A Validity Assessment of the Centers for Disease Control and Prevention/ Agency for Toxic Substances and Disease Registry Social Vulnerability Index (CDC/ATSDR SVI)

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Contents

Executive Summary

Social vulnerability refers to the varying ability of communities to prepare for, respond to, and recover from natural or manmade hazards due to the socioeconomic, demographic, and cultural factors that characterize each community. Hazards are defined here as events that pose risk or cause harm to a community, such as a hurricane, pathogenic disease outbreak, or chemical spill. The Centers for Disease Control and Prevention/Agency for Toxic Substances and Disease Registry (CDC/ATSDR) Social Vulnerability Index (SVI) is an estimate of community-level social vulnerability based on demographic and socioeconomic indicators. The SVI identifies U.S. populations at the census tract and county levels that are more likely to be adversely affected by such hazards. This tool was developed to help local officials assess social vulnerability within their communities, identify populations in need of additional support over the course of disaster management, and to understand the specific factors driving a community's level of social vulnerability.[1]

Social vulnerability is a dynamic condition that cannot be measured directly. Thus, indices using commonly accepted metrics have been developed within the discipline as proxies to compare relative social vulnerability among populations. As the use of the SVI has increased substantially since its introduction in 2011, the need for its ongoing validation has also become increasingly apparent. We used a psychometric assessment framework to investigate the validity of the SVI. Psychometric evaluations are designed to determine the efficacy of measurement tools, such as questionnaires, indices, and tests.[2] We assessed the original SVI (2000, 2010, 2014, 2016, and 2018) using a range of tests and materials. Validation of the revised SVI (2020) is ongoing, due to its recent release in 2022.

Document Purpose and Objectives

This white paper is an assessment of the SVI validation literature and outlines the scope, utility, and limitations of applying the SVI in all phases of the disaster cycle: preparedness, response, recovery, and mitigation. The purpose of this assessment is to better understand the scope and applicability of the original SVI tool and to provide a transparent record of its utility to SVI users.

This document provides: (1) a description of social vulnerability and the history of the SVI tool, (2) an introduction to the field of psychometric assessment and its applicability to the SVI, (3) a summary of our validation activities and findings to date, and (4) recommendations for future iterations of the SVI.

Key Findings

Overall, we find that the CDC/ATSDR SVI performs favorably in measures of validity. It is most applicable to response and recovery efforts for moderate and severe hazards and least applicable as a predictor of morbidity and mortality in sudden, short-term extreme disasters, such as deaths during hurricanes or tornadoes. During short-term extreme events, factors related to physical vulnerability that cannot be mitigated by community-level resilience, such as widespread physical damage, may render an entire community highly vulnerable. However, the SVI tool performed well in all recovery scenarios included in this validity assessment, regardless of the severity of the initial hazard.

Background

The CDC has a mission to increase the health security of our nation, with ATSDR tasked to protect the public from hazardous substances in the environment.[3,4] Understanding the resilience of communities is essential for CDC and ATSDR to meet these missions. The SVI has been among the many important tools for assessing resilience equitably nationwide.[5] In the years since the original CDC/ATSDR **Social Vulnerability Index (SVI)** was first released in 2011, the SVI team has performed ongoing validity assessments of the **index**. In addition, researchers and practitioners have completed their own evaluations.[6-10] For instance, the New York City Department of Health and Mental Hygiene's Office of Emergency Preparedness and Response examined several **social vulnerability** indices, including the SVI, in their white paper "Vulnerable Populations: A Function-Based Vulnerability Measure for the New York City Region."[11] The authors concluded that the SVI compares more favorably to the functional index developed by New York City than any of the other indices included in their analysis. In a study funded by the U.S. Army Corps of Engineers and conducted at the University of Arizona, researchers sought to compare and empirically validate five U.S. disaster-related indices, including three resilience indices: the Baseline Resilience Indicators for Communities (BRIC), Coalition for Disaster Resilient Infrastructure (CDRI), and Resilience and Coping Intervention (RCI); as well as two **vulnerability** indices: SoVI® and the CDC/ATSDR SVI.[6] The authors determined the SVI was easy to use and performed well in explaining property losses and fatalities relative to the CDRI, BRIC, and the RCI. Results of both studies, therefore, suggest the SVI compares well to other social vulnerability indices.

In this white paper, we present the results of our own validity assessment using a formal psychometric framework outlined in DeVon et al.[12] as well as other methods. We first define social vulnerability and present the SVI as an instrument to measure social vulnerability. We then describe the **psychometric assessment** framework and methods and present our results.

Social Vulnerability

Vulnerability is a factor of **susceptibility** and **resilience** in the face of hazardous events.[13] **Susceptibility** refers to the likelihood of exposure to a **hazard**, whereas resilience is the ability to cope with and recover from a hazardous event. An individual or community may be susceptible to a hazardous event, such as a tornado, but not vulnerable because of high resilience in the form of access to resources, such as accessible storm shelters. The most vulnerable communities are those experiencing high susceptibility and low resilience; these factors usually appearing in tandem. Under the overall concept of vulnerability are two components: **physical vulnerability** and social vulnerability. Physical vulnerability refers to the characteristics of the built environment (including homes, power plants, roads) and the relative position of a community in the environment (e.g., on a flood plain or at the base of a volcano) that makes a community more or less vulnerable to a hazard or disaster event. Social vulnerability refers to the collective socioeconomic and demographic characteristics of a community and can be viewed as an indicator of the varying ability of communities to prepare for, respond to, and recover from natural or manmade hazards. Specifically, social vulnerability is a product of a constellation of underlying social characteristics among populations or communities, including poverty, race and ethnicity, age, and disability status among other factors, which collectively contribute to community-level inequities in susceptibility and resilience.

Measuring a community's level of social vulnerability is challenging as the human condition is inherently intangible and unquantifiable. As such, a validity assessment of the SVI is difficult to conduct as a commonly accepted "gold" or reference standard for this type of tool does not exist.[14,15] Thus, researchers use proxy measures chosen to optimally characterize a community's social vulnerability. The

component factors of vulnerability are dynamic and affected by cultural and societal norms. Furthermore, the components of social vulnerability are both spatially and temporally dependent. For example, poverty may be the predominant factor of social vulnerability in one location, while crowded housing may be the leading factor in a neighboring area, and either may vary over time. Additionally, social vulnerability is differentially driven by the type of hazard. For instance, access to transportation is much more critical for certain disasters, such as with evacuations for hurricanes and wildfires, than for other hazardous events. Understanding the specific drivers and the extent of a community's social vulnerability are critical for customizing effective response and intervention strategies before, during, and after hazardous events.

The CDC/ATSDR Social Vulnerability Index

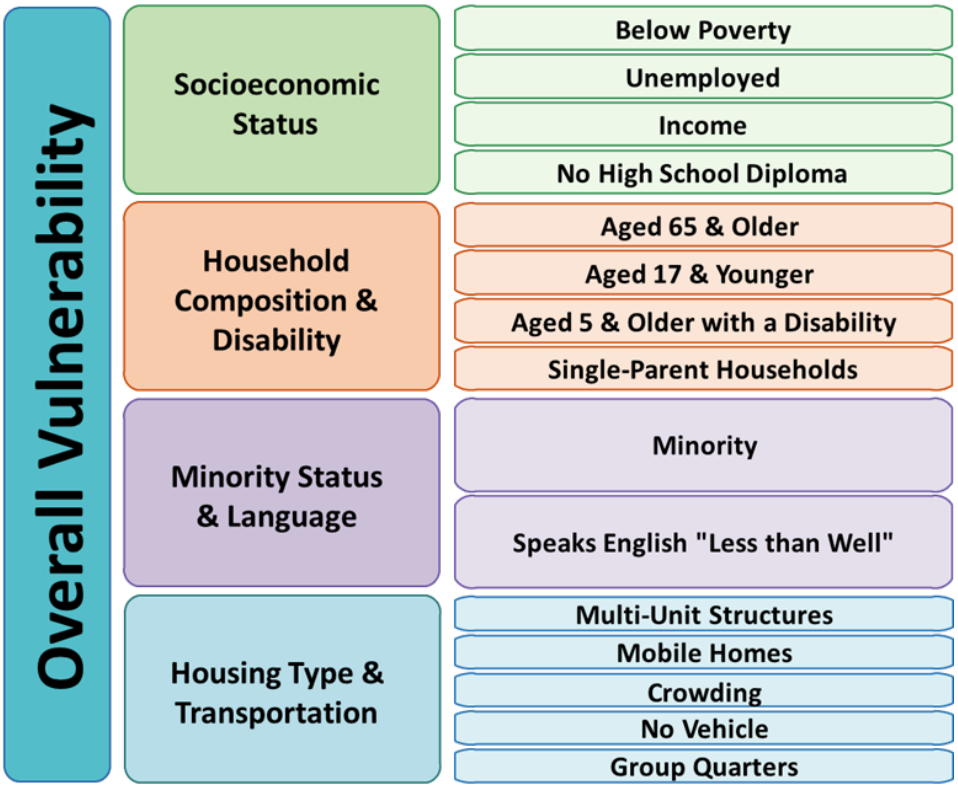
The SVI tool was developed by the CDC/ATSDR Geospatial Research, Analysis, and Services Program (GRASP) pursuant to the Pandemic and All-Hazards Preparedness Act of 2006,[16] which cited public health and medical preparedness and response capabilities as a critical need for the United States. Designed in 2007 as a public health emergency management tool, the SVI facilitates the identification of socially vulnerable communities, so that local officials may provide additional support to such communities at all stages of the disaster cycle.[17] Social vulnerability assessments are further used to distribute resources to where they are needed most, inform preventive interventions, and for future planning efforts in order to reduce the impact or effects of future disaster. Moreover, because the concept of social vulnerability is closely related to that of social determinants of health, the SVI has been applied beyond its original intent to inform research and applications in public health, policy, and environmental justice among others.[18] The diversity of SVI applications to date suggests a broader applicability than originally anticipated.

The initial SVI tool used the 2000 U.S. decennial census data from the U.S. Census Bureau to assess social vulnerability among communities in the United States. Its development, including the justification of variables selected for inclusion, is described by Flanagan and colleagues.[17] The variables that compose the SVI were chosen following a broad review of the literature on disasters and natural hazards. The index was calculated from summed percentile ranks of fifteen U.S. census variables. These rankings were aggregated into four distinct "domains," each a collection of related variables understood to drive social vulnerability. Thus, the SVI is a **hierarchical index** in which indicators are grouped into domains, or subindices, which are then combined to form the overall index.[19,20] Subsequent iterations of the SVI were developed (i.e., 2010, 2014, 2016, 2018, and 2020), with planned updates every two years. The 2010 SVI incorporates 2010 decennial census data and five-year American Community Survey (ACS) estimates from the U.S. Census Bureau, whereas indices for the following years (2014, 2016, 2018, and 2020) only use the five-year ACS estimates.

The original domains or subindices, since retitled as "themes," are as follows: socioeconomic status, household composition and disability, minority status and language, and housing type and transportation. The database portion of the SVI tool includes all of the raw data for individual census variables, percentage calculations, margins of error, percentile ranks for each individual variable, percentile ranks for the four composite themes, and an overall percentile rank (**Figure 1**). These components, along with detailed documentation, add transparency so users can see how calculations were performed as well as understand the amount of sampling error for each enumeration unit. Raw counts for individual census variables enable more nuanced planning and response efforts given the variation in census tract or county populations. The components also enable users to modify the SVI (e.g., recombine individual variables or add/subtract variables) to make the SVI more relevant for a specific hazard and/or geographic region. Hence, the SVI databases provide comprehensive raw census

data for emergency planning, in addition to social vulnerability rankings for U.S. counties and census tracts.

Figure 1. The 2018 CDC/ATSDR Social Vulnerability Index: Themes and Variables



Text-Only Version of Figure 1 - The 2018 CDC/ATSDR Social Vulnerability Index: Themes and Variables

- Overall Vulnerability
  - Socioeconomic Status
    - Below Poverty
    - Unemployed
    - Income
    - No High School Diploma
  - Household Composition and Disability
    - Aged 65 and Older
    - Aged 17 and Younger
    - Aged 5 and Older with Disability
    - Single Parent Household
  - Minority Status and Language
    - Minority
    - Speaks English “Less than Well”
  - Housing Type & Transportation
    - Multi-Unit Structures
    - Mobile Homes

- Crowding
- No Vehicle
- Group Quarters

Based on a body of applied work over time, we can measure the value of the SVI in practice. Given the diversity of applications beyond its original intent as an emergency response tool, we believe it is timely and important to continue to assess the validity and scope of the SVI as a measure of social vulnerability.

Psychometric Assessment Framework

We primarily used the psychometric framework described in DeVon et al.[12] to assess how well the SVI measures social vulnerability. Given the latent and abstract nature of social vulnerability, using this framework provides us with a systematic approach for assessing the validity of the SVI. Our goal was to employ a diverse set of analyses identified in psychometric assessment literature to test the validity of the index values in the SVI. **Psychometrics** is a branch of psychology concerned with mental measurements and testing and is designed to measure various **constructs** relating to individuals, such as intelligence, personality, and personal perception of safety.

Research into validity may extend beyond the individual to evaluate community-level metrics using a psychometric approach.[21,22] As previously mentioned, the SVI is a composite index designed to assess social vulnerability at the community level. Instead of test or questionnaire results from individuals, the input variables of a psychometric analysis of the SVI are based upon aggregated census data across geographic areas.

Validity

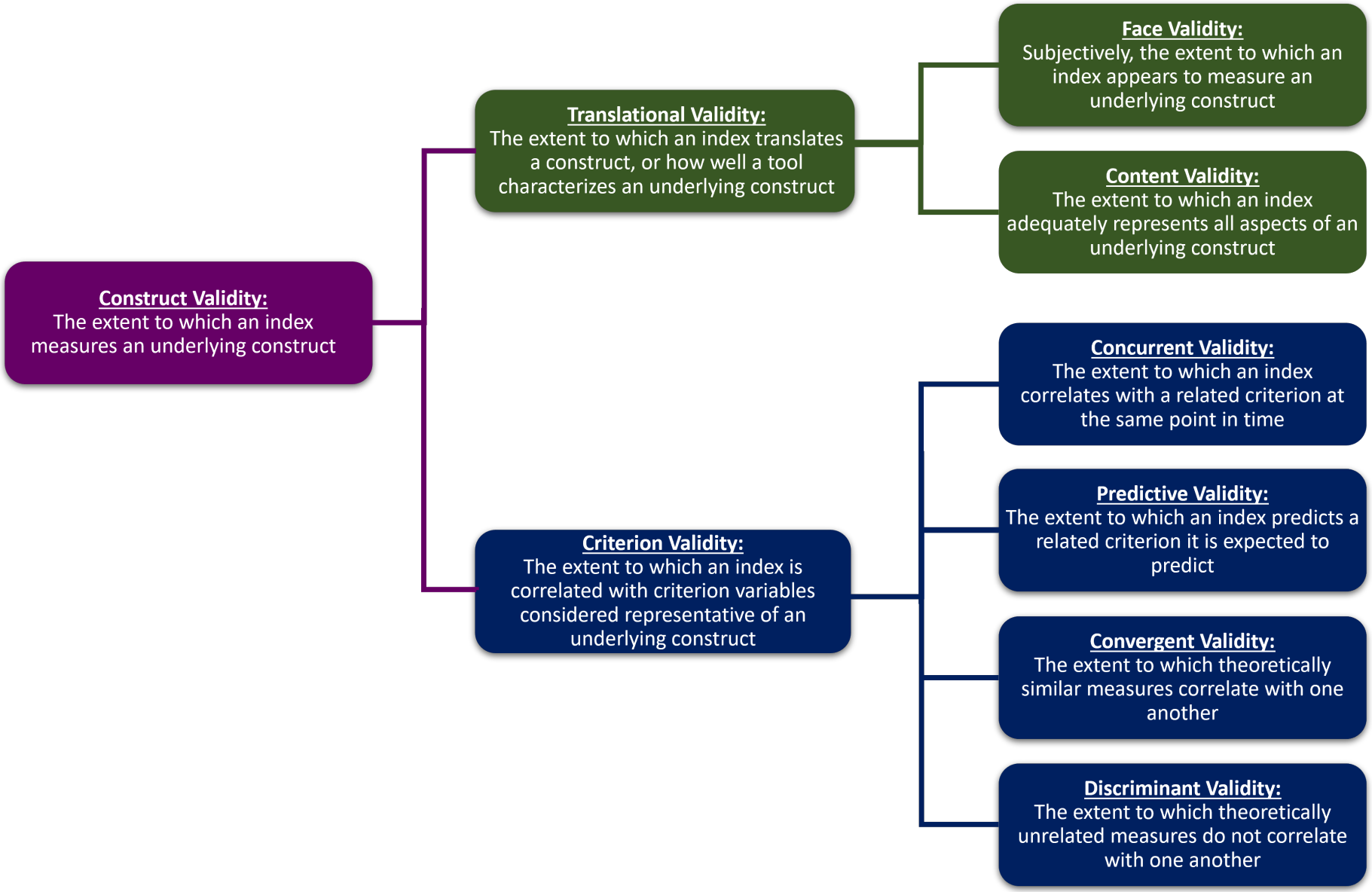
The structure of the relationships between various forms of psychometric validity, as described by DeVon et al.[12] is shown in **Figure 2**. For an intangible, latent construct, **construct validity** is the extent to which a measurement tool (e.g., the SVI) designed to measure an underlying construct (e.g., social vulnerability), effectively measures that underlying construct. Construct validity, also known as theoretical consistency, is an ongoing process encompassing all other types of validity. **Translational validity**, or "translation to the construct," is the degree that a measurement tool characterizes an underlying construct. Referred to as expert judgment, translational validity comprises **face validity** and **content validity**.[23] Face validity, a purely subjective type of validity, means that, "on the face of it," the measurement tool appears to measure the underlying construct. For example, the SVI likely meets the criteria for face validity, as it contains variables associated with the underlying construct of vulnerability, and thus appears to be measuring vulnerability. Content validity indicates the measurement tool adequately represents all aspects of the underlying construct. To achieve content validity, non-statistical activities involving subject matter experts and literature reviews are required to make sound assumptions about the variables that make up the measurement tool. Examples of these activities include relying on research, stakeholders, and expert guidance to support variable selection and index construction methods. For the SVI, subject matter experts conducted extensive literature reviews to determine which of the many different applicable variables to include in the SVI.[17]

Criterion validity, sometimes referred to as empirical validity, means a correlation exists between the measurement tool and a criterion variable considered representative of the underlying construct. For example, after a disaster of comparable magnitude across communities, a socially vulnerable community would likely require a longer recovery time than a less socially vulnerable community. In this instance, recovery time is the criterion variable. Criterion validity comprises concurrent, predictive, convergent, and discriminant validity. **Concurrent validity** is the degree to which a measurement tool is

correlated with a related criterion variable at the same point in time, meaning that locations with similar levels of vulnerability should have similar recovery times after a disaster. **Predictive validity** indicates whether a measurement tool effectively forecasts the phenomenon it purports to measure. For example, a tool with predictive validity would show that more vulnerable locations recover more slowly from all similar disasters than locations with lower vulnerability. However, it is important to note that predictive validity in social vulnerability indices is difficult to assess due to the nature of vulnerability and the unpredictability of disasters. **Convergent validity**, also referred to as external consistency, occurs when theoretically similar yet separate measurement tools designed to measure the same construct positively correlate with one another. In this case, the SVI would have convergent validity if it were found to be positively correlated with another established vulnerability index. Conversely, **discriminant validity** exists when theoretically unrelated measurement tools designed to measure different constructs do not correlate with one another.

Because the SVI quantifies social vulnerability using composite sets of discrete variables, it functions as a proxy measure of social vulnerability. Thus, psychometric evaluation is an appropriate approach to assess the validity of the SVI's estimates, while providing useful information for future improvements to the index.

Figure 2. Construct Validity and its Sub-Components



Text-Only Version of Figure 2 - Construct Validity and its Sub-Components

- Construct Validity: The extent to which an index measures an underlying construct.
    - Translational Validity: The extent to which an index translates a construct, or how well a tool characterizes an underlying construct.
        - Face Validity: Subjectively, the extent to which an index appears to measure an underlying construct.
        - Content Validity: The extent to which an index adequately represents all aspects of an underlying construct.
    - Criterion Validity: The extent to which an index is correlated with criterion variables considered representative of an underlying construct.
        - Concurrent Validity: The extent to which an index correlates with a related criterion at the same point in time.
        - Predictive Validity: The extent to which an index predicts a related criterion it is expected to predict.
        - Convergent Validity: The extent to which theoretically similar measures correlate with one another.
        - Discriminant Validity: The extent to which theoretically unrelated measures do not correlate with one another.

Methods

To evaluate the scope of the SVI and its measurement of social vulnerability, we conducted validity assessments of five SVI databases (2000, 2010, 2014, 2016, and 2018) using the framework described in DeVon et al.[12] Our analyses establish the groundwork for understanding the full scope and limitations of the SVI in addition to validating the use of separate themes and the justification for variable groupings.

We assessed the composition of the SVI and measured overall construct validity. Overall construct validity assessed by an **exploratory factor analysis (EFA)**, a **confirmatory factor analysis (CFA)**, and an evaluation of **Pearson's correlation coefficient (Pearson's r)** indicated if each SVI theme comprises an appropriate subset of variables. An EFA identifies whether a significant relationship exists between the observed variables (e.g., poverty, limited English proficiency, age, minority status) and underlying latent constructs (e.g., social vulnerability). In contrast, a CFA requires an *a priori* model that specifies which variables are grouped thematically and determines if these groupings are sound.[24] We used the R package "stats" to conduct an EFA to identify how the census variables included in the SVI naturally group together. Within the four SVI themes, we used the R package "lavaan" to conduct a CFA and determine if the grouped variables were consistent with our predetermined themes.[25] For the CFA, we also calculated **root mean square error (RMSE)** values to determine how closely the models predicted a measured value. Lastly, we calculated Pearson's correlation coefficients to indicate whether the variables in each theme exhibited multicollinearity, or undesired correlation.

The translational validity of the SVI, including face and content validity, was evaluated qualitatively. The criterion validity of the SVI, specifically discriminant and predictive validity, was evaluated quantitatively and statistically. The discriminant validity assessment compared the SVI to unrelated variables (e.g., the area of a census tract) to determine if there was evidence that a false-positive relationship occurred.[10] This type of validity assessment tests the ability of the SVI to perform strongly only when used for its intended purpose. For the discriminant validity psychometric test, we compared the SVI against a

theoretically unrelated census variable using a Pearson's correlation coefficient test. Lastly, the predictive validity assessment analyzed associations between the SVI and different types of related criterion variables using various aspatial and spatial regression techniques and spatial cluster analyses. This type of psychometric test assesses the predictability of the SVI regarding outcome variables the index is theoretically expected to predict. All statistical analyses were run using R 3.2 software.[26]

Results

Overall, our findings support the validity of the SVI as an instrument to measure the construct of social vulnerability (**Table 1**). The qualitative components of the translational validity assessment (face validity and content validity) are met. The original SVI team of subject matter experts, including social scientists, public health professionals, and statisticians, conducted a thorough literature review to determine the census-based variables most applicable for defining population vulnerability. The initial SVI manuscript outlines the scientific rationale for each of the variables in the SVI database.[17] Regarding translational validity, the SVI has face validity because the SVI subjectively appears to be a valid measure of the sociodemographic characteristics that describe social vulnerability and as it is similarly constructed as other vulnerability indices. Likewise, we can claim content validity, because the literature supports the inclusion of the variables selected for the SVI tool to represent social vulnerability. In addition, the original SVI team concurred on the content validity of the SVI. However, it must be noted that these two types of translational validity are subjective as they were assessed qualitatively with varying levels of subjectivity.

Tests for construct validity show that the four SVI themes are appropriately and distinctly grouped, based on conceptual congruence rather than statistical similarity. Exploratory factor analysis of the census tract-level 2000, 2010, 2014, and 2016 SVI databases demonstrated that the indicators explain 70%-75% of variation in social vulnerability when grouped into five or fewer factors. Confirmatory factor analysis provided support to the exploratory factor analysis. Using our *a priori* groupings, the four-themed SVI outperformed the deconstructed baseline model with small RSME values. Furthermore, Pearson's r correlations demonstrated that the Overall SVI is correlated with its four themes, whereas the four themes were not correlated with each other. This distinction is supported through the use of discriminatory validity analysis, which indicates an appropriate level of disassociation between constructs and supports their individual inclusion.

The SVI was found to be highly predictive of vulnerability in emergency events; however, the SVI may be less applicable in the context of immediate, extreme, and "random" events, as two studies found little to no association with shared vulnerability characteristics, such as older and younger age groups during extreme weather disasters (e.g., tornadoes and hurricanes).[27,29] This suggests that the SVI is best used for identifying areas that are the most socially vulnerable during widespread or long-lasting emergencies (e.g., extreme heat, air pollution) and in tracking recovery of communities.[30,31] The SVI was determined to perform well across a variety of widespread emergency events, including detecting areas susceptible to heat morbidity and asthma diagnoses, though it did not perform as well in predicting patterns of mortality for more extreme natural disasters, including the April 2011 deadly tornado outbreak in the southeastern United States[27] or the 2012 landfall of Hurricane Sandy.[28] This psychometric assessment of the SVI against various public health emergency events, indicates that the SVI performs strongly in the context of public health outcomes research and practice.

Table 1. Summary of the Validity Assessment of the CDC/ATSDR Social Vulnerability Index			
Validity Type	**Topic**	**Research Objective**	**Findings**
Construct Validity – *How well does the CDC/ATSDR SVI measure the construct it is intended to measure?*	CDC/ATSDR SVI Factor Analyses[10]	To determine how well the SVI measures social vulnerability as it was intended to measure it	• In exploratory factor analyses of the census tract-level 2000, 2010, 2014, and 2016 SVI databases, the variables explained 70-75% of the variance in social vulnerability when grouped into five factors. • In confirmatory factor analyses of the census tract-level 2000, 2010, 2014, and 2016 SVI databases, the SVI variables in each respective theme were not similar measures but, instead, were related conceptually. RMSE values were all < 0.2, except for the 2016 SVI where RMSE = 0.215. • Using Pearson's correlation coefficient, the overall SVI was found to be correlated with the SVI themes, but the themes were not correlated with one another.
Criterion Validity (Discriminant) – *How dissimilar are the CDC/ATSDR SVI estimates to constructs that are theoretically dissimilar?*	CDC/ATSDR SVI Comparison with Unrelated Measures[10]	To determine how the SVI rankings correlate with census tract area	• Using Pearson's correlation coefficient, the 2000, 2010, 2014, and 2016 census tract-level overall and theme SVI scores had Pearson's r values ranging from -0.042 - 0.024 with census tract area.
Criterion Validity (Predictive) – *How well does the CDC/ATSDR SVI predict related criterion variables in the future?*	Hurricane Katrina Recovery Study[17]	To examine the association between SVI rankings, Hurricane Katrina-related drowning deaths, and post-Hurricane Katrina mail delivery resumption	• Census tracts with high socioeconomic vulnerability using the 2000 SVI were slower to recover, despite experiencing only moderate flooding, when compared to surrounding, less vulnerable tracts with higher flood depth. • Of the 15 census tracts with a statistically significant higher number of drowning deaths than expected, 8 were in the top tertile for the 2000 SVI variable of population aged 65 years or older, 7 were in the middle tertile, and only 1 was in the lowest tertile.
	Hurricane Sandy, CDC/ATSDR SVI, and HIV Testing Rates Recovery Study[28]	To explore the association between SVI rankings, HIV testing rates, and FEMA impact zone levels related to the 2012 Hurricane Sandy disaster	• Bivariate local Moran's I identified many significant clusters of extreme negative relative change in HIV testing rates in areas with high FEMA impact ranks. Changes in testing rates decreased over time. Social vulnerability, as measured by the SVI, had a negative effect on HIV testing, but physical/infrastructural vulnerability appeared to have a greater effect.

	2011 Alabama Tornado Fatalities Study[27]	To explore whether SVI rankings modified the relationship between tornado exposure and mortality during the April 2011 tornado outbreak in Alabama, Georgia, Mississippi, and Arkansas	• Results of Poisson regression analyses do not support the hypothesis that the SVI modifies the association between the presence of tornadoes and mortality in this outbreak. Estimated rate ratios exhibited wide confidence intervals, likely due to the extreme nature of the tornado event and low number of data points.
	Hurricane Sandy Fatalities and the CDC/ATSDR SVI[29]	To analyze the relationship between Hurricane Sandy fatalities and the SVI	• Although Hurricane Sandy-related deaths were spatially clustered, researchers found no significant association between the SVI and death counts or rates. There was little evidence that census tracts with higher social vulnerability experienced more disaster-related fatalities.
	Air Quality, Social Vulnerability, and Asthma[30]	To analyze the relationships between the SVI, exposure to $PM_{2.5}$, and emergency hospitalizations for asthma at the county level in states with National Environmental Public Health Tracking partnerships	• Overall, the SVI was a significant predictor of asthma emergency department rates although the strength of prediction varied across counties in the study area.
	Georgia Extreme Heat and the CDC/ATSDR SVI[31]	To explore the relationships between SVI rankings and emergency department (ED) visits and mortality rates at the county level in Georgia	• Moran's I analysis revealed significant spatial clustering of high SVI ranks and high heat-related ED visit rates (0.211, $p<0.001$) as well as high SVI ranks and high smoothed mortality rates (0.210, $p<0.001$). • Poisson regression analysis revealed that for each 10% increase in SVI ranking, heat mortality rate significantly increased by a factor of 1.31 (95% confidence internal = 1.16-1.47), and that all heat-related ED visit rates significantly increased by a factor of 1.18 (95% confidence internal = 1.17-1.19).
Criterion Validity (Convergent) – *How does the CDC/ATSDR SVI compare to similar social vulnerability tools?*	Social Vulnerability Indices: A Scoping Review[32]	To characterize social vulnerability indices through 2021 and detail differences in composition and use	• The SVIs are composed of similar items and domains.
	Comparative Analysis of Social Vulnerability Indices: CDC's SVI and SoVI®[6]	To analyze and compare two popular methods for social vulnerability mapping	• Correlation direction and significance between indices is as expected. • The CDC/ATSDR SVI better represents a measure of damage and morbidity, while SoVI® better represents occurrences of disaster.

Discussion

The Social Vulnerability Index is hierarchically structured, which has generally been shown to be the most accurate method among comparative indices.[19] However, it is crucial to evaluate the validity of any vulnerability index, including the SVI. Psychometric methods are a suitable assessment framework, as social vulnerability is a construct unmeasurable by conventional methods. Our evaluation addressed overall construct validity, as well as its subcomponents: content, discriminant, predictive, and convergent validity. Generally, our results support the hierarchical construction of the SVI using four themes. Validating the SVI against other social vulnerability measures identified key strengths of the index. The SVI is unique in providing users the ability to add or eliminate individual raw data variables or the four themes of the index to address a particular context, area, or need. This flexibility has allowed the SVI to be applied in numerous analyses across a wide field of public health research and application.

The SVI performed favorably in most of the predictive validation efforts. However, the variation in performance of the SVI across our study sample provided insight into situations where the index is most and least applicable. Although the SVI can be used to examine the course of all emergency events, we observed that the SVI was particularly well-suited for recovery scenarios, or less catastrophic events, such as air quality and heat events. For example, high heat morbidity and mortality in Georgia were positively associated with high SVI scores.[31] In contrast, the SVI does not appear to perform favorably when applied to more localized and immediate extreme events where morbidity or mortality risk is high regardless of social vulnerability levels in a community.

Both studies that reported poor performance of the SVI applied it to mortality in disaster events of an extreme nature (i.e., tornado, hurricane), but the index was unable to predict mortality associated with these extreme disaster events well (**Table 1**). In these studies, fatalities were primarily associated with the location(s) of impact, rather than with high social vulnerability. These findings suggest that, in certain extreme situations, normal variance in a population's social vulnerability may be eclipsed by the severity of the event, rendering the entire population approximately equally highly vulnerable to harm. Although the SVI may be ill-suited to predict the impact of immediate extreme events, we find that the index performs well during event aftermath. Regions identified as highly vulnerable were slower to recover in both Hurricanes Katrina and Sandy (**Table 1**).

Additionally, although not part of this initial validation, the SVI has been applied by external researchers to non-emergency or recovery scenarios, such as physical activity[18,34] and obesity[35], and the index performed favorably. Given that many of the variables associated with social vulnerability are components of social determinants of health, it is very likely that the scope and utility of the SVI is applicable well beyond public health emergency preparedness and response.

Limitations

Limitations of this assessment have been identified in an effort to contextualize findings and promote further investigation into the validity and utility of the SVI. It should be understood that because of the nature of social vulnerability as an intrinsically holistic human quality, there is no gold standard or fixed set of variables that will precisely reflect this human condition at the community level over time and place. The indicators we have selected for the SVI function as proxies at best for the human condition of social vulnerability. While this assessment examined the SVI through a number of validity constructs, concurrent validity of the SVI was excluded given the absence of an existing "gold standard"

measurement for social vulnerability. While it remains outside the scope of this assessment, future studies may benefit from examining serial concurrent validity within the SVI and how the validity of the SVI changes over time.

Second, while the psychometric assessment framework used for this analysis is an established and accepted method for assessing validity, it is not without limitations. The limitations frequently mentioned in literature include the subjective view of subject matter experts, ill-defined constructs, and item exclusion.[37] While comparison between exploratory factor analysis and confirmatory factor analysis highlights the appropriateness of items included, it may also be beneficial for future studies to examine additional variables that were not considered for inclusion. Furthermore, the breadth of the utility of the SVI in research serves to highlight the diversity in its critical examination from a wide array of researchers and experts, but a more methodological approach to the utility of the SVI would likely be beneficial.

More recently, the SVI has been leveraged beyond natural disasters and has become a popular research tool for those investigating human health and disease. The SVI has been utilized to better inform outcomes spanning non-communicable diseases such as diabetes[38] and heart disease,[39] communicable diseases such as COVID-19[40]and HIV,[41] and healthcare systems research exploring topics such as post health procedure recovery.[42] This utilization beyond natural disasters is likely due to the combination of the ability of the SVI to characterize social environments and the social and population-based inequities rooted in many of these health outcomes.

Beyond these methodological limitations, a conceptual limitation has also been identified. Due to the geographic and temporally unpredictable nature of disasters, assessing the validity of the SVI in the context of preparedness remains challenging, as knowledge of community preparedness itself is difficult to ascertain and assess given the broad scope of disasters and limited accessibility to more timely and granular data. Future efforts to address this challenge are likely to require advanced and innovative methods still yet to be developed.

Next Steps

Index assessment of the SVI is an ongoing process. This initial effort defines the scope of and validates the original CDC/ATSDR SVI versions, prior to 2020. CDC and external researchers using the SVI will continue to clarify the utility of the index, especially in contexts beyond public health emergencies and disasters. With the 2020 COVID-19 pandemic, use of the SVI has increased nationwide both for examination of the pandemic, as well as a myriad of applications to other health and social phenomena. The use of the SVI for preparedness has also increased since 2020, such as how the SVI was used solely or with other approaches for COVID-19 test or vaccine distribution in 28 states and the District of Columbia.[42] Future assessments will evaluate the validity of the SVI since 2020 as well as the reliability of the SVI by incorporating a diverse set of tools and methods from Spielman and colleagues,[15] Tate,[20] and the *Handbook on Constructing Composite Indicators: Methodology and User Guide.*[35] In future assessments, we will also examine the construct reliability of the SVI, which refers to the consistency of the measurement tool. Construct reliability, or internal consistency, is the ability of a tool, such as the SVI, to measure a construct consistently. We plan to continue the assessment of the SVI by evaluating the reliability of this index through uncertainty and sensitivity analyses. As the 2020 SVI includes important additions and revisions relative to previous iterations, our focus of validation will shift to the revised 2020 SVI.

Conclusion

Our psychometric evaluation suggests that the CDC/ATSDR SVI performs favorably overall in response and recovery contexts in widespread public health emergencies, although it may not be suitable for predicting mortality in extreme and immediate localized events, such as tornados.

Glossary

Confirmatory Factor Analysis – A type of **factor analysis** in which the researcher begins with a hypothesis about the structure of factors that make up a construct, such as social vulnerability, to determine if the construct is composed of the appropriate variables.

Concurrent Validity – The degree to which a measurement tool is correlated with a related criterion variable at the same point in time.

Construct – A subjective idea or theory containing various conceptual elements. Social vulnerability is an example of a construct.

Construct Validity – The extent to which an instrument designed to measure a particular construct is able to measure that construct. In this case, construct validity refers to the extent to which the CDC/ATSDR SVI measures the intangible construct of social vulnerability. Construct validity is an ongoing process that encompasses all other types of validity, including translational validity, criterion validity, and discriminant validity.

Content Validity – An instrument has content validity when it adequately represents all aspects of the construct it is designed to measure. To achieve content validity, non-statistical activities involving subject matter experts, literature reviews, and more, are required to make sound assumptions.

Convergent Validity – Also referred to as external consistency, occurs when theoretically similar, yet separate, measurement tools designed to measure the same construct, positively correlate with one another.

Criterion Validity – A type of construct validity that involves correlation between the measurement tool and a criterion variable (i.e., outcome) considered representative of the construct. Criterion validity encompasses concurrent, predictive, convergent, and discriminant validity.

Discriminant Validity – Exists when theoretically unrelated measurement tools designed to measure different constructs do not correlate with one another.

Exploratory Factor Analysis – A type of factor analysis that is conducted without a hypothesis in mind, where the data indicates whether a significant relationship exists between the observed variables and underlying latent constructs.

Face Validity – A purely subjective type of validity, which means that “on the face of it” the measurement tool appears to measure the underlying construct.

Factor Analysis – A statistical technique to reduce individual, related variables into a smaller, more understandable number of factors to define a construct, such as social vulnerability. Factor analysis is used in tests of construct validity.

Hazard – Any natural or human-related event that poses risk to a community, such as a hurricane, pathogenic disease outbreak, or chemical spill.

Hierarchical Index – An index in which indicators are grouped into themes, or subindices, which are combined to form the overall index. The CDC/ATSDR SVI is an example of a hierarchical index designed to estimate social vulnerability.

Index – A set of composite indicators to measure or estimate a phenomenon. The CDC/ATSDR SVI is an example of an index designed to estimate social vulnerability.

Pearson's Correlation Coefficient (Pearson's r) – A statistical tool used to measure the strength of a relationship between two variables. A high value for Pearson's r, for instance, means that the two variables are positively correlated (i.e., when the value of one variable increases, the value of the related variable also increases).

Physical Vulnerability – Refers to characteristics of the built environment (e.g., homes, power plants, roads) and the relative environmental position of a community (e.g., on a flood plain or at the base of a volcano) that make a community more or less vulnerable to a hazard.

Predictive Validity – How well an instrument forecasts the phenomenon it purports to measure. After a disaster, for instance, we would expect communities with high social vulnerability (as measured by CDC/ATSDR SVI) to demonstrate longer recovery time than communities with low social vulnerability.

Psychometric Assessment – Methods used to validate and assess tools that attempt to measure or quantify constructs. These methods include questionnaires, indices, and tests for construct validity and reliability.

Psychometrics – A branch of psychology concerned with measuring mental measurements and testing. The intelligence quotient (IQ) test is an example of a psychometric test claimed to measure intelligence.

Resilience – The ability to cope with and recover from an event. In the context of community resilience, it is the differential ability of communities to cope with, respond, and recover from a hazardous event.

Root Mean Square Error (RMSE) – A measure of the difference between known values and corresponding estimated values. The lower the RMSE, the better the estimates.

Social Vulnerability – The intangible construct of vulnerability that arises out of the differential ability of communities to prepare, respond, and recover from natural or manmade hazards, due to various social factors (e.g., poverty).

Social Vulnerability Index (SVI) – An instrument designed to measure the construct of social vulnerability. The CDC/ATSDR SVI is composed of census data used to estimate and rank the relative social vulnerability of U.S. communities.

Susceptibility – The likelihood of exposure to a hazard. An individual or community may be susceptible to a hazardous event, such as a tornado, but not vulnerable because of access to resources, such as accessible storm shelters.

Translational Validity – The degree to which a measurement tool characterizes an underlying construct.

Vulnerability – An umbrella concept variously defined within multiple disciplines and generally including factors of susceptibility (i.e., the likelihood of exposure to a hazard) and resilience (i.e., the varying ability of a community to cope with or 'bounce back' from a hazard).

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