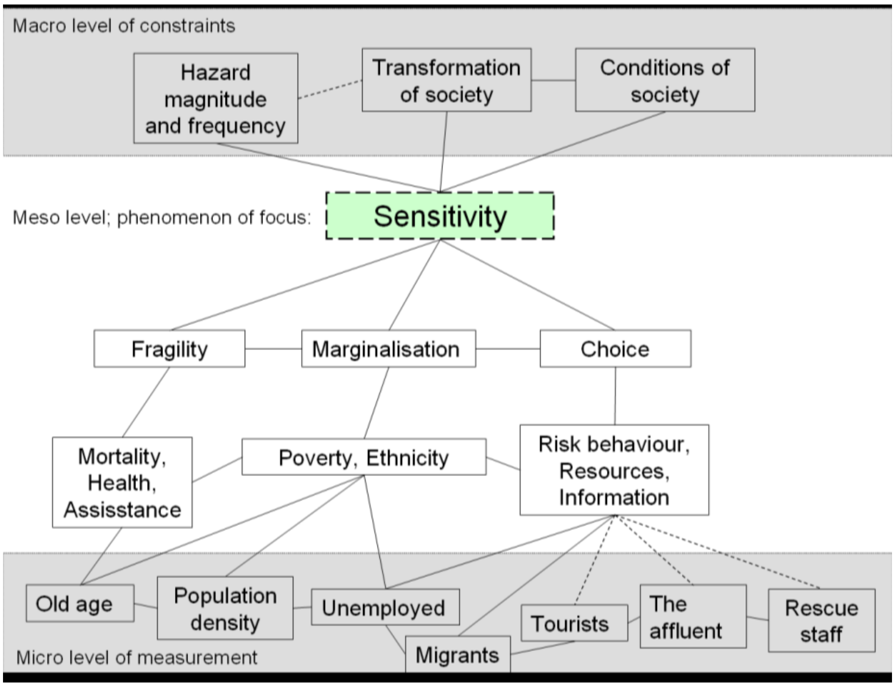

Figure 15. Hierarchical tree model of sensitivity. Sensitivity as an analytical term is embedded within upper and lower interlinkages and constraints

Sensitivity is an analytical concept of vulnerability that encompasses negative and passive characteristics of people. Sensitivity measures several phenomena; *fragility*, *marginalisation* but also *choice* (see Figure 15). These phenomena can be observed for the vulnerable human groups of interest; the *elderly*, *unemployed*, etc. The vulnerable groups and the whole system of observation on county level are subject to longer term dynamics on the macro level.

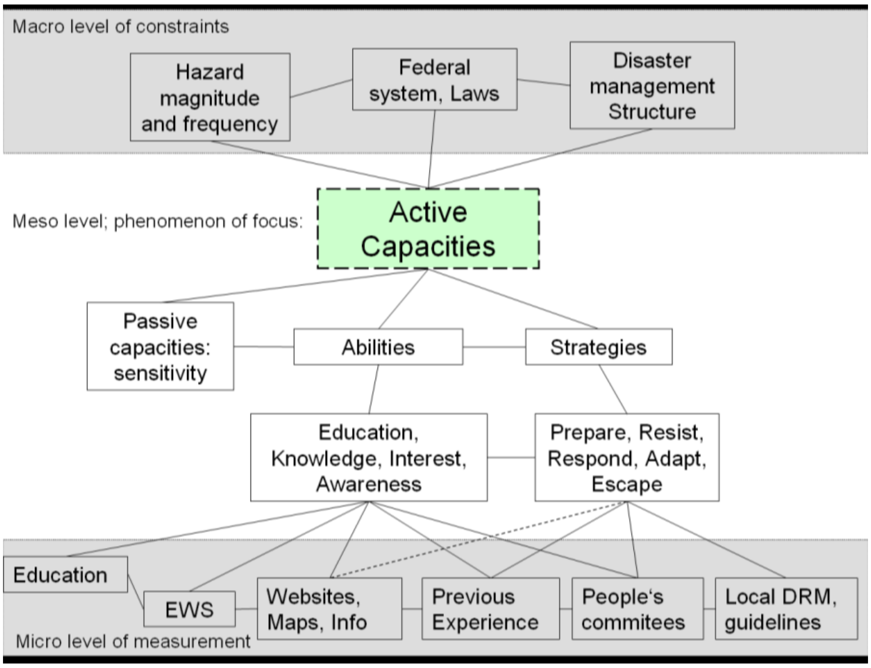

Figure 16. Hierarchical tree model of capacities. Capacities are as an analytical term embedded within upper and lower interlinkages and constraints

Capacities are more than the other side of the coin of sensitivities (Cannon, 2006: 48). The choice of individuals, but also emergent social behaviour and organisation, are active properties of human actors. Capacities can be measured in two ways; as the positive side of *sensitivity* and by *abilities* and *strategies* (see Figure 16). Abilities are skills acquired by *education*, *interest* and they create personal characteristics like *awareness*. Strategies are the actions undertaken towards flood mitigation like to *prepare*, *resists*, or *adapt*. Measurable indications of active capacities are Early Warning Systems (*EWS*), *previous experience* with floods, *people's committees*, available flood information, etc.

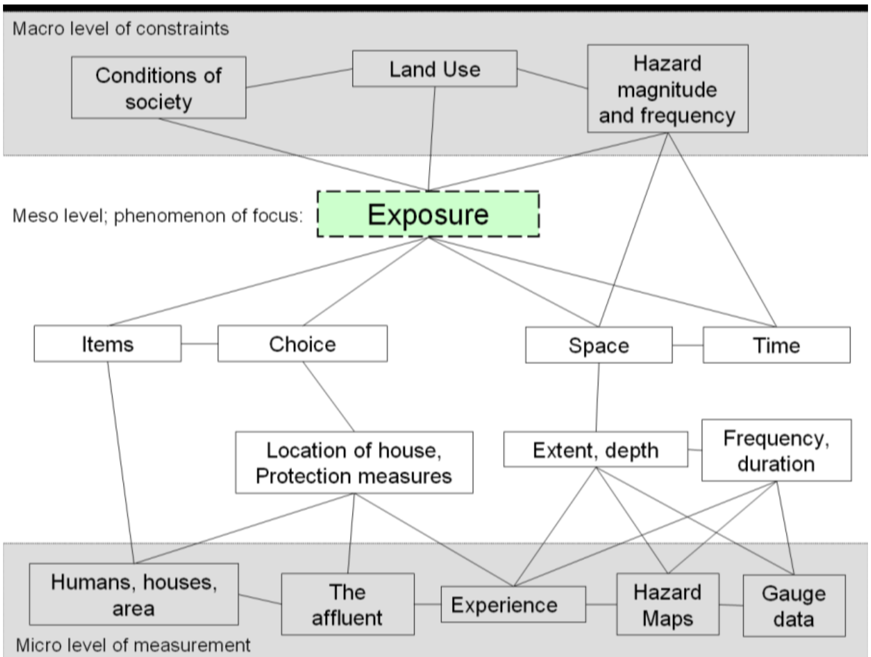

Figure 17. Hierarchical tree model of exposure. Exposure as an analytical term is embedded within upper and lower interlinkages and constraints

Source: author

Exposure is more than just the location of assets within a threatened area. It is the interface between dynamics on the macro level of constraints and the spatial manifestations on the micro level of measurement (Figure 17). The intricate web of connections and interdependencies shows what is behind exposure as a measure. Exposure is composed of physical *items* and non-physical *choices* of humans. The knowledge about exposure influences the choice of the *location of houses* and *protection measures*. Exposure is on the other hand the component of vulnerability that is most visibly connected to *space* and *time*. Exposure is the interface between hazard and social system. Exposure couples the *hazard magnitude and frequency parameters* with the *conditions of society* and *land use*. These parameters of exposure are measurable by *gauge data* and *hazard maps*, and the number of *humans, houses* or *area*. The *experience* of floods is steered by the hazard patterns and can influence the choice of location.

3.2.6 Resilience as trajectory of the system

Adaptation and resilience are aspects of vulnerability that attract much attention in research recently. It seems however, not quite clear what adaptation exactly is. Resilience is sometimes a component and sometimes the overarching term of vulnerability. The following sub-chapter explains the stance of this study to this recent debate. This is necessary because adaptation and resilience are important properties of humans and social systems towards disaster risk. Without them, vulnerability would remain a solely negative characteristic.

The SUST or Turner model (Turner et al. 2003) takes resilience as a sub-component to vulnerability in coupled human and environment systems. Resilience is in this notion the equivalent to the adaptive capacity component. It is somewhat surprising to find resilience as a sub-component to a system. Other authors take resilience as the trajectory of stability of a whole system (Holling et al., 2002) It is difficult to grasp why resilience is at the same time a property of the system elements. The adaptability of the elements of the system is certainly part of the overall stability and adaptability of the whole human-environment system. However, the adaptability of the system is more than the sum of its parts, inheriting from ideas of complexity theory and general system theory (Research and Assessment Systems for Sustainability Program, 2001: 5). It seems necessary to discern adaptation and resilience more clearly.

Adaptation is a longer-term process (Research and Assessment Systems for Sustainability Program, 2001: 33) and includes several phases of human reaction towards the hazard, vulnerability, risk and disaster. Adaptation is not just the opposite of sensitivity, since a lack of a certain characteristics like young age is not the solution to adaptation. Adaptation is more than bouncing back from a given impact immediately. Adaptation involves longer-term recovery but also implicitly some internal adaptation of the human mind-set, which can be regarded as a dynamical evolution. Adaptation is in this respect the flip side of sensitivity but is even more since it does not only compensate sensitivity, but also exposure. Even more, adaptation is both a characteristic of the system components (e.g. humans) and a characteristic of the whole system. Resilience is even greater than the two aspects of adaptation, since it includes the positive but also the negative aspects of the general trajectory of instability and stability of the system (see Figure 18 below). Resilience encompasses the history but also the future states of a system. Resilience is therefore the umbrella term to adaptation, vulnerability and disaster risk (Figure 18). Even disaster risk is just one component of a system that is also driven by evolution, growth, interaction, etc.

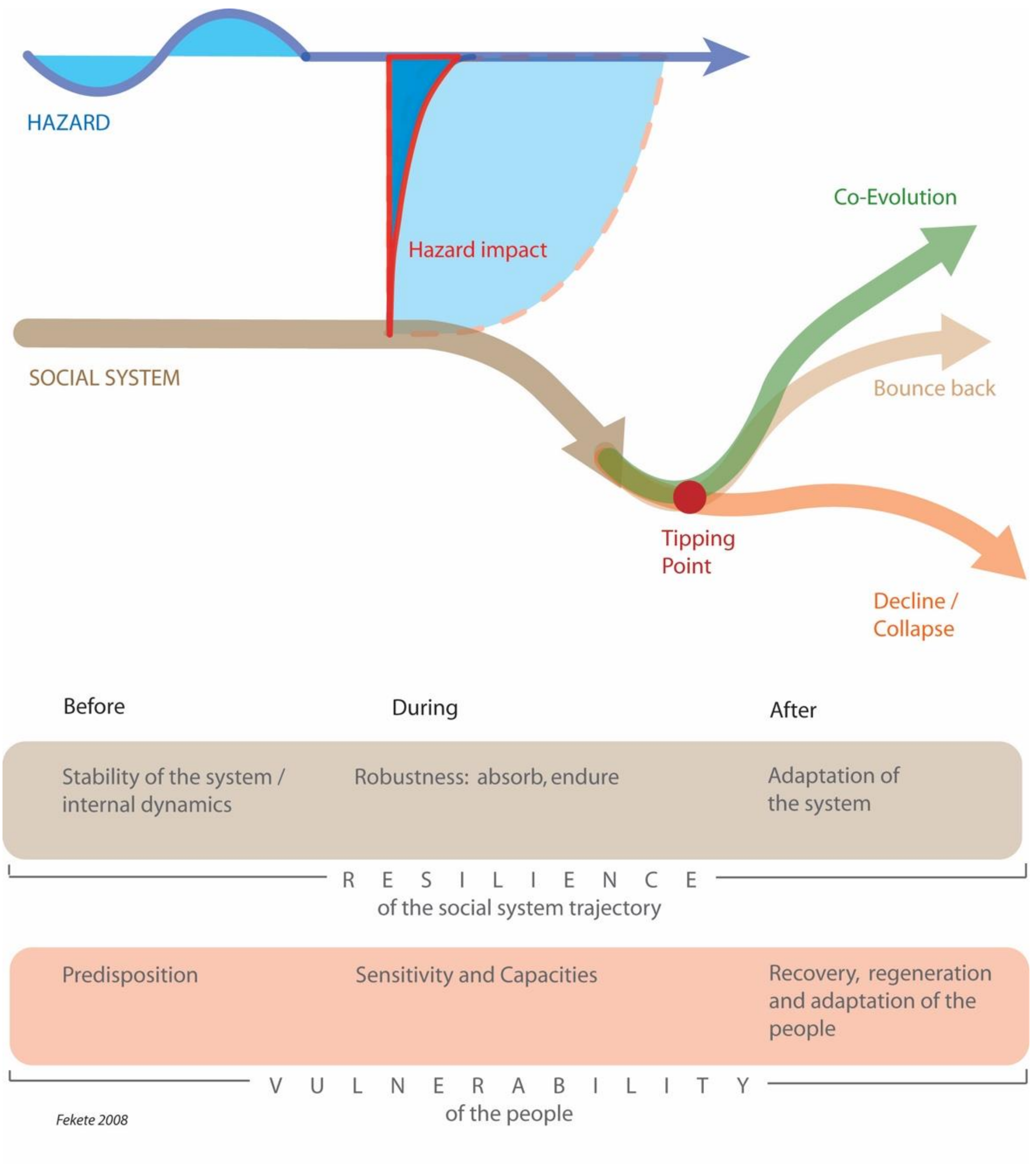

Figure 18. Trajectory of the social system in reaction to hazard dynamic

Source: modified after Bogardi 2006, as published in (Villagrán de León, 2006): 51

The diagram outlines the reaction of the vulnerable system to flood hazard (Figure 18). Two systems are displayed at once, the river system, comprising hydraulic and hydrologic systems and the social system. Both are within flux of time and consist of non-linear reactions and behaviours. With the river system this is sketched by drawing the hazard time line of the system not as a line but in waves and a sudden pit. This displays both cyclic behaviour of river systems as well as sudden positive and negative feedbacks to external and internal events that put the (social) system off the equilibrium line (Holling, 1973: 19). For matter of simplification, the social system is drawn as a line, while in reality the social system itself is in permanent dynamic change. Both systems are constantly in interaction. In this diagram, however, only the interaction is displayed when an impact is exceeding a certain threshold of river system behaviour. This impact may last an unknown and varying time period, expressed by the course of the dotted line of the hazard system.

In the moment when the impact of a flood exceeds the balance with the social system, this event imposes a shock, which is a sudden, short connection of the impact with the social system within time (Figure 18). The social system has capacities to resist or moderate the impact. When this buffering function is used up, the active capacities of the social system for coping can mitigate the outcomes of the disaster to a certain extend. Active capacities are set together by preparedness measures taken before the event and by emergent organisation of the humans during the event. For example, emergency organisations or neighbourhood help. When this is used up, the disruption potential will reach its maximum extent. When a certain threshold of tolerable impact in combination with capacities is exceeded, a tipping point is reached. This tipping point decides whether the future trajectory will be disaster by collapse of certain system properties or if the outcome will be a gradual recovery or whether the outcome might be even positive for the social system (Figure 18). The later could be described as evolution or co-evolution with the hazard system.

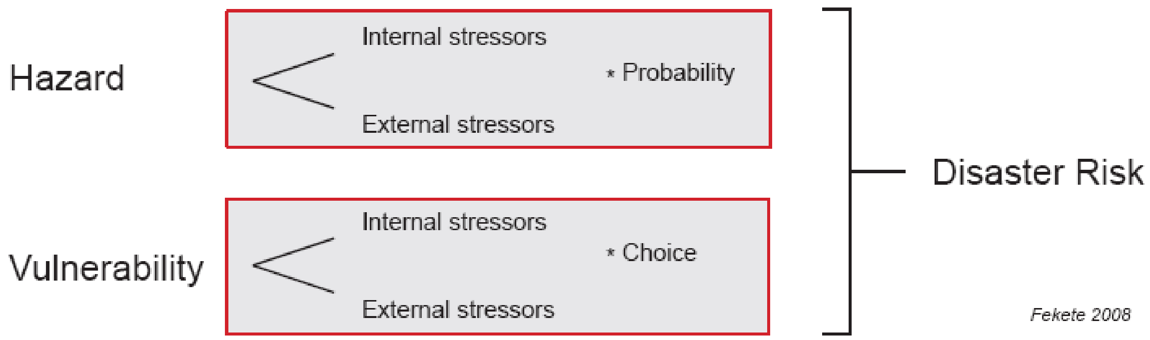

Figure 19. Disaster risk as composed of hazard and vulnerability, including probability and human agency

Vulnerability of a social system comprises both external and internal factors, such as internal abilities and external relations, resources, etc. (Figure 19). Vulnerability can be divided into a revealed vulnerability, which is revealed by the hazard impact and into the potential vulnerability, which is the maximum thinkable vulnerability of a society. The latter can also be revealed in various hazard, civil conflict or stress situations. Resilience on the other hand deals with the state and degree of stability and dynamic of the system under observation. Resilience describes the trajectory of a system which is the history and future course of its stability (Figure 18). In this case resilience comprises the temporal phases of preparedness, coping and adaptation of the vulnerable system. Resilience is therefore more than just the coping capacity part of the vulnerable elements. It encompasses all temporal phases and, the capacities of the vulnerable system as a whole. This includes emergent properties of adaptation and is not limited to static susceptibility characteristics of the system elements. After the exposure to the hazard impact when the impact declines and after the tipping point of maximum system criticality, recovery sets in and adaptation to the new situation leads to a new stability or balance situation in time (Figure 18). It is not necessarily to be the same state as before.

3.2.7 Embedding vulnerability in disaster risk management

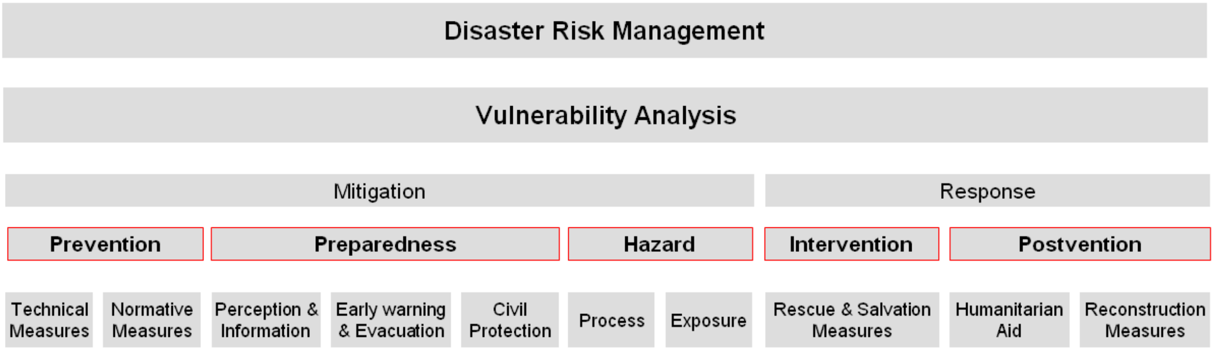

Figure 20. Sub-divisions of the disaster cycle phases

Source: modified after (Weichselgartner, 2002): 152

Vulnerability and disaster risk exist in the perspective of this study at all-time phases of the risk - disaster progression. The human reaction towards the hazard can be assorted to the time-line of before, during and after a disaster. These disaster phases can be described accordingly as preparedness, response and recovery phase (Figure 7). As is the case with vulnerability terms, there exist many additional sub-divisions to these phases that are sometimes overlapping (Figure 20). However, these terms are useful to identify different strategies of disaster mitigation (see the boxes on the bottom line of Figure 20). The distinction between the disaster phases is difficult and simplified, for example, it might suggest a regular succession and does not include new states. In reality, the recovery phase is blending over into a preparedness phase. The distinction drawn here is merely of conceptual nature in order to help understand and structure various aspects of vulnerability. The well-known disaster cycle (for example as used by (Wisner and Adams, 2002: 3, 19, DKKV, 2003: 10) illustrates this process in a cycle as does the model by Birkmann (2006). For schematic structure in case of a river flood it is very useful, as for example social vulnerability is different before, during and after the flood event itself. In order to 'measure' vulnerability, it has to be clarified; vulnerability of what (element), when (disaster phase), on which spatial scale, under which types of causes, pressures and conditions.

Table 7. Social vulnerability to floods per disaster phase

Sensitivity side	• Poverty • Exclusion • Non-Knowledge • Conflict • Land Use of Flood Plains • Choice of settlement location: driven by needs or by wants (the rich) • Climate Change	• Drowning • Not able to move • Loss / Damage • Surprise	• Drowning in cellar / heart attack • Secondary hazards: ground water rise, diseases • No electricity, heating, potable water • Health problems • Lack of money • Loss • Looting	
recurrent states	**Before**	**During**	**After**	**Before**
Capacities Side	• Prevention: dykes • Technical preparedness • Insurance • Institutional preparedness: land use regulations • Building knowledge, education • Resettlement	• Evacuation • Assistance for special needs groups • Technical aid = Protection • Institutional help, Disaster management • Early warnings • Volunteers • Willingness to be evacuated	• Nursing / Assistance • Police – public security • Financial assistance • Institutional reactions: measures implementations, compensation payments	

The table presents both negative (sensitivity) and positive (capacities) aspects of social vulnerability to flood hazards (Table 7). It must be emphasised that the focus here lies in the sorting process and it is not an objective to provide a complete listing of all possible factors of vulnerability. The position of the vulnerable system on a time line before, during or after a disastrous event influences greatly the composition of the social vulnerability. Also, the duration of one of the three time phases, for example, the duration of the time of the flood event itself has a great impact on the vulnerability of the people affected. In case of a home inundated longer than three weeks, food and water resources may be depleted, health being affected by diseases, building structure weakened.

3.2.8 Disaster risk as an issue of human security

The linkage between the various theories can be established by taxonomy of human needs. Abraham Maslow developed a 'hierarchy of needs' in his paper *A Theory of Human Motivation* (Maslow, 1943). The basic needs are the baseline, followed by security, social relations, social recognition and as the final peak of human want, self-actualisation. These aspects are those who shape human behaviour, the first four being deficiency needs, and the last one a growth need of human self-actualisation. The underlying idea is that higher needs in this hierarchy only come into focus once all the needs that are lower down in the hierarchy are mainly satisfied. This concept of Maslow based on psychological research is not undisputed, for example by lack of evidence by the relatedness to western individualistic society (e.g. Neher, 1991). The main focus on individualistic behaviour is criticised for not taking into account the value of social relationships that might rank higher for many individuals and societies. Still the concept gained much recognition and application and its advantages lie in linking causality to ranking of human needs.

Applying all the aforementioned theories requires the recognition of human values and norms behind all observation. Human values are key to understanding human needs and actions (Kolsky and Butler, 2002). Values and normative goals are also guiding vulnerability and disaster reduction. Human security is a paradigm of research on the human-environment nexus (Bogardi, 2004). Its major goals, freedom from fear, freedom from want and freedom from hazard impact (UNU, 2000: 8, Brauch, 2005: 77) draw from similar background like Maslow's hierarchy of needs (cf. Gasper, 2005, and see Table 9). "Human security can be considered the condition when and where individuals and communities have the options necessary to end, mitigate, or adapt to risks to their human, environmental, and social rights; (…). This is a people-centred concept (…)" (O'Brien, 2006: 1).

Table 8. Comparison of Maslow's hierarchy of needs with the human security concept

Maslow's hierarchy of needs	Maslow's concept's goals	Human Security concept goals	Human Security needs	Social vulnerability needs	Social vulnerability challenges
Basic needs	Deficiency needs / survival	Freedom from want	Resources, Access	Initial well-being Social inequality	Survival, Poverty, Livelihood
Safety		Freedom from fear	Security	Social insecurity	Political, institutional, global, economic
Belonging			Networks	Social relations	Exclusion, Minorities
Esteem			Entitlement and Dignity	Social recognition	Migration and integration problems, social status, hierarchies
Self actualisation	Growth needs / evolution	Freedom to	Development and evolution	Social development	Globalisation, Climate Change, Demographic development, Urban Sprawl

Source: modified after Maslow 1943, UNU 2000, Brauch 2005

The hierarchy of needs can be found in parts of the human security concept and linked to social vulnerability reduction strategies (Table 8). It provides the fundament to link a people-centred perspective of human actions to the research lens of exposure, sensitivity and capacities. The progression in Figure 21 starts with the motivation of humans that can be traced back to survival needs, evolution or development goals in context of the individual. Also important is the context of society in which behaviour and action is a result of political system, values, objectives and decision made by society. Both internal and external motivations and constraints are the setting where action and agency germinates. Human actions then result in either modifications or creation of structures (row of actions and counter actions in Figure 21). Structures can be physical objects like buildings or land use patterns, but also non-physical structures like networks. The whole range of human built structures, conditions and actions make up the activation of social vulnerability from the human side. In this perspective of humans as architects of their environment, disaster is human made. It originates due to exposure, sensitivities and capacities (bottom line of Figure 21). But these analytical categories have to be traced back to analytical root causes of human structures in feedback to the environment. Lastly, these structures and actions are created by even more fundamental motivations.

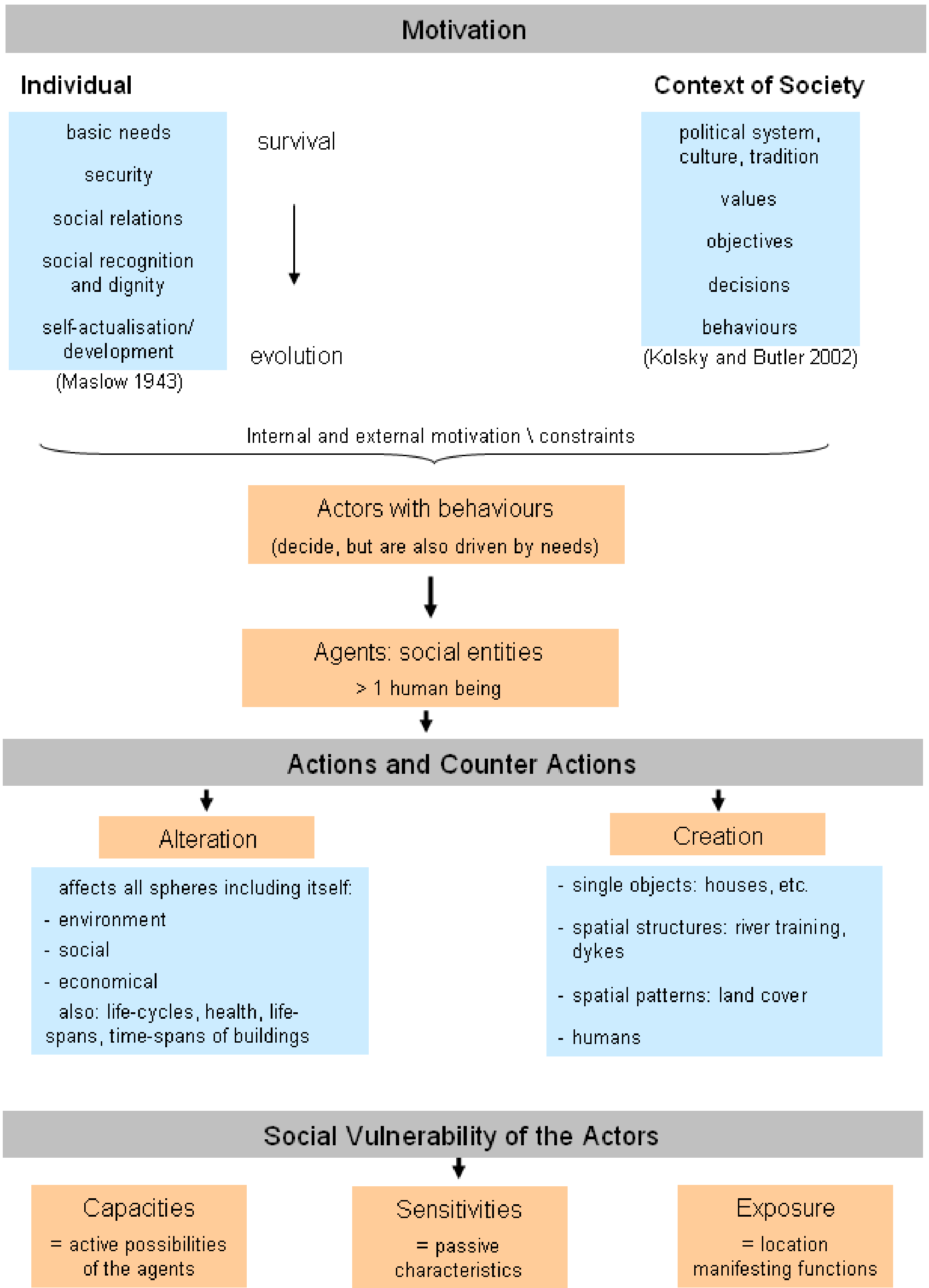

Figure 21. Activation model of social vulnerability. The figure displays the actions that originate and interlink social vulnerability structures of the actors involved

The activation model links basic needs and values to the human security concept and to the three vulnerability components; exposure, sensitivity and capacities. Social decisions are nested on the basic needs and values concept. Outcomes of human action are alterations of existing states and resources as well as the creation of new structures and patterns. This activation model closes the circle from the stepwise development of a theoretical frame of social vulnerability measurement. It embeds the humans as elements of interest and how the vulnerability of society as a social system is created by motivations and actions of the humans themselves. The resulting social vulnerability conditions are at the same time the research lenses for the observer, the scientists who aims at assessing this situation. The activation model shows to which theoretical concept of basic needs and values the vulnerability lenses can be connected. This delivers a clear link from the elements of interest to the theoretical categories of observation and the analytical theories behind it.

3.2.9 General disaster risk framework

For the application of the previously presented theoretical considerations, the following disaster risk concept is derived (Figure 23). It embeds the social system of observation and the hazard system in a place-based approach and links it to the analytical construct of a disaster risk. The focus here is not on economic damage, on the hazard or on social networks only. The vulnerability of the social system and the convergence to disaster risk under the activation by hazard events are the central topics of this framework. Quite often, vulnerability, hazard, risk and disaster assessments are treated separately. This framework attempts at joining these fields by an integrative disaster risk framework (Figure 23). The normative goal of this study is disaster risk reduction.

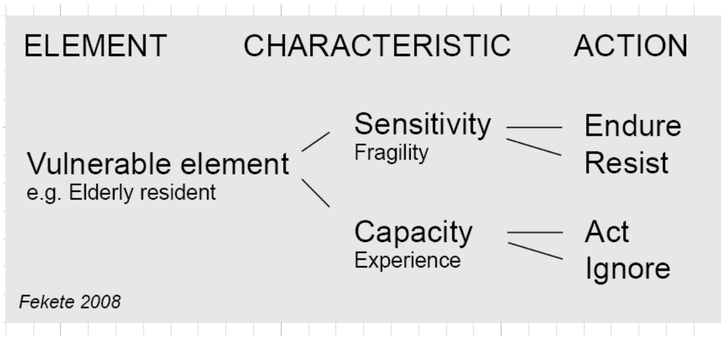

Figure 22. Options for actions of humans

Disaster risk is a human construct which includes both technical and social aspects like probabilities, dynamics and behaviour. Focusing only on risk as probability would be an immense shortcoming, since it would neglect the human choice factor and social construction of risk (Kasperson et al., 1988, Bradbury, 1989, Renn, 2008). Disaster risk is the negotiated balance of being vulnerable, being exposed to a hazard and being at risk (Figure 23). Even without active choice or awareness of the hazards or vulnerabilities, the risk exists due to ignorance or not-knowing (Figure 22). If no human is exposed to a hazard, it is still at risk to other hazards or of modifications and unexpected developments of the hazard. Therefore, human beings are constantly at risk, either to known or unknown hazards or vulnerabilities. The risk parameters are determined by the vulnerabilities and hazards. For example, skills like knowledge or ignorance determine the vulnerability profile of a person, a community or a whole state.

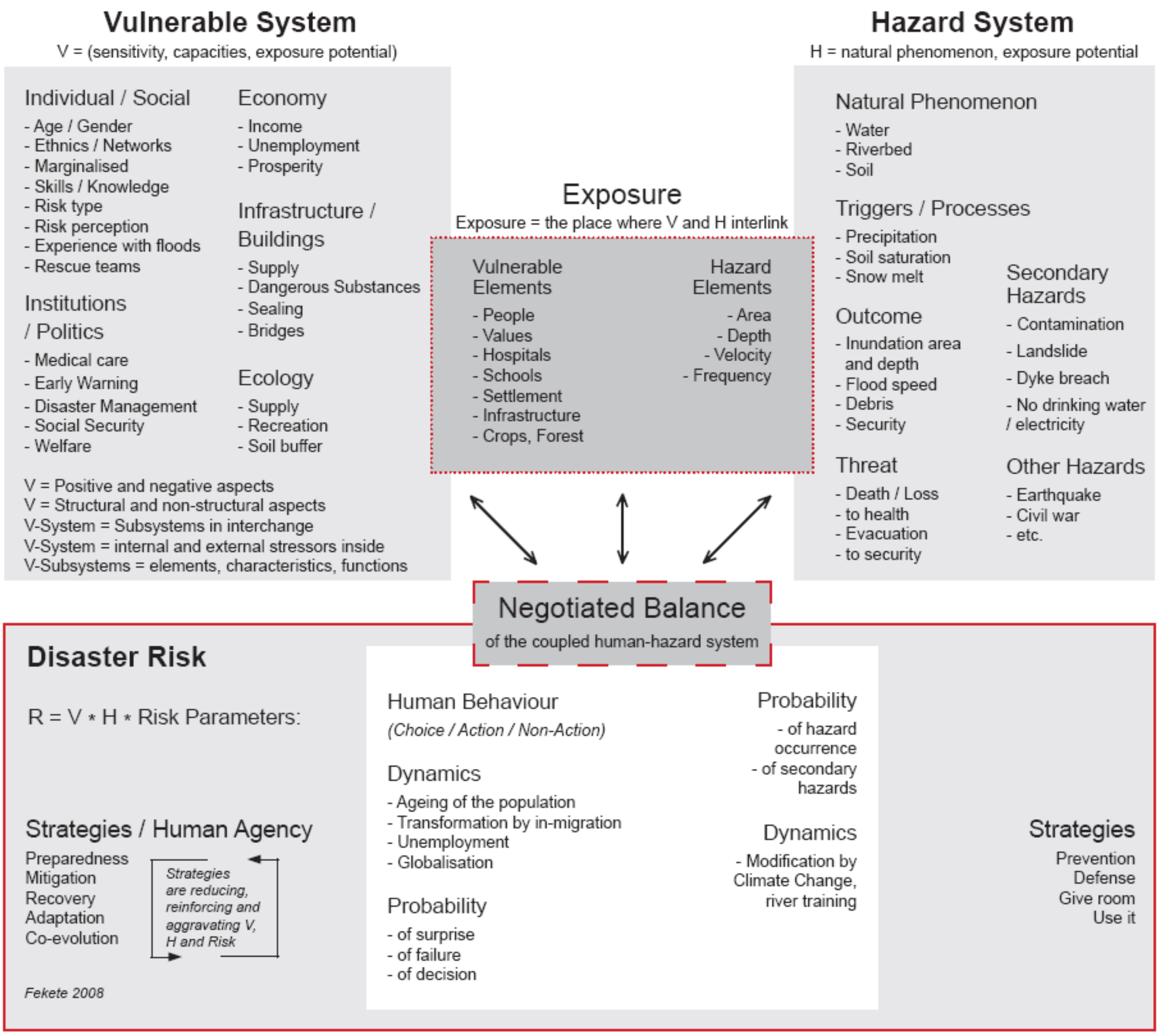

Figure 23. General Disaster-Risk Framework on the example of floods.

Aim of this framework (Figure 23) is outlining the parts of risk necessary for vulnerability indicator assessment. Vulnerability, hazard and risk perception are combined in a coupled human-hazard system perspective. Purpose of the framework is an overview and breakdown of the aggregation and analysis procedure. The elements of this conceptual framework are the input for the formula to calculate disaster risk: Risk = f(Vulnerability, Exposure, Hazard, Risk Parameters). The framework is an idealised checklist of aspects to consider while the real measurement might not be able to acquire all necessary data. The major advancement of this framework is the integration of risk parameters like risk perception into a coupled human-hazard system analysis. Further, risk is not reduced to the probability of hazard parameters only, but contains probabilities of the social system as well. Dynamics like modifications of both hazard and social system are explicitly mentioned as well as strategies for disaster management of both systems. This framework is therefore an invitation to both social and natural sciences to integrate their outputs into an integrated risk calculation.

Summarising, Chapter 3.2 reveals how difficult it is to capture the theoretical frame of vulnerability. By tackling a complex phenomenon, it must bear an explanation of complex relationships. In this chapter it is showed how the often-applied assessment of vulnerability can be structured and embedded in existing theories. Many of these are not 'real theories' in the sense of explaining the world.

Yet, certain research perspectives have provided input for vulnerability assessments. However, for the aim of measuring a complex phenomenon by indicators it must be outlined which elements and processes are to be explained by which methods, lenses and which goals are behind that. Figure 9 and Table 5 at the beginning of section 3.2 show the conceptual procedure of this study and the following section demonstrates how this concept is applied to the creation of social vulnerability indicators.

3.3 Concept of the vulnerability indicators

Based on the vulnerability concept in section 3.2, vulnerability indicators are created. Objective, structure and selection of the indicators are derived from the theoretical concept.
Steps in creating indicators for this work include:

- The identification and definition of the goal of this study: the detection of spatial patterns of vulnerability for the whole area of Germany on county-level.
- Scoping: Domain of research is the German society. The target audience is scientists and decision-makers.
- Temporal and spatial spans: data of one year on county level to enable a snap-shot of the current vulnerability conditions. This serves as a starting point for monitoring.
- The selection of appropriate theoretical frameworks: (see in section 3.2).
- Identification of potential indicators (see in section 2.4 of the thesis)
- Selection of the final set of indicators (see in Chapter 4 of the thesis)
- Assessment of indicator performance (see in Chapters 4 and 5 of the thesis)

From at least the 1960s, social indicators have been used for monitoring social processes (Simpson and Katirai 2006). The attraction of indices lies in the summation of complex information into intuitively conceivable numbers. In regard to this study they allow for spatial and temporal comparison of vulnerability between different communities. General problems known for indicators and indices include subjectivity, bias, weighting, aggregation, normalisation and selection of indicators and data sources. The purpose of building indicators is to derive general approximations over a number of research units and to be able to draw comparisons on these units. The aim is to organise information in order to derive knowledge about spatial distribution patterns, thus attempting to ‘measure’ social vulnerability in this case. Indicators are numerical values that represent real world phenomena in a highly reduced form. An indicator can itself be either a single variable or a composite number of various variables. However, it seems generally accepted that there is a progression from information to data to indicators to indices (Birkmann, 2006: 59, Simpson and Katirai, 2006): 2).
Other terms like attribute, metric, parameter, value or variable are used to explain the components of indicators as pieces of quantified data that contain an order, ranking or more generally, direction. An indicator is thus the contrary of unorganised and non-valuing information. An indicator and its composite form, an index, are manipulated single values to portrait an index score or rank. It is oftentimes a statistical measurement value which in its variations signifies a change of magnitude, but is usually not an accurate measurement of a phenomenon easily observed in the real world (Simpson and Katirai, 2006).
Various sources provide an introductory overview on characteristics of vulnerability indicators (Birkmann 2006, Villagran 2006). The design of indicators is dependent on their expected use, inherent properties of the phenomenon of research, methodologies and, the availability of data (Villagran 2006: 26). The selection process is key to ensure the quality of indicators (Briguglio, 2003, Hahn et al., 2003, Villagran 2006) and receives special attention in this study.

Why measuring vulnerability? Answers to this discussion were provided in the UNU-EHS / MunichRe foundation summer academy on water-related social vulnerability at Schloss Hohenkammer in 2006:

- To define, where the most need is (Erich Plate)
- Assess socially distributed vulnerability (Anthony Oliver-Smith)
- Alert the public, improve the intervention tools (Melanie Gall)
- To represent social responsibility (Ursula Oswald Spring)
- Taking the naturalness of natural disasters (Ben Wisner)
- Anticipate undesirable states (Ricardo Guimaraes)
- To look at the social roots of vulnerability (Dirk Reinhard)

Indicators are linked to distinct objectives and context (Birkmann, 2005: 3). These objectives are pursued by three parties – science, decision makers / politics and society. Consequently, there are three chains of influence on the development and use of indicators (Figure 249: Indicators develop in a progressing chain from values to objectives and link to decisions (see Figure 24, cf. Figure 23 and Kolsky and Butler, 2002). Values are goals like disaster risk reduction, objectives are for example "no flood damage". Indicators, which point at specific phenomena are imperfect surrogates for both the aspects they try to describe and the objectives they indicate. Thus, each step in the chain loses a lot of the facets and content of the previous step. Despite the limitations, indicators bear the function not only to describe performance (or process) but also to point the way towards appropriate decisions.

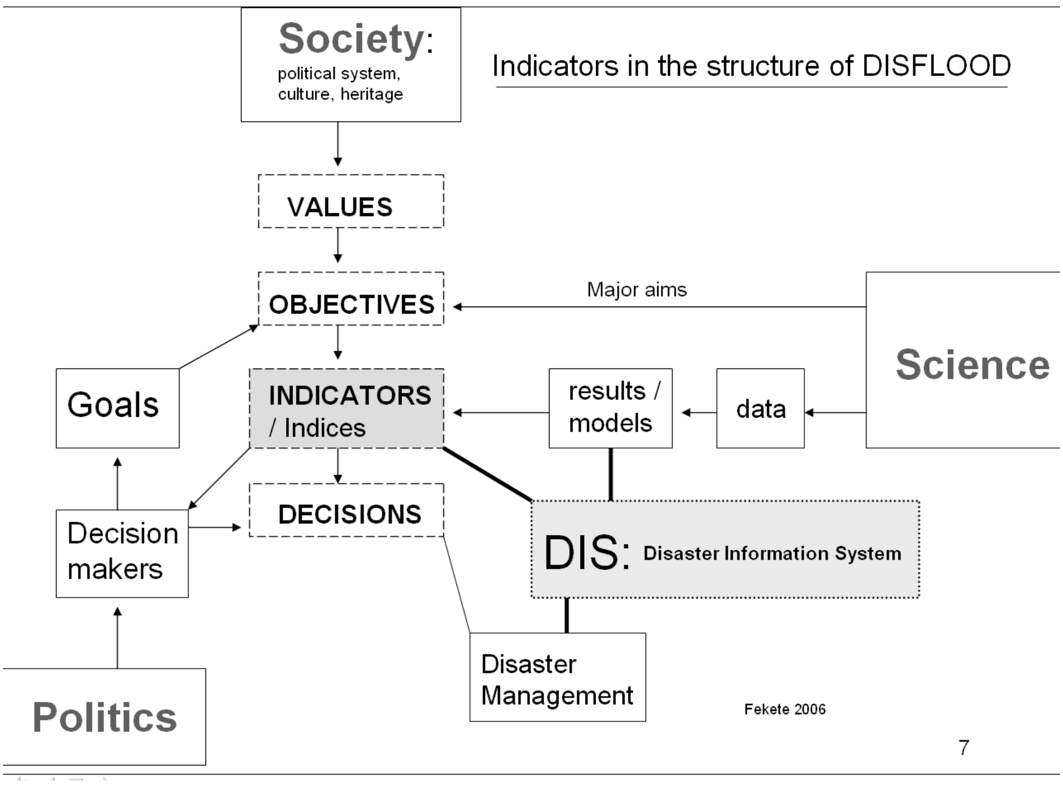

Figure 24. Indicators as result of demands of politics, science and society

The indicators of social vulnerability derived from this study will be part of the DISFLOOD project (see Chapter 6 of the PhD thesis – Fekete 2010). Therefore, the objectives guiding the construction of the indicators are also dependent on the demands of this project, as well as on the potential end-users, like disaster risk managers and scientific audience.

There is no single causation in vulnerability to flooding (Table 10 below). It is a difficult task to subdivide vulnerability and to bring it into single causation chains that can be tested. The starting point of an indicator development should be the description of a single goal; the respective indicator is to explain. In the case of vulnerability there a multiple goals and single variables indicate several goals at a time. A starting point for structuring the goals of vulnerability reduction has to be found. Taking Maslow's hierarchy of needs, the baseline is termed basic needs (Table 9). What are the basic needs in Germany that can be linked to river flooding hazard? The starting points are extremes. The first need is survival. In the most extreme case, humans get killed due to drowning, cooling or heart attack, triggered by inundation, flow velocity, coldness of the water. There are numerous additional or secondary hazards, like slippery and muddy surfaces, surprise, unawareness and overestimation of skills. The key question is who is especially vulnerable to this type of mortality or severe health effects triggered by flooding?

Table 9. Order of human risks to flooding, taking into account the first basis step (basic needs) of Maslow's hierarchy of needs

Human risks to flooding	Maslow's hierarchy of needs
	Basic needs of survival
Death	Life
Severe health consequences	Health
	Basic needs of livelihood
Evacuation – losing home (temporarily or longer)	Security of shelter
Monetary difficulties	Security of food
Looting, civil unrest	Security
Loss of family members, relatives, friends	Social relations
Loss of status, threat of precariousness	Social recognition and dignity
Lifestyle	Self-actualisation / development

Source: based on Maslow 1943

According to Maslow's hierarchy of needs, human risks to flooding can be put into a priority order (Table 9). The focus in this study will narrow down to the first priority need, basic needs of survival, and the second priority, basic needs of livelihood. As an example, mortality is analysed as how it can be structured into measurable components (Table 10).

Table 10. The limits of mono-causal explanation of human risk to flooding

Goal of the indicator explanation	Components of the indicator	Explanation, what the components indicate
Death as the negative outcome of risk (also: severe health consequences)	The already ill The elderly The very young Disabled people	Lack of fitness to survive or evacuate themselves Dependency on other people's help and assistance
	Additional factors that increase the risk to die:	
	Risk behaviour	Overestimation of skills
	Experience	Surprise

Table 10 illustrates that even mortality is a composite vulnerability phenomenon and cannot be reduced to a single group of people or to a single set of behaviour. The phenomenon to be explained is what composed the basic needs for survival to river floods in Germany. The indicator for these basic needs of survival can be termed "fragility". Fragility is composed of several components or types of vulnerable people (see the bottom line of Figure 21). In the hierarchy theory model these components are what is measured on the micro level. The explanations of what renders these components vulnerable can be generalised. These generalisations of observations can be analysed as an abstraction on a higher analytical level. This is the meso level of observation, where the overall phenomenon of interest can be analysed as a general pattern. The following figure explains this intricate tree of interrelations that bundle in the fragility indicator. The fragility phenomenon is constrained by macro forces (cf. Wisner et al. 2004: 51) on the macro level of constraints.

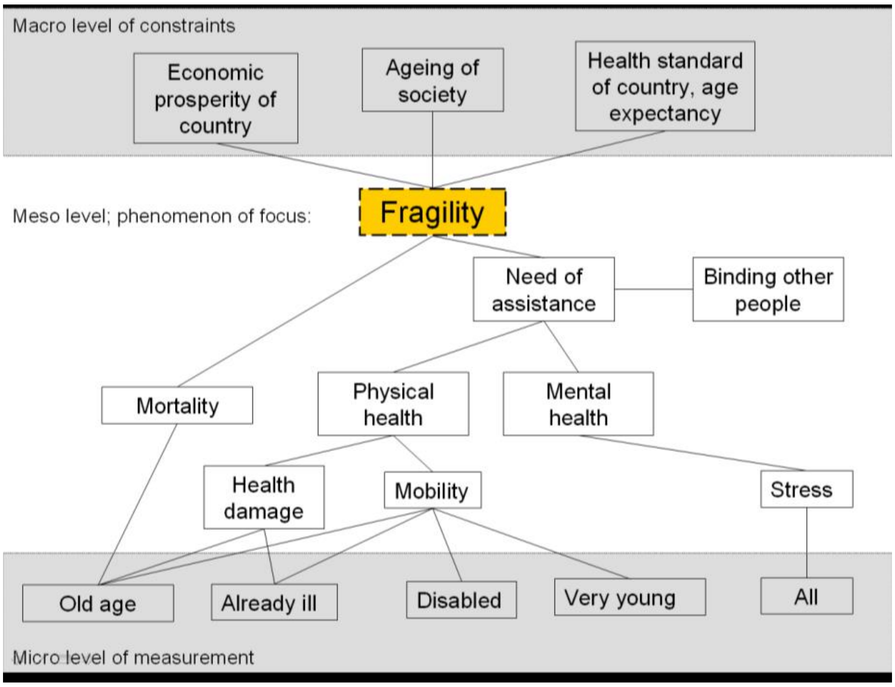

Figure 25. The term fragility and its interrelations with vulnerable groups in a tree structure

This theoretical conceptualisation of social vulnerability indicators shows how the construct, what is measured by an indicator, for example "fragility", is related to the levels of analytical observation and measurement. In the following vulnerability assessment, an extensive analysis on various demographic variables will be carried out on identifying potential social vulnerability indicators like fragility. The assessment will apply the research conceptualisation of Chapter 3 and test it on the empirical findings of the data.

Table 11. Concept of the social vulnerability indicators in this study

Steps	Analytical indicator components	Conceptual step
1	Variables containing human characteristics	Humans as elements of interest
2	Counties as units of measurement	Social system concept of a place-based approach
3	Vulnerability identification categories: exposure, sensitivity and capacities	Vulnerability frameworks
4	Goal: indication of weaknesses and strengths towards disaster risk reduction	Disaster risk as a component of the human security concept.

The developed indicators are to identify the humans as elements of interest, how they form a social system and how that system is vulnerable to river-floods (Table 11). Vulnerability is observed under the theoretical categories of exposure, sensitivity and capacities. This concept is guided by the vulnerability frameworks that link vulnerability to the hazard and risk chain (BBC framework, SUST framework and general disaster risk framework of Figure 23). The goal of risk reduction and the overall normative frame are provided by the human security concept. While this is a static status quo assessment of vulnerability, it considers all phases of the disaster cycle and as serves as a starting point for monitoring social vulnerability and the resilience trajectory of the coupled human-environment relationship.

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Comments

Only slight corrections were made in the manuscript, such as typos corrected, and papers indicated as 'submitted' updated so they can be found. Essay number 3 is a nice example of an unfinished text on trying to comprehend vulnerability theoretically, that failed. It was a chapter in a PhD thesis that tried to lay a conceptual foundation for the vulnerability indicator analysis that followed. Indeed, the endeavour to understand what was going to be measured by (social) vulnerability indicators and how it can be put into practice was the real work and struggle in the PhD. But it was abandoned, since it was not ripe, mature and concise, and cutting it, also enabled to write the PhD thesis more in one direct line, stripping it from theoretical ballast. And while the PhD thesis and its vulnerability index and indicators were direct 'outcomes', the real longer-term 'impact' was the intellectual debate on what actually is vulnerability. This stimulated a number of articles critically reviewing such indices, by colleagues (de Sherbinin, Rufat, Steinführer & Kuhlicke, Tate, and others) and by the author. And also stimulated publications about related topics such as scale dependency, long-term monitoring options and policy application limitations and opportunities, by the authors of this volume. But since the real debate lingering behind the final products or outcomes often is not seen, when it was never published or when two co-authors are struggling to find a compromise, this also limits fellow colleagues to comprehend and debate vulnerability, or resilience. Therefore, not only this essay is included, although it originally failed, but we also wrote an additional perspective comment from both our sometimes aligning, sometimes opposing views. This actually just follows an old tradition, now mostly abandoned, when scientific journals would publish not just the articles but also the letters as a reaction and ensuing defences by the authors, too. We have added such comments sections only at essays where we still have on-going arguments that warrant a comment rich enough to stimulate discussion other colleagues may also share.

Comment on terminology (Fekete)

This article originally was intended being a chapter in a PhD thesis (Fekete, 2010a). The manuscript of this chapter was partly used in the PhD thesis, 3.1 is contained in the thesis but some figures and sections were left out and 3.2 and 3.3 mostly cut and left unfinished in Nov. 2008, after being decided that it would not fit into the thesis. Therefore, relations to other chapters can best be understood when comparing with the PhD thesis manuscript. For example, references to tables or figures (as in Table 5) are not consistent with the published thesis, since most of the figures from this chapter were not used and numbering in the final thesis also changed. Wordings and terminology have been adjusted in the final PhD thesis (Fekete, 2010a) and professional language editing applied in the later published version by UNU-EHS (Fekete, 2010b).

One important terminological explanation must be provided for using the term "sensitivity" here in this chapter, while the PhD thesis uses the term "susceptibility". The reason for originally selecting "sensitivity" was that it was based on an article by Adger (2006) that is based on a comparison between various vulnerability definitions and that found sensitivity as a common denominator. Another reason was that susceptibility is closer to vulnerability in its meaning of 'prone to be affected', and also, therefore closer to 'exposure'. Sensitivity, on the other hand is more neutral in its direction; one person can be sensitive to a stimulus, in this case, a hazard and the reaction can be both a rather negative or still, a slightly 'positive' one. 'Positive' reaction is understood here as being emphatic, insightful perceptive or receptive to being aware of hazards and ready to enact upon it. 'Negative' reactions would entail more readiness to lose or give up, being damaged or hurt. But from recent perspectives, it must be conceded that there does not seem to be a great difference between sensitivity and susceptibility in this respect. It felt more that sensitivity would leave it more open how the reaction to a hazard would be (reading Gallopin 2006 this way, too), while susceptibility seemed to indicate a tendency towards negative affectedness or passiveness. This whole discussion must be understood noticing that a decade ago, there was discussion about the direction of meaning of the term vulnerability at another stance and basis as it is today. Discussion topics were whether vulnerability would contain only negative aspects, and resilience being the more positive counterpart. This also had an impact on the number and type of components of vulnerability; would vulnerability include exposure, or be separate, as in the former notions

(Davidson & Shah 1997), or not being included, as in the VCA assessment and matrix (Anderson and Woodrow 1998)? The other component, capacities (in VCA), is it natural and logical part of vulnerability? Capacities can compensate negative attributes of vulnerability, often named 'susceptibility' or 'sensitivity', but are capacities then just counterparts, or the inverse of susceptibility? It is interesting to note that the official UN definitions in context to disaster risk (formerly UNISDR Terminology on their website, now UNDRR) have experienced developments, changes and in some cases, even steps back to former definitions. For example, it could be observed that the definition of the term vulnerability evolved to contain more and more components and make it broader than just designating negative and passive attributes about people or communities. But in the recent definitions of UNDRR (observed 2018, 2919), vulnerability almost equals susceptibility. Resilience on the other hand, has become the 'umbrella term' as can be seen in the development of the UNISDR/UNDRR definitions; more and more components that formerly were known under the vulnerability definitions also were found within resilience; most fundamentally, a wide range of capacities or capabilities for the phases before during and after a disaster. From nowadays perceptive, it seems to make a lot of sense of differentiating the terms vulnerability, exposure and capacities much more, especially for those who wish to use these terms as components for calculations or analytical logical frameworks or models that work best when avoiding duplications and confounding effects, such as in semi-quantitative indicator approaches. Quite a number of studies were struggling with long discussions whether a phenomenon / data set would represent vulnerability or exposure or resilience. Sometimes, such debates were invigorating, stimulating to consider more phenomena/aspects than before. But at the same time this also often just wasted time and resources without advancing real knowledge about risk.

Since the chapter above was not finished then, it is left rather 'unpolished' and with the term sensitivity as it was written, since back then the dual meaning of sensitivity was in mind when writing; a potential reaction of a human being or community, or technical system, to react to a hazard stimulus without prior judgement whether this reaction needs to end positively or negatively or whether it could/should be stated a posteriori by external analysts whether this reaction is to be regarded 'positive' (in the meaning of will save the person, right decision, 'good' attribute to a person) or 'negative' (person has attributes that will make it fail or frail and thereby is simply a 'bad' attribute, unavoidable to render the person 'victim' to the hazard). It must be acknowledged, that this was a major discussion also between the PhD supervisor and the PhD candidate, but it led to a number of thoughtful debates and finally, improvement of the PhD thesis. From nowadays' perspective, the PhD candidate is more inclined using the term 'susceptibility', because it is almost a synonym to 'vulnerability' itself. Almost, since vulnerability still emphasises the potential wound much more (Kelly & Adger 2000), and seems more explicitly negative; wounds are mostly regarded as a negative attribute.

In this line of argumentation, it seems also advisable to strip capacities/capabilities and exposure from vulnerability. This stance means that there indeed might exist a vulnerability notion independent from the hazard, which is mainly useful for modelling. And might be justified when thinking that many people living far away from a river might be potentially vulnerable to a flood. Because these people can one day experience a flash flood and be more surprised, less knowledgeable what to do, than those often exposed to rover-floods. Another example, people can drive to a flood plain, unaware of any hazard and being surprised there. Of course, when analysing risk, then the risk formula should contain exposure and capabilities, too. Of course, this example is also dependent on some assumptions, for example, previous experiences. Vulnerability carries this other interesting, often overlooked attribute; that it leaves it open, whether pre-existing wound had already occurred or not (Kelly & Adger 2000). But again, this can best be solved by putting any vulnerability characteristic in context to dynamics and hence, exposure. Exposure too often is simplified in natural hazards research to spatial exposure. But there exists also exposure quality, such as amount and content of dosage and temporal exposure aspects – both exposure aspects (quality, time) observed much closer in medical exposure studies, natech or man-made emergencies and disasters than in natural hazards research.

A special topic is usage of the term fragility. It must be admitted that it was introduced here in 2008 without thorough reflection of existing usages of the term in related literature. Fragility was introduced in figure in order to express one characteristic of sensitivity, next to terms such as marginalisation or choice. True, fragility is within a group of terms with similar meanings such as susceptibility, or frail, delicate, breakable (I still find the visual thesaurus online visualisation quite helpful, next to Merriam Webster). Back then fragility seemed best to express a human health related sensitivity, such as being fragile when being crushed by an earthquake or subject to harm when drowning. Susceptibility alone just as sensitivity could also refer to being susceptible to economic loss, or loss of social ties or else. In the naming of the aggregated indicators from factor analysis in the thesis, variables such as (old) age or medical care centres, this component was named "physical fragility towards mortality or severe health impacts" (Table 7 in chapter of the thesis).

Most interesting for readers could be getting a sense of the intense debate the authors of this edited volume had over the years and in several publications on terminology. In those other publications, the discussion is hidden behind the final decision, and compromise in how risk and vulnerability have to be defined and used. Here, in the tradition of scholarly exchange, this has represented the standpoint and arguments from one author. The following section is the response from the other editor of this volume.

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From intriguing concept(s) towards an overused buzzword: is it time for a requiem for resilience?

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Introduction

Resilience is a term that has gained cross-disciplinary attention in recent years. It flourishes in certain disciplines for quite some time already while more and more other disciplines are at their beginning of discovering it (Béné et al, 2012, Chandler, 2014, Wink, 2016). Increasingly the adjective "resilient" can be found in many conference titles, irrespective of the subject of the event. In some fields such as Disaster Risk Reduction or Climate Change Adaptation, its overuse is already debated. This paper aims at analyzing traces of a possible 'hiatus' of the term and searches for signs of a 'requiescence' of the term. While the scrutiny of resilience by its terminological fuzziness is not novel, this paper seeks to make a case for a focused understanding of resilience, very much in the sense of its original etymological meaning of 'bouncing back', or 'bouncing forward' (Manyena et al., 2011) in order to facilitate its practical applicability.

The seminal paper of David Alexander (2013) describes a two millennia long evolution and usage of the term 'resilience' across different disciplines and epochs. It also analyzes its (rather chaotic) contemporary utilization. This paper shows that resilience has risen in a number of disciplines and that its use dates back way beyond often cited 'ancestor' lines that start, for instance in the field of Disaster Risk Reduction (DRR), in the 1970s. While earlier usages of the term are not necessarily within strict scientific contexts or within the same disciplines, this paper provides a sound basis for tracing history and reconsidering components of resilience definitions and their origins. Inspired by this paper, but also by the abundance of papers critical on fuzzy terminology and apparent overuse of the term 'resilience', it could have been expected that after the publication of Alexander's paper a certain scientific rigor in terminology and restrain in its indiscriminate usages to occur. However, this expectation did not materialize yet in the form of a widely accepted unique definition of resilience or as a consensus to restrict overuse.

On the contrary, resilience or resiliency (the paper by Alexander, 2012 suggests that the two forms are equivalent), fuzzy as it might be, seemingly did not relinquish its appeal yet. Irrespective of the multitude of (sometimes even contradicting) definitions and concepts (Bruneau et al., 2003, Manyena, 2006 and others, see Table 1) which could be counterproductive to popularize it, resilience is not only still widely used, but even penetrates new areas. Usages of the term resilience on non-academic book covers, and in advertisements are a telling indication of a world saturated by the use of the term 'resilience'. The original meaning of the word was changed and the term "appropriated" without much afterthought. Whether the frequent use of the word alone would make the world more resilient (whatever positive meaning it may represent) is yet to be seen. Needless to say that the broadening use in many different fields, but also the frequent redefinition of the term resilience implies, at least on the long run, a certain inflationary tendency.

Definitional laxity, which increasingly characterizes resilience may be helpful to adapt it into new contexts, or, to stimulate interdisciplinary dialogue (Fekete et al., 2014, p. 14). But especially in research aiming for applications of the term resilience, be it qualitative assessments, for instance, in community resilience studies or quantitative assessments such as risk indices or damage functions, more scientific rigor for narrowing down resilience can be observed. For example, new, aggregated resilience metrics are developed and even proposed to replace risk-based performance assessment (Simonovic and Peck, 2013, Simonovic and Arunkumar, 2016, Irwin et al., 2016, Kong and Simonovic, 2016). While the proposed metric enables to monitor the dynamic change of 'resilience' and hence contributes to the comprehensive assessment of how a disaster and the recovery unfold, it is different from the resilience metric (time elapsed between the disaster and the achievement of pre-disaster performance level, see also Fig. 1) as proposed by Hashimoto et al and Duckstein et al. for water resources systems in 1982 and 1987 respectively. Other well-known resilience definitions like Holling (1973, 1986, 1996) are also different as they emphasize the stability of the system, whereas the Hashimoto et al concept focuses on the rapidity of the recovery without considering whether the system left temporarily its original state or not.

Replacements of risk as an overall term in exchange for resilience have been documented at EU and international level in a variety of fields related to disaster risk (Fekete et al., 2014), for instance, in spatial risk assessments (Cutter et al., 2008) or threat and consequence assessments of risks to critical infrastructures (HS SAI - Homeland Security Studies and Analysis Institute, 2010). Béné et al discuss the advantages and drawbacks of the resilience concept for vulnerability reduction and poverty alleviation programs (2012).

The appeal of resilience

What does make 'resilience' so appealing? There might be an appeal of the positive 're' words in general. For instance, some concepts try to boil down a great variety of features of resilience into a handful of recognizable components of resilience, for example, the '4R' model by Bruneau et al., 2003. Terms starting with 're' often characterize reactive behavior, and given that the trigger is usually described as a negative event (disaster, breakdown, impact etc.) the 're' words describe positive development. An admitted weakness of this explanation is however that regret, remorse etc. are also 're' words with less than positive connotations. In most of the papers dealing with this subject resilience is somewhat related to terms such as resistance, reliability, restoration, responsivity, recovery, reduction, reinforcement, renovation, recuperation etc. but also of redundancy, resourcefulness, robustness and rapidity. While these two last ones are 'only r-words', yet they are used, together with resourcefulness and redundancy to serve as the four "features" ('4R' model) of resilience (Bruneau et al., 2003).

While some publications underline the appeal of resilience for its positive connotation and suggest a broadening of the conceptual use of resilience in an encompassing way covering aspects not limited to 'bouncing back' only (Alexander, 2013, Weichselgartner and Kelman, 2015, Folke et al, 2010, Manyena et al., 2011) at the same time also calls for more operationalization of resilience can be observed (Manyena, 2006). Operationalization in the sense of applying resilience, and especially within quantitative applications often demand for a stricter and more limited definition of resilience. At least, for the given components of resilience that are to be analyzed. For those following an analytic approach and especially within a more mathematical or engineering approach, the existence of resilience as an 'umbrella term' meaning several aspects, overlapping with vulnerability or sustainability or with other predefined terms, can be frustrating. In this line, a definition 'cacophony' of resilience is counterproductive to the operational use and could lead to relaxation of scientific rigor.

Resilience is likely to have a justification as an overall umbrella term epitomizing the 'good side' to counter disasters and negative impacts. As such term it is defying definition, though very good to stimulate discussion and therefore, cross-sectoral and potentially cross-disciplinary discourse and exchange. This frequently mentioned excuse for the definitional inaccuracy is strongly challenged here. A discourse cannot be productive in a strict scientific sense if the participants use the same terms but with different meanings and connotations.

A recent article in a fire safety journal (Voßschmidt, 2017) argues for a legal instrument enabling rescue operations to utilize society's resilience, since in a democratic state 'can do' means nothing if actions are not legitimated by a legal 'may do'. Laws usually need crisp definitions. Once a resilience-based or 'resilience friendly' legislation will be drafted for disaster management for example, this would imply the adoption of a single definition. Resilience is described by Voßschmidt in general terms as the increase of the ability of the society to withstand (resist) and to restore (reconstruct). This also differs from previous definitions mentioned also in this essay (see Table 1), but this is not the key concern at this point. However, it is very essential to have scientific consensus on what may be called resilience in order to advance this law-making process.

Typical academic fights over resilience often draw upon traditional stereotypes and lack of acceptance of disciplines and their methods and conceptual approaches themselves. For instance, the fight over qualitative versus quantitative methods or, whether anything but natural sciences should be termed 'science' at all etc. Traditional fields such as mathematics or physics demand terminological rigor because they apply a deductive approach based on laws and formula that are dependent upon precise definitions of resilience. Statisticians applying resilience by using their tools (Maslow's hammers) also need to narrow down resilience to variables that are not confounded by other variables. Of course, the outcome of any model or analytical result is restricted to the model and the narrowed assumptions made. It is the obligation of such research then not to claim to have covered resilience as a general phenomenon.

The positive attribute of resilience likely contributed to its proposed juxtaposition to vulnerability. Resilience is used with preference in overall concepts while vulnerability seems increasingly being used for applications only (Fekete et al., 2014). Resilience, in the context of its original etymological meaning 'to bounce back' might be interpreted as one of the abilities (or capacities as termed by other authors) enabling to reduce vulnerability, but certainly does not substitute resistance, robustness, risk sharing, knowledge and other aspects which may reduce vulnerability to disasters. By aggregating too many features under the umbrella term 'resilience' conceptual clarity is rather lost. Resilience is by its origin a reactive term. Overloading it with other attributes makes it more difficult, if not impossible to be operationalized for practical use. Resilience is an important, but by no means unique ability of the affected system next to absorbing shocks, resisting, buffering, adaptation and others. It characterizes with well-chosen and measurable parameters, the ability to bounce back to the pre-disturbance state or to bounce forward and achieve a new, but desirable state (Manyena et al., 2011).

If interpreted very strictly the Hashimoto et al (1982) and Duckstein et al. (1987) resilience type (see Fig.1) may not even be an ability to mitigate vulnerability properly (as it is measured in time and not in the same dimension as the performance level of the system) but simply the measure of the (hopefully) quick recovery. Interestingly Manyena et al., 2011 also argue against that "the resilience and vulnerability paradigms are still locked together and increasingly being treated as if they are one and the same". Of course the general assumption that lower manifestation of vulnerability usually followed by quicker recovery is most likely valid, however may not be reciprocal.

The reactive nature of resilience implies that this 'response' to a disturbance should be triggered from within the affected system, preferably as self-reaction. This makes the application of the idea of resilience for ecosystems (Holling, 1973), or to social-ecological systems (Moberg and Simonsen, 2014) very appealing. For technical systems as long as the mechanical elasticity of the materials involved suffice to compensate the impact resilience takes place automatically. This can be well observed for example in the case of elasticity during regular operation of railway lines and bridges. Once these material properties are insufficient to trigger automatic resilience, post impact external intervention will be needed to initiate resilience (bouncing back to normal (pre-impact) state. After all no collapsed bridge can rebuild itself.

Resilience etymology and definition: a review of the state of the art

Resilience has the potential to become a 'buzzword' like sustainability. Resilience, albeit its Latin origin, is associated with a practically defunct verb 'to resile', hardly to be found either in the common vocabulary or in the scientific jargon. Oxford Living Dictionaries https://en.oxforddictionaries.com/definition/resile describes this verb as to "abandon a position or a course of action". The verb is dated to the early 16th century. It emanates from the obsolete French verb 'resilir' (to recoil) and the Latin 'resilire' (to jump back). This etymological flashback strengthens the notion to define resilience as the 'bouncing back' process, hardly to be pronounced or even hinted by many recent redefinitions of resilience.

The Publication of the Stockholm Resilience Center (Moberg and Simonsen, 2014) "What is resilience? An introduction to social-ecological research" subscribes already in the title to a broad interpretation of resilience (see Table 1 further below).

Shocks and disasters certainly open "windows of opportunity". But can this process be equated with resilience? Isn't it rather the chance to bounce forward? However, resilience is seen here as an adaptive process, hence cannot be really defined in advance as it reveals itself as a process whereby resilience gets into motion and evolves.

The term resilience is suffering from the relentless efforts of scientists to redefine and to overload it (see Table 1). The "purist" definition of resilience as bouncing back (Hashimoto et al, 1982) what was called by Holling (1996) as "engineering resilience", refers simply to the ability of the system to recover after a disturbance (virtually without extra external help and investment). Hence it could be measured as the time needed to accomplish this bouncing back process based on the inherent elasticity (springiness) of the system after the hazard's impact.

But there are many different interpretations of resilience exist. In one of the most comprehensive studies Bruneau et al., 2003 claim that a resilient system shows the following abilities (Page 4 of the Bruneau et al. paper):

- reduced failure probabilities
- reduced consequences from failures (expressed in terms of lives lost, damage etc)
- reduced time to recovery (to the normal state, preceding the disturbance)

The first entry is de facto the expression of the reliability of the system, or rather the measure of its ability to resist external loads and disturbances without losing its intended functionality. The second entry is capturing what was called by Duckstein et al. (1987) the magnitude of the vulnerability manifested through the damage extent after the disturbance. In fact, the third item represents the resilience (as used by Hashimoto et al, 1982 and Duckstein and Plate 1987). No doubt that all three aspects are essential to capture and characterize the behavior of the system under stress (disaster) conditions. However, combining de facto three dimensions of the performance metric under one term 'resilience' is neither very logical, nor easy to be interpreted. Furthermore, it certainly makes much more difficult to derive a single, physically and monetarily interpretable index for this aggregated three features in one measure called (by Bruneau et al., 2003) resilience. They also introduced four "properties" representing resilience:

> *"Resilience for both physical and social systems can be further defined as consisting of the following properties:*

Robustness: strength, or the ability of elements, systems, and other units of analysis to withstand a given level of stress or demand without suffering degradation or loss of function

Redundancy: the extent to which elements, systems, or other units of analysis exist that are substitutable, i.e., capable of satisfying functional requirements in the event of disruption, degradation, or loss of functionality

Resourcefulness: the capacity to identify problems, establish priorities, and mobilize resources when conditions exist that threaten to disrupt some element, system, or other unit of analysis; resourcefulness can be further conceptualized as consisting of the ability to apply material (i.e., monetary, physical, technological, and informational) and human resources to meet established priorities and achieve goals

Rapidity: the capacity to meet priorities and achieve goals in a timely manner in order to contain losses and avoid future disruption"

Besides the fact that this list reverts back to the 're' and 'r' words it further overloads resilience as an 'umbrella concept'. Robustness and redundancy are eminent features of any technical or socioecological system. They enhance safety and security of the system performance, but they rather mitigate the extent of the impact of a stressor than directly contributing to the speed of recovery (which was seen as resilience by Hashimoto et al. and Duckstein et al., 1982 and 1987 resp.). As redundancy and robustness mitigate the manifested vulnerability the subsequent recovery can of course be shorter due to the reduced amplitude of the perturbation of the system (see Fig.1). Resourcefulness and rapidity, as defined by Bruneau et al., 2003 are clearly virtues of the managers entrusted to operate the respective systems including the recovery after disturbances and rectifying their consequences. All four "properties" as called by Bruneau et al "help" resilience but it is claimed here that they are not directly part of it. Further in their study Bruneau et al. agreed that resilience has four dimensions:

…"resilience can also be conceptualized as encompassing four interrelated dimensions: technical, organizational, social, and economic.

The technical dimension of resilience refers to the ability of physical systems (including components, their interconnections and interactions, and entire systems) to perform to acceptable/desired levels when subject to earthquake forces.
The organizational dimension of resilience refers to the capacity of organizations that manage critical facilities and have the responsibility for carrying out critical disaster-related functions to make decisions and take actions that contribute to achieving the properties of resilience outlined above, that is, that help to achieve greater robustness, redundancy, resourcefulness, and rapidity.
The social dimension of resilience consists of measures specifically designed to lessen the extent to which earthquake-stricken communities and governmental jurisdictions suffer negative consequences due to the loss of critical services as a result of earthquakes.
Similarly, the economic dimension of resilience refers to the capacity to reduce both direct and indirect economic losses resulting from earthquakes.

These four dimensions of community resilience: technical, organization, social, and economic (TOSE) cannot be adequately measured by any single measure of performance. Instead, different performance measures are required for different systems under analysis. Research is required to address the quantification and measurement of resilience in all its interrelated dimensions"…

These four 'dimensions' can be seen as an earlier formulation of what is termed in this essay as 'qualifier' adjectives of resilience. Bruneau et al. are absolutely right in their warning that these 'dimensions' cannot be captured by one single aggregate measure (indicator). These four properties: robustness, redundancy, resourcefulness and rapidity, introduced by Bruneau et al. (2003) resurface, among others, in the publication of Simonovic and Arunkumar (2016), however with a somehow different interpretation.

Holling (1973, 1996), made in 1996 a clear distinction between ecological resilience and engineering resilience, not to be mixed with yet another term 'resilience engineering' (Hollnagel, 2017). The use of the term ecological resilience is justified to measure actually the stability of an ecosystem which returns to its original equilibrium state after the impacts of a disturbance. In fact, if an ecosystem cannot recover and flips into a new equilibrium state, thus proving its non-resilience; in most cases it still remains an, albeit different, ecosystem. These multiple states for a technical system are usually not foreseen. Once tipping point is passed the system's functionality might be irrevocably lost. Its engineering resilience is then characterized by an indefinitely long bouncing back timespan. For example, a reservoir built for storing water for water supply, flood control and energy generation may lose for example all these functions if the reservoir is completely filled by sediments or debris flow of a landslide.

Folke et al. (2010) extend the term and concept of resilience into, what they called "resilience thinking". Within this framework they argue for "general resilience" to be juxtaposed with "specified" resiliencies by claiming that the focused specific resiliencies may be traded off against each other. There is some good reason indeed to differentiated between a general resilience and the several potential specified ones but sticking to the same term, frequently even without using the adjective to distinguish scales and meanings the danger of definitional cacophony cannot be ruled out. By introducing the multiple scale resilience, they drew attention to the difficulty how to delineate a system or in the broadest sense the social-ecological systems. They claim, or better admit, that "the resilience framework broadens the description of resilience beyond its meaning as a buffer for conserving what you have and recovering to what you were". Resilience thinking is described as amalgamating persistence, adaptability and transformability. While adaptability may be called by some phantasy as 'long term' or 'slow' resilience or 'resilience by learning and changing', transformability, by the token of the word itself could be seen as suggested in this essay, the springiness (or the context independent core of resilience), but this term used completely differently in the cited paper. Finally, it is argued that the state or process what is represented by persistence does not seem to fit under an 'umbrella term' resilience. It is not clear, except the already mentioned attractiveness of this well sounding 're' word, why resilience should be used to represent three, otherwise quite clear and distinct processes even if they might happen simultaneously. At this point creating a new term for what the authors call "resilience thinking" would have been warranted rather than adding resilience yet another, widened meaning.

Kelman et al. Climate Change's Role in Disaster Risk Reduction's Future: Beyond Vulnerability and Resilience paper (2015) characterizes the crucial year 2015 with its three major international conferences (Paris Climate Change Accord, Sendai Conference on Disaster Risk Reduction and the UN resolution on the Sustainable Development Goals (SDGs) as a year of missed opportunities by addressing these three areas in separate agreements. One could conclude this is the consequence of the limitations of what may be called 'global governance'. The overwhelming emphasis on climate change draws away resources and interest to address the much faster and widespread occurrences and already felt consequences of population dynamics and land degradation. The paper of Kelman et al. (2015) does not define either vulnerability or resilience. They rather lament about the overemphasis on quantitative approaches of vulnerability and resilience (V+R). It is however doubtful that this is the observable trend. Many features of even a very carefully and simply defined 'resilience' are neither adequately not sufficiently quantified. At least comparisons between different spaces and affected societal groups should be made. The exclusive use of qualitative approaches would jeopardize V+R based prioritization of actions and investments. The 5 points postulated by Kelman et al., 2015

1.) *V+R are dominated by quantitative approaches, even though they are also qualitative. …*
2.) *V+R are presented as being objective, when subjectivity is more realistic….*
3.) *V+R are assumed to have absolute metrics, but proportional approaches are important too….*
4.) *V+R are assumed to be non-contextual, when contextuality and localization tends to be more realistic….*
5.) *V+R are often presented as being the current state, whereas examining the long-term process with a past and future is needed….*

and their elaboration are interesting and touches upon real dilemmas but carry the 'risk' to degrade V+R to nothing more than colloquial/sociopolitical arguments and a narrative rather than providing the foundation for scientifically based metrics. The big value of V+R would be if they were known –preferably quantitatively- before an extreme event's impact (disaster) occurs. We need at least an estimation of these and the comparability of V+R of different localities before their manifestation in disaster losses and recovery phase. Otherwise the value of V+R to be used as guide for disaster preparedness and prioritization of the corresponding investments would 'degrade' from being a diagnosis to a post mortem report on the 'pathology' of the disaster.

Weichselgartner and Kelman's paper, the Geographies of resilience: Challenges and opportunities of a descriptive concept (2015) provides an excellent summary seen through geographers' eyes. It can be agreed with most of their statements warning that rather the risk reduction and sustainability frameworks should be used as overarching models than an untested ill-defined resilience framework. It is obvious that resilience is not absolute. First and foremost, there is the question to be answered resilient to what (this resonates well with the key suggestion of this essay, namely that resilience, like vulnerability should be split into a hazard independent core and to a hazard dependent resilience activated (switched on) through exposure (see also the Section: Looking for the core of resilience). Excellent short descriptions of emerging resilience frameworks in the UK, USA, OECD and COAG (Council of Australian Governments) and UN-ISDR are presented by Weichselgartner and Kelman. Basically, all frameworks are formulated without rigorous definition of the term and without conceptual clarity what is meant by and how to measure resilience. Hence there is no real objective metric to estimate the success of the respective initiative(s). The UK approach reads like an 'orgy of the re-words', whereby resilience is featured as focusing on 4 components: resistance, reliability, redundancy and response/recovery. Again four 'features', four 'r's but different ones than the proposed ones in Bruneau et al., 2003. But why should resilience summarize all four? Can these be measured by an aggregate index? Is it desirable and can serve as basis for real world decisions? In case of a potential aim for a practical use of the concept of resilience the answer is likely to be no, in particular if quantification would be attempted.

The US develops a national resilience framework. This draws attention to the scale issue. For example, the 2002 Elbe river flood event is likely to be a disaster at municipal and at the level of the affected federal states, foremost Saxony, but certainly not on federal scale. A country like Germany can absorb 11-billion-euro flood losses. OECD moves from 'risk' to 'resilience'. By changing words progress won't be guaranteed but confusion will. Resilience is featured as the positive framing of the old challenges like vulnerability and risk, but actually it can be qualified also as old wine in a new bottle (whereby this new bottle could prove to be more 'brittle' than the previous ones).

Scale problems are essential. Actually the term "resilience" should not be used without certain 'resilience qualifiers':

- Spatial reference qualifier: personal, community, urban, rural, national etc. -resilience
- Theoretical context qualifier: ecological, engineering, place-based, psychological, system-theory etc. –resilience
- Single or multi-hazard qualifier: example: earthquake resilience or multi-hazard resilience

Using such qualifier in terminology could help avoiding misunderstandings. The use of very generic slogans like 'resilient city', which is used more and more even as conference titles is not only incomplete but also misleading. A seismically resilient city could be very non-resilient versus flash floods and vice versa. Being more precise in describing the kind of resilience analyzed, for example as a 'multi-hazard urban resilience engineering approach', could help to improve identification. These specifications would help also to counteract what was called the 'dark side of resilience', as corrupt socioeconomic systems indeed proved so far to be fairly resilient. Hence improving resilience per se without proper 'qualifiers' could be a misleading objective.

Table 1. Illustrative List of Published Resilience Definitions (emphases in bold by the authors. Sources as provided and taken from resilience definition collections in: Bruneau et al., 2003, Manyena, 2006, Weichselgartner and Kelman 2015)

ABILITIES FOR ONE PHASE in the disaster cycle
Resilience as coping, withstanding
"the capacity to **cope** with unanticipated dangers after they have become manifest, **learning** to bounce back" Wildavsky 1991, p. 77 "It is the buffer capacity or the ability of a system to **absorb** perturbation, or the magnitude of disturbance that can be absorbed before a system changes its structure by **changing** the variables." Holling et al., 1995 "Local resiliency with regard to disasters means that a locale is able to **withstand** an extreme natural event without suffering devastating losses, damage, diminished productivity, or quality of life without a large amount of assistance from outside the community." Miletti, 1999 "the ability of a system to **withstand** stresses of environmental loading" Bruneau et al., 2003

Resilience as responding
"Resilience is a fundamental quality of individuals, groups and organisations, and systems as a whole to **respond** productively to significant change that disrupts the expected pattern of events without engaging in an extended period of regressive behaviour." Horne and Orr 1998, p. 31 "The ability to **respond** to singular or unique events." Kendra and Wachtendorf, 2003
Resilience as adapting / changing
"Resilience is the ability of an individual or organisation to expeditiously **design** and **implement** positive **adaptive** behaviours matched to the immediate situation, while **enduring** minimal stress." Mallak, 1998 "the capacity to **adapt** existing resources and skills to new situations and operating conditions." Comfort 1999, p. 21 "The term implies both the ability to **adjust** to normal or anticipated levels of stress and to **adapt** to sudden shocks and extraordinary demands." Bruneau et al., 2003 "The capacity of a system to **absorb** disturbance and **reorganize** while undergoing change so as to still retain essentially the same function, structure and feedbacks, and therefore identity, that is, the capacity to **change** in order to maintain the same identity." Folke et al., 2010

ABILITIES FOR TWO PHASES in the disaster cycle
"The **capacity** of the damaged ecosystem or community to **absorb** negative impacts and **recover** from these." Cardona, 2003 "The ability of an actor to **cope** with or **adapt** to hazard stress." Pelling, 2003 "The capacity of a system – be it a forest, city or economy – to **deal with change** and continue to **develop**; **withstanding** shocks and disturbances (such as climate change or financial crises) and using such events to **catalyze** renewal and innovation." Stockholm Resilience Center: Sustainability Science for Biosphere Stewardship: What is Resilience? 2014
ABILITIES FOR MULTIPLE PHASES in the disaster cycle
"Resilience describes an active process of self-righting, learned resourcefulness and growth— the ability to **function psychologically** at a level far greater than expected given the individual's capabilities and previous experiences." Paton, Smith and Violanti, 2000 "Ecosystem resilience is the capacity of an ecosystem to **tolerate** disturbance without collapsing into a qualitatively different state that is controlled by a different set of processes. A resilient ecosystem can **withstand** shocks and **rebuild** itself when necessary. Resilience in social systems has the added capacity of humans to **anticipate** and **plan** for the future." Resilience Alliance, 2005 "The capacity of a system, community or society potentially exposed to hazards to **adapt**, by **resisting** or **changing** in order to **reach** and **maintain** an acceptable level of **functioning** and **structure**. This is determined by the degree to which the social system is capable of **organising itself** to increase this capacity for **learning** from past disasters for better future protection and to **improve** risk reduction measures." UNISDR, 2005

"The ability of a system, community or society exposed to hazards to **resist, absorb, accommodate to** and **recover** from the effects of a hazard in a timely and efficient manner, including through the **preservation** and **restoration** of its essential basic structures and functions."

UNISDR 2009, p. 24

"The ability of assets, networks and systems to **anticipate, absorb, adapt** to and/or **rapidly recover** from a disruptive event."

Cabinet Office, 2011 p. 14

"The ability of countries, communities and house-holds to **manage** change, by **maintaining** or **transforming** living standards in the face of shocks or stresses – such as earthquakes, drought or violent conflict – without compromising their long-term prospects."

DFID, 2011 p. 6

"The ability of a system and its component parts to **anticipate, absorb, accommodate**, or **recover** from the effects of a hazardous event in a timely and efficient manner, including through ensuring the **preservation, restoration**, or **improvement** of its essential basic structures and functions."

IPCC, 2012 p. 563

"Resilience is the ability to **prepare** and **plan** for, **absorb, recover** from, and more successfully **adapt** to adverse events."

The National Academies, 2012 p. 1

One interesting finding in the definitions is that the terms ability and capacity are very often used, but never specified or differentiated. Another finding is that the definitions can be grouped into those mainly capturing abilities within one phase of the disaster cycle, within two or multiple. While this is not exact and liable to perspective, we have grouped them whether related to one phase, such as either 'stay and endure' (coping, withstanding) during the (immediate) disaster impact or, to the following phase where the system reacts and starts to recover from the impact (adapting, changing). This appears to be the most vital conceptual distinction, and can be conceptually located on a system path. In Fig. 1 we have named the first phase as 'resistance', which can be related to 'coping' and withstanding while under hazard stress. The second phase is named 'resilience' in Fig. 1 and relates to the recovery phase after the hazard stress decreases. Resilience is part of the whole process of adapting, but is only the phase to 'bounce back' while adapting can go longer. Usages of 'adapting' in definitions of resilience as well as using multiple abilities and capacities reflect the usage of resilience as a general feature or, encompassing transformation ability.

Looking for the core of resilience

Resilience and vulnerability share some important characteristics. None of them is absolute. Rather, a referent (human being/s/, infrastructure, economy, etc) is vulnerable to a certain hazard (in case of disasters) or other type of impacts. Likewise, resilience can only be visualized if the trigger is taken into context. Thus a system is not resilient per se, but resilient to something. Both vulnerability and resilience became "activated" once the referent is exposed to the particular hazard (trigger or impact). This duality of vulnerability, namely to be composed of a kind of hazard (or impact) independent predisposition which is termed "susceptibility" (for example, Davidson and Shah 1997, see also Fekete, 2010, Bogardi, Damm, Fekete, 2011) which through exposure manifests itself as hazard specific vulnerability may be extended also for resilience. It is argued that resilience should, at least predominantly, characterize reactive behavior (bouncing back to resume the pre-hazard state again, or bouncing forward into a different but 'desirable' state).

The terms 'elasticity' or/and 'flexibility' (in their broadest sense) are very much related to resilience, however might not indicate any direction of the reaction, hence serve as well for the bouncing back and bouncing forward understanding, but also the bouncing aside characteristics of a system under stress and reacting to it. Both flexibility as well as elasticity refer to a dynamic reactivity of a system under pressure that could also be coined 'springiness'. Springiness as a specific form of potential reactivity to any stressor by its inherent characteristic could be conceptualized as a hazard independent (core) feature. This split would enable to estimate the 'system elasticity' (flexibility) as the stressor (hazard) independent core property of the referent (people, infrastructure or socioecological systems) by using similar general characteristics as used for susceptibility assessment (Fekete, 2010, Damm, 2010). However, the term "elasticity" has different meaning in physics and in economics (https://www.merriam.webster.com/dictionary/elasticity). Therefore, in order to counteract potential definitional and terminological complications it is suggested resorting to the relatively seldom-used term 'springiness' to describe this inherent, 'stressor free' (core) feature of resilience. Thus the pre-event assessment of resilience could then focus on both on the springiness of the system and the exposure element as the one activating and co-determining the hazard (or stress) specific resilience.

Another aspect to be considered is whether resilience or, springiness, point to an active or passive characteristic. Going back once more to the literal (Latin) meaning of the word resilience, it does not reveal clearly whether it is an active or passive act. It also does not denominate whether resilience takes place before or after an impact. Resilience is often translated into 'bouncing'. However, thinking about real world examples when resilience can be observed, it seems that the conceptual thoughts in context to disasters often consider resilience to be a reaction of a system to a specific impact. Meaning, the impact pushes a referent into a reactive behavior. Even when the follow-up reaction of bouncing is then conducted by using internal capabilities, it is still motivated and, driven, by the external stressor. Bouncing back does bear some characteristics of a passive behavior. However, thinking about other real world examples for observing resilience it could also be translated into 'jumping back'. Jumping is much closer to direct translation of Latin 'salire'. An example for jumping back would be someone realizing a car approaching while already stepping on a road and jumping back in order not to be run over. This action however, takes place before the stressor hits but after the realization of the approaching disaster. This type of resilience is both reactive and preemptive, but still

dependent on the stressor. However, it is more proactive than bouncing back after the car hit the person. While this 'real world scenario' with its obvious and visible threat is not the ideal example to explain resilience in context to DRR, but there are interesting aspects about it. DRR aims at avoiding situations when it is necessary to rescue and save persons already hit or being wounded. Actions to achieve this however are nested along different time phases in a thought disaster development path. It is necessary to train rescue and emergency personnel way ahead of any accident. So while rescue or, resilience, can be seen as a process in a specific time phase when the stressor is about to hit or, already has hit, the abilities to be resilient, have to be created before the event, but will also develop during and after the event as well. While this seems to be a long explanation of only subtle nuances that are already known, we doubt that the full repercussions have been accounted for so far. Since it could help to dissolve the debates whether resilience is 'just' bouncing back or bouncing forward, whether it has preparedness character or is just reactive. These dilemmas are also often subject of disputes between social and technical oriented researchers. Our explanation may help to sort this out;
We propose to distinguish between and use different terms for:

- resilience: reaction after hazard impact
- presilience: reaction before hazard impact
- springiness: system's inherent, hazard independent core ability for resilience and presilience

Resilience in this understanding is the process of reaction, while springiness is the 'resilience ability' to enable this process. Presilience being the resilience-like reaction before the stressor hits. Springiness includes abilities that are created well in advance before any hazard strikes but also while and after an event. Springiness includes abilities to be ready to bounce back or bounce forward, maybe even to bounce sideward. Resilience however, is the process in the time phase after the impacting hazard or stressor effect, when the recovery phase begins until the system has achieved a state again mostly independent from the hazard event. That means, the system must not necessarily have regained the absolute level of functionality as before, or, have switched to a new state of existence. But it must be in a condition where the hazard event does not dominate the downward direction of impact anymore. Springiness however, being the ability for resilience, exists all the time, before, during and after the stressor event.
However, this does not imply that springiness of a referent may be constant. Springiness is naturally dependent of the life cycle of all kind of referents (people, infrastructure etc.), but it can also be enhanced by various means.

Box 1. Some thoughts about resilience of nations

Well beyond the realm of classical disaster management an intriguing question of resilience and how difficult to measure it could be the comparison of two Central European countries Poland and Hungary. Both are members of NATO (since 1999) and the European Union since the early 2000s thus being for the time being in fairly similar conditions and protection. Their history, while eminently intertwined and was characterized with historically always friendly relationships are completely different. Poland was divided for centuries among Russia, Prussia (Germany) and Austria. It was resurrected as independent state after the first World war (and then briefly swallowed again by Nazi Germany and the Soviet Union for a couple of years during World war II). Along these processes especially the Eastern and Western borders of Poland were frequently redrawn by its less than friendly neighbors. In the meanwhile, Hungary, irrespective of crushing defeats by the Mongol, Ottoman, Habsburg, Russian (and latest by Soviet) armies and medieval pressures from the Byzantine Empire could preserve a more than 1100 years long uninterrupted statehood, even if on varying and ultimately on strongly reduced geographical area. By surviving as state all of its then glorious imperial enemies tempted the British historian Bryan Cartledge to write his book under the title: The Will to Survive: A History of Hungary (2006). While countries usually define themselves by their victories (see Trafalgar Square in London and Place Fontenoy in Paris for example), Hungary reinvents itself from its defeats as summarized by Stephen Vizinczey in his roman (Vizinczey, 2010). But still, the question is difficult to answer whether the feature of the uninterrupted statehood makes Hungary more resilient, or, if the ability to maintain the spirit of a nation under division and foreign sovereignty and resurrecting itself, once the political constellations are favorable makes Poland ultimately more resilient?

By the token of characterizing resilience only by the metric of time needed to bounce back would give Hungary the lead as its resilience time requirement to regain statehood was zero. But losing independence and statehood may imply for Poland higher historical vulnerability (having been exposed directly to the main thrust of Prussian and Russian expansions) than that of Hungary, rather than worse resilience. From the two, historically comparable medieval countries in size and population the 20th century made odd partners. When both joined the European Union in 2004 Poland, being by size and population about three times larger than Hungary certainly represented more weight and political influence than the smaller Hungary. Thus in the sense of 'long term' resilience (interpreted as the recovery of its previous importance in European context) Poland could be seen ahead of Hungary.

Could the suggested concept of the hazard independent core of resilience (springiness) be applied for Poland and Hungary? Finding a comprehensive answer to this question by an analytical approach would need first and foremost in-depth research and scientific consensus on 'springiness' and on how to measure it. Then the respective components and suggested indicators are to be assessed and compared for the two countries. This exercise is well beyond the limits of the present essay.

This hypothesis is to be proven by comparative research studies of political science, econometrics, educational and cultural levels, religious studies and history.

Conclusions

No doubt that irrespective of critical warning words (Alexander, 2013, Weichselgartner and Kelman, 2015 and others) the metamorphosis of the original Latin expression for 'bouncing back' towards an all-encompassing umbrella term for many positive features and processes counteracting system collapse and disturbances is still going strong. Intergovernmentally acknowledged and internationally used, the term 'resilience' is likely to gain further momentum. Regretfully, the more it is used, the less it might be understood. Thus ringing the bells for the requiem of an interdisciplinary buzzword could be as of 2017 a premature gesture. As of a quantitative, practically useful and crisply defined resilience is concerned mourning cannot be ruled out (Sword-Daniels, 2017) unless much intellectual effort and consensus thinking is invested towards its resurrection. With its focus on the recovery process resilience studies could provide the much-needed contributions and extensions to the trigger and disturbance (collapse) oriented hazard, vulnerability and risk studies. Towards this renaissance this essay proposes to explore the dual nature of resilience; hazard- independent or hazard-and-system-process-bound. By considering a hazard-independent core part (springiness), general features of resilience could be assessed for different systems. This essay argues to confine the use of the term resilience to 'bouncing back' processes within the broader context of recovery phases. Resilience of course may occur simultaneously at different time scales (fast and long-term recoveries etc.) and in different fields (dimensions by the terminology of Bruneau et al., 2003). This essay introduces the pre-emptive form of resilience, avoiding an impact by 'bouncing forward' before it hits, as 'presilience'. Certainly further conceptual elaboration needed.

For meaningful quantification resilience metrics should rather focus one by one on these different resilience trajectories than amalgamating them in an amorphous (and ill-defined) all-encompassing resilience measure. Hence it is likely that several resiliencies have to be acknowledged and need to be monitored parallel to each other. These distinct resiliencies may be set into motion by the exposure of the referent to certain sort and level of hazard impacts. By looking at resilience through this lens then the need for focused research is obvious. It seems however, that serious resilience research should urgently emancipate itself from the ongoing 'buzzword generation'.

What have we gained by this academic exercise? We have lamented the plethora of resilience definitions – as had numerous others already done before. However, most still agree with the mainstream by adding more and more clothes to 'resilience as the emperor'. While still most are confused and busy with understanding the growing conceptual fuzziness around resilience, no one dares admitting that the emperor is rather naked. It is unlikely that Béné et al., 2012 used the term "new tyranny" incidentally in the title of their critical analysis. We also do not agree with the seeming acceptance or even praise of the multitude of definitions. We try to swim against the current and dare arguing for requiescence, and a stricter restriction and reduction of the term. This might be less fashionable than dressing in more and more clothes, but in our experience in trying to operationalize the complex term, we find the need for definitional rigor. Less is more here, especially, since so many overlapping terms already exist, in methodology and as criteria, and the real question that remains is: what does a 'diluted' resilience offer as a criterion that has not already been covered by other metrics?

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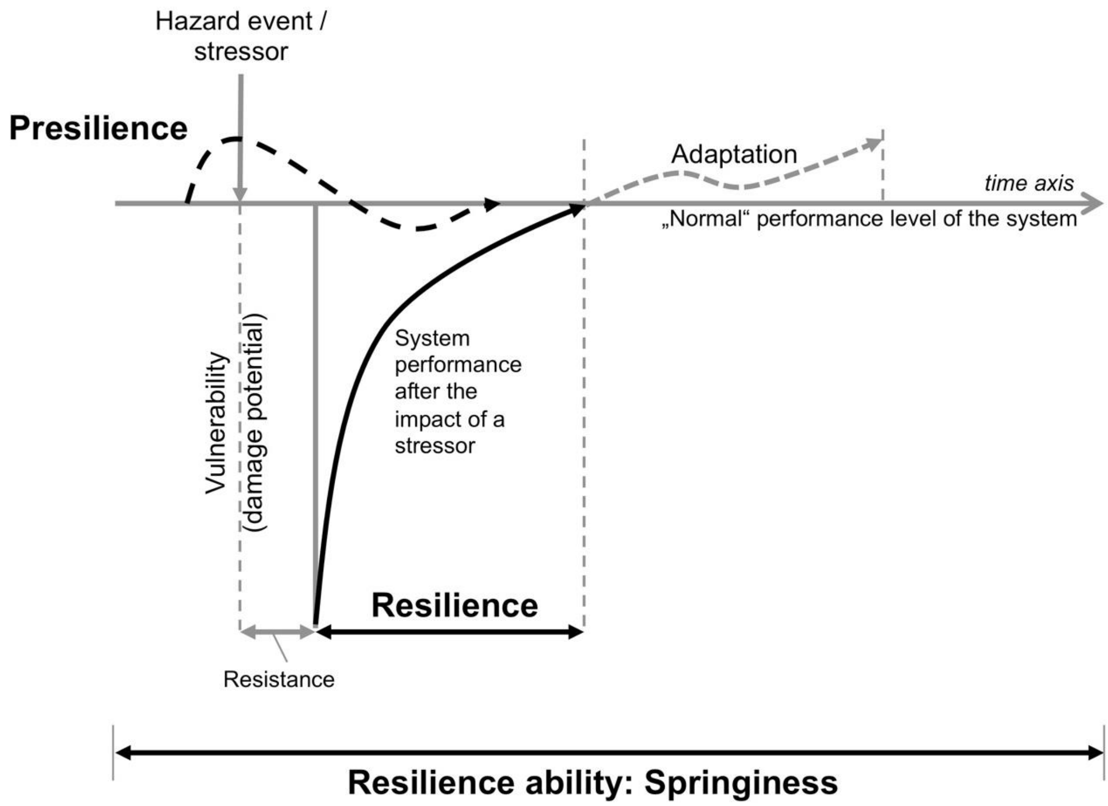

Fig. 1. Visualization of the concept of resilience, the pre-emptive form of 'presilience' and the general ability for resilience termed 'springiness'

Comment

Essay 4 is a piece of real essay character where, let us put it bluntly, frustration about a cacophony of usages of the term resilience were expressed by the first author, and the second author struggled to keep it at bay. We feel it is important to express not only concerns about a proliferation of application of a term losing its original meaning and usage. We also sense that many researchers often share concerns about unclear usages and a hype-character of terms such as resilience, but after at least a decade of intense debates, are also often tired of it and pragmatically adopt, adapt and adhere to the funding logic following the bandwagon of buzzwords. Even more, we found it challenging trying to express an opinion that runs contrary to a certain mainstream. Resilience is loudly acclaimed to must contain components X, Y and Z by quite a growing number of people, academics and practitioners. It is standard procedure in academic debate to promote views and defend them strongly, also, to find common definitions. However, it is worrisome, when it becomes the character of forcing others to believe and follow suit. This is the case, when trying to influence others also in forbidding usages of certain interpretations or even wordings. Essay 4 therefore provides a counter standpoint that may be provocative, especially to those rejecting simplistic reduction of resilience to its literal translation; to bounce back. While we sympathise, that dealing with risk demands more than just bouncing back behaviour, we challenge that this necessarily must be covered by the term resilience. Of course, transformation, adaptation, community preparedness, oversight etc. etc. are all important topics in dealing with risk. But when trying to separate vulnerability and resilience and their components, we found that it may make sense to keep resilience at its verbatim definition, to bounce back, recover or similar. The definition and description of resilience expressed in essay 4 and in our other publications from 2018 therefore is a clarification and also makes a suggestion for moderating and integrating those differing viewpoints. But we also wish to remind of another old academic tradition; that papers are expressions of a standpoint, not necessarily the person. This is known by attacking not *ad hominem*, but respecting each paper as an expression of a line of argumentation. And not mistaking that a single paper by an author is actually what that author would always be arguing.

What comes next after Resilience? Reflections about a trend phenomenon and its perceptions by experts

Alexander Fekete, Celia Norf

Abstract

This paper explores a set of reasons why resilience has become a trend phenomenon across a wide range of scientific disciplines and practical applications, especially within disaster risk and security related areas. It also looks into aspects that may have supported the spread and rise of resilience in some research areas, but also into reasons that might explain a certain scientific saturation and hiatus of a concept. This article does not intend to suggest a dawn or replacement of resilience. But it argues that it is necessary to reflect the extensively use of the resilience concept that is widely used in academia as well as within international agendas such as the 2015 adopted Sendai Framework for Disaster Risk Reduction.

Based on a small expert survey conducted in 2011 and repeated in 2013, opinions on the question what might come next after resilience were collected. In 2011, most experts in the area of disaster-related risk research responded that first of all resilience needs to be further analysed and brought to application, before a follow-up concept could be conceived. However, some guesses about future follow-ups captured concepts already existing such as sustainability or 'hardening'. To compose this article, in 2018 the same experts have been asked again about changes in their perceptions of 2011 and 2013. Moreover, for this article, a further number of experts have been involved in order to gather responses on the question: what comes next after resilience.

Background – motivation for this article

The rise of resilience is remarkable regarding its widespread impact in many fields associated with risk and security. For instance, the United Nations Office for Disaster Risk Reduction (formerly, UN International Strategy for Disaster Reduction, UNISDR) is a strong promoter of the term resilience, for instance, within the Sendai Framework for Disaster Risk Reduction (SFDRR) 2015-2030or the "Making Cities Resilient" campaign 2009-2013. Also a great number of other UN agencies, but also other international platforms are utilising the terminology of resilience. In science and academia, the trend phenomenon of resilience has been cautiously observed (Prior and Hagmann 2014), regarding its replacement of older, similar concepts such as vulnerability (Cutter et al. 2008), but also, seen continuous usage (see Figure 1). While resilience continues spreading across scientific disciplines, within a range of disaster risk and security-related studies, it is important to track its rise, and identify also first traces of downtrends, when occurring.

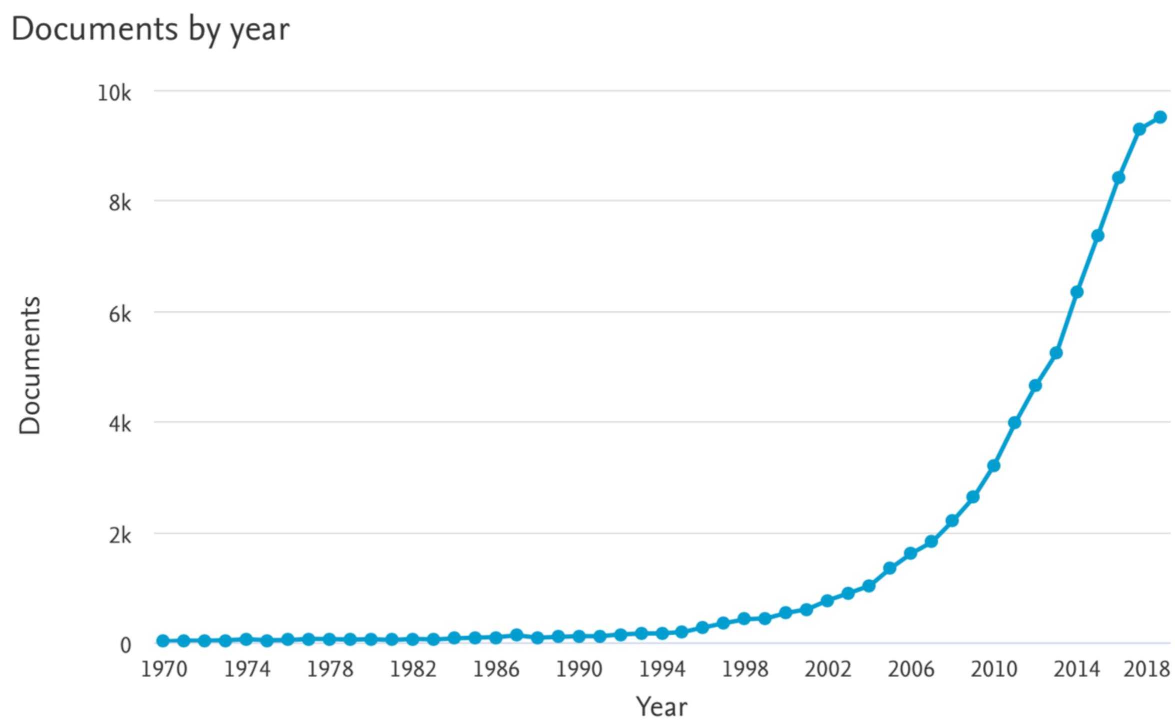

Fig. 1 Scopus on 74.970 documents (all types, over 48k are articles) on the term "Resilience", accessed 20. Nov. 2018

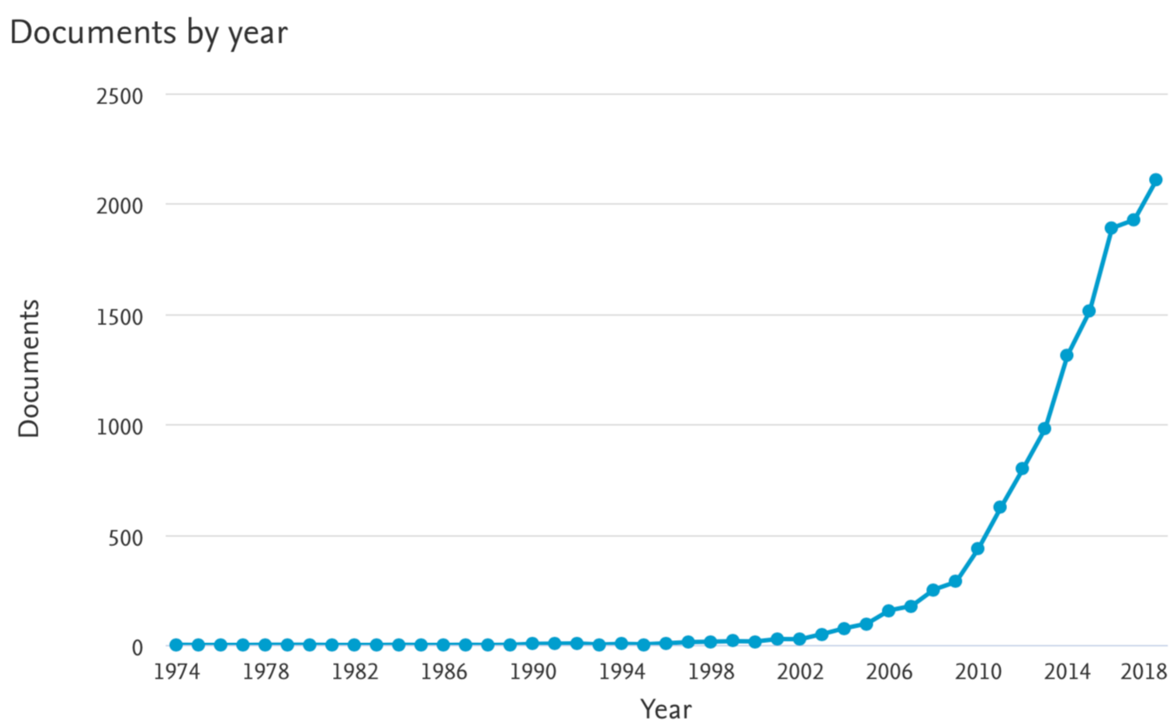

Fig. 2 Scopus on 12.842 documents (all types, over 8k are articles) on the term "Resilience AND Disaster", accessed 20. Nov. 2018

Not just in science, but also within the private sector, resilience has widely been adopted. As just one example, the term resilient cities has been adopted by the Rockefeller Foundation as well as by Siemens company and bodies of public administration, especially of native English-speaking countries have often used the term resilience in strategies or plans related to contingency or risk topics. Moreover, popular culture, beginning with science-journalism (Zolli and Healy 2012) but then also in the form of guide-books for coping with stress and lifestyle advice, resilience has been booming.

While numerous articles have been written about the rise of resilience, and the advantages of a new, positive and encompassing, holistic concept, less has been written about the caveats related with such a trend, except for (seemingly) endless academic terminology definition debates or demands to finally bring it to practice. Some authors actually are considering whether the terminological vagueness can be a positive asset of resilience as a concept by fostering creativity rather than precision (Strunz 2012). We, the authors ourselves have partly been part of this, both working on and with defining, clarifying, attempting to apply and, also a bit less, trying to criticise shortcomings of resilience. However, to self-reflect the consequences of adopting a concept and surplus achievements of utilising it versus not using it, should be a major part of scientific work. But also to reflect on what is uncovered, side-lined by it or which concept could simply be better than resilience is part of our work This article will addresses these concerns and reflect; what characteristics made resilience a trend – which in turn could also help to explain a possible hiatus or even end of its lifespan as a rising trend. And while such considerations should not be crystal-ball speculations, especially when it is still way too early to declare the concept of resilience in disaster risk expired, this article still dares to ask which concepts, or at least, components and demands of concepts following resilience could be extrapolated from today's limited information.

This article's motivation not only stems from a curiosity working with a concept that is holistic but hard to capture, but also from the question how much of conceptual and deductive research designs are subject to trend phenomena. It is hypothesised that addressing and analysing trend phenomena characteristics while utilising such terms and concepts could help to enhance scientific results as the boundary conditions for the analytic framework and 'lens' of the researcher are elicited and documented (Fekete 2012).

Approach of this article

In this article, expert knowledge is gathered by two opinion surveys in 2011 and 2013, conducted by the lead author. 14 experts from the fields of disaster risk reduction, risk in general, social-ecological systems, civil protection and development have been asked a single line question by personal address via email and asked to respond by email. In 2011 the question was "What is the next big issue after resilience?", and in 2013 the same experts were asked "What is the next big issue after resilience - new perspectives?". Those experts are personally known to the lead author through meetings at conferences, workshops or similar ways of academic cooperation or exchange (see table in annex). The replies quotes are provided without direct name reference, in order to focus on the content and not on who said what.

The replies quoted in this article are modified only when obvious spelling errors have been corrected. Replies in German language have been translated by the lead author.

For the recent perspective, the experts have been asked to contribute directly to writing this article.

The following sections will first separate the replies from 2011 and 2013 into sections related to certain common aspects raised in the replies. Interpretations from recent perspectives were added by some of the authors in 2019. After that, a chapter on Components of the next paradigm follows, which is based on two questions to all experts from 2011, 2013 and co-authors of this paper.

A discussion chapter then looks into key aspects for interpreting resilience as a trend and identifying its future pathways and the article is finalised by a conclusion, that cannot be understood as a conclusion to the debate on resilience or what comes next in general.

Understanding the existing paradigm in 2011-2013

“First and foremost, I think we have a long way to journey with Resilience before we move past it.” (A2, Jan. 2011)

„In my view it seems more important not to replace the existing approaches and concepts in more or less regular intervals by a new „buzzword“ or hype, but to focus on those contents, that allow for a concise methodological and (preferably) quantitative evaluation.” (A3, Jan. 2011)

“In certain natural-science driven research, the concept of resilience hardly touched ground. Still busy with solving the ‘vulnerability’ conundrum, and much work ado, one should “just do the job properly, before one rushes on to the next one .... in other words: SLOW SCIENCE”. [translated from German] (A4, Jan. 2011)

“ Very interesting question since we at the moment have the discussion (…) if we should use word and concept "resilience" in our strategy for societal functions (critical infrastructure) instead of "protection". A lot of people said: no, do not introduce something new again in crisis management!” (A5, Jan. 2011)

“Yes it is interesting how many of these concepts have been around for some time but then suddenly become ‘flavour of the month’ so to speak.”
“With regards to the term resilience, and perhaps other terms, it seems that it is the context that changes or rather that people realise that certain concepts can be applied in different situations e.g. applying resilience to socio-economic systems as well as ecological ones.”
“I think that resilience is going to be around for some time yet as different groups and stakeholders work out what it means for them and how to address it.” (A11, Jan. 2011)

“(…) I see resilience or interdependencies not as isolated components, but rather as integral elements within the topic of critical infrastructures. In my opinion, the methodological sophistication is still wanting, since there are many interesting approaches in resilience from biology or economics, which still would have to be transferred to technical systems and technologies in adequate and quantifiable ways. For this I would wish for advancement in methodology first, before the next hype starts.” [translated from German] (A3, Jan. 2011)

„I do not think there will be a ‚next big thing'. Hopefully, it will be recognised that everyone actually means a similar issue, which will finally be put under one umbrella." [translated from German] (A7, Jan. 2011)

„I do not think there will be a ‚next big thing' in the sense of a larger paradigm shift. What I hope is that the different concepts and terms can be related to each other, so that a complete and clearer picture on the pre-conditions of risk and impacts can evolve under a common umbrella."
I think my statement from two years ago has some validity. What I recently observed, is the consolidation of terms and approaches between the DRR and CCA communities. I think such progress helps the research and policy community a lot. I do not oppose the resilience concept, I think it has interesting concepts to integrate (such as the role of transformation etc), however, I guess it is often used nowadays as a 'label', as it offers a more positive view. So probably people prefer these days to look at the positive side than always on the negative-vulnerability one. (A7, Apr. 2013)

„I am also still convinced that resilience is the better concept or at least notion for promoting and achieving risk reduction aiming at higher levels of safety for people, assets, societies, ecologies, etc. It is better as compared to notions like risk reduction or vulnerability as it is a positive goal, includes the process of recovery and goes thus beyond the definition of just thresholds for security. As process it is obviously – even to the hard-core engineer – related to societal issues, social, economic and ecologic boundary conditions and processes. However, I would distinguish between resilience concepts and the societal, social, legal, economic and ecologic boundary conditions and processes within which one can improve resilience. Resilience concepts should refer to specific targets (a community, a socio-technical system, system of systems, etc.) in order to keep it measurable. Measurability does not only mean 'indicators' but also the experience of the people involved. If they don't see or feel progress, if they don't take ownership, the sustainability of resilience enhancements remains questionable." (A13, June 2019)

Characteristics and components of resilience in 2011-2013

"(…) It is a good idea to something unconventional. We are living at a time when new thinking has become critical. Given the increasing unsustainablity of the global system, (ecological, economic and social) resilience as a concept would also become less and less relevant and useful unless the global system itself is drastically transformed. But the world leaders are in no mood to think of alternatives but make every effort to maintain the present system. So, the question is whether we are prepared to live differently in order to create an alternative global system. This is unlikely to come from the top but will have depend on the pressures from below. Given the high degree of present global connectivity, it is possible to launch a global public discourse to see whether people are prepared to change the way people live, work and enjoy. This is certainly not a short response but an attempt to articulate the present predicament." (A6, Jan. 2011)

"I'm still grappling with the concept of resilience but I tend increasingly to narrow it down to the notion of threshold in social-ecological systems - I thus tend less and less to try to link it with the broader concept of vulnerability but use the latter to provide some elements linked to livelihoods which can then serve as variables to track in terms of their thresholds. So how is this relevant to your question? Well, as you very well know, we all talk of thresholds and are very poor at actually quantifying them. Thus I believe that resilience, in this narrow definition that I am interested in, is here to stay for a while. Indeed, determining thresholds which are not static in time and place will give us (me) plenty of headaches in the future." (A9, Jan. 2011)

"Believe it or not. I have come back to using the word resilience since all the alternatives are even worse. So I just finished a book manuscript in which resilience is given equal weight to efficiency, effectiveness, security and fairness. So we sometimes make 180degree returns." (A10, Mar. 2013)
„(...) we need to continue with the term resilience and not change our concepts too often." (A10, Mar. 2013)

In essence, I see societal resilience as similar by analogy to resilience in mechanics. In the latter, a resilient material has strength and ductility. Society by analogy needs resistance and adaptability. (A1, Apr. 2013)

„In a nutshell, I think that resilience is still an issue and topic that is of interest and will continue to be for some time (as I suggested last time). Certainly here in the UK resilience is still a term that the government uses and a state that it spires to for

communities in relation to flooding. In fact, we have just been invited to tender for a Defra project on assessing a pilot scheme to help communities become more resilient to flood risk. Whether the attention is 'hype' I'm not sure – some probably is. (A11, Apr. 2013)

„The resilience perspective emerged from ecology in the 1970s, based on the seminal work by Holling. In recent years, the aspects of resilience and interdependencies have become key components within the areas of energy security and critical infrastructure protection. Despite the various conceptual resilience frameworks developed, the level of methodological sophistication is still not fully satisfactory to allow for an objective, (preferably) quantitative, and holistic evaluation of energy security or other complex socio-technological applications. Therefore, further advancements in analytical methods and operationalization of the concept is required before the next "hype" starts." (A3, Apr. 2013)

Table 1 summarizes the extracts from the expert replies as how they are related to describing components of resilience. Resilience characteristics as derived from expert replies

2011, 2013
Governance
Interdependencies
Transformation
Narrow it down to the threshold in social-ecological systems
Resilience is given equal weight to existing concepts like efficiency, effectiveness, security and fairness
Resilience is linked to sustainability
Resilience is linked to the need and readiness for change
Resilience as a strategy to keep up with "political" hype (see A11)

"I am quite surprised that the term economic and/or industrial development does not appear. This may be related to the fact that in western countries the view on disasters was and probably is driven to a large extent by humanitarian views. This may not apply to the World Bank and regional development banks, but otherwise yes. Risk

reduction concepts (against technical and health hazards) in Europe and North America developed primarily with industrialization (the famous steam boiler explosions in the 19th century) and the growth of cities.

However, it would be too simple to say (and the DRR community wouldn't like to hear it) that all we need is economic progress in the poorer countries and similar to poverty risk would be reduced almost automatically by economic growth. But to what extent is the economic boundary condition relevant? My personal view on the relation is that a country needs a certain level of development in economic terms, with regard to human resources, societal coherence (in whatever way this is achieved) but DRR may not happen in reality before an adverse event generates enough awareness for action. I believe, but cannot prove it, that the Tangshan earthquake 1976 hit China, when it didn't have the capacity to change course, apart from the political turmoil in 1976. The Wenchuan earthquake 2008 came when the country had a lot more capacity and thereafter DRR became an integral part of policy. So, it may be a combination of economic capacity and tipping points provided by disasters that effectively changes course." (A13, June 2019)

Terms following or complementing resilience

"My feeling is that resilience is going to be a part of a larger governance issue of how to address, assess, handle, communicate and manage risks. We are working on such a more holistic framework in which resilience based management is one but important component. Yet there is more to explore." (A10, Jan. 2011)

"I think attention needs to be given to linking resilience with Information Assurance and robust security policies. Possibly through an integrated partnership (eg public and private sectors). Also, of interest is resilient communities and this suggests that employment and health care are given more attention. Possibly sustainability is key." (A12, Jan. 2011)

"The next big thing after resilience is hardening." (A1, Jan. 2011).

"PS: If that isn't good enough, sustainability is an emerging big issue:
- how to make disaster risk reduction sustainable so that it doesn't backslide or dwindle away
- how to integrate DRR with sustainable consumption and development." (A1, Jan. 2011)

" I really do not now what the next big issue will be. I think that it will depend on what the next big disaster will be." (A5, Jan. 2011)

"I hope that it will be even more holistic, because it is what it takes if we want to continue to have a good life on this planet. I also hope that it will be more focused on people and that we will realize that the systems we have built are not given by nature. We have a choice and depending on how we choose the consequences will be different." (A5, Jan. 2011)

„I provided you with a very short answer two years ago but I still think that it contains somehow the essential points. Obviously the expectation that natural disasters will be rather covered by the security issue is what is going to happen on the European funding level. My understanding is that in Horizon 2020 there will be no separate funding scheme for natural disaster mitigation.
It will be rather included in the security component and/or the climate change topic." (A13, Apr. 2013)

"I would expand to a certain extent on what I said two years ago by stressing that we also should try to develop a positive economic perspective for disaster mitigation issues. Currently many efforts are aiming at the proof that an investment in disaster reduction now would save you a certain amount of Euros or Dollars in the future so that this type of investment could be considered as a profitable one. This is one very important thing, however, it might be even better to mainstream disaster reduction into economic development by providing more positive aspects that are associated with it such as creating new jobs, creating new job fields like safety and security managers, providing attractiveness to areas with a high level of protection for tourism business and others." (A13, Apr. 2013)

„At the world scale, I believe human rights are the key to DRR. Poor human rights restrict access to knowledge, expertise and the means of making life safer. In countries where conflict reigns, stabilisation needs to be followed by a strongly linked combination of humanitarian and development intervention, with the aim of ensuring the primacy of local empowerment. (A1, Apr. 2013)

Integration of the sustainability of DRR and resilience initiatives into the general sustainability (so that both life and DRR are sustainable) is important – especially so in a world that is consuming five times more resources than it discovers or produces. (A1, Apr. 2013)

“With regard to your question I believe the upcoming topic will be: security, alternatively you can call it safety. This would turn the negative notion of disaster or disaster impact into a positive one. To large extents we look at natural and technological disasters from the point of view of the event and its subsequent influences, which in the end, reach the 'victims'. From this perspective we have to call it disaster. Another view is to look at these items from the perspective of the vulnerable people or objects and stress the needs of protecting them, providing security, etc.“ (A13, Jan. 2011)

Other people are still talking about vulnerability when most of us are bored with it nowadays. Adaptation is also a key term that is still promoted a lot from what I see, certainly here in the UK and also as far as our current EC and wider projects in Asia are concerned. The other term that we hear a lot of talk about these days – another buzz word - is ‘governance’ (specifically good governance – however that is defined!) – and it seems that (as with resilience) not everyone knows what it means, uses it in the same way or again agrees on the definition.“(A11, Apr. 2013)

„Responsibility, Sustainability (haha), Social Capacity Building” (A8, Jan. 2011)

“I will need to give some thought to your question to answer it properly, but I notice that the idea of human security (or even just security) is gaining ground amongst people who work in relief and development agencies so perhaps this is the next thing? I am teaching a new module on resilience this term - a difficult assignment, as it has so many different meanings and interpretations. (A14, Jan. 2011)

Table 2. Terms or characteristics mentioned to follow or add to resilience

Single terms
Adaptation Hardening Responsibility Safety Security (also: human security) Social capacity building Sustainability

Table 3. Future components mentioned by the experts (2011,2013)

Single terms	**Comments or phrases**
Hazards Human rights Impacts	• *Integrate DRR with sustainable consumption and development* • *Linking resilience with Information Assurance and robust security policies* • *Make disaster risk reduction sustainable* • *Dependence on the next big disaster* • *More focused on people* • *Be even more holistic*

The phrases are all highly relevant but to a large extent they represent research topics. For instance, the role of human rights may be considered important. However, meanwhile we face a societal model (China) where human rights are not a priority yet, but resilience enhancements have occurred in the past two decades. I would rather pose the question: To what extent and under what circumstances are human rights more or less important? (A13, June 2019)

Components of the next paradigm

"The difficulty lies, not in the new ideas, but in escaping from the old ones, which ramify, for those brought up as most of us have been, into every corner of our minds."

John Maynard Keynes

Which components could the next paradigm or concept after resilience

a) continue
b) add or replace?

"I assume that most terms such as

- *Adaptation to changing ecological conditions*
- *Responsibility/ accountability*
- *Safety/ security*
- *Social capacity building/sustainability*

have to be components of any future concept.

What may play a much larger role could be

- *Self-organized processes (via social media); the informal processes are often ignored as it is easier to deal with institutions*
- *Large private investment and action: Several firms of foundations have much more power than many states*
- *Competition for the better concepts (Chinese vs. western model in developing countries)"*

(A13, June 2019)

ANNEX

Information about the anonymous experts

A1: University, UK

A2: Consulting business, NZ

A3: Research institute, Switzerland

A4: University, Austria

A5: Public service, Sweden

A6: University, Sri Lanka

A7: University, Austria

A8: Research institute, Germany

A9: Research institute, UN

A10: Research institute, Germany

A11: University, UK

A12: University, UK

A13: University, Germany

A14: Development institute, UK

Additional replies

> *"My impression from what is going on in the UK is that the engineers and physical scientists will always be focusing on the hazards and how to predict and mitigate for them. For policy makers and social scientists there is going to be more focus on the impact and mitigating impacts as well as building future resilience, and importantly working out how to get people to adapt their behaviour – again the concept of adaptation being applied to human behaviour and systems rather than just ecological/physical ones. So learning to live with natural hazards, and helping people do this by promoting effective action (and working out what IS effective action), is something that will be a focus for some time I think. Certainly here the emphasis is on the local scale, local communities and bottom up approaches – particularly since our new government introduced its polity of 'localism' – which is still being worked out! But I get the impression that this situation is similar in other parts of Europe/the world.*
> *Just to clarify a point I made! When I said that the engineers and physical scientists will always be focusing on the hazards and how to predict and mitigate for them I did not mean that they are not adopting new ideas and approaches – they are also using terms such as resilience and vulnerability, and also increasingly prepared to work with social scientists to seek solutions, and indeed realise and accept (some of them still with some scepticism) that they must do this. What I meant was that their training and expertise inevitably focuses them on the hazards/structural/physical aspects. There is also a focus on capabilities here and building capacity but not just focusing on reactive measures but also proactive ones." (A11, Jan. 2011)*

Major issue: the world is becoming more and more unequal. This strongly militates against DRR. The trend needs to be reversed. The drug trade, armaments trading and the exploitation and trafficking of people (including forced migration) make up an important part of the world economy and need to be brought under control. Climate change adaptation will continue to merge with DRR, understood as the management of (climatic) extremes.

Most of the theory in disaster studies dates from the period 1945-69. We need up-to-date theory that is as dynamic as society is in the early 21st century.

There is a major, major problem with the humanitarian sector. Humanitarianism is deeply in crisis. In many recent cases, post-disaster and post-conflict interventions have worsened situations rather than ameliorated them. See the books of Linda Polman for graphic descriptions. Humanitarianism is now so far from the ideals of neutrality elaborated at the founding of the Red Cross in 1859 that it needs to be completely redefined." (A1, Apr. 2013)

Crises propelling into disasters – trajectories of resilience

Christchurch earthquake [comment by Fekete: this refers to the earthquake before Feb 2011]:

"The initial quake was stronger than Haiti, but no lives were lost; bit of luck in when the quake occurred before the central business district was active. But the real issue that mitigated against both loss of life and loss of property asset was a strong building code enforced by a system that has very low corruption on a global scale.

Without doubt a tipping point was reached for people in Haiti where the devastation and loss of life engendered a social mood of "despair", whereas this tipping point was not reached in Christchurch. Was there fear - absolutely; was their despair - you had better believe it. But not on a scale that reached a "tipping point" that propelled the city into a social mood of despair, with all the consequential outcomes to that mood." (A2, Jan. 2011)

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Comment

Essay 5 is a collection of responses of colleagues to a question poll on what could evolve as a follow-up concept to resilience in January 2011. The poll came into being as an alternative to the then common Christmas and New Year emails, out of curiosity. The responses were enlightening, sometimes witty, and not intended to be published. However, the question on whether resilience would be a mere trend phenomenon persisted and the poll was repeated two years later in 2013. Interestingly, resilience continues being a growing trend phenomenon and to this day, decreases are visible only in few disciplines, overall, it is rising (we are busy on this in other publication drafts). Any efforts in developing it to an essay have failed so far and the richness of information actually is contained in the responses of the researchers, so we decided to leave it, raw as it is.

Ex-post resilience assessment of Critical Infrastructure and society impairment of mid-sized cities by a maximum destruction event in WWII

Alexander Fekete

Introduction and scope

An inherent problem of many natural hazards studies is lack of longitudinal data. This case study may help to inform readers about how other hazard types such as wars permit data mining and analysis to advance the understanding of resilience measurements. This study aims at uniting general risk analysis methodology, man-made and natural crises and urbanity research. German cities and war destruction are in a long line of research (Hewitt 1993; Hohn 1991a; Brakman et al. 2004), yet this study aims at utilising destruction as well as recovery data ex-post for the advancement of current risk analysis methodology, notably, of urban resilience indicators. Infrastructure such as energy or water supply is vital for urban populations. The concept of resilience is being increasingly applied to assess vital functions in disaster risk research. However, quantitative assessments of losses and recovery are often not available due to rarity of certain disaster events and paucity of data especially for critical infrastructure in an urban context. In this chapter, data sources and specifically quantitative information on World War II losses of infrastructure and the impact on the population are processed and structured based on secondary data such as city archive statistics and city council entries during and after the war. Exemplified for the cities of Schweinfurt and Würzburg in Germany, the years before, during and after the war (1930-1950s) are covered as a time period in order to generate measures for identification of key resilience components – impact depth and number of losses, recovery speed and persistence of a city based on the resilience of its critical urban infrastructure. This chapter specifically investigates effects of World War II (WWII) as how they can serve as an example to identify data for measuring resilience in the first step in order to improve resilience of society towards disaster impacts in later steps.

This chapter provides disaster risk researchers and urban planners as well, measurement categories and examples of benchmarks of historical disaster resilience.

While this study also wants to contribute to pre-disaster conception of disaster preparedness, this study rather focuses on a real-case opportunity for observation of recovery from a major disastrous impact – World War II. Given the range of hazards thinkable in an all-hazards approach, war is certainly one of the deadliest hazards. It is a human-made, intelligently and deliberately planned form of mass-destruction. It differs therefore from natural hazards that often strike unexpectedly but also often hit certain hot-spots while sparing other areas. While critical infrastructures such as bridges and railways had been hit in the weeks and months before, the attacks during the end of the war deliberately sought human settlements (Hohn 1991a). The bombings of German cities were a reaction to the bombings of the Hitler regime during WWII of cities like London and attempts at "erasing" cities in Poland, for instance. Warsaw lost 80% of its built environment, and Danzig up to 90% (Skowronska et al. 2012). Therefore, WWII and the relation to the destruction of cities makes it very suitable for an analysis of maximum destruction of and concurrent questions of resilience.

For the purpose of this study it is important to note the nature of war as a hazard in order to delineate this case study and its transferability to other (especially natural) hazards.

There already exists a wealth of studies on risk to be composed not only of the hazard but also on the vulnerability and resilience of the system impacted by the hazard (Blaikie et al. 1994; Wisner 1993). Especially within natural hazards research, the researcher speaks of a paradigm shift from a hazard-centred view until the 1990s and a probability and damage extent risk formula to a focus including the sensitivity, exposure and coping capacities of a system – termed vulnerability (Adger 2006). Coming from this perspective and experience, this study approached the field of war as one of the most extreme forms of hazards. In WWII literature it was found that a majority focuses in hindsight on the history of how the war unfolded, on the procedures of the attacks and counter-attacks and on the losses of population. Comparing with the natural hazards, this is similar to hazard- and damage-centred analyses. Interestingly, also a paper by Hewitt (1993) whose earlier work is often cited to be part of the paradigm shift in the 1970s from a hazard to a vulnerability perspective, equally elaborates on the air raids and damages in total numbers. Detailed analysis of the vulnerability composition is provided concerning women and children deaths and reasons behind the death tolls such as evacuations (Hewitt 1993). In his work the cities of Würzburg and Schweinfurt are listed in the building damage categories, with Würzburg also among death tolls. Like the work of Hewitt, but in much more detail, Hohn (1991) analyses the distribution of deaths and building damage degrees per cities in Germany. There is also literature on reconstruction and urban planning after the war (Nipper et al. 1994).

Concept

This is an explorative study that investigates data sources dating back to the time of WWII according to their usefulness for comparison of several cities and their destruction and recovery for time lengths of decades in order to capture major impacts and changes upon society. The underlying intention is to identify more explicit vulnerability and resilience indicators than those hitherto developed by the author which were more based on a hypothetical pre-event perspective than on retrospective real impact measurements.

Data mining and handling of Critical Infrastructure (CI) is severely hampered by data sensitivity and security concerns of operators or national security agencies. The case studies presented in this volume will therefore investigate old data from WWII in order to avoid revealing recent vulnerabilities that could be exploited by saboteurs or terrorists.

The chapter will collect and aggregate secondary statistical data and qualitative descriptions of destructions and recoveries after WWII. It will identify data from city archives which are not easily accessible, especially for non-native speakers and residents.

This data will be analysed in the sense of examination of the usefulness for developing benchmarks of resilience in order to further utilise it for comparisons of cities regarding war impacts but also concerning other types of natural hazards such as floods, cyclones and earthquakes, economic and climatic decline, political and strategic swings and else.

At a broader level, the aim of this study is to contribute to the current research in the field of disaster risk science by identifying suitable criteria and data for measuring the urban resilience. Criteria and measurements are undertaken for the most extreme forms of recorded destruction, in order to gain knowledge for recovery.

Research questions

The main research question of this essay is: What role do infrastructure and their criticality play in the ability to derive information about a city's resilience?

Research sub-questions derived from this are:

- What can be learned from past events such as WWII about the different conceptual phases covered by disaster risk and disaster resilience – a) hazard-attraction b) loss and decline c) recovery d) persistence and transformation?
- How can this information be used to establish indicators for resilience assessments of a city or settlement?
- Are indicators like impact depth, recovery speed and quality useful benchmarks for setting boundaries to allow later comparisons with other events?
- Is infrastructure in all its forms mainly a factor advancing or delimiting city evolution?
- Is infrastructure criticality mainly a factor advancing or delimiting city survival?

Known limitations of this approach

However, this chapter will not manage to address all of this in full detail, but will exemplify the usability of critical infrastructure information on selected World War II affected cities in Germany. It will focus on two middle-size cities with different societal and economic characteristics – Würzburg (also found as Wuerzburg in English literature) and Schweinfurt. This study will help to advance the field of resilience measurement and specifically with special focus on indicators. These indicators will include maximum impact depth and speed as well as on recovery speeds and quality. Such resilience benchmarks are useful for a number of risk assessment aspects, such as establishing databases for comparisons of recent events, and in a more conceptual sense, for starting with similar benchmarks for other hazard types, including natural hazards, too. Specifically, for resilience aspects of CI, this chapter will help to identify useful indicators and data sources, but also address certain identification and handling problems. Finally, such benchmarks can help to assess the resilience of cities and settlements by delivering indicators for urban crisis impacts and their recovery footprints.

Data limitations

Regarding data, this study unfortunately has to rely on single sources for large sections, which is sometimes due to the sensitive nature of key strategic war decisions on targets. Another factor was the difficulty in finding and accessing such literature. Despite the many cursory entries in online sources, original literature could only be obtained in the city archives of Schweinfurt and Würzburg. It is also one intention of this study to make the research communities aware of such data categories and sources and to recommend them for further research. Limitations of the results will certainly lie in the original quality of secondary data, inheritance of errors and retrospective problems of verifiability. This study furthermore does not adopt any really scientific methodology other than what might be related to classification, typologisation and structured observation in the line of Charles Lyell in Geology (Lyell 1830-33) or Oscar Montelius in Archaeology (Montelius 1885).
This study does embark on the system theory perspective of resilience in the line of ecology (Holling 1973) and cybernetics (Bertalanffy 1968/2006) which is now commonly found within adaptive systems research (Holling et al. 2002; Gunderson and Holling 2002) or complexity theory (Waldrop 1992; Lewin 1992).

Case study area and selection: risks in mid-sized towns Würzburg and Schweinfurt, Germany

Selection arguments for mid-sized cities: Würzburg and Schweinfurt have been selected as research area for several reasons. Internationally, German cities such as Dresden, Berlin, Frankfurt, Hamburg, Munich or Cologne might be known and related to massive destruction in WWII. However, amongst major cities in Germany with over 100.00 inhabitants, there are other, less known cities with even higher rates of destruction. Würzburg was one of the cities receiving the greatest destruction. 80% or more of the city area had been destroyed in 1945 (see Sources in table below and Hohn 1991). Next to the bombing, on 16.3.1945 the subsequent fire caused great losses of human lives and to demolition of buildings. Specifically, more than 1600 people had been killed in this event.

Schweinfurt is a neighbouring city, yet has a very different industrial profile, which makes it interesting for comparison. Schweinfurt was targeted early on in WWII for its pivotal role in ball bearing industry. Such cities with maximum destruction, offer good starting points for measuring resilience in terms of city and population persistence and recovery and transformation, it is expected. However, this study will focus on the system performance of a city after the destruction.

Another reason for the selection of Würzburg and Schweinfurt is the familiarity of the author with these locations, which is regarded as an advantage from the point of in-depth local experience. Midsized towns and cities bear many advantages for research – an overview is easier, given the city sizes. Würzburg is a middle-size German city, of approx. 130.000 inhabitants at present. It does have a number of suburbs with a semi-rural character. But it is a regional centre with considerable attraction for surrounding villages and rural areas. Schweinfurt has around 50.000 inhabitants and is also a regional centre but in contrast to Würzburg, it can be characterized as an industrial town.

The following table (Table 1) is the starting point of finding baseline comparable data that signify the extent of destruction to cities. While WWII data on casualties and spatial extent of destruction is one of the most trivial data to find, in many online sources and history books - they represent secondary data of often-mixed reliability. The identification of reliable data sources was therefore necessary. This data is either original literature in the sense of either being dating back as close as possible to the event or, consisting of authors with original first hand observations. Such trivial data such as casualties and extent of destruction of buildings have the advantage of being available for most destroyed cities of any kind, region or type of hazard that destroyed it. It was found to be difficult to find other data categories. For example, health statistics, infrastructure statistics, especially maps, but also even most common demographic data such as city population per year are very difficult to obtain for certain cities even in Germany when going back a few decades.

The following table contains some benchmark criteria of strong deviations from the normal status of a city, as possible starting points for measuring return, recovery or, bouncing back:

Table 1. Fatalities in WWII in selected German cities in comparison

	Population before event	Fatalities	Evacuations	Loss of city area of built environment	Population after event	Other casualties of various kinds	Source
Bombing Würzburg during WWII, 16.3.1945		1632 / up to 5.500 >4.000("2)	94.000	89%	39.000 (in 1945, 11.6.)("3) 74.000 (in 1950, March 16th)		(Domarus 1982): 235 ("2) (Dettelbacher 1974) ("3) Stadt Würzburg 1945_1
Bombing Dresden during WWII, 14/15.2. 1945	630.000	18.373-25.000, 4% of population	350.000	50%			Domarus 1982: 234
Bombing Schweinfurt, WWII, 1943-1945				50% of housing, 80% of industry			Skowronska et al. 2012: 69
Bombing Aschaffenburg, WWII, 1945				50% of housing			Skowronska et al. 2012: 79

Those cities most severely hit by the bombings in WWII were also regarded as 'great need cities' (German: "Großnotstädte") within Bavaria (Stadt Schweinfurt 1950) after the war, referring to the amount of destruction (see Table 1).

Risk context example of WWII - Assessment of risk and resilience: exposure, impact depth and losses

Cities were major targets in WWII - the German Nazi regime bombed cities in Poland, UK, Russia, etc. and then cities in Germany were bombed by the allied forces. During long phases of WWII, key infrastructure was a main target; in Schweinfurt, as a specialised industrial city with ball-bearing industry, especially. But also Würzburg with its strategic importance as a traffic hub was an early target and particularly its bridges. Later on in WWII, destroying German morale was a key factor and one of the major reasons that cities were targeted and wide-spread destruction accepted. W. Churchill for instance declared German cities with armaments factories as war zones and urged the residents to leave in flysheets distributed on 1 September 1943 (Urban 2013): 37). However, cities were targeted in other wars not only due to their population size, but also due to their strategic importance as industry and infrastructure hubs. Studies during the Cold War Era (Openshaw and Steadman 1983) show how a nation could be targeted most effectively with the least possible use of atomic weapons by selecting key cities. This source also provides historic evidence of another era in which data sensitivity and public awareness of threats and targets were not yet major concerns.

Exposition – Criticality as Exposure and Target Attractor

The "Background of the Selection" (USSBS - United States Strategic Bombing Survey Equipment Division 1945) of Schweinfurt as an industrial target for air raid missions was the importance of the anti-friction bearings industry. Bearings improve efficiency and reduce energy loss. The reasons for selection, in the words of the 'Casablanca directive' were "...the progressive destruction and dislocation of the German military, industrial, and economic system to a point where... capacity for armed resistance is fatally weakened." (USSBS 1945: 3).

In selecting the industrial system types, oil, aluminium, or electric power were not selected because of this argument: "In choosing such a system, the capabilities of the air force were as decisive a criterion as the merits of the proposed systems" (USSBS 1945: 3).

Regarding the terminology of criticality, the following statement is interesting, since it names three criteria or categories of criticality: "Three general suppositions underlie the choice of the industry as a target system:

a. The industry's pivotal place in the economy

b. Its concentration

c. The difficulty of recovery"

(USSBS 1945: 4).

This source also provides a temporal measure of recovery that is interesting in terms of the 'Mean Time To Recover' often used in Critical Infrastructure Protection (CIP) studies: Due to the "pivotal place of bearings in the economy" it was assumed that "many and varied users of bearings would, it was felt, begin to feel the pinch of shortened supplies within a month of a successful attack on the centres of its production" (USSBS 1945: 4).

Such strategic war considerations also include assumptions of accumulated criticality: "Six cities were believed to be responsible for 73% of the entire output of bearings available to the German economy ..." (USSBS 1945: 4).

Broken down, these six cities were Schweinfurt 42%, Stuttgart 15%, Paris & Annecy 9%, Leipzig and Berlin 7% (USSBS 1945: 4). Thus, Schweinfurt was obviously the key target.

Interestingly, difficulty of recovery is a key feature of target selection and argumentation and this relates strongly to resilience. "The most important factor determining recovery is the ability to reconstruct but equally crucial is the possibility of the effect of the raids being absorbed during the reconstruction and repair period" (USSBS 1945: 5). This recovery capability was also named "cushion". This cushion was expected to be broken through "the lavish use of bearings in German design" with a much higher proportion than for instance, in British or American models of air planes of the time and the therefore expected high demand for repair and maintenance. The limited storage availability of semi-manufactured bearings for a maximum of six months was expected to contribute to a shortage to soon affect German forces. It was expected that first non-military users would suffer most, such as truck customers. "A nine-month' loss of output, however, would be bound to reach even to producers with top priority" (USSBS 1945: 6). A central shop for repairing machines, Koenig and Bauer in Würzburg was later on selected as a target to thus indirectly affect bearing production recovery (USSBS 1945: 41).

At a different level of technical infrastructure elements, or "Vulnerability of Departments" (USSBS 1945: 39) "...the following points of sensitivity to damage have been observed:

the more complex and valuable the machine, the harder to replace", specialised items such as "dies used in stamping retainers" and "damage to utilities during raids hindered fire-fighting and re-building as well as production" (USSBS 1945: 39-40).

In summary, the figures and arguments for selecting cities as a target indirectly reveal their criticality – for both attacker and defender – in the planning phase of an attack. From such literature, several useful criteria can be derived: Relative importance and ranking of cities, Mean Time To Repair (MTTR), and other criticality and resilience factors.

Attack Effectiveness and Costs of Resistance - Resilience during the War

Only 80 of 954 explosive bombs dropped on industry in the city of Schweinfurt hit their target. Most bombs hit the fields around Schweinfurt (Müller 2013). One source claims that the attacks were limited in success since even in 1943, and production of bearings continued at full scale (Müller 2013: 17).

Table 2 shows an example of risk transfer and additional production costs to cope with bombings in Schweinfurt in order to keep up war production industry.

Table 2. Additional production costs due to air raid attacks for FAG company.

	Costs (in million Reichsmarks)
Damage costs	71.2
Losses of unused capacities	10
Transfer costs	44.1* above ground: 11.1 underground: 34.1
Construction of secure rooms and running costs	2
Total	127.3

Source: (Golücke 1980): 371

*there appears to be a mistake in the table cited - it states 34.1 as total sum

Monthly running costs were in the range of 584,000 Reichsmarks (RM) for transfer to subcontractors and additional costs of 170,000 Reichsmarks monthly for the subcontracting. Another example of coping with critical infrastructure damage are the costs of 500.000 RM for emergency bridges (German terms: Notbrücke and Notstege) (Stadt Schweinfurt 1950), (Stadt Schweinfurt 1954). As a comparison, the reconstruction of the Marienbrücke after the war cost 242,000 Reichsmarks (480.000 DM) (Stadt Schweinfurt 1950: 60).

In summary, this brief section highlights additional production costs and costs for emergency measures as possible resilience factors for the phase when the attacks were already unfolding. These numbers can also be used to be compared with the assumed delays and additional costs by the attackers during the planning phase.

Examination of data sources for deriving benchmarks of resilience – Loss of population

Literature dealing specifically with casualties' numbers reveals the difficulties in estimating these numbers. While casualties can be considered as one of the most definite and accessible figures for measuring disaster impact, it is proven to be more difficult. This is important to consider for civil protection authorities, insurance companies or other risk managers, to take care before using casualties for risk calculations. For example, Domarus (1982) claims Würzburg to be the most destructed city with more than 100.000 inhabitants. The author bases this observation on the number of casualties, but also on the area size destructed and number of evacuees. Domarus (1982) adds an estimated 4.500 casualties additionally to the 1632 (official number of city of Würzburg in 1949, (Stadt Würzburg 1945) that result from other bombing attacks during WWII. This already shows how aggregation of data from the original source poses a problem of latter comparability. A second problem is analysed in depth within the dissertation thesis of Hohn (1991) which shows the conflicting numbers of destruction of German cities by first-hand sources after WWII. It is basically a problem of defining the limits of a city, the city center and the ways of measuring full or partial destruction.

The other observations of Domarus (1982), of larger number of evacuees and destroyed city area of Würzburg as compared to Dresden support his argument, but there are other cities with similar numbers such as Cologne that are not drawn to this comparison. This small section just serves to underline the challenges of finding criteria and data for benchmarking disaster impacts.

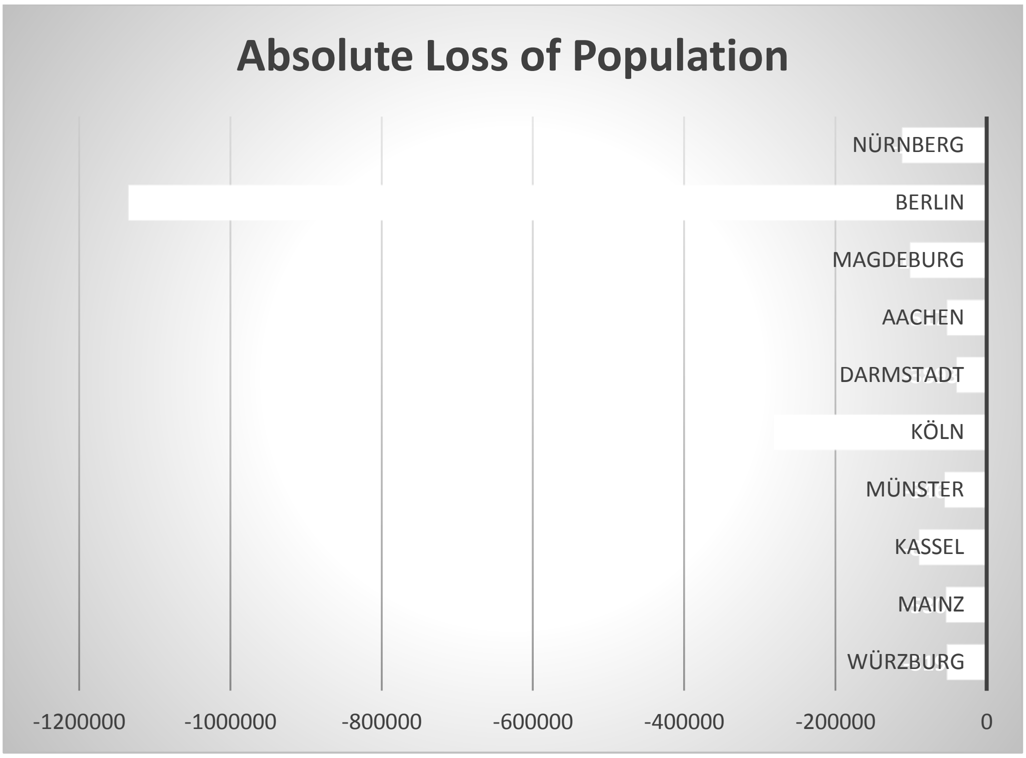

Figure 1. Absolute losses of total population in cities over 100.000 inhabitants, between 17.5.1939 and 29.10.1946, data taken and modified from (Hohn 1991a).

The bar chart indicates that a selection of most exposed cities, for example for the hazard of cyclones or earthquakes, based on previous highest absolute losses, could be misleading. The focus on absolute losses disguises the real impact to a cities'' capacity and resources, which is better displayed by relative impacts. In the case of the most hit cities during WWII with more than 100.000 inhabitants, Würzburg ranks behind at least 5 other cities within the absolute losses within our selection of cities, based on Hohn (1991). However, within the relative ranking per total population of each city Würzburg has the highest losses (see Hohn 1991 for loss figures of a great number of other German cities with equal or smaller sizes).

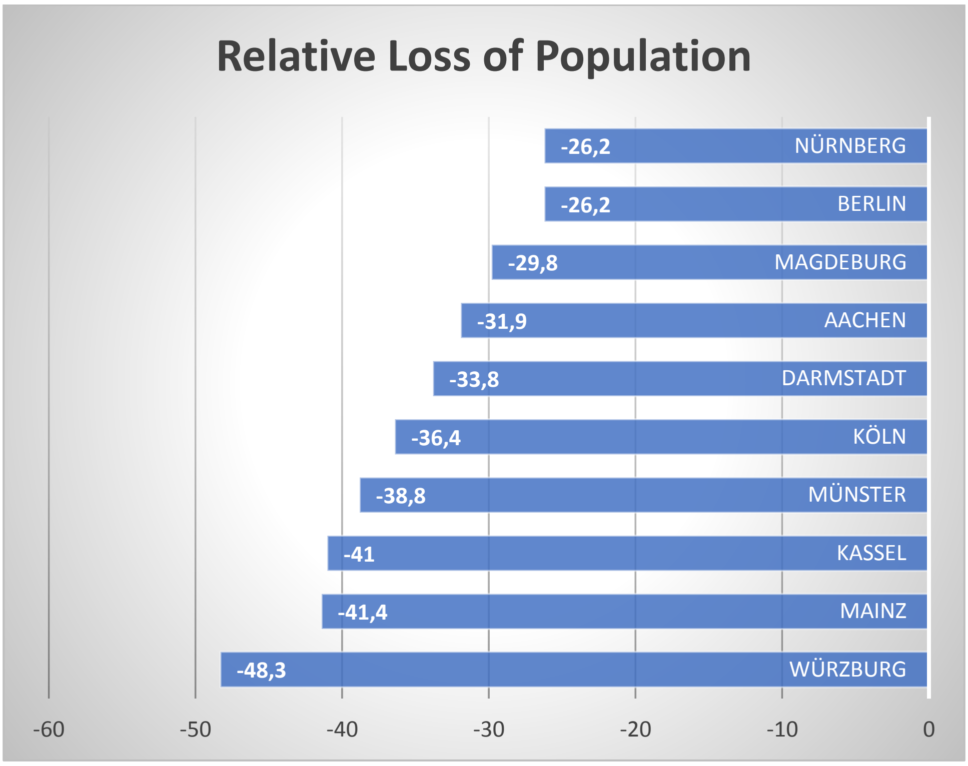

Figure 2. Relative decrease of total population in cities over 100.000 inhabitants in per cent, between 17.5.1939 and 29.10.1946, data taken and modified from Hohn 1991.

While it would be great to obtain more differentiated pictures of demographic profiles of human loss, as is a current major focus of research within the fields of 'social vulnerability indicators' (Cutter et al. 2003), 'livelihood approaches' (DFID 2000) or 'community resilience' (Cutter et al. 2008), there are only cursory findings in city archives and dispersed among several publications, thus difficult to collect and compare according to the same criteria.

One example is the following data table from a source of the city of Schweinfurt.

Human losses

Table 3. Schweinfurt civil population losses

Bombings (from 1943-1945)	Casualties in total	Men	Women	Children	Unknown	Among them: Foreigners
	1079	312	283	118	6	360

Source: Stadt Schweinfurt 1954

In an alternative source, 3700 losses and missed persons are registered (Stadt Schweinfurt 1950: 33). The losses on the attacker's side should be taken into consideration regarding the analysis. The risk for the attackers could be calculated based on figures such as that on Aug 17th 1943, when 16,4% of the planes did not return. 36 air planes (bombers) went down, 68 crewmembers died. About 140.000 aircraft crew members died in WWII in total, both on British and American sides. 21.000 planes were lost (Müller 2013: 17).

Loss and Damage of Physical infrastructure and Critical Infrastructure

For Critical Infrastructure in general, it is often very difficult to obtain data, which are openly accessible. Unfortunately, data for loss and damage are not an exception here. It is, however, somewhat easier to obtain data concerning the reasons and criteria of criticality in the selection of a target (sub-section 2.1), as well to obtain data concerning buffer costs during an observed crisis (sub-section 2.2).

The following table lists destroyed assets in the city of Schweinfurt during WWII. For a criticality assessment, loss numbers are interesting mainly if they are in relation with the overall number of similar type assets or with other additional information. From a resilience concept perspective, loss and damage data mainly help to describe the impact size but often do not provide much information about the recovery itself apart from direct replacement need of amount and costs.

Table 4. Destroyed infrastructure assets in Schweinfurt

Infrastructure type	**Assets destroyed**
Electricity	20,000 Volt system: destroyed at 48 locations 3000 Volt and low voltage system destroyed at 453 locations 26 transformer stations completely or partly destroyed
Gas	Low pressure distribution network destroyed at 550 locations Mid-level pressure distribution network destroyed at 62 locations Loss of one controller station, 4 gas tanks damaged
Hospital	St. Josef hospital was severely damaged
Rail	28 km, 126 switch points
Roads	25 km (of 65 km), 2 bridges
Sewage	10,600 meters (16.2 %) totally destroyed, 2000-3000 additional meters severely damaged
Telecommunications	Cable net 50% destroyed, 30% of cable canal net
Water	Water system interrupted at 473 locations 139 (of 750) hydrants destroyed Main pumping station repeatedly damaged Main river pumping station and Oberndorf water station destroyed Water supply interrupted through blasting of the two bridges for Schweinfurt, at Niederwerrn and Dittelbrunn

Source: Stadt Schweinfurt 1954: 30, 31, 53

For the city of Würzburg, such data could not be found in the given time of this study. Only one source mentioned 19 damages that occurred in the water pipe system (Stadt Würzburg 1945): 31). However, such information as in Table 4 provides important data on the extent and volume of interruption in relation to the overall system. Additional data on recovery speed and extent would be ideal.

Housing and shelters are not typically found in many Critical National Infrastructure registers yet they can be included here since they are a basic, indispensable infrastructure. Tables 3 and 4 give an impression of data and sub-categories to account for the built environment and its assets in cities at that time.

Table 5. Degree of destruction of cities in Bavaria

City	Apartments totally destroyed in %	Based on property tax (German: Realsteuer Kraftzahlen) in %
Würzburg	74.7	69.04
Nurnberg	49.3	40.95
Schweinfurt	49.28	39.82
Munich	33.2	32.82
Augsburg	24	21.61

(Stadt Schweinfurt 1950: 3)

Table 6. Buildings destroyed in Schweinfurt

Buildings damaged 608 totally damaged 818 heavily 1825 minor Of the apartments in 1939 4,800 totally destroyed 2,498 middle to heavy destruction 2,000 minor	Of the 12,989 housing units in 1939, 6,402 were totally destroyed, 4,300 more damaged. 83 industrial buildings totally destroyed or badly damaged. 64 buildings of railway system 2 post office buildings 2 bridges (blasted)
Source: (Handfest-Müller 1994): 118, citing the first situation report of the city mayor Otto Stoffers to the military government from 24 Nov 1945	Source: Stadt Schweinfurt 1954: 30

The cross-comparison of building damage literature sources reveals that conflicting numbers are a problem. Often, this stems from different points in time of reporting, differing definitions of central city parts and other reasons (Hohn 1991b).

Table 7. War damages in Schweinfurt (in Reichsmarks)

Household content	25,514,692
Trade	12,802,861
Buildings in total	44,820,438
Others (losses through rail transport etc.)	2,303,794

Industrial damage (buildings, trade damage, loss of use of 12 companies)	162,216,640
Total	247,658,525

(Stadt Schweinfurt 1954: 32-33)

In summary, war damages in monetary terms are also relatively common to find and such numbers could be related to costs at that time to rebuild and thus provide estimates of economic recovery and resilience (see section below).

In the whole region around Würzburg and upstream to Schweinfurt, destruction of infrastructure was prevalent especially for the bridges. Most were destroyed by the German military just before the invasion of the allied troops in order to hinder their advance. While this was mostly ineffective regarding the allied forces, it severely hindered restoration of travel and accessibility for the German citizens after the end of the war that soon followed.

Table 8. Destroyed bridges around Würzburg

Year of destruction	Cause of destruction	Location of bridge	Reconstruction	Source
1945 Feb. 23rd	Air raid attack (by allied troops)	Connecting Sommer- and Winterhausen		Halbleib; Halbleib and Kretzer 2008: 37, 112
1945	Deliberate blasting by German troops	Ochsenfurt	1958	Halbleib; Halbleib and Kretzer 2008: 107-109
1945	Deliberate blasting by German troops	Segnitz	1948/1949	Halbleib; Halbleib and Kretzer 2008: 113
1945	Deliberate blasting by German troops	Randersacker	never rebuilt	Halbleib; Halbleib and Kretzer 2008: 114

Resilience measured after the impact momentum: buffers and recovery

Buffers – ways to reduce human losses during the war

Bunkers and evacuations were major factors to reduce the civilian toll during WWII. Since 13. April 1943, 4223 persons could be sheltered in 1414 housing units in emergency shelters in Schweinfurt. 170 persons could be sheltered in 153 single-room apartments (Handfest-Müller 1994). Factors increasing the number of casualties in Würzburg during the war, in comparison to northern and western German cities during WWII were few concrete bunkers, few air shelter (German: Luftschutz) exercises, and few early stage evacuations (Domarus 1982). By comparison, around 60.000 citizens of the city of Düsseldorf had been evacuated in earlier stages of WWII to surrounding rural areas (Stadt Würzburg 1945). Interestingly, Würzburg at that time was also one of the evacuee reception towns (Hewitt 1993: 37). In other words, preparedness in terms of early evacuations of their own population in Würzburg was already lower than in other cities . On the other hand, the violence and experience of the air raids was higher towards the end of the war, when Würzburg was hit. Therefore, not only resilience but also the hazard magnitude played a role, which is why several air raids even within WWII are difficult to compare, when focusing on fatalities and other impact numbers. This is even more true when comparing war impacts with earthquake impacts, although the effects such as fires and destruction as well as the results seem similar.

Recovery of population

Recovery needs: Most immediate needs after the bombings were water, gas and electricity, burying the corpses and thus avoiding epidemics, cars and gas for delivering food and construction materials (Oppelt 1947). Also important were lack of living space and telecommunication to ease business (Oppelt 1947: 190). The same author however, mentions a few pages later a slightly differing listing for the different city quarter descriptions; "worries in the first months were around most needed livelihood conditions such as food, water, electric light, housing, heating materials" (Oppelt 1947: 219, translated by the author).
Another recovery and re-start need was on the number of resident population in total and on specific workforce.

Table 9. Recovery starting-point account of city of Würzburg

Assets	Source
Total population 39.000 23.600 women and children	11.6.1945 Stadt Würzburg 1945: 12
Workforce: 3.000 women, 6.000 men	" "
200 lorries provided by allied forces for supply with food etc.	25.6.1945 Stadt Würzburg 1945: 21
Apartments: 30.000 in 1939 20.000 - 22.000 not usable in 1945	23.7.1945 Stadt Würzburg 1945: 28

However, there is also a discrepancy between how researchers today and city administration back in 1945 would normatively value the impact of human loss and the remaining population. Especially interesting in the

document from the first city council protocols (German: Ratsprotokolle, for example: (Stadt Würzburg 1942-44) after the bombings in March 1945 (Stadt Würzburg 1945, 11.6.1945), is the entry that "from 23.600 women and children, 20.600 are either below 16 or above 50 years of age, sick, fragile, or "Kopfarbeiter" (German expression, meaning 'brain worker'), so that only 3.000 would remain for the physical use for city reconstruction." (translated from German by the author). For immediate recovery it could be interpreted that not the sheer number of survivors was of interest for the disaster recovery planners, but those suitable as workforce. From 15.400 male inhabitants, 6.000 were regarded 'suitable as workforce'. Certainly, the tone of the time of 1945 must be considered when reading such statements.
On the same page, the growing discontent of the rural population with having to take care and feed the city evacuees is mentioned, 3 months after the bombings (Source: Stadt Würzburg 1945). This is especially interesting for investigating the interplay of the resilience of a city and its interdependency with the rural hinterland and its own resilience that is contributing to the overall resilience of a city.

Recovery observation: Compared to other hazards such as floods, but also compared to WWI and wars in 1870, the impact of WWII was the most significant. Around a decade after WWII ended, the city had the same population in numbers than before the war (Stadt Würzburg 1942-44). The data gaps in the table show up a severe problem in finding even the basic demographic data for regular intervals such as per year or even per 5 years.

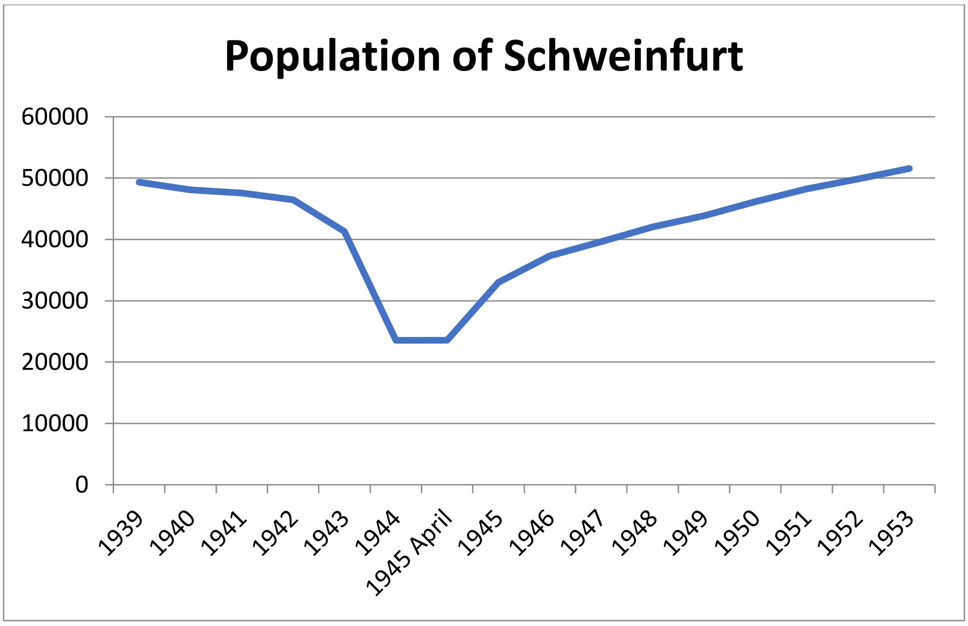

Figure 3. Population development in Schweinfurt (Data source: Wikipedia 1.5.2014)

The figure on population numbers in Schweinfurt during and after WWII reveals a typical crisis curve with a steep decline and more gradual recovery. In comparison with other cities more severely hit, this recovery process is relatively fast with about one decade. Many other cities from our selected top 10 big cities over 100.000 inhabitants took around 15 or more years to recover (see figure 4).

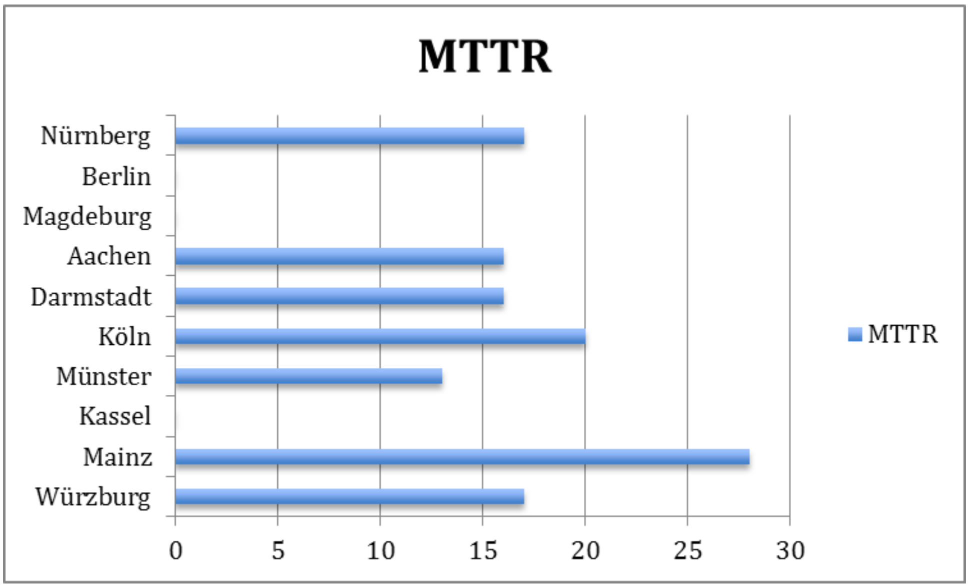

Figure 4. Mean Time To Recover (MTTR) of total population in cities over 100.000 inhabitants in per cent, between 17.5.1939 and 29.10.1946, data taken and modified from Hohn 1991.

For Würzburg, the figure additionally includes the time before WWII. However, the figure shows the large data gaps and often, only every 5 years' data is available. The diagram consequently omits interpolation and curve display. The data source is Wikipedia, and for the purpose of showing up the usability of such data for resilience benchmarking it must be added that the numbers are comparable for this city to the numbers found in other sources.

What is visible is a visually similar decline and recovery as in Schweinfurt, and additional, smaller declines around 1915-20 during WW1 and in the late 1970s. The decrease in population from 122.00 (1965) to 112.000 (1976) in Würzburg is due to a shortage of building sites, which led to migration into the surrounding areas (Stadt Würzburg 1995: 72). This highlights again the interlinkages of city growth with topography, but also with administrative boundaries, even when city walls and fortifications did not block development any longer.

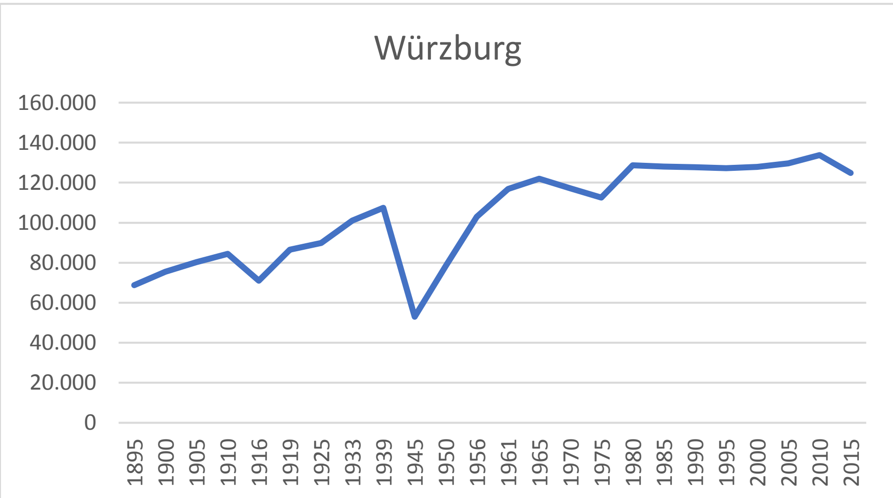

Figure 5. Annual population numbers for Würzburg, 1895 - 2015. Data source: Wikipedia, accessed 20. Nov 2019

The dangers of data interpolation often used in displaying annual population data can be exemplified when having monthly data at hand. For example, the development in the city of Cologne during the critical year of 1944-1945. It shows that there is a similar curve as in the interpolated curve of Schweinfurt. But it also shows that taking only annual numbers would have shrouded this additional decline and the gradual processes of recovery.

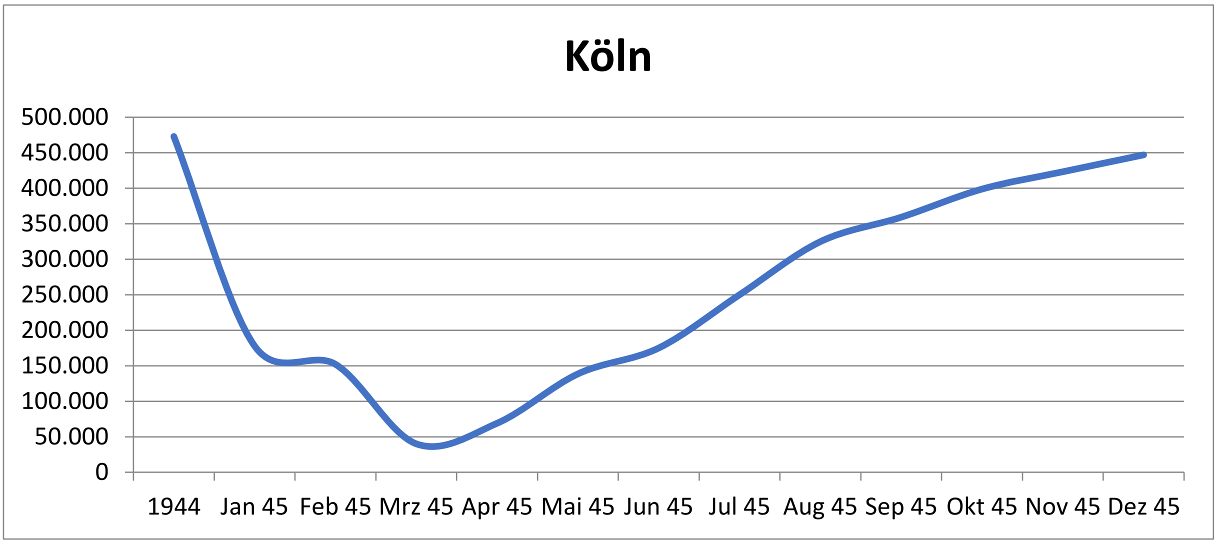

Figure 6. Monthly population numbers during the end of the war for Cologne. Data source: Wikipedia, accessed 23. July 2014

Detailed population numbers for Würzburg 1945 in months from June 16th to Dec 16th 1945 can be found in Oppelt 1947: 208. But this data availability is an exception and limited for this specific time frame. Even research in the city archive and the state archive of Bavaria (in August 2014, pers. com.) revealed no data recorded in annual or 5 years' intervals for most time periods even after 1945.

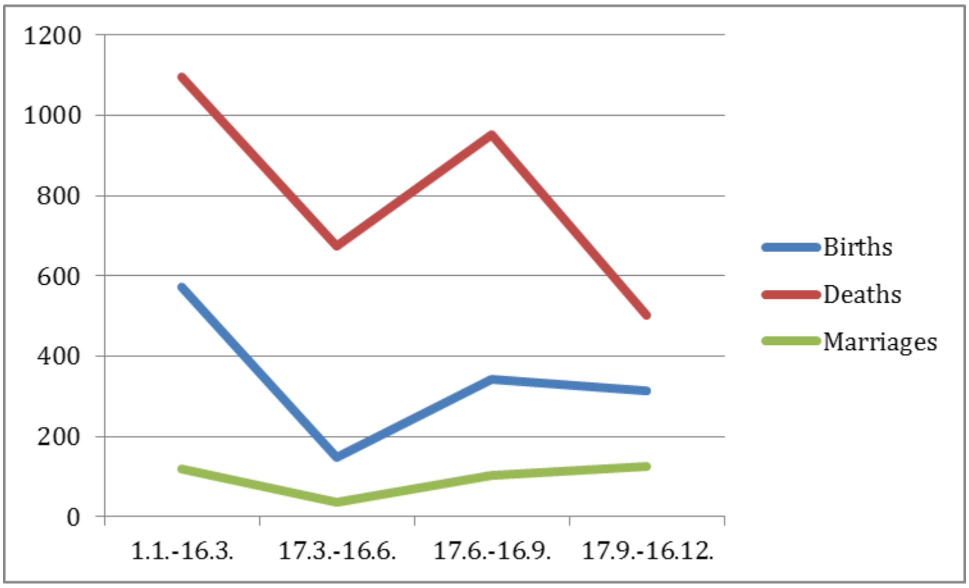

Figure 7. Official reports of the register office of Würzburg 1945. Data source: Oppelt 1947: 210.

The official reports of the register office reveal a bit more detail than just absolute population numbers, such as births, deaths and marriages. The intervals are not fully equal and the curve display is glossing the developments in-between, but it shows that there is more differentiation in a society impacted by war than just decline. A point display was found to be more confusing. While deaths went up due to the bombings in August of 1945 in Würzburg, surprisingly, also births and marriages increased.

Recovery of Basic Survival Needs and Infrastructure Services

While the previous sub-sections of section 2 dealt with the planning and the war phase itself, the following section is especially relevant for obtaining resilience information; the recovery phase. This sub-section will assess three main characteristics of criticality in more detail and relate them to recovery data that could be found: Criticality as measured by volume, speed and quality (Fekete 2011).

Table 10. Indicators of infrastructure recovery speeds after bombings of Würzburg and Schweinfurt

Infrastructure service	**Würzburg** (bombing on 16.3.1945)	**Approximated estimated recovery periods**	**Schweinfurt** (bombings from 1942-1945)	**Approximated estimated recovery periods**
Bridges	Rail bridge in Heidingsfeld provisionally repaired on 3 Sept. 3 1945 ("6)	6 months		
Electricity	Supply restored after 2 days ("1); May 1945 ("2)	days	after 3 days a small part of the city centre, the city hospital, and the city water utilities station ("10) fully restored in 1952 ("11)	days (parts) years (fully)
Food			a few days ("15)	days
Gas	23.11.1945 ("3)	8 months	still expected to work soon on 24 Nov 1945 ("13)	months
General practitioners / doctors	on 26 April 1945: 20 in the city, 22 in the Landkreis ("4) 2 Hospitals in the city, 13 in the Landkreis ("4)	days – 1 month		
Mail	12 July 1945 ("1)	4 months	21.6.1945 ("14)	
Rail	10.5.1945 ("1)	2 months		
Sewage			restored until the end of 1949 ("12)	years
Waste removal	26.4.1945 ("5)	1 month		

Water	Supply restored after 2 days ("1); May 1945 ("2)		restored for most people in Aug. 1945 ("10)	months

Sources: ("1) (Dettelbacher 1974); ("2) (Oppelt 1947): 200; ("3) Oppelt 1947: 249; ("4): (Will 1988): 391; ("5) Stadt Würzburg 1945: 31; ("6) (Oppelt 1947: 245); ("10) (Handfest-Müller 1994: 115); ("11) (Stadt Schweinfurt 1954: 66); ("12) (Stadt Schweinfurt 1954: 69); ("13) Handfest-Müller 1994: 120); ("14) (Stadt Schweinfurt 1954: 61); ("15) (Handfest-Müller 1994: 123).

While there was little accompanying information in the sources used for Würzburg, the sources in Schweinfurt revealed more information in addition to the raw numbers which also provided valuable qualitative information. The following section includes some of the qualitative additional information about Schweinfurt: The *Electricity* supply was badly damaged and its repair was hindered by lack of construction material. Despite this, after 3 days, a small part of the city centre, the city hospital, and the city water utilities station could be supplied with electricity (Handfest-Müller 1994: 115). Electricity consumption peaked in 1942/43 and decreased towards the end of the war. In 1952, electricity was restored and the grid was increased in comparison to pre-war times to 50%, as was street lamp lighting by 50% and the related power consumption (Stadt Schweinfurt 1954: 66).

This example is interesting as it depicts the different aspects of what the term "restored" can refer to – to certain vital parts of a city or to the overall population. This can make a significant difference, as can be seen in the table.

Food supply was restored after a few days concerning bread and milk and potatoes - vegetables continued to be a problem. Supply was supported by UNRRA = United Nations Relief and Rehabilitation Administration and the military government (Handfest-Müller 1994: 123). This example shows that restoration of a service as such does not necessarily mean that the same quality in the sense of completeness of products and variety is restored.

Many parts of the *gas station* were repaired on 9 Aug 1945 (for instance, a 4,000 cbm tank). However, it was then still unknown when supply would be possible - this depended on coal delivery (Handfest-Müller 1994: 116-117). By 24 Nov 1945, supply was still not possible, but it was expected that the gas station would soon be functional again. (Handfest-Müller 1994: 120). This example shows that repair data should not directly be taken as the starting date of restoration of supply of services such as gas. When certain installations are still dependent on other infrastructure services and goods such as coal, but also roads, electricity, personnel, it might delay the recovery of the system.

The *sewage* system consisting of 11 km of canalisation was restored by the end of 1949, with costs of 1,031,000 Reichsmarks (RM), around 154,000 Deutsche Mark (DM) (Stadt Schweinfurt 1954: 69). For the recovery period of 1949 - 1954 a total of 6,264,350 DM were used and another 9,500,000 DM were regarded as necessary. The sewage system was more badly damaged than in any other Bavarian city. Until 1945 there was no real sewage system, only drainage into the river Main. Costs estimated for new system were 9,280,000 DM, and a construction phase of 6 years (Stadt Schweinfurt 1950: 5). The repair of the supply net for water and power was estimated at 5,750,000 DM for 5 years. (Stadt Schweinfurt 1950: 8). This example for the sewage system shows the difficulty in handling differing estimates of costs. Accordingly, it was difficult to compare cost numbers even after adjusting the numbers for differing categories of infrastructure system elements as well as adjusting for inflation.

The *water* supply was restored gradually from June 1945 onwards, with an increase of 65,000 cbm to a total of 217,000 cbm. (Handfest-Müller 1994: 116). Restoration included re-installation of pumping stations on higher ground, (at Obertor and Teilberg) and therefore high-lying city quarters could be supplied (at Kiliansberg, Maibacher Höhe, Gartenstadt, Niederwerrn). Water supply had been restored for most people by Aug. 1945 (Handfest-Müller 1994: 116).

This process of gradual recovery indirectly shows that high-lying parts of the city and surrounding outskirts were supplied later. This means a higher vulnerability of high-lying parts of the city, which is interesting to note for risk zonation planning of cities. Another interesting aspect is that certain services had increased demand and consumption during the war. For example, water consumption increased during the war due to the increased demand for water for fire fighting. Therefore, restoration is based on a different level as compared to other numbers such as housing, or total population.

In summary, this sub-section has shown the richness of recovery data to be obtained in hindsight and underlines the heterogeneity of data sources and descriptions. While it is tempting just to use the quantitative data, qualitative sources are indispensable in order to capture context and restraints in this data. The qualitative sources also offer valuable arguments for understanding the overall ex-post, de facto, resilience of a city.

Reconstruction Costs

Table 11. Reconstruction costs in Schweinfurt

	1948 in Deutsche Mark	1949 in Deutsche Mark
Volksschulen (elementary schools)	74,192	405,024
Berufsschulen (vocational schools)	53,763	494,179
Oberrealsschulen (high schools)	9,404	39,315
Public buildings (hospitals, police stations, slaughter houses, etc.)	86,095	763,166
Clearing of debris	157,183	160,512
'Marien' bridge	127,465	269,286
Sewage system	41,335	39,992

Source: Stadt Schweinfurt 1954

The numbers provided in the table above may serve for comparison with other cities; by themselves they do not allow for the interpretation of, for example, weighting the importance of one reconstruction asset over the other. However, it is interesting to observe that between 1948 and 1949, the sewage system and the clearing of the debris received no significant increase in budget as compared to all other posts. Furthermore, it is interesting to note that schools, as well as the bridge, received reconstruction funding from early on after the war.

Reconstruction cost figures can also be found for individual elements of infrastructure systems. For instance, one large new water storage tank in 1954 in Schweinfurt cost 600,000 DM (Stadt Schweinfurt 1954: 67). Similarly, random individual figures can be found for individual bridges or other elements, but it is difficult to obtain any category for all destroyed elements of the infrastructure of one sector.

Damage measured in monetary terms for Würzburg is documented in detail for different types of buildings, public and privately owned housing, but also damage to commerce, personal belongings, loss of rent and looting damage (Oppelt 1947: 41-43). However, such data is very heterogeneous and fragmented and categories are often difficult to compare with other cities. In Schweinfurt, rebuilding costs of public buildings between 1948 and 1949 were 2,720,917 DM (Stadt Schweinfurt 1950: 3).

Service Provision Before, During, and After the War

It is interesting to look at the development of infrastructure supply and not just at the loss figures. In the language of resilience, the loss data is about the magnitude of the impact while the overall process of decrease and bouncing back allows for a more comprehensive picture of resilience – the starting points of decrease, of recovery and the temporal dimension. However, it was difficult to obtain such data, and therefore the following table only depicts the city of Schweinfurt and only 3 time periods: During the war, after the war and in irregular intervals. For the city of Würzburg, such data could not be found during this study.

Table 12. Consumption of electricity, gas and water in Schweinfurt 1939-1954

	1939/1940	1945/1946	1953/1954	Per cent of 1945/46 in relation to 1939/40
Electricity				
Production in mio. kWh	73.3	24.6	84	33.6
Own production within city in mio. kWh	6.8	6.4	6.5	94.1
Total dispatch in mio. kWh	71.9	21.2	82	29.5
Street lighting, lamps	779	9	1750	1.2
Street lighting, fixtures	604	9	1049	1.5
Overhead power lines in km	66	60	100	90.9
Cable in km	107	110	158	higher than 100%
Number of power meters	16,550	12,000	20,441	72.5
Gas				
Production in mio. cbm	4.5	0.7	6.5	15.6
Dispatch mio. cbm	4.1	0.5	6.0	12.2
Pipe system in km	65	62	86	95.4

Number of gas metres	9,194	7,414	10,670	80.6
Water				
Production mio. cbm	3.7	2.3	4.4	62.2
Dispatch, mio. cbm	3	2	3.5	66.7
Pipe system in km	88	85	104	96.6
Number of water metres	4281	3870	5061	90.4

Stadt Schweinfurt 1954: 67, last column added by the author

The table on consumption shows the sharp decline of production of electricity, gas and water from 1939/40 to 1945/46 and the recovery to same and even higher levels visible in the years 1953/54. Gas supply was reduced to the lowest level in comparison, to only 15.6% of the previous supply, while electricity remained at 33.6% and water at 62.2%.

The numbers neither show the exact minimum of production nor the exact year of recovery to previous production levels. The numbers show that the city's own production of electricity could be maintained with only minimal decrease.

In summary, such data on infrastructure service provisions is ideal to capture resilience, as depicted in Figure 1, in an elasticity model. Apart from infrastructure as a data source, it is also possible to obtain data on population numbers and other figures, which will be covered in another study.

Discussion of results

Discussion of Lessons to Learn for Urban Resilience from Historic War Data

In general, the comparison between Würzburg and Schweinfurt offers valuable knowledge for researchers making use of such data. First of all, it is difficult to compare the two cities because of the difference in the cause of the damage: Schweinfurt was damaged by continuous bombings over several years; Würzburg, in contrast, was subject to one single major bombing occurrence. Würzburg also experienced several bombings before but the massive singular event at the end of the war when most of the city was still functional offers a much better and precise starting point for measuring recovery. Another difficulty lies in comparing the very different focus of the bombings, which in the case of Schweinfurt focused on crippling the infrastructure whereas in the massive bombing of Würzburg, morale, housing and the whole city were the main targets in the large-scale bombing. Another shortcoming of this comparison is visible by the many gaps in the tables. It was difficult to find comparable data for both cities. Still, this comparison of data sources provided helpful indications as to what challenges must be watched out for when utilising such data.

While much of the qualitative information of original sources provided here might seem anecdotal, in CIP research it is often very hard to find any, even imprecise, numbers of duration of recovery or MTTR for certain infrastructures. The following table shows an estimation of the usefulness of the data presented in this study for further analysis and interpretations regarding a city's resilience.

Table 13. Categories for measuring resilience of a city considering infrastructure and its criticality

	Example used in this study	**Information type**	**Usability for interpretations of resilience**	**Data a) difficulty of accessibility b) reliability**
Exposition				
	Attractiveness as a target by its specialised and important infrastructure	qualitative	Relevance of the system observed and likeliness of impacts	a) sensitive data, difficult b) sometimes reliable
	Limiting recovery		Recovery times	a) sensitive data, difficult b) sometimes reliable
Resistance and buffers				
	Risk transfer and repair costs	quantitative	Buffer capabilities	a) mixed b) estimates
Loss				
	Infrastructure assets destroyed	quantitative	Critical elements and depth of impact	a) not common b) ok
	Building damage	quantitative	Depth of impact and recovery demands, recovery priorities	a) relatively common b) ok
Recovery				
	Recovery speed of infrastructure services	quantitative/ qualitative	Recovery times and abilities	a) difficult b) often vague, sometimes contradictory
	Reconstruction costs	quantitative	Shift of prioritisation	a) sometimes available b) ok
Continuity of the city				
	Sewage system of Schweinfurt to new standards (not into the river)	qualitative	Could be used to see whether WWII led to several overdue innovations	a) sometimes on history websites of utility companies b) good, but difficult to fixate to a date
	Building and construction type of houses, architecture	qualitative		Difficult to collect
	Urban layout and planning	qualitative		Many publications, but often available only in the respective city archives or libraries.

The inheritance of errors, or estimations is likely, which means that errors in the original observations will propagate throughout the later stages of data processing and interpretation.

Shortcomings of the data assessments in this study exist due to the focus on these two specific cities and the few literature sources that could be found. As another shortcoming, this study uses the elasticity model of resilience and thereby limits itself to certain paradigmatic viewpoints on what resilience is and how it can be quantified. The quantification and representation of complex phenomena such as resilience by utilising a few narrow indicators are a matter of academic controversy. This study will not embark on such debate here, as the author is aware of alternative models of resilience (panarchy, community resilience, organisational resilience, etc.). The main point here is to investigate if and how a measurement of resilience using the elasticity model is possible and what kind of data can be used. Another shortcoming of this article is the focus on a few selected types of critical infrastructure. For instance, the irreplaceable loss of cultural heritage and archive documents constitutes another category related to cultural assets, which is important in order to capture the overall societal picture and is often counted as national critical infrastructure (Oppelt 1947: 43, 70). In Würzburg, a great number of cultural heritage sites, such as the residence 'Residenz', and also movable art could be saved in advance or during the attacks even with the support of the allied forces. It would be worthwhile expanding the data source research undertaken here to other CI sectors. Lastly, of course, the factors presented above represent just a tiny fraction of what makes a city resilient. Therefore, the following section will assess selected other factors that were found in the literature analysed in this study.

Discussion of Infrastructure-Related Factors Enabling and Delimiting City Survival and Continuity

Urban development (German: Städtebau) is different now than it was in the past century (before 1900); it is a "product of technology, hygiene, administration and art" (Stadt Würzburg 1945: 37, entry from 26 July 1945). The estimated costs for rebuilding the apartments were 50-60 million Deutsche Mark (Stadt Würzburg 1945: 38 entry from 26 July 1945), which is around 25-30 million in €. However, the entry also describes that Würzburg as a city did not just consider monetary aspects in rebuilding, but also included gardens, fields, vineyards and forests for a long-term perspective into the urban development plan. The city planners regarded the following criteria as significant and beneficial for this long-term perspective and in a sense, the long-term sustainability and survivability:

1. the favourable traffic location,
2. the economic area
3. the cultural significance since the 8th century (Stadt Würzburg 1945: 39 entry from 26 July 1945).

For rebuilding, the city aimed at a) continuing to be the regional capital (of the administrative district of Unterfranken: Lower Frankonia), b) continuing to be the cultural and economic centre and c) develop a reputation as a tourist and art-city (Stadt Würzburg 1945: 39 entry from 26 July 1945). The most important factors distinguishing the city's character were regarded by the same source to be

1. topographic location
2. history
3. traffic lines
4. built environment
5. natural environment
6. city hygiene demands
7. the human being

These statements are interesting since there had been an on-going, though less official, discussion right after the bombing to abandon the "tomb at the river Main" and rebuild the city upstream of the river Main, south of Heidingsfeld in a floodplain of the river Main (Süß 1995). The destroyed city should be left as a warning monument for future generations. It is therefore especially noteworthy to look at how the city organised itself and argued at that time for its own survival. For this investigation, this is a key element of a resilient city, since in recent perspectives of natural hazards, cities are often regarded as almost certain to be rebuilt at the same spot. And it is interesting to observe that the selected spot for relocation would have been a floodplain, itself a zone of both risk and opportunities. But it needs to be said that Würzburg had originally been founded at a location with floodplains already.

Natural and Man-made Infrastructure Persistence

"*Würzburg's fate is its position in a bowl*"
(Stadt Würzburg 1945: 40 entry from 26 July 1945)

The position in a bowl had worried the city already during the Middle Ages regarding space for its city walls and the extensive and elaborate city fortifications of the 17th/18th centuries. In 1945, other challenges of the bowl-shaped position were known, such as high expenses related to building along the slopes, building up supply infrastructures to the high-lying locations, aesthetic demands, blocking the skyline views etc. (Stadt Würzburg 1945: 41 entry from 26 July 1945). It is interesting to observe that they concluded with the decision not to build on the slopes and not to expand the city beyond its natural dimensions. The topography and setting of Schweinfurt is similar regarding the location at the river Main and the early selection of the location because of a river ford. The Schweinfurt city area also covers slight hills in the surrounding city quarters.
The natural river 'Main' that flows through the city is a resource for water, as well as fisheries and trade, and the ford at this position was probably the main impetus for the persistence and development of the city of Würzburg (and probably Schweinfurt as well) (Süß 1995: 11). For many cities founded along rivers and even in pre-historic times, distance to rivers and other water sources was a main location selection factor (Schier 1990a), besides fortification.
Concerning the critical infrastructure perspective that focuses less on natural infrastructure but more on man-made infrastructure, Würzburg had already been described to be a node of several national rail lines, national highways, roads and water ways such as the Rhine–Main–Danube Canal in 1945 (Stadt Würzburg 1945: 42-44 entry from 26 July 1945). This infrastructural importance was one factor that contributed to the selection of Würzburg for bombing raids in WWII. Schweinfurt was mainly selected because of its importance in industry, especially in the ball bearing industry. However, at the same time, this infrastructural hub was one of the major factors determining the survival of both cities in the aftermath, despite almost 90% destruction. Schweinfurt still produces ball bearings and both cities are important traffic hubs. It may, however, certainly be hypothesised that other factors such as human will, tradition, and lack of alternatives in a post-WWII landscape, where many other cities and villages were just as destroyed, play important roles as well.

Exposition as result of location choice and Natural CI services

Reasons for selection of settlement site

Proximity to water source, exposition to sun (slope aspect), slope degree, closeness to river valley, absolute height and other parameters play a role in identifying the earliest of human settlement traces in prehistoric times in the Main river valley and surrounding areas (Schier 1990). Location close to rivers is predominant in an area in southern Germany (Schier 1990b). Wells have mostly been dug in areas without closeness to rivers (Schefzik 2001). For each culture and settlement period, the preference of choice of settlement location vary, however. It seems that first, accessibility was a main factor, so main river valleys were preferred. Then fertile soil, but of course, also water supply and protection. The statistical analysis of prehistoric settlements finds a mean distance (modus) from water source of around 150m preferred slope degrees around 4,8%, and distance from side valley of around 350m (Schier 1990b).

That leaves to interpret that while main river valleys may have been a natural choice, other site selecting factors such as height for protection of accessibility to better soil played a role just as well (on the Gau area, löss soils are prevalent in the Franconia Main area). Additionally, later cultures sometimes settled in previously not settled areas.

People's minds and culture – Learning through Resilience?

It might be proposed that learning emerges through either repetitions of exposure to information or through sharp change events. Hazards and risks provide opportunities for both; recurring river floods as well as recurring wars train a population to react to it. Sudden events such as unexpected and extreme events also train a population. However, learning resulting from both continuous repetitions as well as from singular extreme events is not always straightforward. For example, recurring floods with a certain flood height might wrap a community in false perception of being safe from higher floods (White 1945). Also, extreme disasters occurring once within a life span of a generation might have a significant, lasting learning impact – or are quickly forgotten and overtaken by other significant developments or events.

It might be argued that German society learned from WWII in a quite sustainable way regarding the period without war after 1945 until today. This sustainability is also visibly within the many institutionally and culturally manifested regulations, rituals and declarations against war and towards forgiveness and remembrance. However, looking back before WWII, there was WWI and another war in 1870s where after German society obviously was still "war-hungry" despite the great losses and impacts. It could be hypothesised that the repetitions of three wars made the learning effect, but of course, the sheer scale of WWII also contributes to the situation after 1945 as well as the severe political and cultural control by the allied forces. In the terminology of resilience, Germany and the other affected countries bounced back, recovered from WWII, but there were also significant transformations according to the war; new city structure and architecture, new economic products, political set-up and cultural transformation – in West-Germany the long-lasting impacts of the Marshall plan and Anglo-American culture, in East Germany the impacts of socialist politics and culture. Are there specific learning types recognisable from either recovery or transformations due to WWII? This would be the task for another study.

For the city of Hannover it is reported that the inhabitants had difficulties to recognise their city after the destruction and it took time for them getting used to the new appearance and face of the city after reconstruction (Urban 2013). A new city landscape was planned (Auffarth and Dorn 2010)with settlement cells widely distributed into the hinterland. The chief town planner Karl Elkart argued in favour of rebuilding the city in its old location. This gives a hint of a presumably similar situation to Würzburg, where reconstruction at the same site was a point of consideration for a certain period immediately after WWII.

Infrastructure - Impeding or Stimulating Urban Growth and Resilience?

The fortifications were an impediment for urban development until they were officially allowed to be opened and deconstructed on 28 September 1856. After that date, Würzburg quickly developed into a metropolis (German: Großstadt) (Süß 1995:26). The connection to the growing rail system in 1854 was a major driver towards opening the city walls.

For 850 years, the old River Main Bridge had been the only bridge crossing the river. The railway system was once more a major driver of growth and development of the city of Würzburg. Within just a century, two more bridges were built, in 1888 and 1895. A city tram, operated first by horse power beginning in 1892, was soon electrified 1899, and thus added to the major role that traffic infrastructure played as a motor of development. However, because of their importance, which was gained within a relatively short period, the bridges were also the target of attacks of the allied forces during WWII. However, in Würzburg, the first bridge attacked and destroyed on 23 February 1945 was upstream, outside, of the city and this attack probably was a mistake. The other bridges in Würzburg city were in most cases destroyed by the Germans themselves for strategic reasons until their surrender on 1 April 1945 (Will 1988: 327).

In WWII, Würzburg was one of the last cities hit by an air raid. Würzburg citizens assumed that Würzburg's status as a hospital city (German: "Lazarettstadt") would save the city from bombing. In 1945 it housed 42 emergency hospitals. The fact that Würzburg had no significant industry, in comparison to cities such as Schweinfurt, and was mainly an administration city contributed to the public belief that Würzburg would be spared during the air raids. Würzburg's diversification as mainly an administrative city and as the location of many schools and churches certainly supported its long-term persistence, up to recent times, despite its lack of industry. However, in 1945 this did not save it from destruction.

In summary, this leaves an ambivalent picture of infrastructure: While defence infrastructure on the one hand inhibited growth for a long time, another type of infrastructure, rail, led to a fast development on the other hand. At the same time, however, this importance led to Würzburg's selection as a prime target, a hazard which could severely interrupt daily life. The diversification of the public sectors and hospitals also did not save the city from destruction, while these factors did, however, allow for recovery and persistence of both cities up to modern day.

Gaps of this case-study

At the start of the study much hope was on making use of health and disease data as an important proxy indicator for measuring the societal resilience of the population. However, within the research period it was found very difficult to obtain such data from city archives and public administration. For the city of Schweinfurt, it could be found that there were no significant increases of diseases right after the war, except for tuberculosis, due to the food situation and sexual diseases (Handfest-Müller: 124.) In the city and rural areas generally, an increase of hygiene related diseases were observed.

Conclusion and Outlook

Regarding the **main research question** of this chapter - what is the role of infrastructure and its criticality to allow deriving information about a city's resilience? – this study aimed to show the multiple roles and aspects of infrastructure: highly developed infrastructure may lead to a city's selection as a target, infrastructural systems can be extensively damaged during wars, infrastructure not only consists of technical elements but also of man-made and natural elements that are deemed important for the long-term survivability of a city. Regarding these **research sub-questions,** this study highlighted the prevailing role of infrastructure throughout the different conceptual phases covered by disaster risk and disaster resilience – hazard-attraction, buffering, loss and decline recovery and persistence. The study also reflected on some key shortcomings of data and sources analysed, as well as of the simplified resilience model applied. Certainly, to assess a city's resilience, many more aspects must be addressed, such as citizen's and communities' aspects of resilience, and the aspects of transformation in a city beyond disaster impacts. The study also tried to show, especially in the section about the city continuity and survival, that infrastructure is a factor that both advanced and delimits a city's evolution; on the one hand, fortification provides security to a city while, on the other hand, it hinders city growth; on the one hand electricity and rail accelerate the development of a city, on the other hand these assets themselves are severely hampered by war attacks and as quickly as a society becomes used to such a novel infrastructure, it becomes vulnerable to the loss of its functionality.

As an outlook, this study can only be a rough starting point meant to stimulate more cross-disciplinary interlinkages between the academic communities of disaster risk research and climate change adaptation, with critical infrastructure resilience, but also with urban planning, history and architecture. It would also be worthwhile exploring the commonalties between natural and man-made infrastructure and the concepts of ecosystem services and critical infrastructure. Regarding the question as to what resilience actually is and how it can be measured, a lingering question behind such multi-dimensional constructed concepts is to identify what actually is the outcome measure intended to relate to: How can it be measured or benchmarked if a city is or was resilient? Here, criticality assessment not only offers a valuable addition to existing vulnerability and resilience indices regarding another sector to add, but also in terms of finding a prioritisation method and threshold identification method. Especially interesting would be to advance the identification and prioritisation of key values or risk protection goals endorsing security or resilience. However, the field of criticality assessment is still in an explorative phase regarding the examination of natural hazards or larger human crises, including wars. One outlook is that it will be necessary to collect more data and compare it with natural hazard impacts on cities.

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Comment

Essay 6 is another chapter that was excluded, from a habilitation thesis in 2018. Indeed, it also failed twice to be accepted in journals. It was excluded when one of the reviewers doubted how and whether war damages could or should be used to compare risk or in this case, criticality with natural hazards such as river-floods. This is interesting, since it has been observed in the last decade by the author, that there appear to be streams within disaster risk research running in parallel, such as man-made and natural hazards research, but despite many crosscutting themes such as climate change and growing interdisciplinarity, especially in this field, still there are fields not known or integrated yet. An example is the field of Critical Infrastructure (CI), which emerged on the topic of terror attacks and since the early 2000 years has started to be discovered also within natural hazards research and policy. While CI are now even officially included into the Sendai Framework for Disaster Risk Reduction, still the concepts and methods vary to traditional natural hazard and risk approaches. For example, criticality is introduced as another methodological components next to hazard, vulnerability and resilience assessment steps. Criticality was already included in the methodology of FMECA - Failure Mode, effects and Criticality Analysis in a military standard by US Defense Department in the 1940s and is widely applied within industry. It already contained a criticality and severity matrix, nowadays used as 'risk matrix' in many field such as work safety, nuclear safety, automobile production and civil protection by German national bodies and at community level, for example. However, it often seems as these methodologies and origins are hardly known or at least applied by the majority of natural hazards, vulnerability or resilience assessments. And for criticality, as used in recent integrated risk management guidelines on CI, it is comprehendible that it is not widely used or known as a conceptual component in natural risk or social vulnerability studies, as it had been treated as a technical structure model mostly. But human dependency on it, human vulnerability factors, institutional aspects and many more must be integrated, why this is a great field for advancement. but back to the question if and how a war like WW II could be compared to natural hazards? The standpoint of Ci is a paradigm shift towards acknowledging that the hazard or threat side is important, but there is more demand to understand impacts and their chains much more. A so-called all-hazard approach has become accepted where all kinds of hazards, natural, man-made, technological and others, are integrated. And the methodology of criticality explicitly side-lines the question of hazard in order to first priories the most severe impacts on society and / or supply chains. This priorisation is what is lacking in most vulnerability and risk studies, by the way; there is some tradition of research of identifying thresholds and risk acceptance levels, but criticality directly goes in depth here, also enabling to connect human values and strategic targets. This is one reason why WWII had been selected to be analysed next to river-floods; the methodology not only permits its, but all-hazard approaches demand for it, too. Another reason was that the case study region, Würzburg city in Germany had seen destructive river-floods as pronounced representatives of natural hazards, but how to identify critical thresholds in a novel way? In vulnerability studies, benchmarks are often missing, and criticality analysis provided this; the most destructive event, worse than any river-flood was WWII with over 90% of the city destroyed. proof of severity and criticality but also resilience could be found by reading the criticality criteria from the Allied Forces and the city hall protocols in the immediate weeks after the bombings; which critical infrastructure had been hit, and which needs and demands existed on the population side.