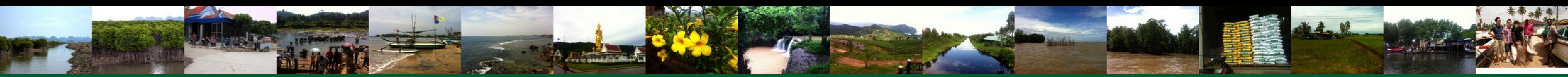

# Risk assessment of rail infrastructure in India to support business continuity plan

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**Abstract:** Rail infrastructure in India is the main transport mode for passenger and freight transportation. But rail infrastructure assets are frequently exposed to multi-hazards and disruptions like disasters have the potential to interrupt the organization's entire operations and preventing them from continuing the business in a normal way. The SDG 11 and the Sendai Framework for Disaster Risk Reduction calls for understanding risks through risk assessments towards avoiding frequent disruptions in operations and losses to rail business due to disasters. Risk to existing railway infrastructure in this study is defined as per UNDRR terminology, which is a function of hazard – the probability and severity of an event; exposure – assets subject to the hazard; and vulnerability – physical, social and economic susceptibility of assets to suffer damage under hazard of given severity. The planned infrastructure like HSR corridors are analysed on the urban vulnerability of loss of green space around the HSR stations. Further, frequency of emergency situations recorded in the system are also utilised as a comprehensive indicator of risk assessment as it combines all the factors of risk. Therefore, this study focuses on creating an enabling environment towards disaster risk informed investment on critical infrastructure and business continuity planning for safe rail operations.

**Keywords: Multi-hazards, Vulnerability, Exposure, Green Space, Sustainability.**

## Background

Absence of risk assessment studies incorporating actual local vulnerability of key safety affecting railway elements like bridges and level crossings; Similarly, haphazard state of urbanization with loss of green space is causing increased surface runoffs (Mumbai city suffering from floods every year) and lack of planning the same for transport infrastructure is a key issue; Further, there is absence of risk studies due to systemic issues highlighted by emergency situations;

## Objective

1. Risk assessment for existing rail infrastructure exposed to hazards under local compounding vulnerabilities,
2. Planned rail infrastructure under urban vulnerabilities,
3. Risk assessment under consequential emergency cases.

## Methodology

**Fig 1. Research flow for the study**

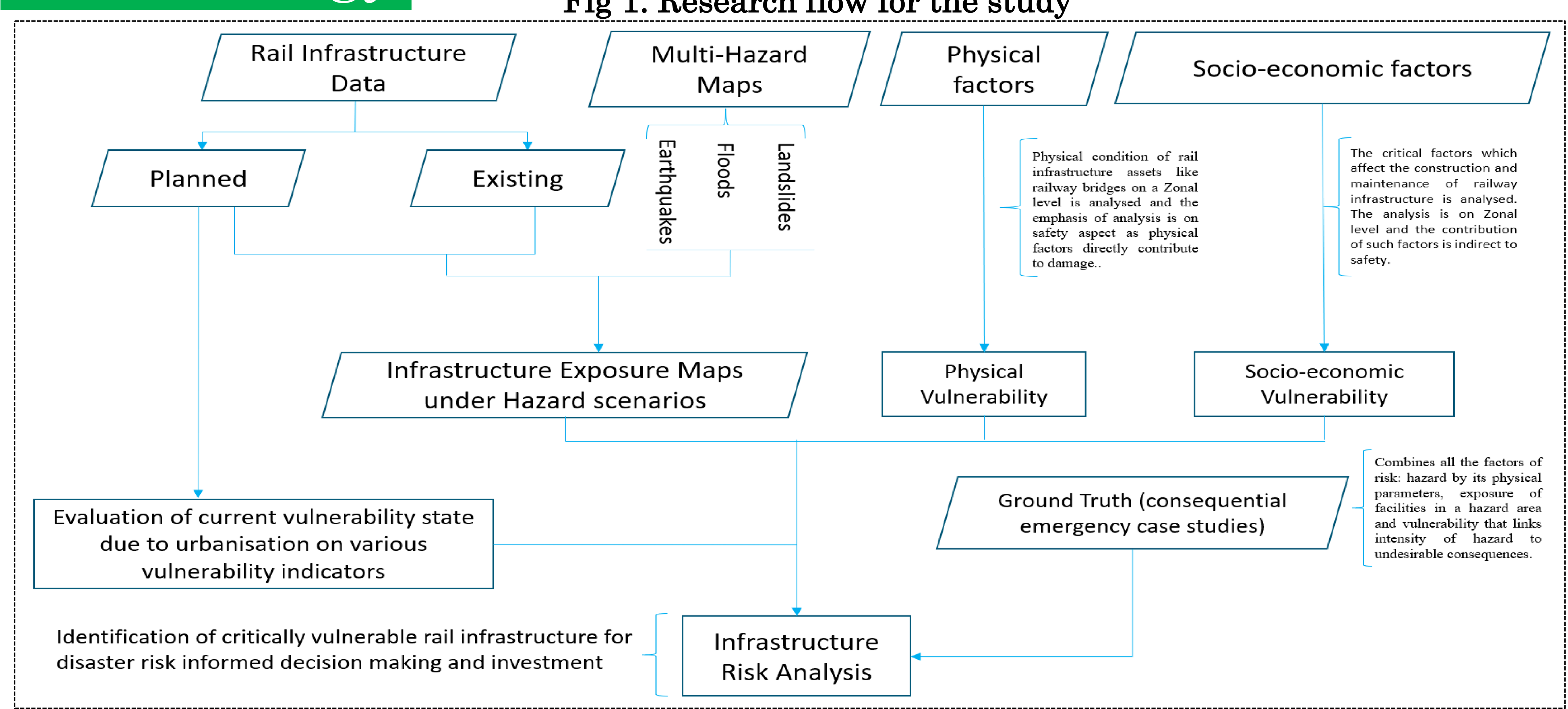
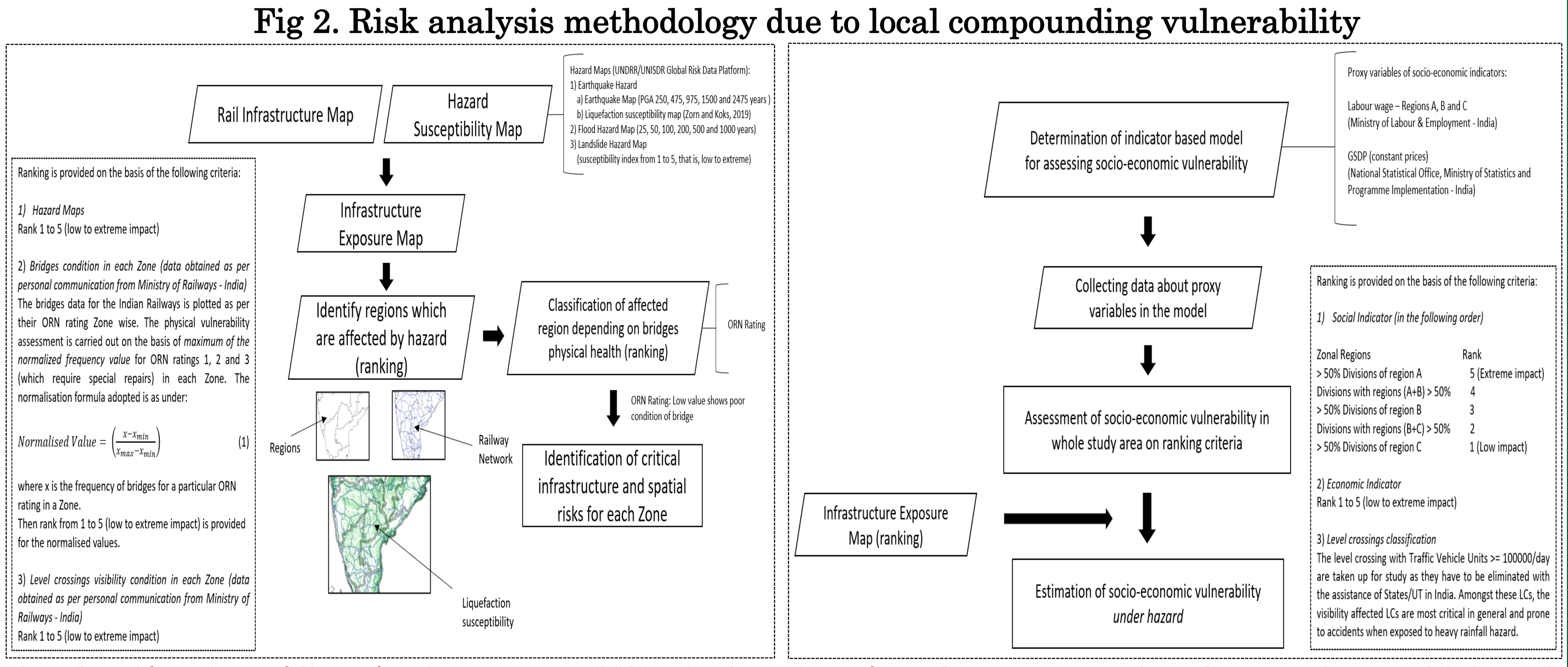



**Fig 2. Risk analysis methodology due to local compounding vulnerability**




The classification of liquefaction susceptibility is done into five classes – very low, low, moderate, high and very high with very low value corresponding to $V_{S30}$ > 620 m/s (Koks et al, 2019). Different scenarios of earthquake hazard events are considered (hazard map obtained from UNDRR and resolution calibrated at 1.2 Km) with liquefaction susceptibility (1.2 Km resolution map obtained from Koks et al, 2019). The bridges data for the Indian Railways is plotted as per their ORN rating Zone wise for physical vulnerability. Similarly, the labour wages and GSDP (at constant prices) across the regions in India level crossings is presented in under social and economic vulnerability respectively.

*Ranking criteria and key equations utilized in the study:*

Ranking Criteria

*Earthquake Hazard:*

PGA <= 50 cm/s$^2$ – 1 (Low)
50 < PGA <= 150 – 2
150 < PGA <= 250 – 3
250 < PGA <= 450 – 4
< PGA – 5 (Extreme)

*Floods Hazard:*

Inundation depth (ID) <= 180 cm – 1 (Low)
180 < ID <= 360 – 2
360 < ID <= 540 – 3
540 < ID <= 720 – 4
720 < ID – 5 (Extreme)

*Landslide Hazard (triggered by precipitations):*

Hazard Index – 1 (Low) to
Hazard Index – 5 (Extreme)

*Liquefaction Susceptibility:*

Hazard Index – 1 (Low) to
Hazard Index – 5 (Extreme)

*Physical Vulnerability:*

Normalised Index (NI) <= 0.0133 – 1 (Low)
0.0133 < NI <= 0.09 – 2
0.09 < NI <= 0.1909 – 3
0.1909 < NI <= 0.3909 – 4
0.3909 < NI – 5 (Extreme)

*Economic Vulnerability:*

GSDP <= 19300 (10 millions) – 5 (Low)
19300 < GSDP <= 112755 – 4
112755 < GSDP <= 382218 – 3
382218 < GSDP <= 621301 – 2
621301 < GSDP – 1 (Extreme)

*Social Vulnerability (checked in the order):*

> 50% Divisions of region A – 5 (Extreme)
> 50% Divisions of region A+B – 4
> 50% Divisions of region B – 3
> 50% Divisions of region B+C – 2
> 50% Divisions of region C – 1 (Low)

$$Emergency\ Risk = \left(\frac{e - e_{min}}{e_{max} - e_{min}}\right)$$

where, e = average annual frequency of accidents/emergency situations recorded in Railway Board/Zonal Railways
$e_{min}$ = minimum average annual frequency
$e_{max}$ = maximum average annual frequency

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

where, NIR = spectral reflectance in near-infrared spectrum,
RED = spectral reflectance in red (visible) spectrum

NDVI is assumed constant seasonally as well as during the study period. The NDVI values are assumed representative of vegetation fraction and the values of NDVI varies between -1 to +1. The value of NDVI for threshold of vegetation is assumed as 0.2 (Wong et al, 2019; Sobrino et al, 2004).

## Results

**Fig 3. Spatial risk assessment under multi-hazards**

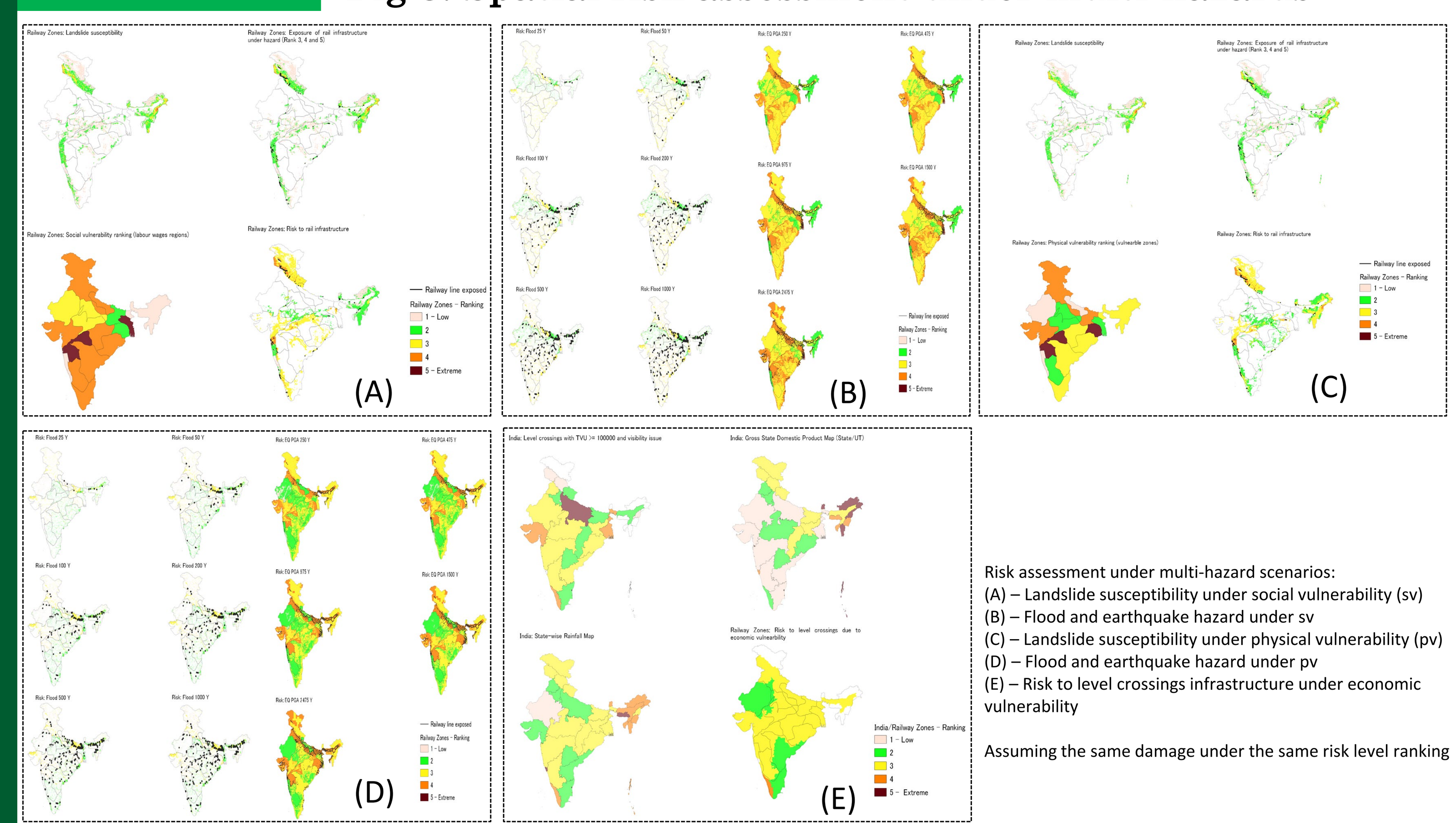
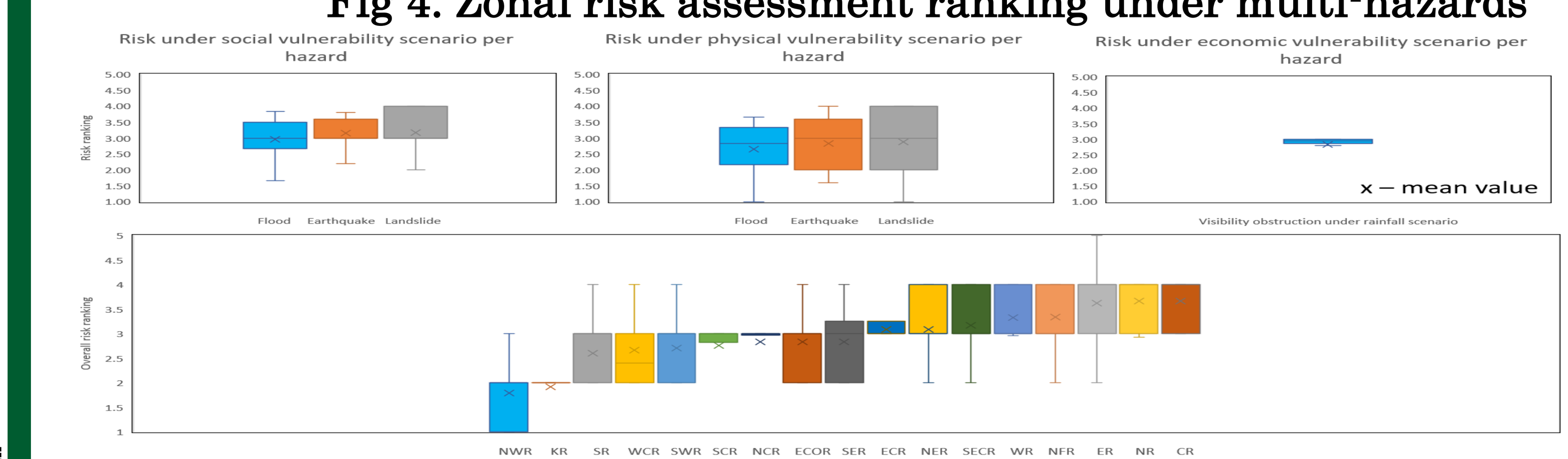
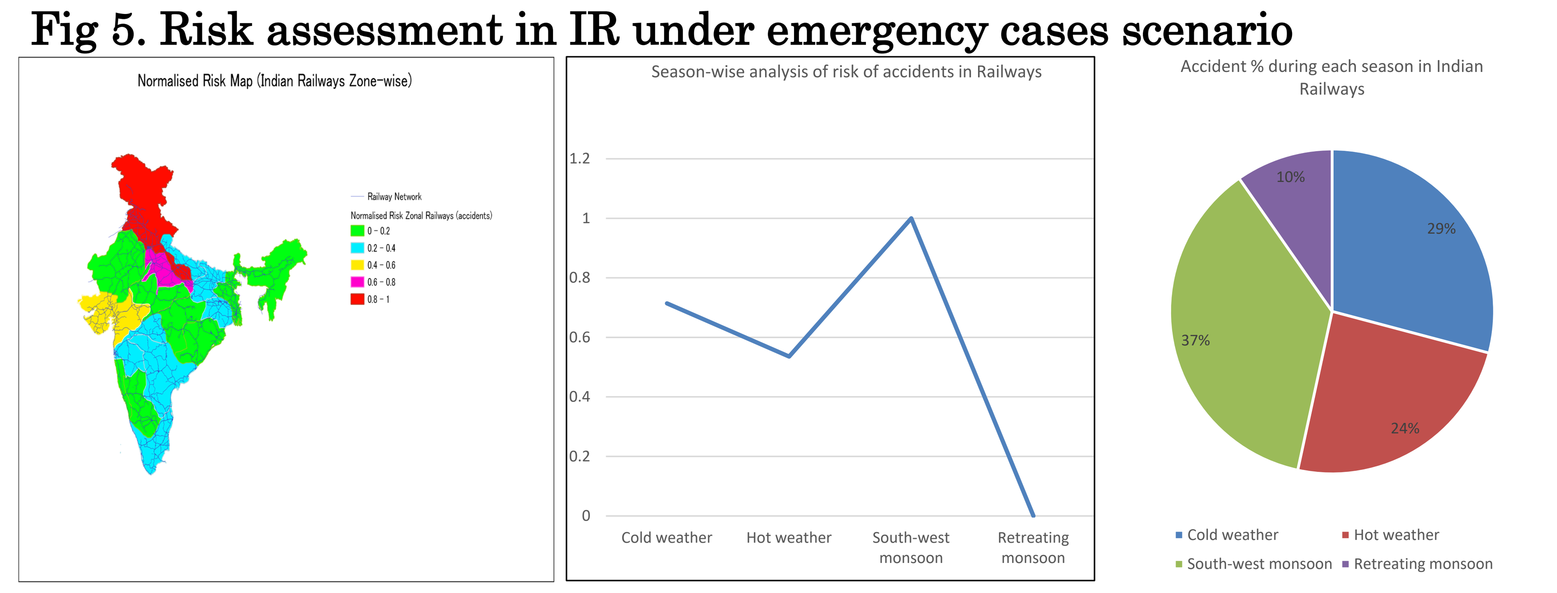



**Fig 4. Zonal risk assessment ranking under multi-hazards**



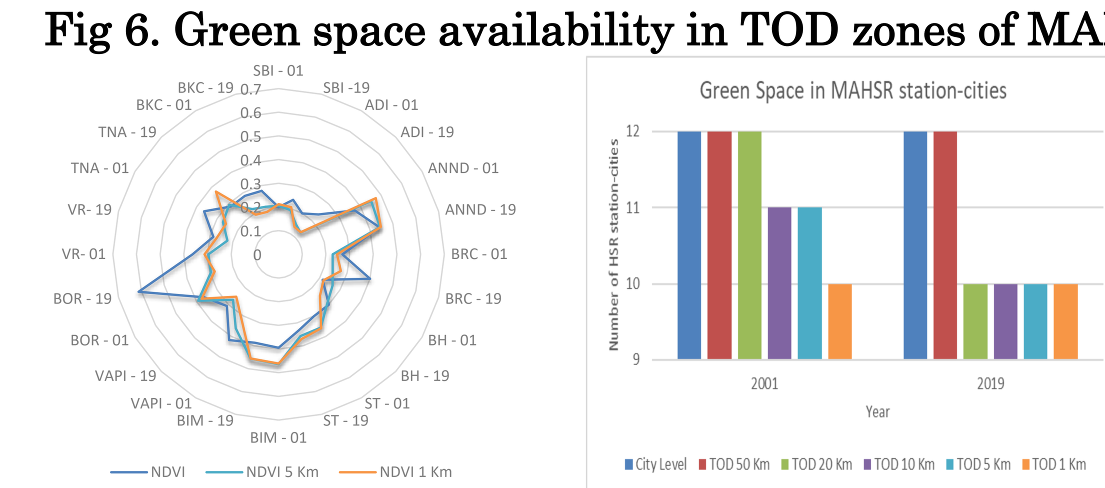

- The zones of NR and CR have highest risk while NWR has lowest risk.

**Fig 5. Risk assessment in IR under emergency cases scenario**




- The zone of NR has highest risk while zone of NWR is amongst lowest risk.

**Fig 6. Green space availability in TOD zones of MAHSR stations**




- There is decline in MAHSR station-cities from 2001 in green space for critical TOD zone of 5 Km in 2019.
- Need for integrated urban and transport planning.

## Conclusion

- Consideration of local vulnerability is critical in understanding nature of risk.
- This study is good enough as first step in spatial risk assessment and risk informed decision making towards investment for improvement of critical infrastructure.

## FUTURE TASK

- Risk analysis under environmental vulnerability scenario
- Quantifying aspects of hazards damage (currently assumed same under similar vulnerability rank)

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