Reply on RC2:

We thank the reviewer for reading our article and the comments. In the following, the texts with blue font are the reviewer's original comments, the texts with normal font are authors' responses and the texts with italic font are authors' responses in the revised manuscript. Our detailed responses are as follows:

At first, we have to address this issue and also we have described this in the discussion part: Why and how we did this work?

Why we did this work: In existing studies, vulnerability curves to link hazard characteristics and exposures are rare for both regional and national scales. Hence this work aims to use multi-source empirical data to build the vulnerability model and further assess the risk to railway infrastructure in China associated with rainfall-induced hazards. The developed vulnerability model adds new to existing researches. Furthermore, the approach to constructing vulnerability model presented in this research also has implications for other researchers to create vulnerability curves for their region and finally may lead to a global transportation vulnerability model database. This will greatly facilitate transportation risk assessment.

How we did this work: In this study, we use multi-source data collected from news and yearly book to generate vulnerability curves. For this purpose, the descriptive damage state damage of railway from news is converted to damage ratio by using a custom damage ratio table. The hazard intensity is extracted using the news and the CN05.1 daily precipitation dataset. Combining the fitted vulnerability curve, precipitation product, and railway infrastructure exposure, we estimated the risk of the national railway infrastructure. The overall railway infrastructure risk results are broadly correlated with the yearbook average direct economic damage from 2000 to 2017, which is 3.29 billion RMB. The results reveal that the vulnerability and risk of railway infrastructure can be estimated accurately using multi-source empirical data.

1) The unclear and not described methodological approach

Response: We apologize for the unclear description of the methodological approach. In the revised manuscript, we have rewritten the **Fitting the vulnerability curves** part to make the method clearer. We have added the following description in lines 1-4, page 14 and lines 1-14, page 15:

3.1.3 Fitting the vulnerability curves

We choose the cumulative log-normal distribution to fit the vulnerability curve as shown in Eq. 2,

$$F(x;\mu,\sigma) = \int_0^x \frac{1}{x\sigma\sqrt{2\pi}} exp\left(-\frac{(lnx-\mu)^2}{2\sigma^2}\right) dx \quad (2)$$

$F(x;\mu,\sigma)$ *is the damage ratio,* x *is the precipitation intensity,* μ *is the median value of* x *and* σ *is the standard value of* x*(Porter et al., 2007). A cumulative log-normal vulnerability function is chosen because it is a parsimonious two-parameter distribution with positive support (ensuring that unrealistic negative loads cannot occur) and has many precedents for its use in fragility analysis (Porter et al., 2007).*

To eliminate the noise and significant changes in the damage ratio, a moving average method is used to smooth the damage ratio in each precipitation intensity range. We add up all the damage ratios of points for a specific precipitation intensity range and divide it by the total number of points. In this study, we use the criteria for classifying the precipitation intensity issued by the China Meteorological Administrator (2008), which is presented in Table 5, to apply the moving average method. An example to illustrate the moving average method is presented in Appendix Table A2.

Table A2 An example to illustrate the moving average method. There are 3 damaged records among Light rain (0.1-9.9), the damage ratio range is 0.0065-0.2145 for record 1, 0.0015-0.0495 for record 2 and 0.0009-0.0297 for record 3. After using the moving average method, the lowest value is 0.002967, the average and highest value is 0.050433 and 0.0979, respectively. The precipitation intensity by using the moving average is 5mm.

	Precipitation intensity	*Total precipitation*	*Damage ratio range*	*Damage ratio by using moving average method*	*Precipitation intensity by*

		, *in 24 h/mm*	*of records*		*using moving average method,in 24 h/mm*
Lowest value	*Light rain*	*0.1-9.9*	*Record 1: 0.0065-0.2145 Record 2: 0.0015-0.0495 Record 3: 0.0009-0.0297*	$\frac{0.0065+0.0015+0.0009}{3} = 0.002967$	*5*
Average value				$(\frac{0.0065+0.2145}{2}+\frac{0.0015+0.0495}{2}+\frac{0.0009+0.0297}{2})/3 = 0.050433$	
Hightest value				$\frac{0.2145+0.0495+0.0297}{3} = 0.0979$	

2) The unconventional data gathering, merging sources that describe damage without the date of the occurrence, news, and rain of different length all together and finally merged to monetary values of infrastructures.

Response: Due to the difficulty of gathering and merging data, regional and national vulnerability curves are rare for many regions, which limits the progress of related risk assessment work. In this study, we try to use multi-source empirical data to build the vulnerability model. The sensitivities of influenced parameters are considered to give a range of vulnerability models. For all these records, we collect information about the occurrence date of the damage, the damage location, and the descriptive damage state by using online publicly available news sources. The information of all the damage records used in this study can be found in supplement material. The approach to constructing the vulnerability model also has good implications for other researchers to create their own local specified vulnerability curves.

3) The creation of damage curves without explain the type of data used and the methodological approach.

Response: We have described the data used in this work in the Data collection section, including precipitation data, historical railway damage by rainfall-induced hazards, railway damage yearly data and railway market value. In addition, we have described the methodological approach in the Methods section, including vulnerability curve estimation and risk assessment.

4) Impossibility of replication of the approach because it is described in a confused manner.

Response: We apologize for the unclear description of the methodological approach. In the revised manuscript, we have rewritten the **Fitting the vulnerability curves** to make the method part more clear. The estimated parameters of the fitted vulnerability curve are also provided in Table A3. In addition, we provided all the damage records which can be used to replicate this work, and the data can be found in the supplementary material.

Table A3 Estimated parameters of the fitted vulneribility curve

Region	***maximum_μ***	***maximum_σ***	***maximum_R^2***
Nation	*7.17*	*2.94*	*0.91*
South China	*6.76*	*2.17*	*0.89*
Southwest China	*6.88*	*2.17*	*0.91*
East China	*6.86*	*2.31*	*0.79*
Central &North China	*6.71*	*2.04*	*0.87*
Northeast China	*6.45*	*2.05*	*0.85*
Northwest China	*6.88*	*2.83*	*0.87*
Region	***average_μ***	***average_σ***	***average_R^2***
Nation	*8.25*	*3.16*	*0.92*
South China	*7.49*	*2.28*	*0.91*
Southwest China	*7.40*	*2.21*	*0.93*
East China	*7.81*	*2.57*	*0.78*
Central &North China	*7.71*	*2.45*	*0.84*
Northeast China	*7.19*	*2.07*	*0.91*
Northwest China	*7.58*	*2.85*	*0.90*
Region	***minimum_μ***	***minimum_σ***	***minimum_R^2***
Nation	*9.48*	*3.14*	*0.90*

South China	*8.06*	*2.04*	*0.90*
Southwest China	*7.80*	*2.04*	*0.93*
East China	*9.06*	*2.74*	*0.74*
Central &North China	*9.72*	*3.20*	*0.76*
Northeast China	*7.30*	*1.38*	*0.94*

5) Figures not explicative, with low graphical standard.

Response: In the revised manuscript, we have regenerated more clear figures, including the followed Fig. 3 and Fig. 5, to satisfy the graphical standard.

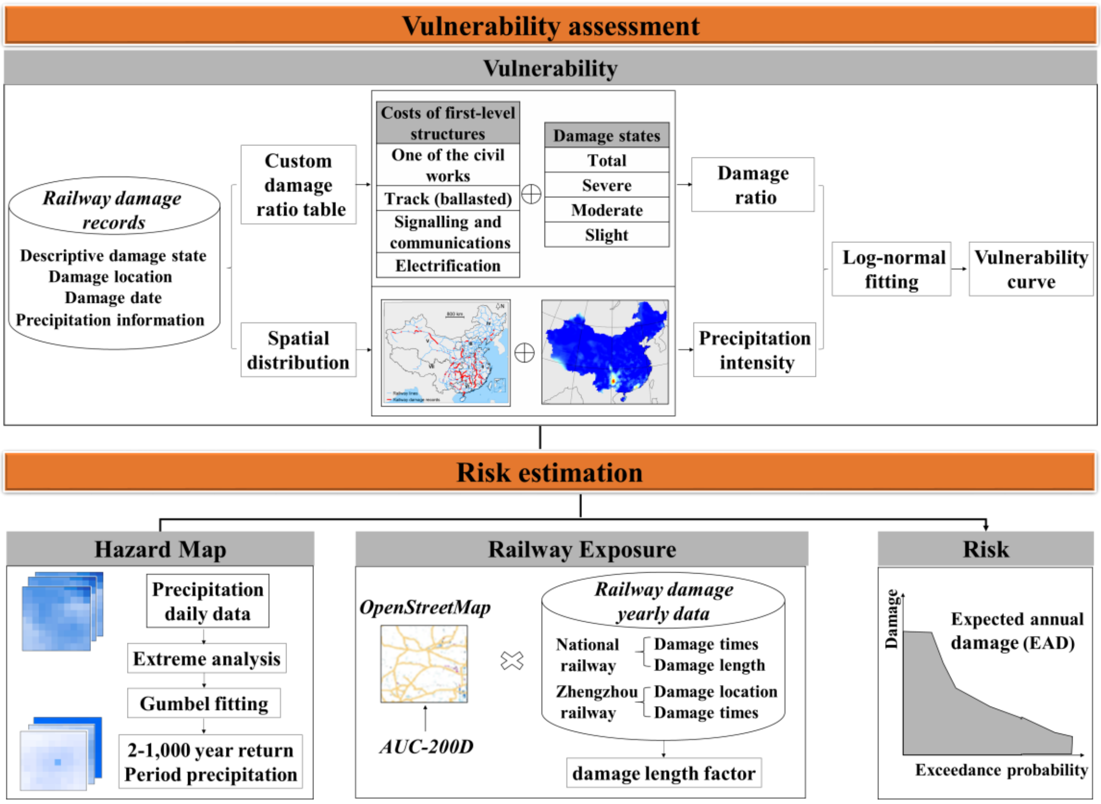

Fig. 3 Methodology of using the multiple sources of data to estimate vulnerability and risk. Railway geometries © OpenStreetMap contributors 2019. Distributed under the Open Data Commons Open Database License (ODbL) v1.0.

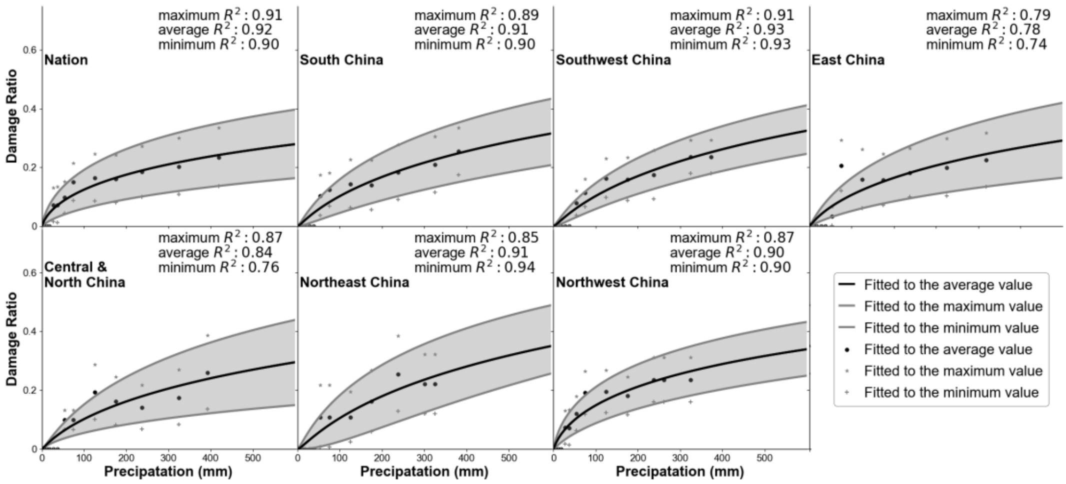

Fig. 5 National and regional vulnerability curves between precipitation (mm) and damage ratio. The maximum R^2 is the R square for the maximum vulnerability curve, the average R^2 is the R square for the average vulnerability curve, the minimum R^2 is the R square for the minimum vulnerability curve.