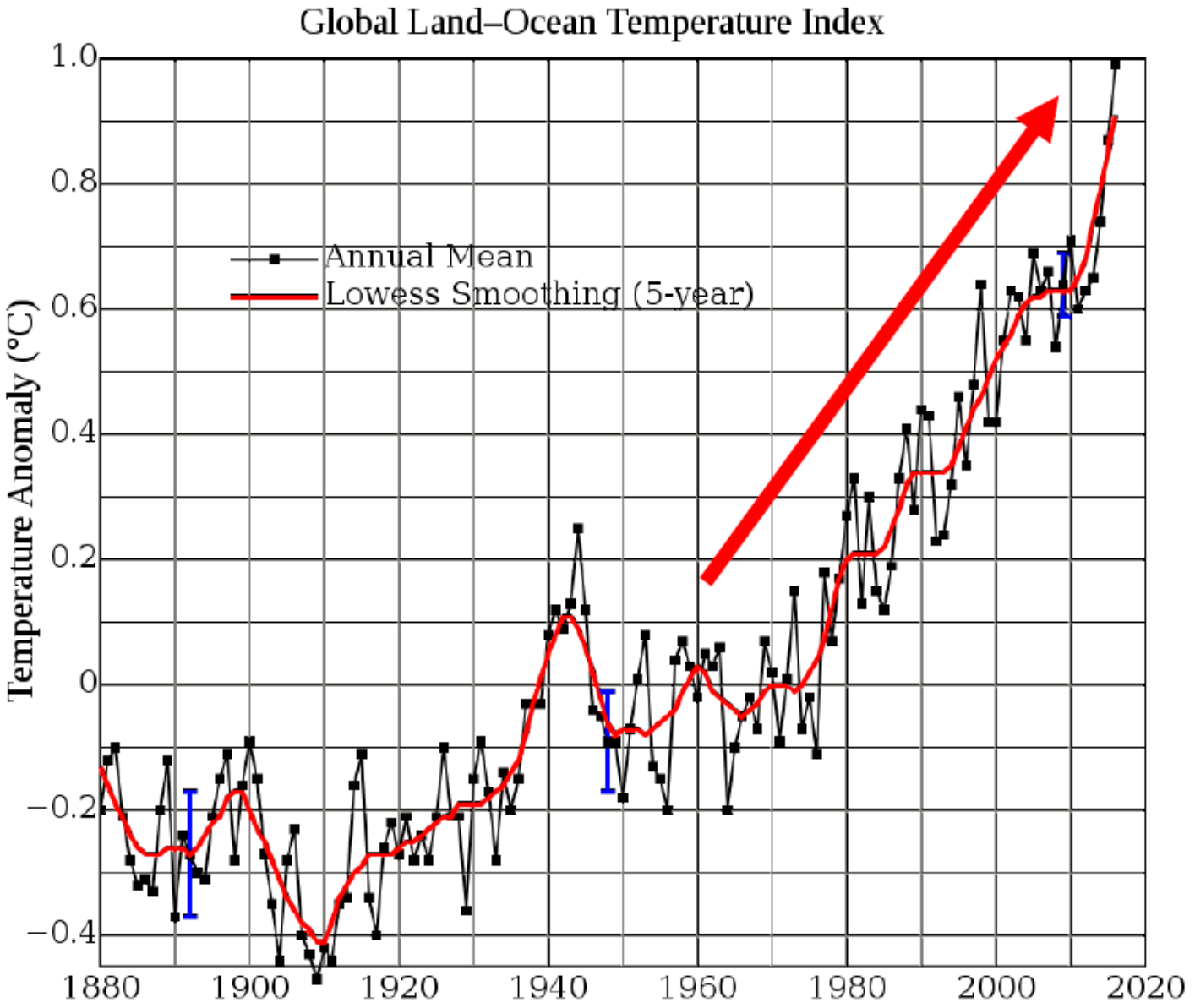
Risk assessment of Chinese railway subject to rainfall induced hazards

Kai Liu

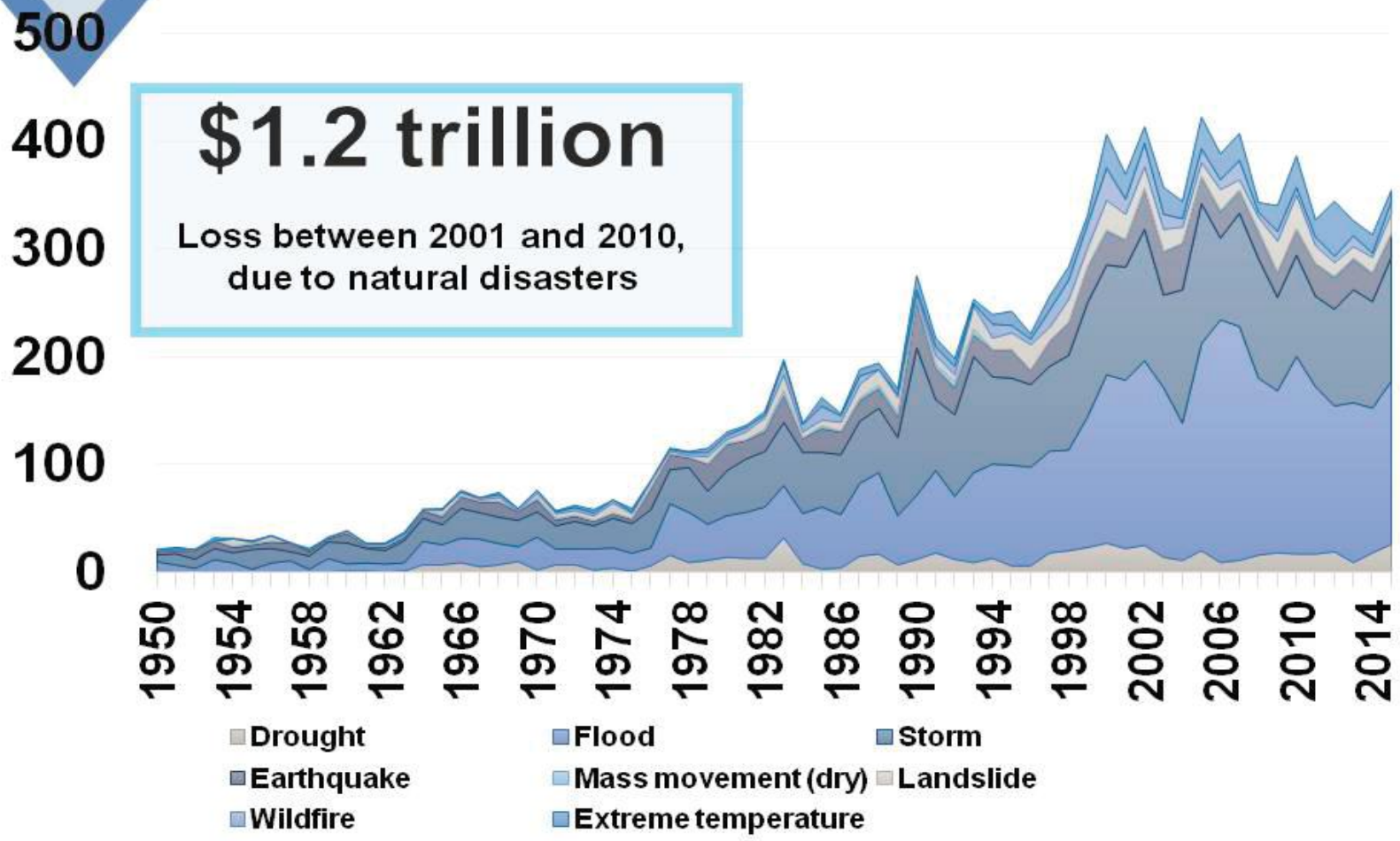
Beijing Normal University



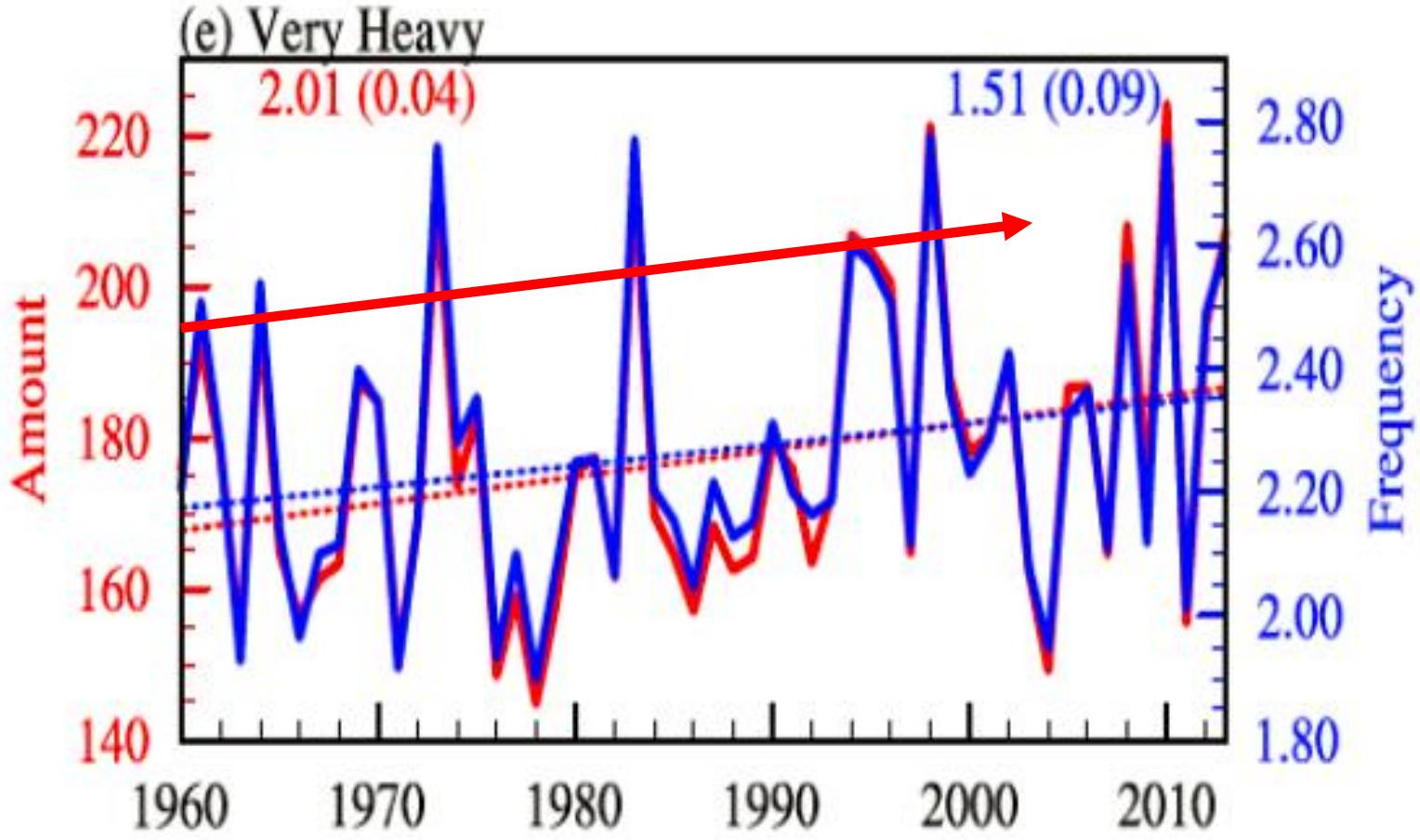
From wikipedia

CLIMATE CHANGE

INCREASING NUMBER OF INCIDENTS



Increasing trend of extreme precipitation in China




中国铁路交通地图2014
Www.OneGreen.Net
图 例
中国首都
外国首都
省级行政中心
其他交通中心城市
铁路管理局
国界、未定国界
省级界
特别行政区界
地区界
军事分界线
高速客运专线
铁路
南海诸岛

宝成线德阳至广汉
K165两节车厢坠入江中

沪昆铁路江西省余江至东乡段
K859次旅客列车发生脱轨事故

陇海线窑村至临潼段铁路线路中断

畲汕铁路畲江段一处坍塌现场

News 商报济南消息（记者孙姮）昨日，记者从济南铁路局获悉，连日来南方湖北、安徽等多地普降大雨，造成京九线、宁芜线、川黔线等部分铁路线遭受水害影响，7月5日至7日，多趟途经我省的直通客车列车停运。

途经我省具体受影响的列车有6对，分别为7月5日北京开K101/4/1次，7月7日温州开 K102/3/2次停运；7月5日福州开K46次，7月7日北京开K45次停运；7月5日包头开Z184/1次，7月7日深圳东开Z182/3次停运；7月7日北京开 K101/4/1次，7月9日温州开 K102/3/2次停运；7月7日福州开K46次，7月9日北京开K45次停运；7月6日贵阳开K1202/3 次，7月8日 烟 台 开K1204/1次停运。

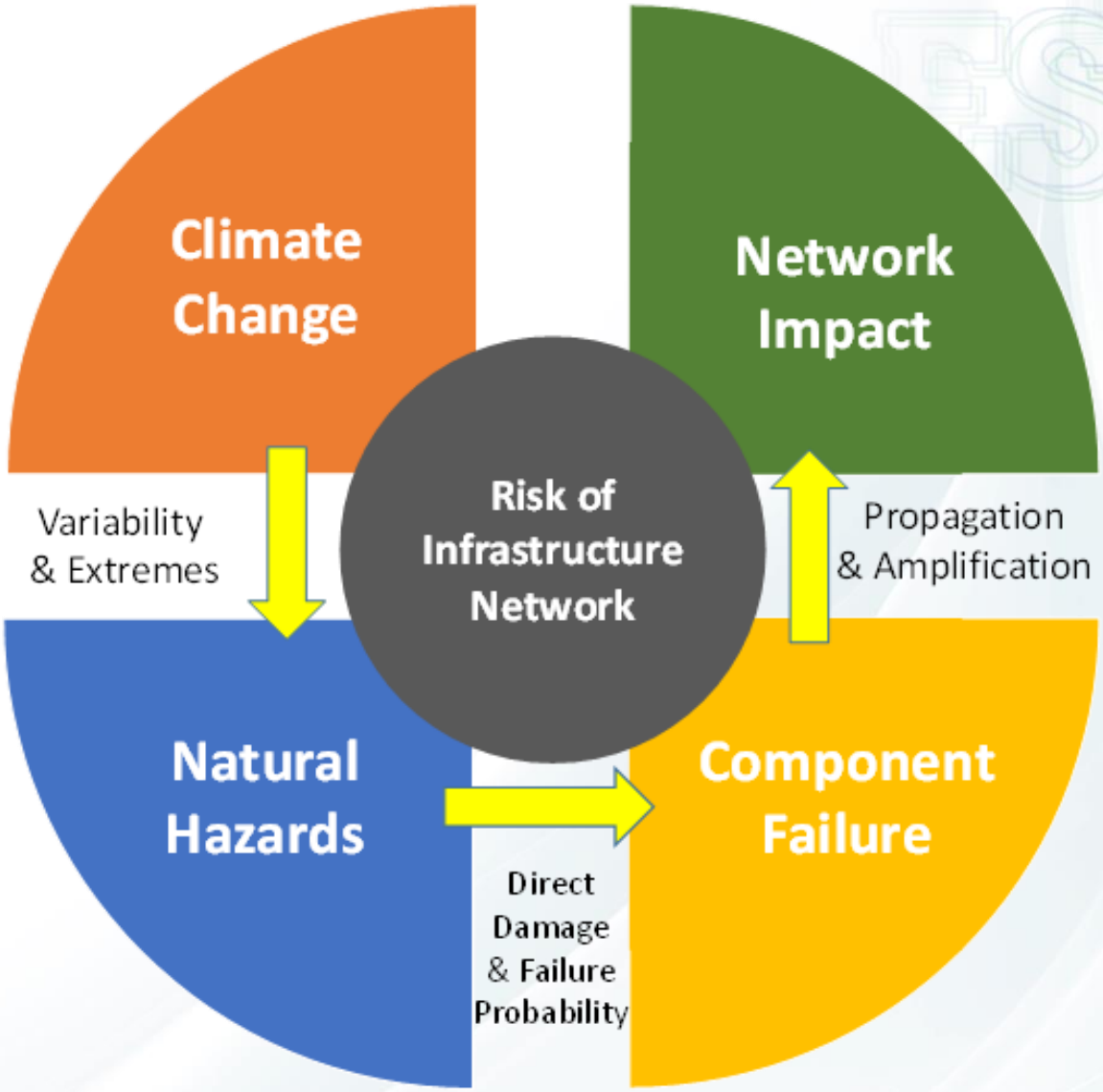
More than 300 high speed trains were canceled

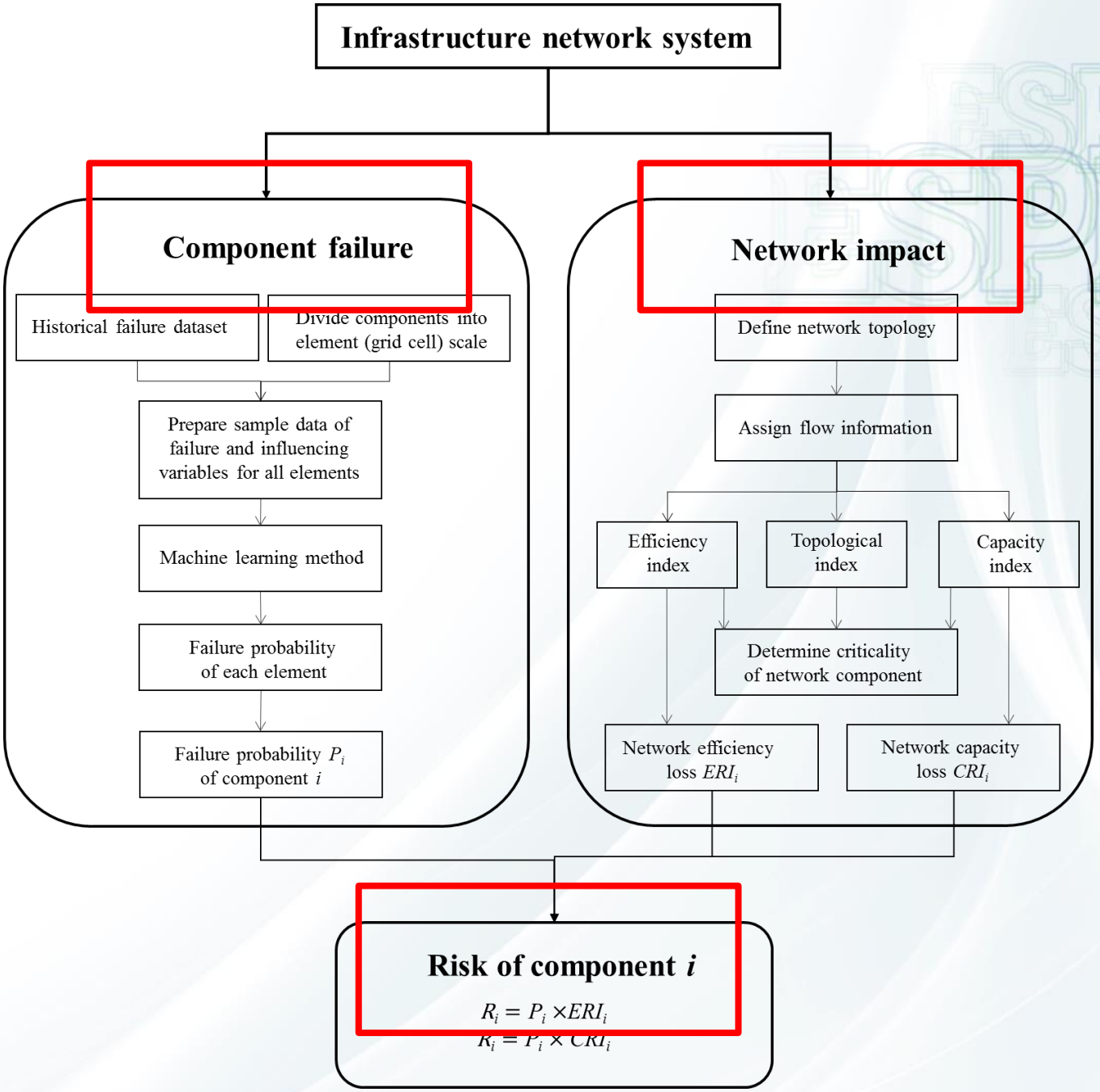
【福建福鼎严重内涝 还将迎暴雨到大暴雨】台风过境福建，强降雨来袭。福鼎市下午大暴雨，城区严重内涝，部分区域有山体滑坡，动车组停止运营。气象预测，未来几天福鼎市还将有暴雨到大暴雨，累积雨量50-80毫米，局部超100毫米。目前还没有伤亡报告。

RailAdapt

Designed to provide UIC members with a strategic framework to build long-term resilience

Methodology




Infrastructure network system
Component failure
Historical failure dataset
Divide components into element (grid cell) scale
Prepare sample data of failure and influencing variables for all elements
Machine learning method
Failure probability of each element
Failure probability P_i of component i
Network impact
Define network topology
Assign flow information
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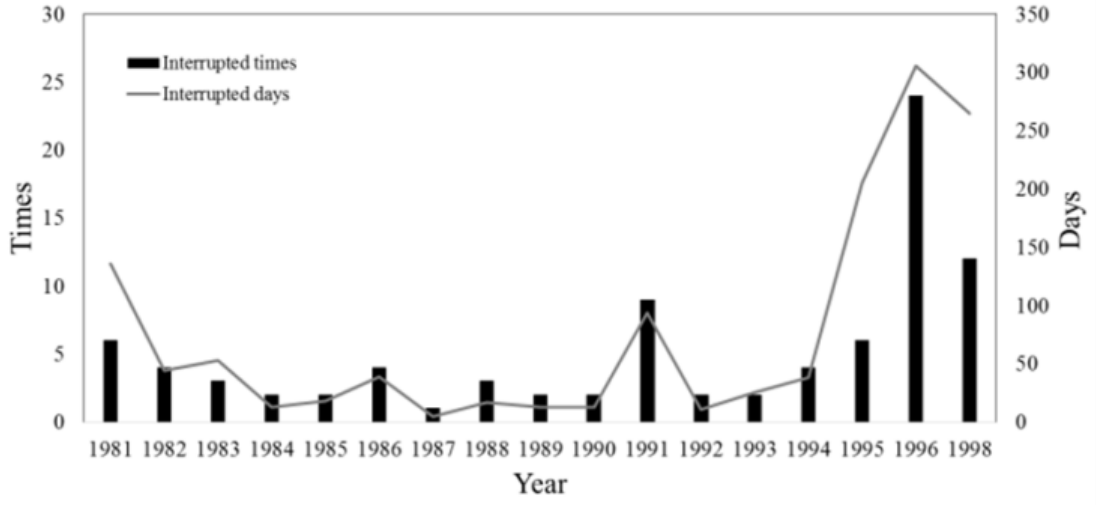
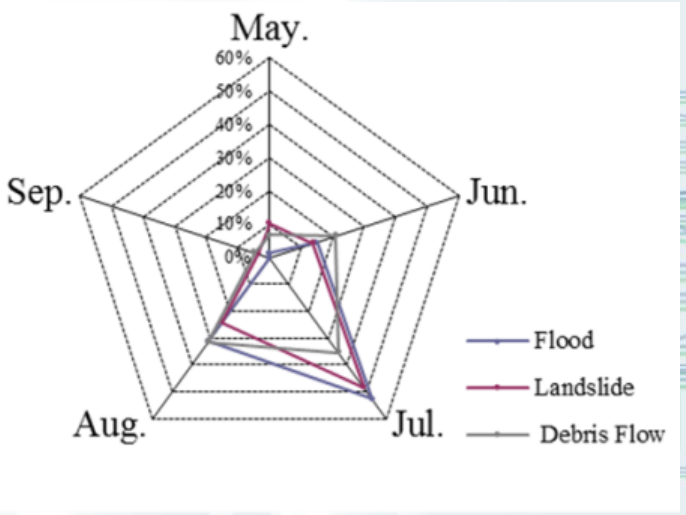
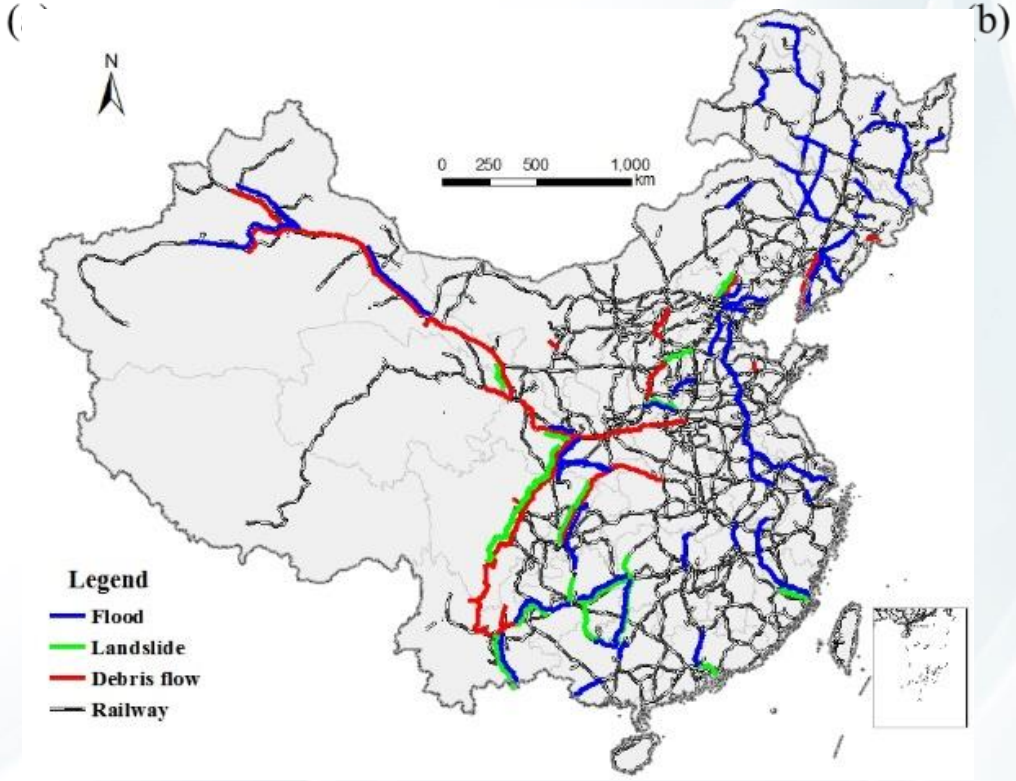
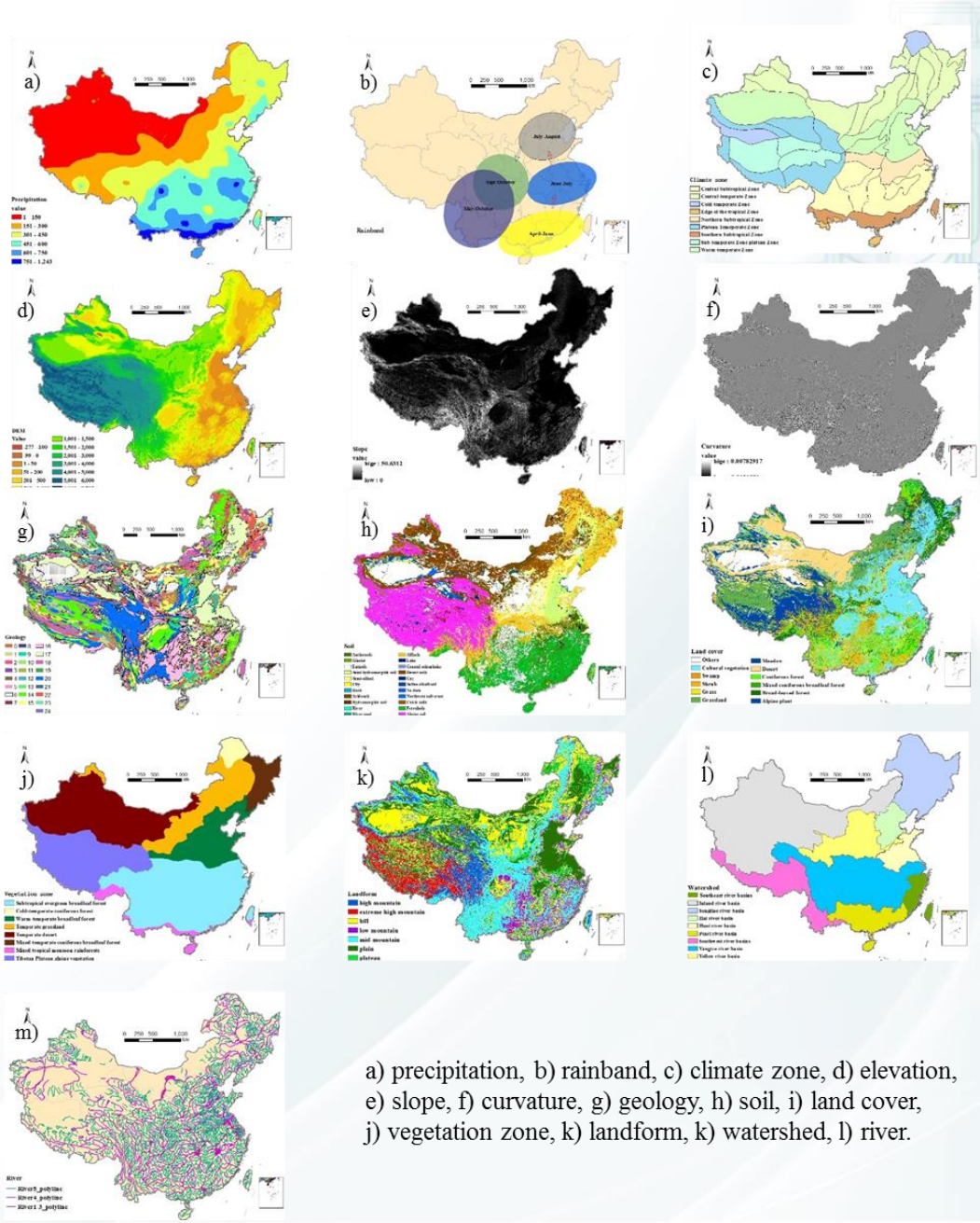






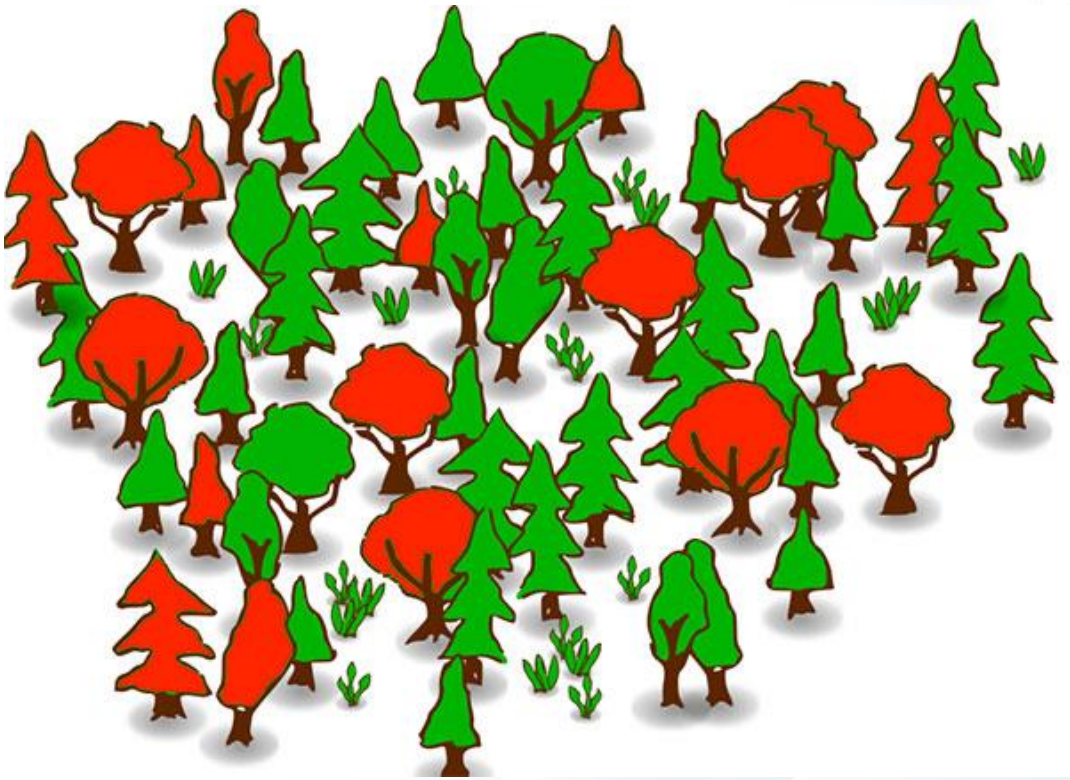
Historical railway hazards

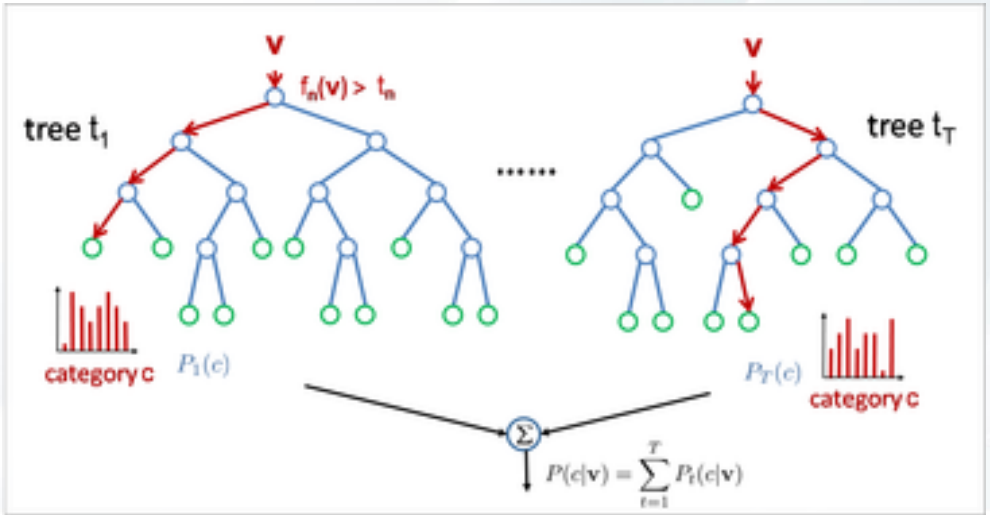
Variables that potentially influence infrastructure failure

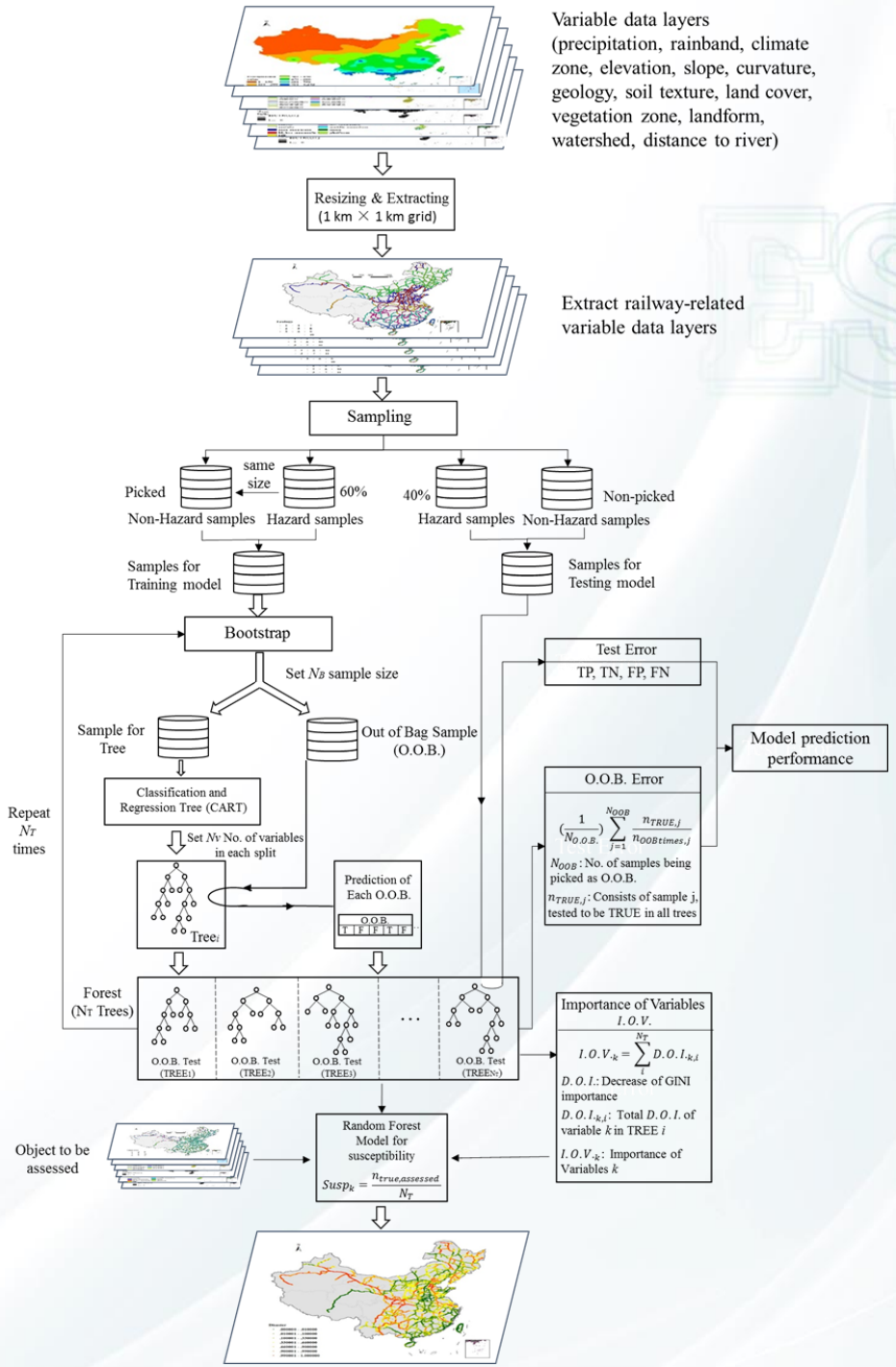


a) precipitation, b) rainband, c) climate zone, d) elevation, e) slope, f) curvature, g) geology, h) soil, i) land cover, j) vegetation zone, k) landform, k) watershed, l) river.

Random forest model






Variable data layers (precipitation, rainband, climate zone, elevation, slope, curvature, geology, soil texture, land cover, vegetation zone, landform, watershed, distance to river)
Resizing & Extracting (1 km × 1 km grid)
Extract railway-related variable data layers
Sampling
Picked
same size
60%
40%
Non-picked
Non-Hazard samples
Hazard samples
Hazard samples
Non-Hazard samples
Samples for Training model
Samples for Testing model
Bootstrap
Set N_B sample size
Sample for Tree
Out of Bag Sample (O.O.B.)
Classification and Regression Tree (CART)
Repeat N_T times
Set N_V No. of variables in each split
Tree$_i$
Prediction of Each O.O.B.
O.O.B.
T F F T T F
Test Error
TP, TN, FP, FN
Model prediction performance
O.O.B. Error
$(\frac{1}{N_{O.O.B.}}) \sum_{j=1}^{N_{OOB}} \frac{n_{TRUE,j}}{n_{OOBtimes,j}}$
N_{OOB}: No. of samples being picked as O.O.B.
$n_{TRUE,j}$: Consists of sample j, tested to be TRUE in all trees
Forest (N_T Trees)
O.O.B. Test (TREE$_1$)
O.O.B. Test (TREE$_2$)
O.O.B. Test (TREE$_3$)
O.O.B. Test (TREE$_{N_T}$)
Importance of Variables $I.O.V.$
$I.O.V._k = \sum_{i}^{N_T} D.O.I._{k,i}$
$D.O.I.$: Decrease of GINI importance
$D.O.I._{k,i}$: Total $D.O.I.$ of variable k in TREE i
$I.O.V._k$: Importance of Variables k
Object to be assessed
Random Forest Model for susceptibility
$Susp_k = \frac{n_{true,assessed}}{N_T}$

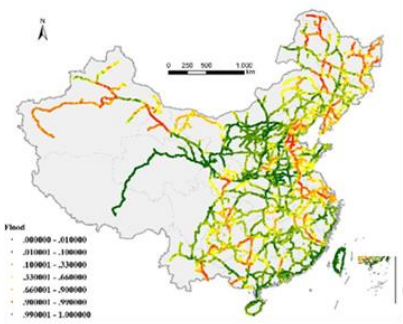
Susceptibility of Chinese railway to hazards

Flood

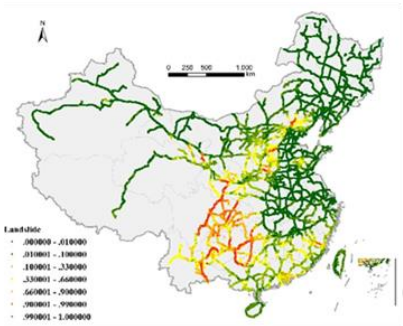
Landslide

Debris flow

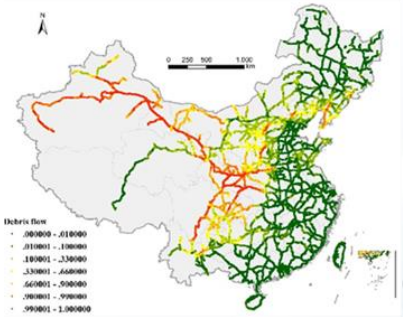
Multi-hazard



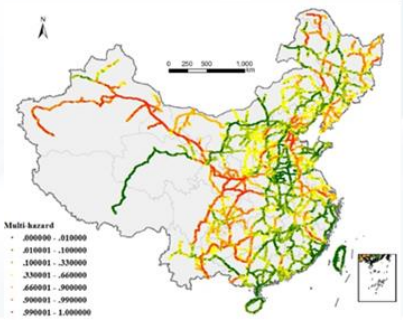
(a)



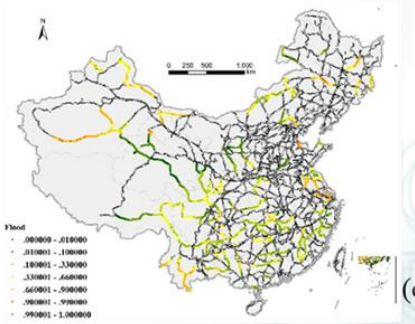
(b)



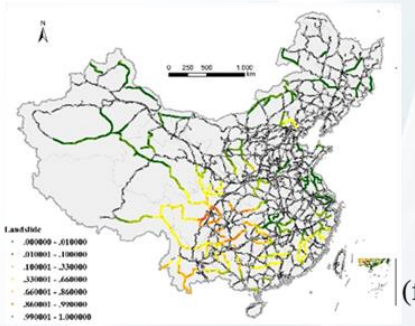
(c)



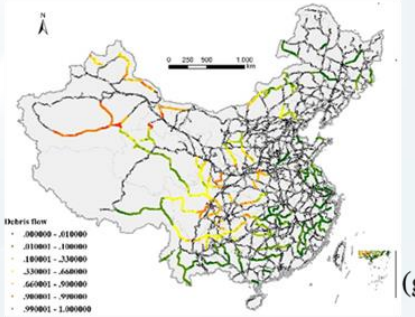
(d)



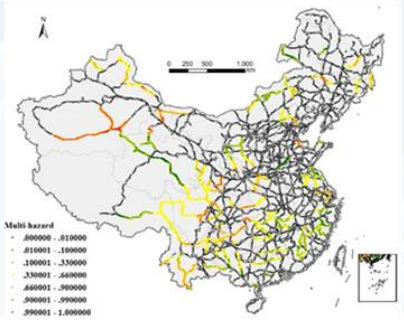
(e)



(f)



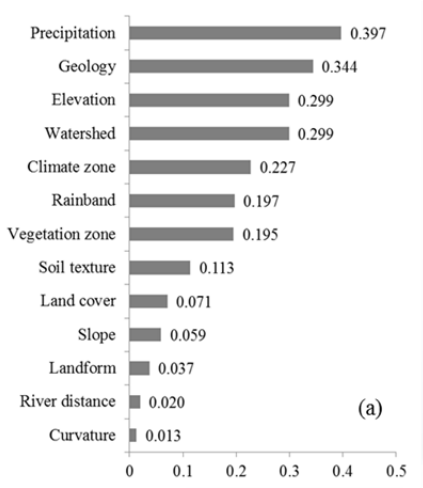
(g)



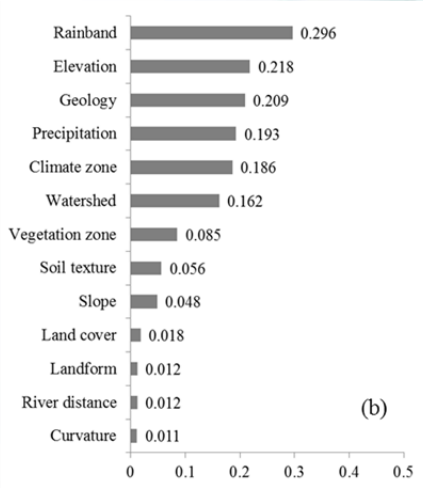
(h)

RF model	Model accuracy (%)		
	Training	Testing	Complete
Flood	98.13	94.71	95.86
Landslide	97.75	92.60	93.23
Debris flow	99.10	96.96	97.38
Multi-hazard	98.12	95.30	96.70

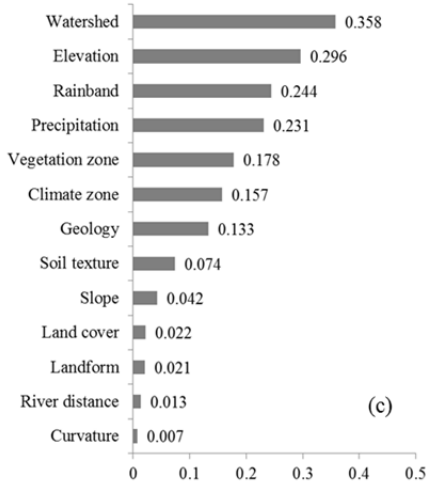
Flood



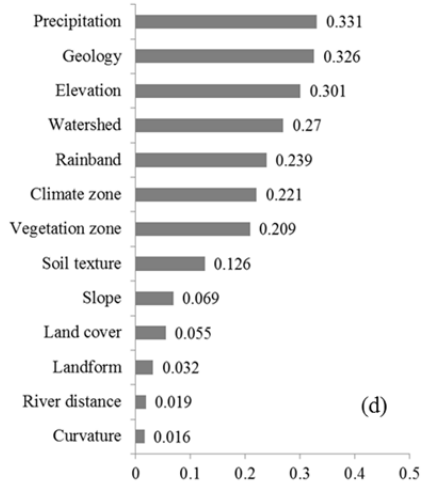
Landslide



Debris flow



Multi-hazard



Question：How to identify critical components and assess failure impact?

Input-Output modelling

$$B_j^i = \frac{x_j^i}{X^j},$$

$$X^i = \sum_{j=1}^{N-1} x_j^i + x_N^i$$

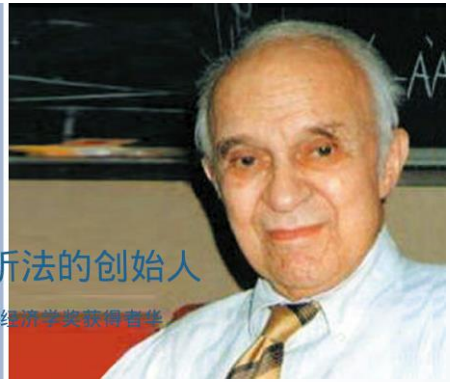
$$= \sum_{j=1}^{N-1} B_j^i X^j + y^i,$$

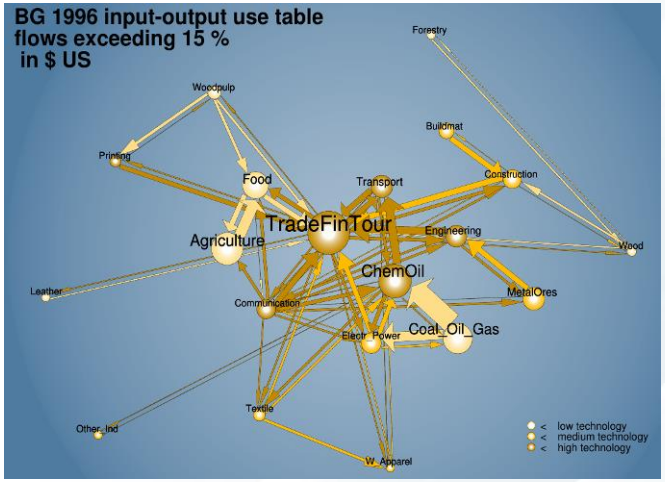
$$X = BX + Y,$$

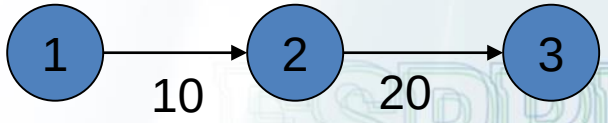
$$X = (1-B)^{-1} Y,$$

$$X = Y + BY + B^2 Y + \cdots,$$

$$\Delta X = \Delta Y + B\Delta Y + B^2 \Delta Y + \cdots$$





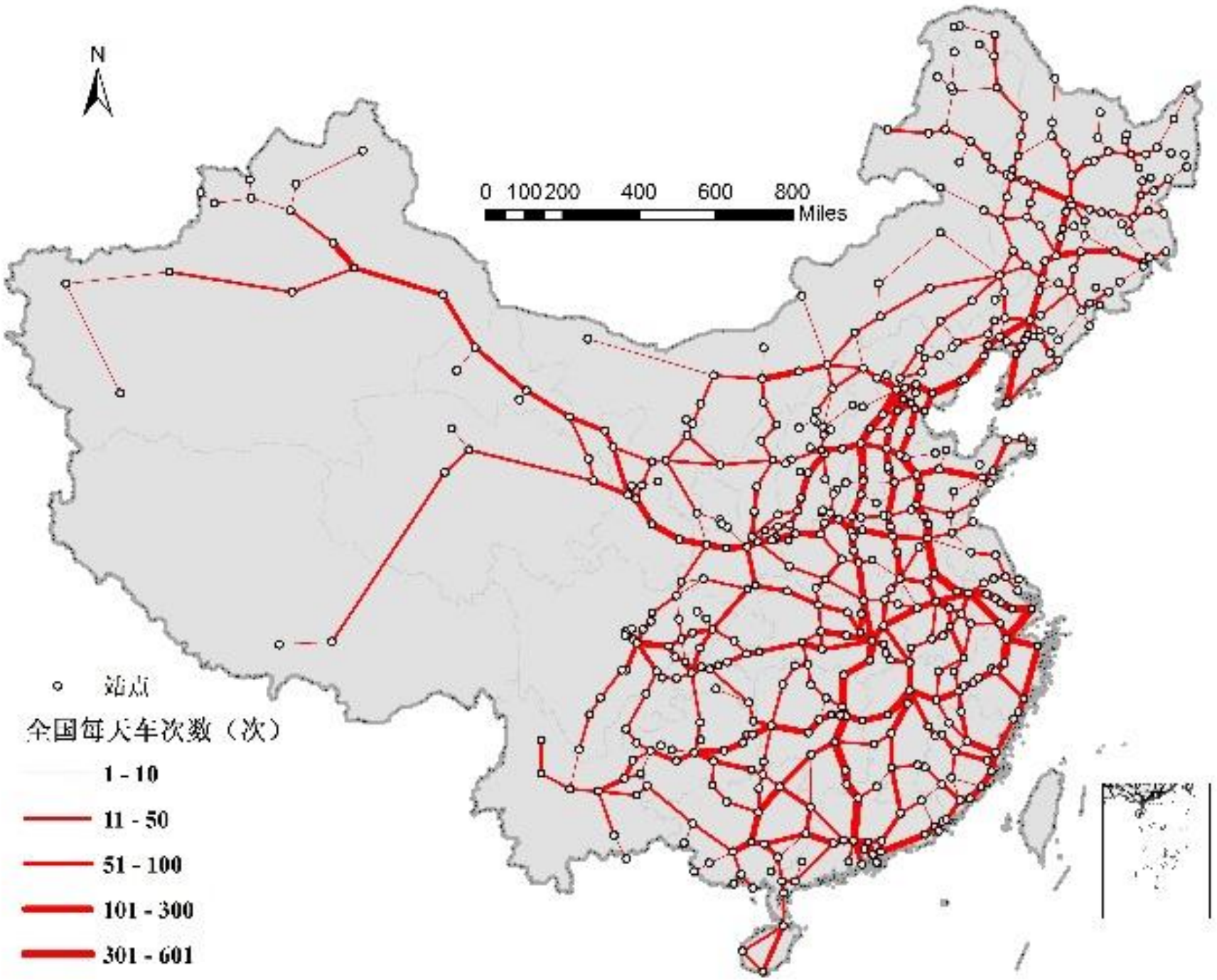


0	10	0	0	10
0	0	20	0	20
0	0	0	20	20
10	10	0	N	
10	20	20		X

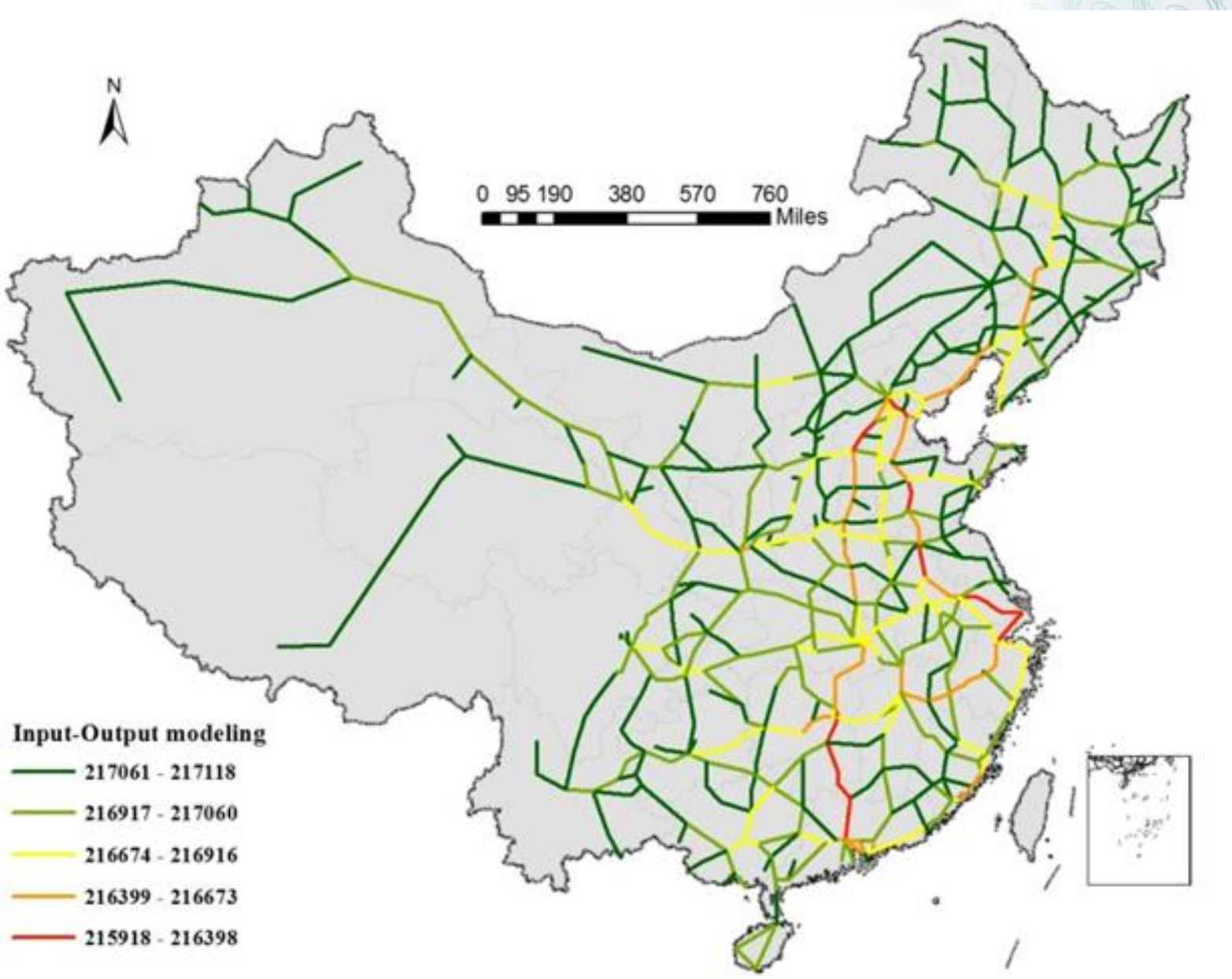
V

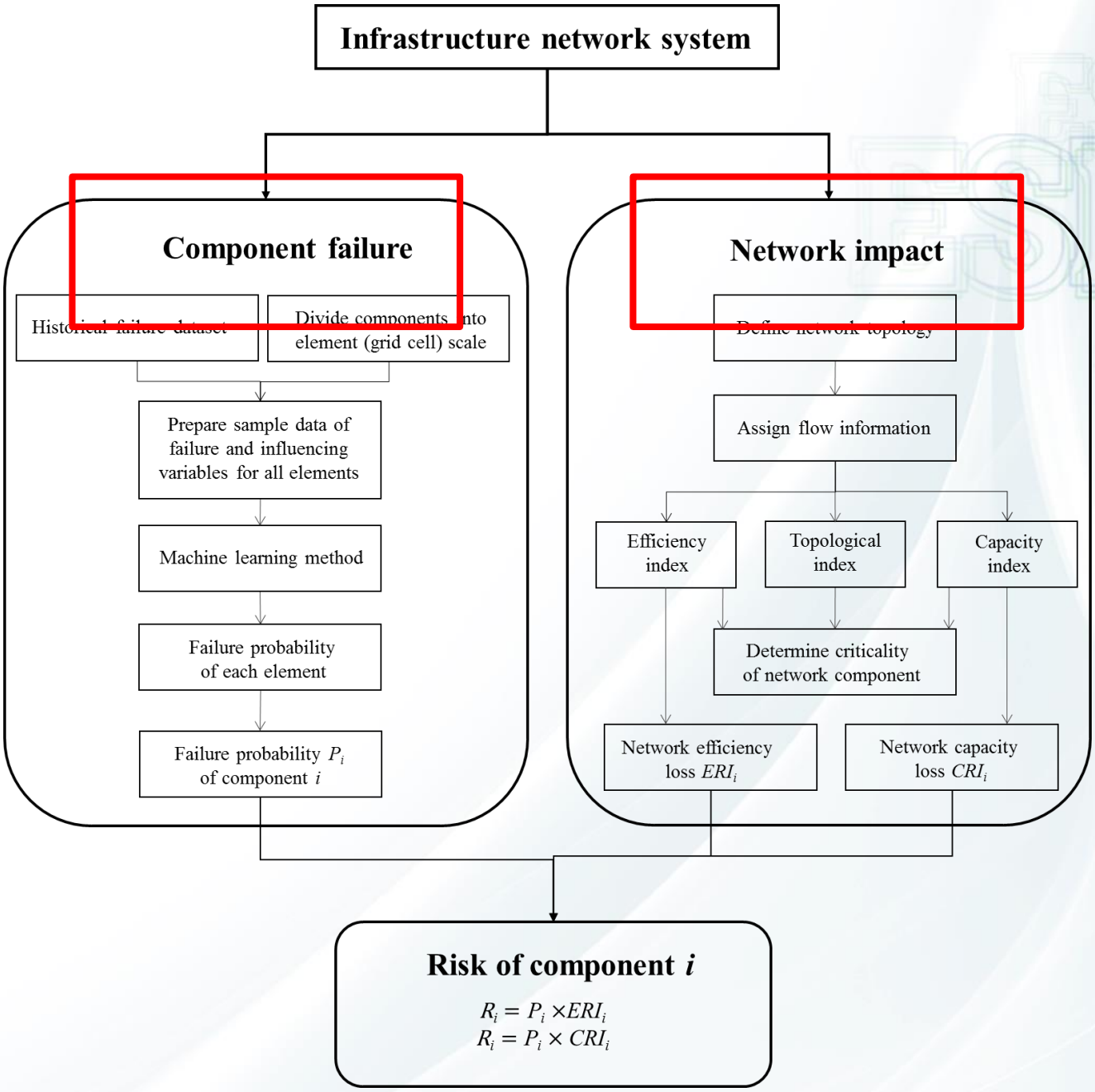
$$B_j^i = \frac{x_j^i}{X^j}$$

Leontief W W. The structure of American economy. 1951.


N
0 100200 400 600 800
Miles
站点
全国每天车次数（次）
1 - 10
11 - 50
51 - 100
101 - 300
301 - 601

Criticality map of Chinese railway

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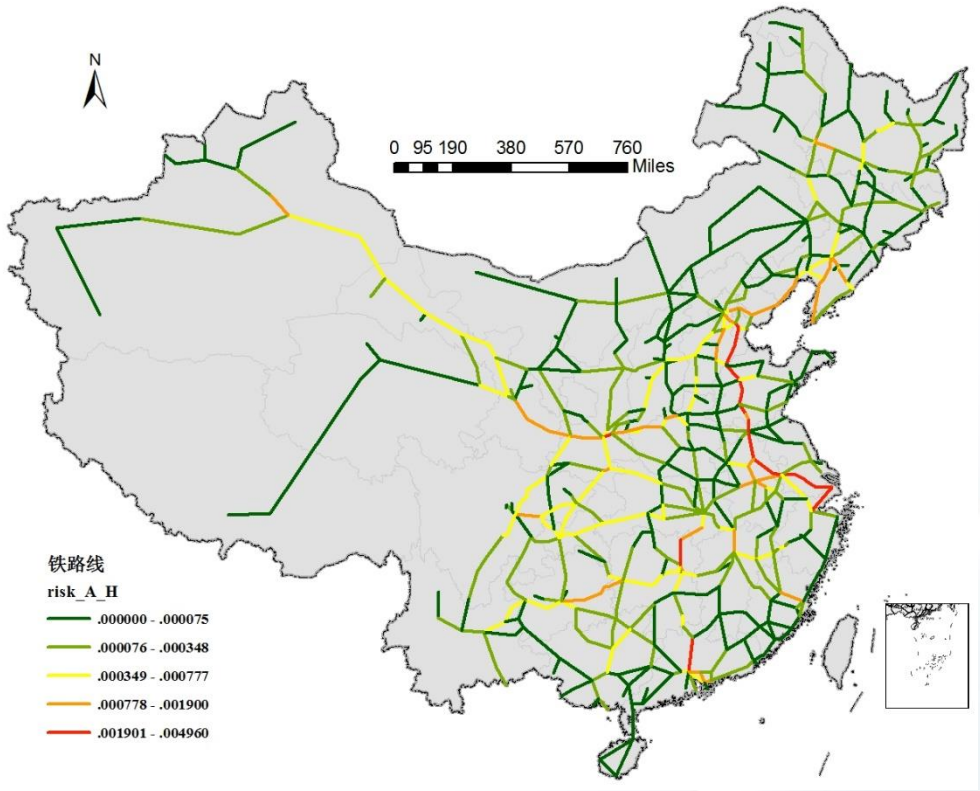
Risk map of Chinse railway due to rainfall induced multi-hazards



Higher-risk level

- Higher failure probabilities
- High criticality
  - ✓ Beijing–Shanghai
  - ✓ Beijing–Shenyang
  - ✓ Jiaozuo–Lanzhou

Moderate risk levels

- Highest failure probabilities.
- Reduced influence on whole-network efficiency
  - ✓ Lines in Northwest
  - ✓ Lines in Southwest

Lower risk level

- Lower failure probability
- Higher criticality
  - ✓ Beijing–Wuhan
  - ✓ Beijing–Jiulong

Provide scientific proof for railway hazards management

Conclusions and Discussion

- A risk map that provides critical information on potential risk impacts on Chinese railway is generated.
- The risk map can be used to inspire decisive action on investment in preventative and adaptive measures
- The susceptibility of railway under future climate change should be considered

Thank you!

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