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The state-of-the-art review of vulnerability indices: With a special focus on urban flood

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Definitions of Vulnerability

Definitions	References
The characteristics of a person or a group in terms of their capacity to anticipate, cope with, resist & recover from the impact of a hazard.	Blaikie et al (1994)
Refers to a measure of a person or a group's exposure to the effects of a hazard, including the degree to which they can recover from the impact of that event.	
Refers to the potential for loss of property or life from environmental hazards.	Cutter et al (2000)
Refers to the degree to which a system, sub-system, or system component is likely to experience harm, due to exposure to a hazard.	Turner et al (2003)
A human condition or process resulting from physical, social, economic, & environmental factors which determine the likelihood & scale of the impact from a given hazard.	UNDP (2004)
Vulnerability is used as the magnitude of the threat of poverty, measured, before the veil of uncertainty has been lifted.	Calvo & Dercon (2005)
Refers to the state of susceptibility to harm from exposure to stresses associated with environmental & social change & from the absence of capacity to adapt.	Adger (2006)
Refers to the degree to which a system is susceptible to, & unable to cope with adverse effects of climate change, including climate variability & extremes.	Parry et al (2007)
Refers to a function of the character, magnitude, & rate to which a system is exposed.	
Refers to the conditions determined by physical, social, economic & environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards.	UNDRR (2016)

Hyogo Framework (2005-2015)

- About **WHAT** are the risks that affect DRR
- 10-year plan to make the world safer from hazards
- Endorsed by UN General Assembly
- Explains, describes, details the work to be done to reduce disaster losses

- **GOAL:** To reduce
  - Disaster losses by building the resilience of nations & communities to disasters
  - Loss of lives & social, economic & environmental assets when hazard strikes

PRIORITIES

#1
Ensure DRR is a national & local priority with strong institutional basis for implementation

#2
Identify, assess & monitor disaster risks & enhance early warning

#3
Use knowledge, innovation & education to build a culture of safety & resilience

#4
Reduce the underlying risk factors

#5
Strengthen disaster preparedness for effective response

Sendai Framework (2015-2030)

- About **HOW** to reduce the losses associated with the risks
- 15-year plan to make the world safer from hazards
- Endorsed by UN General Assembly
- Role of all stake holders in DRR

PRIORITIES

#1 Understanding disaster risk	**#2** Strengthening disaster risk governance to manage disaster risk
#3 Investing in DRR for resilience	**#4** Enhancing disaster preparedness for effective response & to "Build Back Better" in recovery, rehabilitation & reconstruction

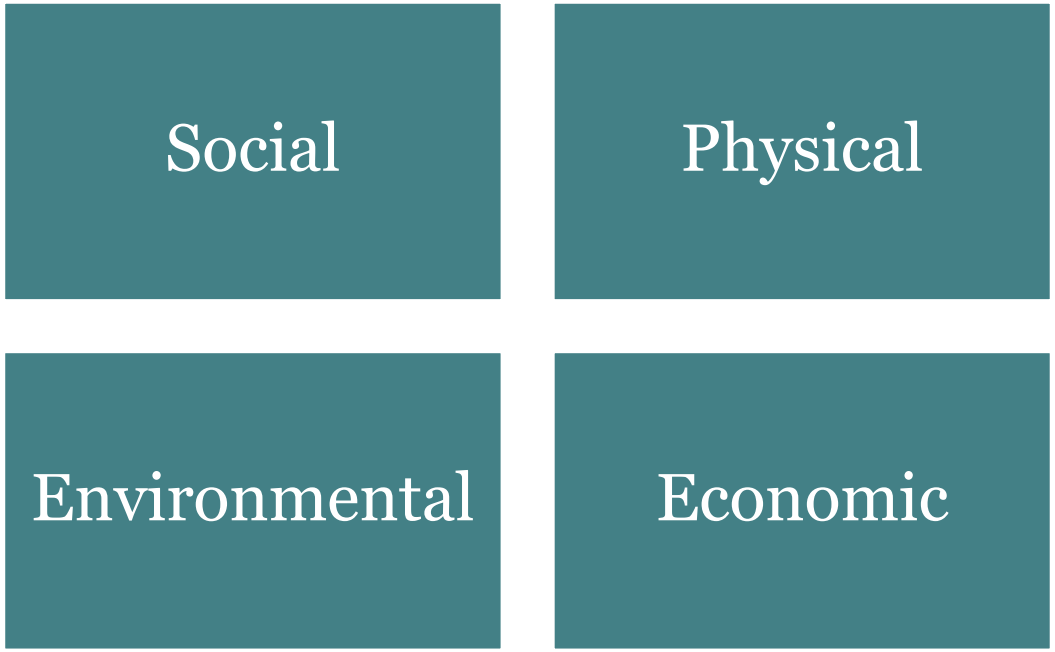
- **GOAL:** To reduce
  - Disaster risk & losses in lives, livelihoods & health
  - Disaster risk & losses in the economic, physical, social, cultural & environmental assets of persons, businesses, communities & countries
- **TARGETS:** (To reduce)
  - Global disaster mortality
  - No. of affected people globally
  - Direct disaster economic loss
  - Disaster damage to CI & disruption of basic services

(To increase)

- No. of countries with DRR strategies
- International co-operation
- Availability of & access to multi-hazard early warning systems

Types of Vulnerability

- No universal definition – can be broken into Social, Physical, Environmental & Economic



Systematic Review

- **OBJECTIVE QUESTIONS**
  - What are the Vulnerability Indices (VIs) in the last 20 years (1998-2018)?
  - Can VIs be classified into different types — social, physical, environmental & economic? Are there other types?
  - What indicators are most used for each VI type?
  - What techniques are most used for developing a VI?
  - Are there any VIs which is composed of more than one type?

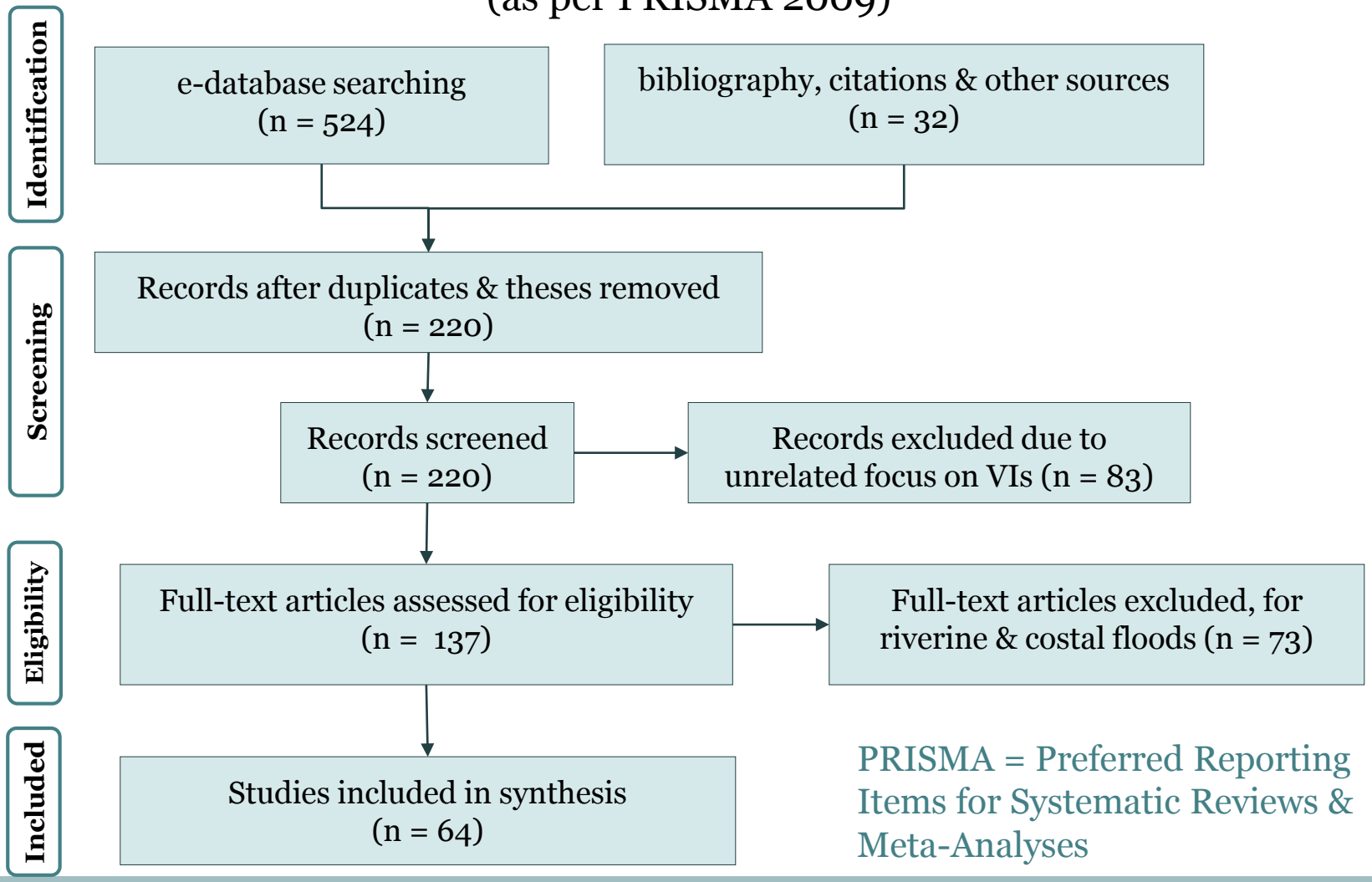
- **DATABASE**
  - SCOPUS
  - Web of Science
  - Google Scholar
  - Science Direct
  - Taylor & Francis Online

KEYWORD SEARCH

- Initially over 500 papers – duplicates, coastal floods, riverine floods excluded
- 64 research papers – 38 journal articles, 21 conference proceedings, 5 technical reports

Proposed Methodology

(as per PRISMA 2009)



PRISMA = Preferred Reporting Items for Systematic Reviews & Meta-Analyses

Types of Vulnerability Indices

Parameters	Social	Physical	Environmental	Economic
No. of references	17	09	28	10
Focus area	Population	Property	Environmental degradation	Monetary transaction
Type of loss	Direct tangible, Indirect tangible, Intangible	Direct tangible	Indirect tangible, Intangible	Direct tangible, Indirect tangible

- Types of urban flood impacts as per Hammond et al (2015) – Direct tangible, Indirect tangible & Intangible
- All three impacts adequately represented by Social & Physical VIs

Social Vulnerability Index

- Demographic characteristics, socio-economic status & health – important factors
- Risk perception and coping capacity not adequately represented
- Depends highly upon context
- Methods –
  - Relative scoring (9 out of 17~53%)
  - Principal Component Analysis (18%)
  - Factor analysis (18%)
  - Balanced weighted average (11%)

Factors most utilised:

Education: loss of learning days, mode of travel to school etc. (15 out of 17)

Health: no. of deaths, type of water-borne diseases, etc. (13 out of 17)

Income: loss of man days, monetary loss per day, etc. (12 out of 17)

Others: (average 5 out of 17)

- Dependency on public infrastructure (drinking water, sanitation, waste disposal)
- Special conditions during UF (safety during UF, power-cuts, etc.)
- Household information (no. of heads, years of stay, etc.)

Physical Vulnerability Index

- Physical — focus buildings (8 out of 9)
- Site condition (slope, soil, etc.), building typology, building parameters – important factors
- Direct effect of flood water on buildings not adequately represented
- Depends highly upon depth & duration of flood water
- Methods –
  - Depth-damage curve (4 out of 9~44%)
  - Hazus-MH loss estimation (5 out of 9~56%)

Factors most utilised:

Flood depth: (6 out of 9)

Flood duration: (2 out of 9)

Flood damage in monetary terms: (7 out of 9)

Others: (1 out of 9)

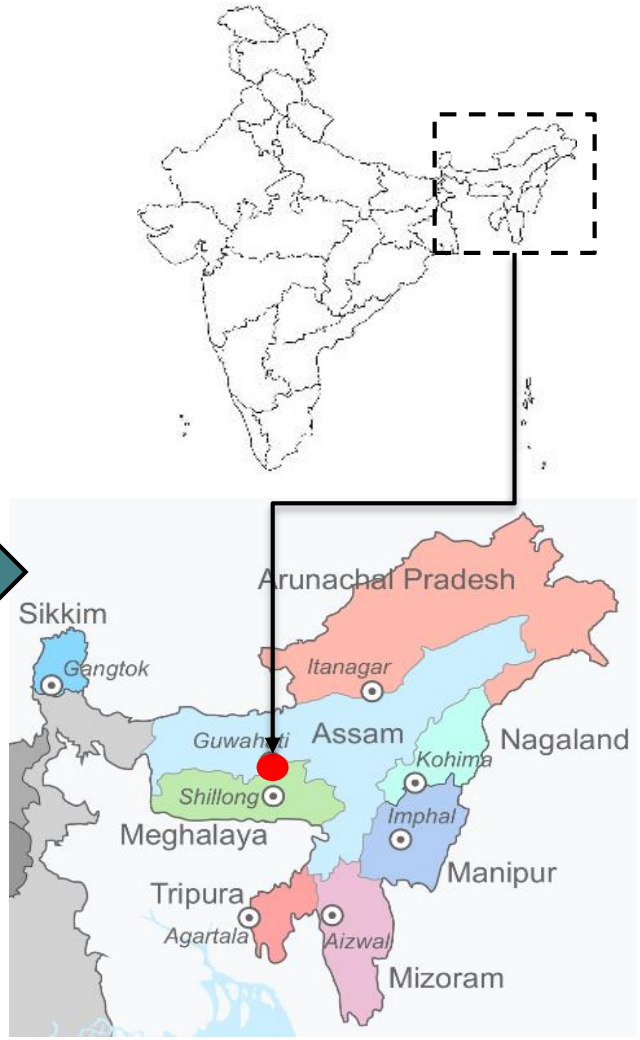
- Building components (building material, presence of basement, presence of open storey, year built/ age, etc.)

Proposed Index

- Need for an index which is able to describe the vulnerability of an urban area in terms of its population and property
- Proposed for a social + physical index
- Social – Human VI or HVI
- Physical – Building (private or public) VI or BVI
- **As the city is built by the people and for the people both human and building vulnerability are critical**

Case study area:

- **Guwahati**, capital of Assam state in North-East India
- The region is sole connection between NE states and mainland – therefore strategically important
- Prone to riverine flood, earthquake and landslide — therefore disaster hotspot
- Growing population took over the hillocks and wetlands — soil erosion, choked natural drainage, landfill of natural basin



Location map of Guwahati

Human Vulnerability Index (HVI) – Existing Condition

Disruption of livelihood – Hard for daily wage earner

Disruption to education

Impact on commerce

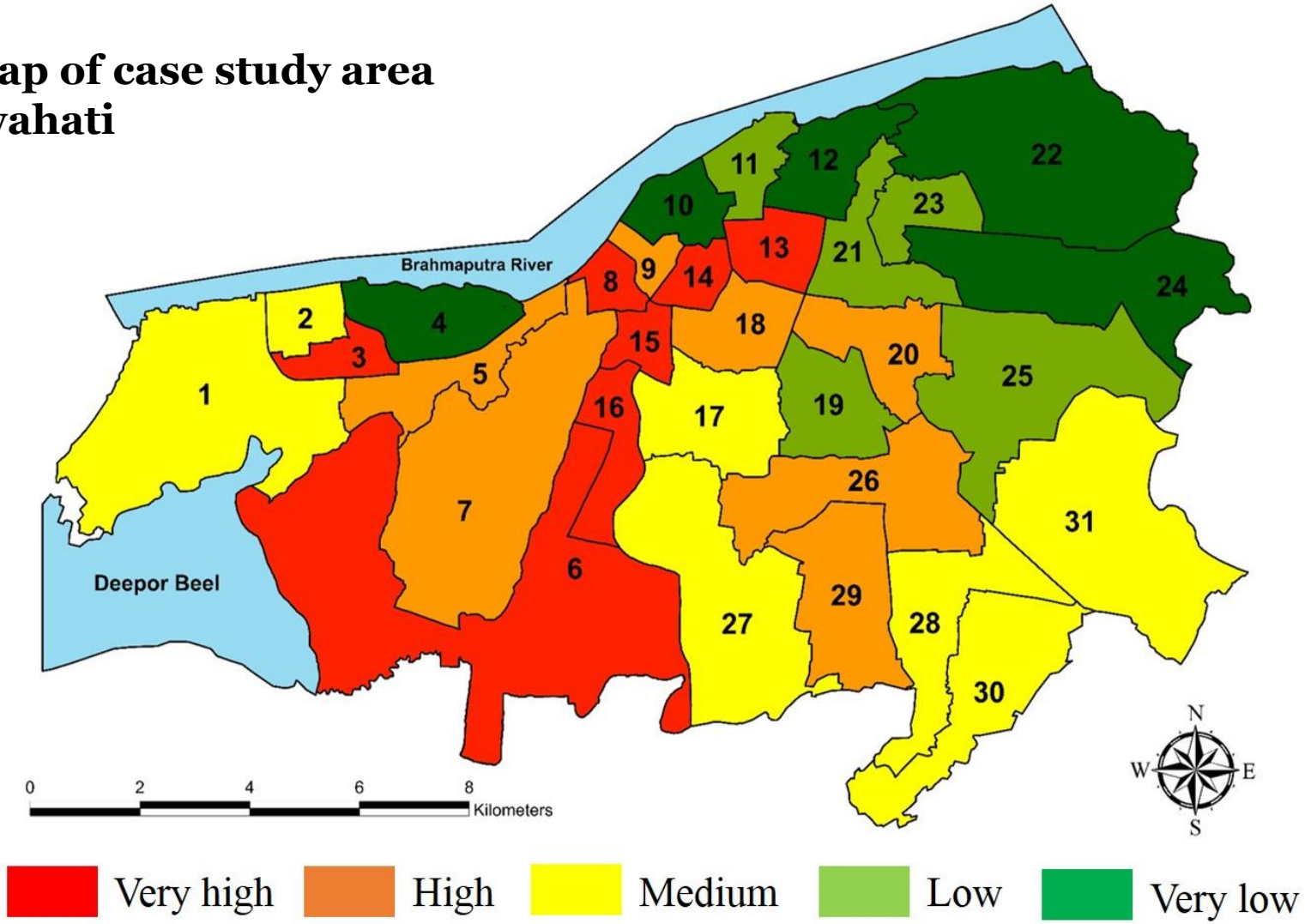
Impact on public health

Human Vulnerability Index (HVI)

- Wards of Guwahati were graded in terms of human vulnerability using a 5-point scale (very high to very low)
- Questionnaire survey was modified from HDI
- Sample size = 1023 residents
- Questionnaire consisted of 31 indicators (parameters) grouped under 6 constructs:
    - Household
    - Education
    - Health
    - Income
    - Dependency on public infrastructure (drinking water, sanitation, waste disposal)
    - Some special conditions during urban flood

Human Vulnerability Index (HVI)

HVI map of case study area of Guwahati



Building Vulnerability Index (BVI) – Building Typologies

RC frame structure
(burnt brick in cement mortar infill walls with RC slab roof)

Ekra house
(wooden frame with mud/ cement plastered Ekra or elephant grass infill walls and CGI sheet hipped roof)

Confined masonry structure
(Columns and burnt bricks in cement mortar as infill walls and CGI sheet pitched roof with wooden under-structure

Building Vulnerability Index (BVI) – Existing Condition

Building settled till sill level under action of flood water

Building basement filled with mud brought by flood water

Building's settled till plinth level under action of flood water

Building Vulnerability Index (BVI)

- Buildings – Critical Infrastructure (CIs)
- CIs of Guwahati were graded in terms of building vulnerability using a 5-point scale (very high to very low)
- Questionnaire survey was modified from RVS for seismic hazard by US-FEMA
- Questionnaire consisted of 20 indicators (parameters)
- Sample types
  - RC Frame structure
  - Confined Masonry structure
  - Ekra houses
- A newest approach to urban flood assessment
- A quick & comprehensive method for practitioners and local authorities

Conclusions

- Vulnerability measurement is social, physical, environmental & economic
- Systematic review suggests that there is no index which can assess the vulnerability of human & buildings together, in an urban flood prone area
- Cities are built of both buildings (physical) and human (social). Thus, HVI and BVI will give a holistic picture
- This can provide a measurement tool with an enhanced range and sensitivity for assessing comprehensive vulnerability
- Scale will be useful in showing which areas are more vulnerable for the population and buildings together
- This information could be used for prioritisation and fund allocation
- Advantageous for decision makers as it helps to set the framework for evaluating specific goals, & helps to monitor capability over a longer term
- Methodology usable for Tier-II Indian cities such as Ahmedabad, Jamshedpur, Srinagar, Surat etc. which are prone to urban flood
- Similar method can be applied to other types of vulnerability measurement, in combinations, to derive specific findings

Thank You

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