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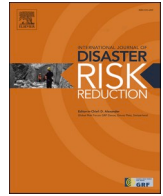
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Measuring social resilience: Trade-offs, challenges and opportunities for indicator models in transforming societies[☆]

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ABSTRACT

More than any other facet of resilience, social resilience raises the inherent tension within the concept between identity or persistence, and transformation. Is a community the people who make it up, or the geography or physical infrastructure they share? What about the resilience of communities that transform, as a result of a sudden disaster or over time? In this paper, we explore the impact of this tension on how social resilience indicators can be developed and used. Beginning with a close look at the ways in which our concepts of resilience and our use of indicators interact, several points are raised. First, that how we identify a community and frame its resilience conveys particular conceptualisations of resilience, which in turn have normative implications for the communities themselves. In part, this is because of the difficulty in capturing important adaptations and transformative actions within and by those communities. Further, measuring and comparing the resilience of communities, and aspects of quantification that go along with selecting, aggregating and comparing indicator values, ensure that the decisions made about how indicators ought to be used carry normative weight. Through this exploration, we identify several normative implications of choices in indicator design and application. We conclude with recommendations for moving forward with greater transparency and responsibility toward those communities whose social resilience we hope to measure in order to improve.

1. Introduction

It has been accepted for a time that many of the aspects that make a populated area, such as a city, more or less resilient are social factors (eg. Ref. [1–3]). Such aspects have to do with the relationships formed between members of the community within that area, the resources that are socially available (that is, beyond and including the functions of physical infrastructure), and the resources required by certain social groups that make them more or less adaptable to extreme disruptions in their environment. Resilience is as much about the people in a community as it is about the transportation, energy and other technical systems present in that area; so-called ‘social resilience’ and resilience in general are intertwined.

However, as we argue here, there is a fundamental duality within the

very concept of resilience that makes measuring these social aspects of resilience particularly difficult. This duality is best described as a tension between resilience as a characteristic of a community as it now exists, and the transformations that will happen within and to that community, should it survive a severe disruption. The primary way to measure such aspects of resilience is indirectly, through *indicators*, since resilience itself is a complex concept. However, current indicators of ‘social resilience’, we argue, fail to capture this tension in various ways, and yet they are increasingly being used for policy and to describe the resilience of populated areas. In this paper, we highlight how they can constrain our ability to describe two things: the importance of adaptive or transformative qualities that social groups can contribute to a community’s resilience, and the normative implications of how we decide to frame communities and their qualities as indicators of resilience.

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We focus on the use of social indicators in Western, contemporary, communities and cities. We see, however, many of the points that we draw upon from the literature and that we raise ourselves here as generalizable, although in this paper we have only room to make suggestions toward that generalizing work. We argue that many of the limitations of current indicators used in this context, as they are formulated, arise out of the dual nature of resilience itself, as both transformative and aimed toward recovery. Further, developers and users of indicators need to make decisions about the scope, scale, and constitution of the social group, or community that is the subject of analysis. As we argue, these decisions are normative: they not only posit an ideal target community, they also have direct and indirect implications for the people whose social resilience is being measured. Consideration of the normative question leads to a different type of indicator than those already proposed and in use – in the conclusion of the paper, we draw on the observations made throughout to highlight how indicators could be better formulated and used to describe and measure social resilience. These can thus be seen as basic criteria for social resilience indicators.

We cannot here provide a systematic review on social resilience or indicators ourselves, but rather depend on recent literature that offers a comprehensive review of current trends and practices in developing and applying social resilience indicators. For such a general classification as well as a specific evaluation of current indicator approaches, Cutter's, "The landscape of disaster resilience indicators in the USA" [4], and Saja et al.'s, "A critical review of social resilience assessment frameworks in disaster management" [5], are suitable sources for an introduction to the key issues: Cutter is a well-cited author in the field, who has developed and consolidated indicators under the category of social resilience; Saja and colleagues provide a recent review [5] that focusses explicitly on indicators for social resilience. We thus use these sources here to give a brief description of the current status of indicator research in the area of social resilience. While the issues we will address are not necessarily novel, they remain implicit and underdeveloped as a move toward making such indicators more representative and responsive to the transformative aspects of social resilience and the normative implications of measuring it.

Saja and colleagues [5] differentiate between hazard-specific approaches, geographical contexts (where a specific area or region is the basis), and hierarchical concepts (where borders are used to delimit a system, be it city borders, regional borders or whole nations). They classify approaches in four ways, as based on: social capital, coping, adaptive and transformative/participatory (CAT) capacities [6]; social community and interconnected dimensions; or structural and cognitive dimensions. Cutter [4], on the other hand, differentiates between assessment types: indices, scorecards, and tools. She then defines further categories for different approaches, such as spatiality, focus (either on specific assets such as infrastructure or on the whole community), domain ("either characteristics of the [considered] system, or the capacities within them"), and method (top down or bottom up). She also makes a distinction between defining inherent properties of a system (benchmarking) and assessing the "ability of individuals, stakeholders, or communities to learn from and respond to changes" as a dynamic process. Cutter proposes a set of core indicators consisting of the "most often used proxy variables". This set of approximately twenty core indicators, however, only uses one dynamic variable (the "feeling of belonging to the community"), which illustrates the current focus on static, relatively easy to measure values.

Both Saja et al. and Cutter conclude that the evaluation of dynamic processes has not yet been made sufficiently measurable. Saja et al. [5] point out the, "difficulty in making the resilience indicators easily measurable that are not outcome related, but related to social mechanisms"; and Cutter [4] claims, "it normally is a process involving social learning, but it can also have a measurable outcome". Saja et al. [5] also emphasize the difficulty of consistently defining those already hard-to-measure CAT capacities, and critique the neglect of

"participative capacities" – the capacity of a social system to apply adaptive and coping capacities in times of crisis (eg. in Ref. [7]). Thus, the importance of transformative capacities versus dedication to what should be preserved has at least been acknowledged in the literature.

We can see this in other, broader, contemporary approaches to resilience as well, for example in Norris et al. [8]. Their capacities approach views resilience somewhat philosophically as a process rather than an outcome. Resilience consists of four resource pools: social capital (e.g. the "sense of community", "informal ties", "enacted [and] expected social support"...); community competence (e.g. "problem solving skills", flexibility and creativity...); information and communication (e.g. "trusted sources of information", "responsible media"...); and economic development (e.g. "level and diversity of economic resources", "fairness of risk & vulnerability to hazards"...). Many of these are interlinked; some are measureable, some rather not.

In sum, others have already noted the lack of defining characteristics and the difficulty of measuring transformative capacities within the concept of social resilience, and many of the resulting difficulties with measuring social resilience through indicators and otherwise. It remains the case, however, that those who wish to evaluate social resilience today can choose from an enormous set of indicators, of which almost all are only capable of measuring an outcome or benchmarking static conditions of a system. Further work thus needs to be done. We take a multidisciplinary approach in this paper, combining the expertise of authors who specialise in philosophy of the city, ethics of technology, systems and risk analysis, and emergency management. These diverse approaches combine to highlight several aspects of social resilience that make indicators difficult to develop and to use, and that we feel current indicators ought to address more effectively and transparently.

To start, in the next section we further elucidate the nature of the duality we see as part of contemporary understandings of resilience; above, we drew upon recent reviews of the literature to summarize how indicators have already engaged that duality. Next, we offer an exemplary use of indicators to demonstrate where we see more effort is needed to resolve key issues. Consequently, in Sections 3 and following, this paper contributes to the literature with additional considerations and, in particular, by calling attention to the normative aspects and implications that remain underdeveloped.

2. Social indicators and social resilience

Indicator selection refers to the system variables (features or properties) thought to determine a system's resilience. Yet, because of the different socio-technical-environmental contexts to which resilience is applied, there are no agreed upon standards or guidelines that would allow one to compare resilience across systems. There is a lack of consensus on whether resilience is to be understood as a set of (networked) capacities [8], as social or economic capital [9], or as a set of infrastructure characteristics [10,11]. It makes a difference: Meerow et al. [12], for example, highlight the implications that analytical frameworks and their underlying concepts have for how we define urban resilience (see also [13]). From a governance perspective, there is also the question of whether resilience describes a state, or system properties that can be achieved or designed for, or if it is a process that requires continuous vigilance and transformation [14,15]. And finally, there are fundamental differences we will explore in this paper, between understanding resilience as the ability of a system to restore its functionality versus longer term adaptation.

Indicator selection, therefore, is intrinsically linked with the understanding of resilience held by the decision-maker and user; without a common understanding of resilience, indicator models will remain subjective and highly context-dependent. This is both a strength and weakness of the resilience indicator models. A strength, because measurements are adaptive to the specific situation and use. A weakness, because seemingly 'objective' resilience measurements may be subject to omission, misinterpretation, bias or even manipulation. In this

section, we look at how duality permeates and can add confusion to the conceptualization of resilience, and then at how the selection of social indicators can influence assessments of a community's resilience.

2.1. Conceptualising social resilience

The term resilience can be traced back to the Latin “resilire” and can simply mean “jumping back” or “rebounding”. The term was more broadly used in the mechanical sciences (from 1858) to refer to the extent to which materials are able to deform and return to their original state [16]. In scientific theory, the term resilience then spread to psychology and ecology [16–18], and later to a number of other scientific disciplines, such as geography and economics [16,19]. Because of the numerous applications of the concept of resilience in various disciplines, different definitions were developed, and the lack of unity in uses of the concept became apparent (see, eg.: Asadzadeh et al. [20] on the resulting difficulties with operationalization). Consequently, there has been debate about how far the concept of resilience can truly be investigated, due to the lack of specificity and numerous fields of application (eg. [21]).

Resilience is increasingly, however, more generally understood as a “boundary object”, which, precisely because of its limited discrimination, can be used across disciplines and thus promotes interdisciplinary cooperation [17,19,22]. Furthermore, the concept of resilience has undergone an essential development, moving from understanding it via the original meaning of “return to the original state” (build back/bounce back) toward an understanding that a different and possibly better state can be achieved through adaptation and transformation (build back better/bounce forward) [19,21].

Although social resilience was already associated with disasters in the 1990s - and probably even earlier (e.g. Ref. [23]). Keck and Sakdapolrak [19] claim that only socio-economic resilience was considered until Adger [24], in his article “Social and ecological resilience”, first distinguished and defined social resilience as such. In their review, Keck and Sakdapolrak [19] describe the further course of differentiation and definition of social resilience. They summarize the works of Voss [25], Lorenz [7], Obrist et al. [26] and Bene et al. [27], wherein three dimensions are distinguished, describing social resilience through coping capacities, adaptive capacities, and transformative capacities.

Even if there have been approaches or models to evaluate social resilience before Adger (e.g. [28]), probably the best known attempt to make resilience in general—but also social resilience in particular—measurable, is the work of Cutter et al. [29]. Some further approaches have been developed in the years following, as Ostadtaghizadeh et al. [30] state in their literature review, and as Cutter [4] herself suggests in “The landscape of disaster resilience”. The recent publication by Saja et al. [5] attempts to critically reflect on the known and used frameworks for assessing social resilience. The authors distinguish between different types of frameworks and the dimensions, characteristics and indicators derived from them, as well as the resulting possibilities for measuring social resilience. Due to the heterogeneity of the frameworks, it is difficult to derive reliable indicators, they conclude [5].

An additional foundational problem is that sets of indicators being currently developed often inadequately distinguish between different ways of understanding the resilience being indicated: it is not only a quality reflecting either perseverance or transformability, but it can be represented as a process, as an outcome, or as structure-based, depending on which indicators are used and how. That is, although indicators are widely used, there is still no universally accepted definition of what an indicator actually is [31]. For example, some authors consider an indicator to be a proxy measure of some abstract, multidimensional concept (cf. [32,33]), whereas others consider them to be variables that are hypothetically linked to the phenomenon under study, which in itself cannot be measured directly [34]. A distinction is often made between process, outcome, and structural indicators, with process

indicators being a measure of how well the activities or interventions are being run, outcome indicators showing how well certain activities or interventions are accomplishing their intended results, and structural indicators referring to the characteristics of a system that affect its ability to function [35]. Constructing indicators for resilience is in itself already challenging, as resilience cannot be measured directly, so the variables used to construct a resilience indicator are proxies for resilience or, even more indirectly, for a phenomenon linked to resilience. Additionally, we see that the aims of the different indicators do not always match the way they are constructed, and it is not always clear whether the indicators are outcome, process, or structure-based [36]. But this is just one example of the ways in which creating indicators can be complex, both because of the nature of indicators and the nature of the thing—in this case, social resilience—being indicated.

As we mentioned above, we do not presume to provide a systematic review on social resilience here ourselves. Instead, for our analysis, we have drawn principally and intentionally from reviews on this topic that have already been carried out and that are widely used in the scientific literature (e.g. as above [5,29]) or that currently address the limitations of the concepts with which we are here concerned. The underlying idea is that, on the one hand, more widely distributed publications have greater influence on the practical implementation of the measurement of resilience. Published reviews in recent years, on the other hand, also point to the same discrepancy in the delimitation of the various concepts of resilience [5,20]. In Section 3 we take up this thread of critique and further address key issues raised by how social resilience indicators can frame, both empirically and conceptually, the communities, groups and individuals who are assessed by them. Sections 4 and 5 explore normative implications of how indicators measure communities, and of how those measurements are selected and used, respectively. The questions and recommendations raised along the way are intended to guide further research toward a different, more dynamic view on how we might measure resilience. We begin by briefly presenting a case, to illustrate how indicators are currently in use and to point to some concrete practical and theoretical issues their use can raise.

2.2. The 2005 Münsterland blackout

The 2005 blackout in the Münsterland area was the first major blackout lasting for more than a few hours in Germany since the Second World War. For up to six days, as many as 250,000 people were without electricity, mostly in the districts of Borken and Steinfurt [37]. Disaster alerts had been announced and crisis units had been formed in some districts merely 3 h after the beginning of the blackout [38].

The blackout was unexpected, caused by a snowstorm severely damaging the power poles and lines. Even more unexpected, though, was the capability of the people living in those rural areas to cope with its aftermath and effects, despite an extremely low level of awareness about private emergency precautions [39]. In a study later commissioned by the Federal Institute for Agriculture and Food [39], many people criticized the transmission of information to the population (e.g., as insufficient or communicated by hard-to-understand loudspeaker announcements, that communications of offers of help from aid organizations were missed, etc.). However, neighbors helped each other with food, water and candles, gaslights or batteries for flashlights. The distribution of emergency power generators via fire brigades and the German Federal Agency of Technical Relief (THW) went mostly smoothly [40]. Only in the city of Ochtrup were unused generators, due to communication problems, reported [41].

Thus, although heating, public transport, logistics in general, and other critical infrastructures such as telecommunications were severely hindered, people did not panic, but rather became adaptive and creative [38]. Relief organizations distributed warm meals and drinks [42]. In some districts, supermarkets opened on Sunday [41]. Medical aid and transport were maintained in a basic yet sufficient way. Consequently, the incident had a relatively mild outcome with no human fatalities or

major injuries, despite the unusually cold winter days during the blackout [43].

In the following (Table 1), commonly used demographic indicators for social resilience [8,29,44,45] have been surveyed for the affected districts and compared to the average values for Germany [46–48]. The values for the affected districts are mostly close to the German average.

The set of indicators we have chosen for this table reflects common approaches to indicators of social resilience that we find in Cutter's work, particularly in her co-authored and frequently cited 2010 paper, 'Disaster Resilience Indicators for Benchmarking Baseline Conditions' [29]. The percent of population over 65, for example, parallels commonly used indicators that relate percentages of elderly in the population to social resilience, here formulated as a negative indicator (ie. a factor that constrain or lowers resilience). 'Municipal Services', here taken up as the 'Firefighters quota', is a common indicator, set in Cutter [4] as 'Percent municipal expenditures for fire, police, and EMS' (drawn from Sylves [45]). While in Germany firefighters are volunteers rather than paid municipal workers, in both cases the indicators themselves focus on numbers in relation to population and not on the nature of the service itself, so that aspect would not be taken into account. And the 'Quota of people living in poverty' is framed as the 'Income and Equality GINI coefficient' in Cutter [4] and Norris et al. [8].

By assessing these numbers, however, no useful information on the actual resilience of a population in a specific area, or the whole of Germany, can be derived. The low number of firefighters per 100.000 inhabitants, for example, would have led to the assumption that these districts are less prepared for a disaster. But to say that without knowing how well prepared a district would be with an 'average' number of fire fighters is again not useful for the evaluation of resilience. A large number of incidents of similar length and severity would be needed to prove a statistically valid connection between the values of these indicators and the resilience of the affected communities.

Further, if the communication failures in this case were used to measure the resilience of these communities in hindsight, the apparent adaptability of the populace itself to the changing circumstances and failures of normal proxies for social resilience would be missed. The ability of a community to utilize its resources in a new way in response to disruption is a key aspect of the potential transformability that we argue is often part of a community's resilience (see also, eg. [3]). This capacity to adapt when the usual channels for obtaining emergency services and resources may not be robust is often attributed to the kind of 'local knowledge' that leads people in the community to find and to coordinate new uses for existing resources—through social channels—in order to fill those gaps (see, eg. [49]). While often noted as a distinction between rural and urban communities, these stronger or weaker social ties can be both conservative and transformative, and they can be found in different groups within a larger community such as a city as well as in more homogenous rural towns and villages. As we point out throughout this paper, how we draw the lines around the community we are assessing has much to do with how their resilience will be perceived, and whether indicators are seen as positive or negative in respect to that community's resilience.

The "soft" factors adequate to display social cohesion or social

capital, such as neighborhood aid services, civic organizations or community engagement in general, are not only difficult to measure, but also their existence does not lead to an increased social resilience automatically. Commonly used Indices - such as the Resilience Capacity Index [50], the Resilience Index Measurement Analysis (RIMA) from the FAO [51], the Social Vulnerability Index [52] or the Index that can be derived from the indicators in the ISO 37120, all use quantitative, demographic indicators such as those in Table 1. Adaption and transformation capacities are displayed e.g. via voter participation or the socio-economic status such as via education. By that, a broad and diverse participation and usage can be ensured, with enhanced comparability and growing data sets, but with the drawbacks already described as well as disadvantages regarding normativity, commensurability and aggregation that we describe in detail in the following sections.

In sum, we see this as a typical case: social indicators, as currently developed and used, will often lead to mistaken assumptions about the capabilities of people in affected areas. More specifically, by failing to account for the ways disruptions can be transformative via social factors, indicators tend to measure social resilience in terms of the status quo. In this example, the indicators can only describe an assumption, that the number of firefighters or the quota of people living in poverty are linked to resilience. They thereby also imply an "appropriate" value, or norm, for these respective indicators. And, while focusing on vulnerable groups can have profound implications for those groups (see also [53], and the following sections of this paper) more general indicators might have less meaning. Out of the dozens of indicators given in the ISO 37120, for example, we could have likely picked a set where the Münsterland districts indeed show "better" values than the German average. Such manipulability suggests it is particularly important to pay attention to the framing of the very system whose resilience is being measured.

3. Identity and framing of a System's resilience

Indicators are typically designed to measure and compare the level of performance with respect to benchmark cases. They can be designed to measure and compare the resilience of different systems, defined by geographical areas and communities [1], industrial sectors [54] or critical infrastructures [55,56]. Social resilience is inherently embedded in a system, but there are many ways to understand that embeddedness. At its simplest, social resilience necessarily describes an aspect of some community - the characteristics that comprise social resilience are of course *social* in nature, arising from relationships that exist between individuals or groups, be they structural, institutional, geographical, familial, religious or otherwise. However, there is also the question of whether the social context is defined by any particular relationships more than others.

3.1. Geography and culture

Social resilience may aim at capturing the resilience of a social system that can be defined geographically. But does the social resilience of a community overlap completely with, for instance, the resilience of a particular urban area, or more narrowly of a neighborhood within that urban area, or even of a particular group that crosses through several such geographical spaces, united by common beliefs or desires? What counts as the community that demonstrates social resilience is a contextual matter, requiring us to define it specifically for each reference.

For example, if an historical community is our unit of measure, we might see its resilience in terms of its success as a diaspora. The community was defined at one point by its members' shared geography, or continually by their genealogical connections, but in remaining bound together socially, the community seems to demonstrate a high social resilience despite having moved beyond the geographical center of what made it a community in the first place. And, in contrast, if a group stays together at a particular location, despite everything about their way of

Table 1

Comparison of some commonly used social indicators for two districts in the affected region and Germany in general in 2005 -

Area	Population density/ km ²	Population <15 (%)	Population >65 (%)	Firefighters quota in x/ 100.000 inhabitants	Quota of people living in rel. poverty (%)
Borken	260	18,4	16,4	593	12,7
Steinfurt	247	17,6	17,4	717	12,7
Germany	232	14,5	18,6	1.299	14,7

life being changed by a great disruption, such as an influx of mass migration or disaster that destroys their cultural heritage, is it still the same community, despite these changes in social and cultural constitution? Whilst some things may be allowed to undergo transformative change, for a community to be deemed resilient, *something* about it must persist. In turn, what we focus on makes a difference to whether we see the community as resilient or not.

A related concern is that social resilience indicators often imply that vulnerable groups, like those who are affected by disabilities or belong to groups with special needs, have a negative impact on the overall resilience of their communities. Wealth, for instance, can be a positive indicator of resilience. Those who are wealthy have an easier time recovering well from disasters. But it would seem then to follow that the lack of wealth ought to, then, be a negative indicator for resilience, decreasing the resilience of the poorer group and, consequently, of the broader community who must care for them in crises. But this neglects the importance of, for instance, resourcefulness, a quality often demonstrated more by those with fewer resources than by those with many at hand [57]. It could be argued, for example, that the experience of many who are elderly can be useful in crisis situations – they have local know-how, have often survived similar sudden changes and trauma, and can offer care-giving aid where needed. Yet, a higher percentage of elderly population counts as negative against a community's resilience (see Cutter [4]). Further work is needed on how we can use indicators in a way that allows for complexity and nuance in the nature of group qualities and in assessing potential impact on their community's resilience.

Of recent cases in resilience, the case of New Orleans and the impact of Hurricane Katrina was a watershed in terms of how social resilience can and ought to be measured. Several features of this community and event illustrate the points we are making here about framing. Specifically, questions can be raised in respect to the Lower Ninth Ward – an historical and poor, racially African-American community, often considered the soul of New Orleans' jazz scene, and hardest and most devastatingly hit by Katrina when the levee protecting this community broke. This community, thought to be socially resilient in many ways, being a close-knit community of long-term residents, was slow to recover after Katrina. Meanwhile, the broader community of the city of New Orleans has become renowned for its resilience. Thus, the question can be raised, if the 'soul' of a city is not resilient, what does this mean for the city?

On the other hand, a local population of Vietnamese immigrants did recover well after Katrina, remarkably more quickly than other groups across criteria for recovery success. As VanLandingham [58] explores, this community would not have been assessed as highly resilient before the disaster, according to indicators in use. Indeed, they fared less well on several indicators than other groups who recovered more slowly: in terms of economic and occupational health, social isolation and a lack of communication beyond group membership, for example. In those areas where they may have fared equally well as others, there was no hint they would have fared so much better post-Katrina as they did. VanLandingham and his group posit that culture is the neglected factor, and conclude that resilience itself is an inadequate measure for potential recovery [58]. Here, we seek to explore other reasons for indicators missing the mark in such ways, but agree that the inability to take up factors such as values and beliefs is a key problem with social resilience indicators as they are currently imagined.

3.2. Adaptation and transformation

One of the key challenges in defining indicator frameworks for resilience is that crises are moments of disruption with a great potential for transformation [59]. It is well documented that people's behaviour changes during crises or under risk [60–63], when they are trying to rapidly adapt to an environment that has fundamentally changed. Examples include mass migration movements in response to climate crises

or conflicts [64], macro-economic adaptation such as after the 2011 Thailand floods [65], or smaller behavioural adaptations such as switches in means of transportation when there is a warning for extreme weather [66].

Indicator models, however, by their very nature do not take into account such adaptation processes. Rather, they begin and end with current behavioural patterns, values and preferences—what is considered as adequate or ideal, that is, is determined by 'pre-crisis standards'. This implies that rather than unlocking the potential for transformative change in the aftermath of a crisis or so-called 'wild-card events' [67], the indicator models end up being conservative in nature, ultimately protecting pre-crisis standards and ways of living insofar as 'being resilient' is defined in terms of meeting those standards. This reflects that inherent tension within the concept of resilience, as both the ability of a system to resume essentially the same functions that it had prior to a crisis event, typically a shock (e.g. [68,69]), and the ability of a system to adapt to longer-term stresses and challenges, potentially using the shock event as a catalyst for this transformation. While much recent literature and many definitions from practice indeed require that resilience also includes the capacity for adaptation and change [70,71], as we noted above and highlight again here, indicator models tend rather to support (by implication and design) an emphasis on recovery to the status quo.¹

As a result, indicator models should be used carefully, and should be clearly aligned with the underlying understanding of resilience. To capture the transformative aspects of resilience, standard indicators that measure the quality of life or services by proxies such as the infrastructure or means available may need to be replaced by more direct measurements that focus on the *services delivered* instead of the means to do so, e.g., people traveling from A to B instead of service downtimes or road infrastructure measures. In addition, time series of indicators that analyze the *degree and rate of change* in the use of an infrastructure or service are more suitable than static measurements to understand the transformative character of resilience. Finally, benchmarks may need to rely on future or idealized scenarios rather than on comparisons of current systems. In the next two sections, we examine some further implications of indicator models, in terms of decisions made.

4. Implications of measuring communities

Decisions about the scope and scale of the unit of analysis—which community or social group is being measured—affect how indicators can be used to measure social resilience, for instance whether different groups can be compared in terms of their resilience. Decisions about what counts as a social group are grounded in assumptions about what counts as resilience for the broader community to which they belong, assumptions that are seldom made clear. And, many of these assumptions are based on assumptions about the vulnerability of particular groups, when it comes to responding well to disruptions. These and other considerations, once taken up, affect our ability to put social indicators to use in the desired way, to frame policy and to direct efforts toward improving the resilience of particular communities. Highlighting the normative implications of the framing and implementation of indicators is key to understanding how to better develop and use such indicators effectively to attend to and improve social resilience.

Developing (social) resilience indicators is not seen as a goal in itself.

¹ Note that this is the case when we compare resilience literature in the form of academic journal articles and the like – official definitions of resilience do not all include references to, or attend otherwise to the potential for transformation in resilience. In Germany, for instance, where the case we describe in 2.2 takes place, the BBK/Ministry of the Interior gives a definition of resilience that includes both 'adapt' and 'resist' but no version of 'transform'. So indicators deemed appropriate in that country, according to that definition, will not be required to account for the transformative capacities of citizens or groups.

Indicators are instead presented as “decision-making tools” [72] to be used to, “identify which communities require the most immediate attention and where return on investment may be highest” and, “to evaluate resource allocation decisions across neighborhoods, as well as to track a neighborhood’s resilience capacity over time” [73]. According to Burton [74]:

Using indicators ... to assess what makes some communities more resilient than others permits comparisons across space and time and promotes (1) actions to reduce risks such as the development of public policies, (2) focused discussion on resilience building issues, and (3) ideas for integrated actions. (p. 84)

Given the history of social indicators and their use in policymaking since the 1960s [75], the emphasis on policy and decision making (especially regarding the allocation of resources) comes with little surprise. Yet, we need to ask if the general intent to provide tools for decision-makers and stakeholders is sufficient in the context of social resilience. We argue that we need a more detailed understanding of the intended and likely use of the indicators to ensure that the inclusion of social indicators benefits those who are represented in the variables.

The responsible design and use of (social) resilience indicators are challenging tasks. Indicators aim to enable measuring and comparing the resilience of different systems (or one system over time) by reducing complexity to apparently easy-to-read numbers. Tate [72] sees social vulnerability indices, for example, as “potentially powerful tools ... in that they summarize complexity, provide quantitative metrics to compare places and track progress, and are relatively easy for non-experts to interpret”. The use of indicators in a specific context, however, is hardly ever a simple act of application. Scholars rather consistently point to the need to adapt an existing set of indicators to the specific case. For example, Saja et al. [76] highlight the flexibility of their own framework, suggesting that it, “can be adapted to any geographical, hazard, or community context by shifting the priority of the characteristics and indicators according to the context”. Furthermore, they invite potential users to identify “key social resilience indicators,” based on the specific context. Such flexibility not only raises questions about the plausibility of comparing levels of resilience across different communities, but also about the level of competence required for resilience assessment [77]. As we demonstrate in the following section, these challenges are related to the processes of normalization and aggregation in selecting indicators. It also concerns questions of choosing the adequate geographical level, especially if indicators are built on existing data resources such as census data.

For instance, taking into account the presence of minority groups or people with disabilities in the context of resilience-building is clearly preferable to ignoring parts of the population when preparing for disaster situations [78]. But we also need to recognize that resilience-building strategies do not automatically benefit disadvantaged and marginalized groups [79]. As King and MacGregor [75] remind us, there is a history of considering “the very young,” “the very old,” “the disabled,” and “newcomers to the community and migrants” as “major groups that are agreed to be of significance as the sort of people likely to be associated with high levels of vulnerability”. These groups are captured also by social resilience indicators proposed by Cutter et al. [80] and others. For example, a high “Percent of Non-Family households with Under 18 Occupants” or “Percent Population Over 3 Not Enrolled in School,” as well as a high “Density of Adult and Child Social Services Centres” and “Residential Development Disabilities Services Centres” [73], each have a negative weight attached: the presence of, e.g., a larger group of people using social services is seen as being negative in respect to that community’s resilience. The groups singled out through social resilience indicators are thus often presented not only as being at risk but as also being a risk factor. Exceptions, where the presence of minority groups is considered as a positive indicator (e.g. [76]) are rare: when they are, it’s not the mere presence of diverse

groups that matters, but also the degree of their social participation and interaction.

From a broader perspective, the design and use of social resilience indicators can be seen as *anticipatory actions* [81,82]. Essential to such actions is the idea that we might be able to identify variables in the present, which allow us to prevent undesirable future developments. Thus, the focus is on actionable information, in the sense of information that can be translated into and guide activities. That is, we think it important to question *how* specific indicators can be translated into actions and *who* will be the subject and object of these activities.

In their paper on the use of social indicators for measuring community vulnerability, King and MacGregor [75] point out: “If we want to know how vulnerable a community is we must begin with some expectation of what is required of the community in the face of a hazard”. Similarly with resilience: What are the expectations of a community that is considered to be resilient in the face of a hazard? What should people be able to do? Indicators such as the density of Social Service Centres tell us little about what needs to be done, or by whom, to increase the level of resilience. That is, the solution cannot be simply reducing the number of Social Service Centres.

If we want to highlight the transformative aspects of resilience, we need to become more conscious of how indicators do, in fact, suggest and guide actions by various actors. Yet, Malik and Kontokosta [83] present their methodology as only a “preliminary screening tool”. While it seems plausible to frame indicators as a preliminary screening tool, this does not relieve us from the follow-up investigation, and does not mean that the actions taken are independent from the design of the screening tool. Rather, indicators are not neutral tools, and any methodology (or use thereof) must call into question its own (normative) implications for action.

An essential motivation for using social resilience indicators is the recognition that social factors are relevant for resilience building. Yet, contemporary examples of such indicators emphasize the identification of problematic communities where interventions from the outside are needed. On the one hand, this approach runs the risk of eliding the root causes of the problems such communities have and, thus, the need for transformation, by focusing on resilience [21]. On the other hand, they often fail to recognize the agency of community members and their potential contribution to resilience building. Part of the reason for this is that characteristics such as agency are difficult to measure, and thus to compare, an issue we explore in the following section.

5. Implications of indicator selection

The demand for indicators is in itself not surprising. Despite or maybe because of the many definitions of resilience, the concept itself is quite abstract and complex. Hence, there are many calls from practice to operationalize resilience, to turn it into a concrete and measurable concept that lends itself to decision- and policy-making [54,84]. Any attempt to measure and operationalize resilience, however, also has a definitory character - determining for the user what resilience means, and how it can be applied. That is, what we measure and how we relate those measurements to each other has normative implications for who and what are being measured.

5.1. Valence and temporality

The implications of an indicator for resilience, to begin, are far from clear: it is not as evident as many models suggest, whether a high value for an indicator is a positive or negative for resilience. For example, rates of immigration, or numbers of minorities or non-natives, are frequently seen as negative resilience indicators (e.g. [84,85]) - and such evaluations most often go hand in hand with negative indicators of economic prosperity. Yet, these very populations may have a high personal resilience, having been able to make the journey to their current country, and they may also have a high social connectedness. Recall the example

of the Vietnamese immigrants who successfully and rapidly recovered from Katrina in New Orleans [58]. Another example is a high level of advanced or digital services, which, given the vulnerability of a population dependent on such services in a crisis, might be a negative indicator for resilience. In contrast, populations with a negative economic indicator might be frequently confronted with outages or used to navigating without digital services – and thus be more resilient [86].

Such considerations are directly related to how we determine the unit of measurement – the social group or community whose resilience is being indicated. Further, partly because of possible changes in a group or community's location or make-up, much depends on the unit of time over which we measure. Indicators, then, should be highly sensitive to, and transparent about assumptions in respect to the context and timeline to which they apply.

5.2. Normalization

Besides the definition of what to measure, and which contribution an indicator has to resilience, another problem is the mapping of the observed or measured values to a resilience function, typically between 0 (lowest resilience) and 1 (highest resilience). This normalization is needed to aggregate indicators that are measured in different scales and units into a common index.

To perform such a normalization, a user needs to consider what is the ideal state of resilience, and its opposite. Should the number of redundant roads, power cables, or telecommunications masts be 5 or 500 in order to be resilient? Because it is difficult to foresee which properties the resilient system should have in order to be prepared, negative or positive benchmarks for determining the resilience of systems are often constructed from an empirically collected dataset (e.g. [56]). While it is not our intention to discuss the best method for normalization per se, our point is that any use of quantitative indicators unavoidably involves the normalization of these indicators, which is far from trivial.

Most commonly, min-max scaling is used (e.g. [84]), assigning 0 to the worst value in a chosen dataset, and 1 to the best value. All other values x are mapped to their resilience function $r(x)$ between 0 and 1 by $r(x) = (x - x_{min}) / (x_{max} - x_{min})$. The method is advocated for because of its ease of use, its transparency, and because it does not require the definition of any extra parameters or variables [87]. However, this method is highly dependent on the underlying dataset and system. Because of the linear relationship, it is very sensitive to outliers, see for example Table 2 below, where the addition of city D to the dataset dramatically shifts the resilience values that are attributed to cities B (from 0,5 to 0,01) and C (from 1 to 0,02). This means that the choice of scope, but also the additions of new infrastructures (such as a big hospital) may dramatically impact the outcome of the indicator.

As an alternative, exponential or sigmoidal resilience functions can be used, with the exponential functions flattening one end of the distribution, and the sigmoidal function flattening both. In the example, the exponential function is, $r(x) = \frac{1 - e^{-(x - x_{min})/\rho}}{1 - e^{-(x_{max} - x_{min})/\rho}}$, where ρ determines the curvature and direction of preference. As Table 2 below shows, the values of the min-max resilience for A-C are similar to the values for exponential resilience. In other words, the use of exponential (or sigmoidal) functions allows decision-makers to mimic the behaviour of linear functions in a given range, while buffering for outliers.

Other methods, requiring the determination of resilience via expert

judgement, require those experts to define the 'perfect' or maximum state of resilience, or determine how many hospital beds, cars, or fire fighters a community needs to be resilient. This implies that resilience is 'achieved' once a given performance level is reached. Here, the obvious risk is a false sense of security and protection, since the benchmark values are not automatically adapted to new (better) standards that are introduced in other communities – cf. Table 2 and the addition of city D in the hypothetical example above.

Furthermore, most scaling methods assume a monotonous relation between resources and resilience, suggesting that adding capacity is always better; decreasing marginal utility, as is typical for many economics examples, is not considered. However, parameters can lean more towards a v-or bell-shaped resilience function. Diversity, for instance, is a parameter that the literature generally agrees is beneficial for resilience. As pointed out by Newman and Dale [88], "links to a diverse web of resources strengthen a community's ability to adapt to change", whereas enforcing homogeneity of standards, values, norms – and eventually also abilities – reduces resilience. However, too much diversity is likely to lead to fragmentation, unclear responsibilities, a lack of a joint view on the problem. When it came to recovery from hurricane Katrina, for instance, disparate visions of the New Orleans that was resilient came into conflict – distinct social, political, and economic groups within the city had distinct, and conflicting, visions of what recovery meant [89]. As it is an open question, what the best level of diversity vs. homogeneity and cohesion is, defining a function to normalize the value and thereby defining the 'best' mix is likely to lead to distortions.

Finally, we would like to point out the implications of the normalization procedure for community members. As discussed above, normalization is not a 'neutral' process, but has implications for values, in defining the ideal resilient state, and in determining whether and how much a certain population contributes to or threatens the resilience of the community. For instance: should we welcome immigrant groups because they add diversity and thereby resilience? Or should we keep them out, because they are likely to reduce average income and wealth, thereby threatening the resilience of a community? The trade-offs between the different resilience criteria will be discussed below, but here we note that this comes down to the ideal composition of the community itself, and as such has normative weight.

5.3. Commensurability and aggregation

The last challenges for resilience indicators we would like to discuss are the methodological issues of commensurability and aggregation. These issues remain even if we know which specific elements of resilience we would like to measure and how.

In our discussion of normalization, we already touched upon the methodological challenge of mapping the observed or measured values to a resilience function. For a complete resilience assessment, the contribution of several resilience indicators need to be merged into a "resilience index" [90], or "composite resilience indicator" [91]. This may prompt questions of incommensurability, by which philosophers mean the problem of two or more values that cannot be expressed or measured on a common scale or in terms of a common value measure [80]. Different indicators related to resilience often represent quite different aspects of what it means to be resilient. For example, the well-known set of indicators developed by Cutter et al. [29] covers social, economic, institutional, infrastructural, and community resilience. Developing one overarching index for resilience would mean combining the items in each of these five incomparable categories into one overarching scale. But even if we acknowledge that these five aspects of resilience represent incomparable aspects, the same problem occurs if we focus on just one of Cutter et al.'s [29] categories. For instance, their social resilience category comprises the following components:

Table 2
Sample comparisons of resilience values in four hypothetical cases –

City	A	B	C	D
Hospital Beds	5	10	15	500
Min-Max Resilience A-C	0	0,5	1	n.a.
Min-Max Resilience A-D	0	0,01	0,02	1
Exponential resilience (with rho = -5)	0	0,55	0,95	1

- Educational equity: Ratio of the percent population with college education to the percent with no high school diploma;
- Age: Percent non-elderly;
- Transportation access: Percent with a vehicle;
- Communication capacity: Percent with a telephone;
- Language competency: Percent not speaking English as a second language;
- Special needs: Percent without a sensory, physical, or mental disability;
- Health coverage: Percent with health insurance coverage.

These different components represent incomparable items, which is not problematic as long as they are measured separately, but which becomes problematic once we try to merge them into one overarching index, because that would imply that a lower score on one item could be compensated with a higher score on some other item. The list of items in the social resilience category shows that it indeed makes little sense to compensate a low score on transportation access with a high score on, say, health coverage, as the two items are non-fungible. Hence, while the use of a comprehensive index suggests that trade-offs can be made, this is not the case with incommensurable items.

Incommensurability seems especially problematic for outcome indicators, where the outcomes often refer to fundamental human values or human rights that are each worthy of full protection, such as access to food, access to medical care, access to education. For process indicators the incomparability of different indicators is perhaps less principled and a higher score on some process indicators could possibly compensate for a lower score on other indicators. Process indicators are especially helpful to assess improvements, for example by evaluating the quality of specific training methods for fire fighters. However, also here, combining several process indicators into one composite indicator runs the risk of concealing weaker processes that could prove critical in the aftermath of a disaster. For example, in case of a natural disaster, a lower number of trained fire fighters can partly be compensated by a higher number of trained army personnel when it comes to the evacuation of people. However, this does not hold for providing medical assistance. Thus, poor medical support cannot be compensated by well-trained firefighters, but this may not be visible when focusing on the composite indicator comprising all professional rescue and support staff. Hence, also in the case of process indicators, even if we in principle allowed for some trade-offs, it is far from trivial how to make such trade-offs and how much weight should be put on the different items to avoid critical weak links.

This brings us to issues related to aggregation. Whereas the issue of incommensurability refers to the compilation of information about different items or indicators into one number, aggregation refers to the level at which to assess resilience. Resilience indicators could be made for units as large as cities, countries, and even continents, but also for smaller units, such as neighborhoods, households and in principle even individual people. Data aggregated over whole countries or cities tell us little about the resilience of specific communities, let alone households. Even a micro-level approach such as that developed by Prashar et al. [92], which aims to assess the resilience of nine districts in the city of Delhi, lacks sufficient detail to assess the resilience of communities or households. The aggregated data say little about how resilience scores are distributed among the different people in one unit of analysis [36].

Two improvements have been proposed in the literature [93]. Gardoni and Murphy [94] argue for computing the societal impact of a hazard at the level of relevant sub-groups, which might be geographical groups, but could also be ethnic, gender, and age groups, where a process of disaggregation is applied to computed overall impact to examine whether members of specific subgroups are differentially affected. A different strategy is to establish indicators that directly measure or predict how each individual in a community is affected [95]. While the approach proposed by Gardoni and Murphy still requires some level of aggregation, the approach proposed by Tabandeh et al. [95] assesses

resilience at the individual level, which is unavoidably more costly overall. Both approaches allow the different resilience components to be assessed separately. As examples, these show that it is indeed possible to develop indicators which take distributive issues into account – they are headed in the right direction. Still, they do not yet fully capture the transformative aspects of resilience, which would in turn require due attention to the features of a community and characteristics of individuals that enable such transformations.

6. Conclusion

We can now return to the tension between persistence and transformation at the heart of resilience when it comes to social indicators. What happens when the individuals who make up a community change over time, while resilience building is taking place, or during the recovery phase? Vigorous efforts from outside to rebuild the Lower Ninth Ward, once it was accepted that it would not recover on its own, for example, suggest that many believe the recovery of that physical community to be a necessary feature of a resilient New Orleans. When does the maintenance of physical structures require continuance in a community? Alternatively, to what degree can a community transform (or stay the same) whilst still demonstrating its resilience?

These questions are not easy to answer, and as we have noted, how we answer them carries normative implications for those communities. Hence, with this paper we have called on those who develop and use social indicators to consider several things. Of primary importance is the influence of a focus on either continuity or transformation on the use of resilience as a framework for policy development and infrastructure design. Closely following in importance is the need to acknowledge that how resilience is interpreted and, consequently, measured, has profound implications for not only the design of infrastructure, but also the people whose social resilience is being measured. That is, the concept of social resilience in use, the methods by which it is measured, and the uses made of the indicators thereby generated, are all normative.

More specifically, we have argued that resilience will often require transformation – either of the infrastructure itself, by the community who responds to a disaster by adapting their physical environment, or as people move in and out of a geographical site. Therefore, indicators of social resilience ought to (a) consider the features of a community and characteristics of individuals that enable such transformations, even over and above those that enable further continuation of the status quo, and (b) consider the implications of using such indicators in terms of the actions they will enable and justify.

Benchmarks, in turn, ought to be transparently normative – for instance, they can explicitly call to an ideal scenario for comparison, rather than elements of the status quo. This further entails transparency about the context and timeline to which the indicators apply (for example, about what falls into their scope of indication for resilience, or what kinds of resilience they have considered), and about the trade-offs that have been made (and why) whenever overall resilience levels for a group or community are defined.

In turn, we suggest the path forward comprises the following: (i) continuing efforts toward refining and creating methods for dealing with the complexity of community levels involved in social resilience, the city, the group, and the individual, (ii) with an eye to transparency in process and in justifying results, (iii) while acknowledging the inherent normative implications and consequences of setting and using such indicators at all, in terms of actions taken by and on behalf of people, (iv) and by beginning with the consideration of whether the desired resilience, being indicated, is transformative, and how.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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