

Dear Editor,

We would like to thank you for considering our research for publication and for the fast and smooth review process. The reviewers' comments have been extremely helpful in improving the quality and clarity of our manuscript.

Below, we summarize the main modifications implemented in the revised version:

- We added more references and link our research to the general framework of risk assessment, including IPCC definitions and the concept of vulnerability, which were previously lacking.
- Following the suggestion of Reviewer 1, we revised the analysis using 30-year non-overlapping windows to ensure consistency in the results.
- We refined the *Discussion* section, highlighting other relevant hazards.
- We rewrote the *Conclusions* section to better convey the main messages of the study.
- The infographic and statistical tables have been updated for improved clarity and presentation of results. We also included further details on the sensitivity analysis, model resolution, and input data. Moreover, we improved the text of the 'Literature review' highlighting that we are studying recent extreme events (last 15 years).
- We added a new table summarizing the impacts across transport modes and hazards, and strengthened the connection between the two parts of the analysis to improve the overall narrative flow.

Please find below our detailed, point-by-point responses to the reviewers' comments. The revision has been done also with the help of another author, Chris Smith, that is now included in the manuscript.

P.S. Unfortunately, we encountered technical issues generating the tracked-changes file using the `diff` command. The highlighted differences were therefore produced using an online PDF comparison tool. We hope this approach is anyway acceptable for the review process.

Kind regards,
Cristina Deidda

On behalf of all the authors

Referee 1

General comment

Comment:

Firstly, I would like to thank the authors for writing an informative paper with the objective of (I) providing a review of literature about impacts of various climate extremes on Europe's transport network, and (II) analyzing potential future exposure under three emissions scenarios. While the work steps are generally well explained and based on freely accessible data and code, major improvements would make it easier for readers to understand the study's findings and methodology. The results of the literature review should be more concise, highlighting key findings from relevant literature and linking them to the analysis of future exposure. Regarding the exposure analysis, the paper would benefit from including further high-impact natural hazards, namely windstorms and coastal flooding, and excluding tropical cyclones (TCs). In addition, using comparable time windows and providing more information about the sensitivity analysis would facilitate the interpretation of the findings. The paper as a whole needs to be more concise, not just the results of the literature review. The following paragraphs describe my section-specific comments and overarching issues, followed by technical corrections.

Answer:

Dear Reviewer 1,

We would like to thank you for your constructive review, which has been very helpful in improving the manuscript. We agree with most of the suggested revisions and believe that the overall structure of the manuscript has been significantly improved.

Below is a point-by-point summary of the main changes:

1. We have made the results of the literature review more concise, better linking the two parts of the analysis. Some sections have been revised to convey the message more clearly.
2. Windstorms and coastal floods are now discussed in Section 4.2, based on relevant literature, since no database allows for a cross-hazard analysis consistent with the rest of the study. Moreover, in lines 418–422 of the updated manuscript, we specify that these hazards are important and that their future projections are discussed in the Discussion section.
3. Tropical cyclones have been removed.

4. The tables with examples of recent extreme events are now in the Appendix. A new table (Table 3) has been created to summarize the impacts, and we refer to the example table there.
5. We clarified that the literature review focuses on recent events, covering the last 15 years (from 2010 onward). One of the aims of the paper is to provide insights into recent impacts using the most up-to-date information available.
6. Future exposure analysis has been updated to use 30-year non-overlapping time windows. This ensures consistency with the barplot and avoids overlapping windows. All results and analyses have been updated accordingly. While the numbers are lower, the key message remains unchanged.
7. The results of the future projections are now presented as: EMF statistics over the already exposed elements in the past conditions and the newly exposed area, where we have no exposure in the past but exposure in the future. This approach better conveys the message by providing a better overview of all the information. Based on your review, we realized that using the median over all of Europe was not the best indicator to present the results.
8. The infographic has been updated to include mean values, confidence intervals, and the percentage of newly exposed areas, improving clarity.
9. The Conclusions section has been rewritten to be more concise. Additionally, we added more information on the sensitivity analysis in the Methods section and addressed risk and vulnerability topics in the Introduction.

We believe that the manuscript, in its current form, presents the key messages in a concise and clear manner, highlighting the review of recent events. Moreover, the updated exposure analysis provides policymakers with easy-to-interpret metrics and infographics, helping them understand the urgency of adaptation measures and strategies for risk assessment.

Major comments

Abstract

Comment:

In my opinion, the authors should mention the median values of potential future exposure besides the maximum values. It would help to give readers a better understanding of the results, as median values show no increase in exposure to river floods, wildfires, and TCs by mid- and end-of-century.

Answer:

Thank you for the helpful comment. In the reviewed version we modify the way to present the statistics. We realised that the median values over the entire Europe could bring to the not-correct assumption that there is no increasing in exposure for floods and wildfires. In reality, it just mean that the exposure does not cover more than 50% of the network, but anyway reach 20%-30% of the network with very high local peak of increase. In the updated version of the manuscript, we present the EMF statistics for the already exposed elements in past conditions, as well as newly exposed areas. Table 4 is now updated, as well as the infographic. We believe that the current Abstract well represent the results and well communicate the key meaning.

Comment:

Additionally, the abstract would be accessible to a wider audience by mentioning that RCP6.0 best resembles the extrapolation of current climate policies. It would clarify that the findings relate to a 'most likely' emissions scenario (L 8ff). Having said that, a later comment of the review relates to the use of RCP6.0. Another minor issue, the baseline period should be mentioned when reporting the relative differences in exposure under RCP2.6 (L 13ff).

Answer:

Thank you for this helpful remark. We revised the abstract to indicate that RCP6.0 closely reflects the trajectory of current climate policies (L9). We will also specify the baseline period (historical conditions) used when reporting relative differences under RCP2.6 to improve clarity for a wider audience (L15). Moreover, in Line 165-167, we gave more references about the topic of RCP6.0 that closely reflects the trajectory of current climate policies.

Introduction

Comment:

The introduction could be improved by highlighting the key aspects that demonstrate the added value of the literature review (namely the widespread impacts of past extreme events) and the analysis of future exposure, for example, by referencing relevant studies (e.g. Forzieri et al. 2018).

Forzieri, G., Bianchi, A., Silva, F. B. E., Marin Herrera, M. A., Leblois, A., Lavalle, C., Aerts, J. C. J. H., & Feyen, L. (2018). Escalating impacts of climate extremes on critical infrastructures in Europe. *Global Environmental Change*, 48, 97–107. <https://doi.org/10.1016/j.gloenvcha.2017.11.007>

Answer:

We included this reference in line 50.

Methods

Comment:

In case the TEN-T network dataset provided by the European Commission is open accessible, a weblink or citation of the used shapefile would further support the open access approach of the study.

In addition, the authors should make it explicit that they assumed the same extent of the TEN-T network already for the reference period (1965-2005) to conduct the analysis (see, e.g., Figure 8 – years: 1965, 1995).

Answer:

We agree with that, we specified that we use the same extent of the TEN-T network for the whole analysis (lines 199-200). The link to all available and open-access information about the shapefile is already cited (TENT, 2024). Please note that the shapefiles themselves are not publicly available online for security reasons; they were provided by the European Commission exclusively for the purpose of this study.

Comment:

Section 2.2.2 mentions that the GDIS dataset comprises reports about disasters from 1960-2018 (L 85); the same applies for the results section (L 200). However, the study only uses events from the GDIS dataset between 2010 and 2018. It would be clearer for the reader if mentions of the GDIS dataset from before this period were removed.

Answer:

Thank you for this helpful comment. You are correct that our literature review analysis focuses specifically on recent extreme events. We selected the period starting from 2010 to capture the increase in extremes over the last 15 years. The GDIS database provides data only until 2018, so this limitation is due to data availability. We agree that this is not clearly explained in the current version of the manuscript. We revised the text accordingly to specify the period used in the analysis and to avoid any confusion regarding the broader time span covered by the GDIS dataset.

We reviewed the paper speaking of ‘literature review of recent extremes’, not past extremes. Moreover, we specified in the Methods section that the analysis is focused in the recent extremes events, and that the time window considered is: 2010-2018 (lines 97-98), also we specified the timeframe we consider for the DRMKC risk database (L127-128).

Comment:

The lines 99-103 mention that the case studies would be a balanced representation of extreme events in Europe. However, the paper focuses on case studies from Western and Southern Europe. The inclusion of at least one case study of Central and Northern Europe would support their pan-European approach.

Answer:

Thank you for this thoughtful observation. The selected case studies are the results of a large research effort and were chosen based on specific criteria: (a) recent extreme events, (b) very high economic damages, (c) impacts across multiple transport modes, and (d) availability of reports and detailed documentation on impacts to transport infrastructure. These criteria considerably reduce the number of events that can be selected, as transport-specific damage and economic loss information is often difficult to obtain.

Although the selected events do not fully cover the entire European territory, we believe they still provide a representative overview of major types of extreme events and their impacts on different transport modes. The selected cases highlight some of the most significant recent events and mechanisms across Europe, while also reflecting the regions most affected by extremes in recent years. We revised the manuscript clarifying these selection criteria and better explain our rationale (lines 109-111).

Comment:

On page 6, the authors state that they conducted a sensitivity analysis to determine at which threshold localized extreme events (e.g. river flooding) affect nearby transport infrastructure. Based on the ISIMIP resolution of approximately 55.5 x 55.5 km at the equator level, this would mean that approximately 9.6 x 9.6 km of this area would need to be impacted by the event to affect the local transport infrastructure. Further explanations of how the sensitivity analysis was performed (without the need to look into the respective python script) would better justify the 3% threshold.

Answer:

Thank you for the comment. You modified the text giving an additional explanation of the sensitivity analysis would help clarify our choice of the 3% threshold (lines 152-160).

Some of the extreme event datasets express hazard extent as the percentage of the grid cell affected. Setting this threshold too high risks underestimating exposure, as it may

overlook localized but impactful events, particularly river floods. Conversely, a threshold that is too low may overestimate exposure, including cases that are unlikely to result in significant disruption.

To address this, we tested several thresholds ranging from 1% to 5% of the cell area affected. At the 5% level, we observed that most of flood events were not captured in the spatial statistics. At the 1% threshold, however, exposure to hazards such as wildfires was overestimated, with large portions of the network appearing to be affected in nearly every case.

The 3% threshold emerged as a compromise: it allowed for the detection of localized events like river floods while avoiding overestimation from more diffuse hazards like wildfires. We will revise the manuscript to better explain this sensitivity analysis and the reasoning behind our threshold selection, so that the reader does not need to consult the underlying code.

Comment:

Also, on page 6 and the subsequent page the authors mention the first time the ensemble median EMF. It would be beneficial to highlight that the median EMF is based on the ensemble of global climate and impact models that were described earlier. In addition, the terminology should not change throughout the text, for instance, it is referred to as “ensemble median EMF” (page 7), as “multi-model ensemble median EMF” (L 433, Table 6 and A6, and Figure 7-11), and as “impact-climate model ensemble median EMF” (L 513f).

Abbreviations in the figures, tables and in their captions (e.g. GCMs, EMF) should be explained close to the figure/table, so readers could interpret the content without looking up the abbreviations in the main text. Especially, this applies to Table 6 since it summarizes main findings of this study - it would be beneficial to describe briefly the meaning of EMF >100%, <1% and >1%.

Answer:

Thank you for pointing this out. We revised the manuscript to ensure consistent terminology throughout—for example, by standardizing the use of "multi-model ensemble median EMF" across the text, figures, and tables. We also made it clearer that the median EMF is based on the ensemble of global climate and impact models described earlier in the manuscript. We modified (L189-191), giving more details about it.

Regarding abbreviations, we agree that figure and table captions should be self-contained. We reviewed all captions—especially for Table 6 (now Table 4 in the reviewed manuscript)—to ensure that abbreviations like GCMs and EMF are clearly explained. We also modified Table 4, in terms of column titles and caption to better interpretate the values reported. Now, EMF->inf (before indicate as EMF values >100%) is described as ‘newly exposed areas’, and EMF>1, EMF<1 increase or decrease of area exposed.

The paper does not state clearly which countries from the GDIS dataset and the TEN-T network were considered - Figure 2 is misleading in this context as well as similar figures later on. The current TEN-T Network plans include Ukraine, Moldova and Turkey, but exclude Russia and Belarus. However, Figure 2 shows GDIS polygons (but without TEN-T road network) referring to regions in Russia, Belarus and Turkey.

The authors declare their focus on RCP6.0 that “*it most closely resembles the extrapolation of current climate policies into the future*” (L 148), but literature is missing which supports this statement.

Answer:

We selected the polygons that partially or completely fall inside the European boundaries (EU NUTS shapefile). Then, we superimposed the polygons of GDIS database to the current TEN-T network, and then we calculate for each element of the TEN-T the reported extremes. The confusion derive by the fact that some events that have impacted the TEN-T network has a larger extension and so maybe are also covering area that are not included in the TEN-T. We reviewed the caption of Figure 2, specifying that are reported also the Gdis poligons that partially intersect the European boundaries (EU NUTS).

We added some literature to support the statement of RCP6.0 (lines 165-167).

Results

Comment:

The results of the literature review (Section 3.1 and its subsections) should be more concise focusing on the important findings of the review, link them better to the second part of the results section (i.e., the future exposure) and relocate some information, such as Tables 3 to 5 to the Appendix. For instance, the paragraph about the study from Verschuur et al. 2023 is located in the results (L 280 –293) but deals with exposure of port infrastructure worldwide. However, the study area of this paper is Europe, so this paragraph (in its current form) does not fit to this section.

Answer:

We have revised the paragraph on the study by Verschuur et al. (2023) to emphasize the European findings (lines 306-333). The global results are now mentioned only in comparison with the European ones. We thank you for this helpful suggestion.

Comment:

Related to the previous comment, a summary table with all hazard types and transport modes considered should be created, summarizing the damage mechanism and relevance. Such a table would give a clear and concise overview of the key findings from the literature review and better link them to the analysis of future exposure.

Answer:

We added a summary table (Table 3 of the updated manuscript) covering all hazard types and transport modes for which we expect an increasing occurrence from future projections, summarizing the damage mechanisms and their relevance. We modify lines 418-422, to create a better connection among the literature review with the future exposure analysis. In the summary table we included only the hazards considered in the future projection analysis—namely heatwaves, floods, droughts, and wildfires—since these are projected to increase in exposure and, therefore, in their impacts. For windstorms, as now better described in Section 4.2.2 there is currently limited evidence that climate change is increasing their frequency or intensity beyond generating more heavy rainfall (Arias et al., 2021), and projections of windstorm impacts in Europe under climate change remain highly uncertain (Severino et al., 2024). So, for that we did not include them from the start in the exposure analysis.

Comment:

I would also suggest having a look into literature to verify some links between hazards and transport modes. For instance, the cited webpage (Systems, 2024) is about drought impacts on airports in the U.S., but is there also evidence for Europe? The impact factors, like soil type and drought duration, might differ between both continents. If there is no evidence, I would also advise removing the corresponding parts from Section 3.2. (L 474) and Table 6.

Two minor comments regarding Section 3.1:

- Remove Figure 1 as it only contains information already included in the corresponding sentence (L 190-192). In addition, this sentence should be rather part of the introduction as it is not a finding of this study.
- Adapt sentence in line 193ff in the way that it underpins the key message of Figure 3.

Answer:

We revised the text to specifying that the evidence refers to the U.S., but that it should also be taken into account for airports built under similar conditions (lines 264-269). We believe it is important to keep the information about the increasing number of airports and elements exposed to drought in the future in Section 3.2, as this is a result of our analysis and should be presented for consistency and completeness. Moreover, it is important to state it since from future projections we see a spread increase of drought in the following years, so it is important to have it in the radar since it could be a potential future impact. Regarding Figure 1, we thank you for your comments. We believe the figure is informative, especially for policymakers and non-academic audiences, as it provides an overview of the types of impacts. We also modified the text in lines 214–216, adding a sentence that explains the main take-home messages of the figure.

Comment:

In Section 3.2, the authors analyze potential future impacts on different transport modes, including coastal ports. However, they do not include coastal floods as an additional extreme event category in their exposure analysis (see, Table 1), despite they highlight in line 581f the increased risk it poses in a warmer climate; the same applies to storms. In addition, the impacts of coastal floods/storms under current climate are already mentioned (e.g., Sections 3.1.1 and 3.1.2). I would recommend either including coastal floods/storms to the exposure analysis by using an additional dataset or discussing the projected changes and impacts of coastal floods/storms for Europe based on relevant literature (besides Arias et al., 2021 for windstorms).

Answer:

Thank you for pointing this out. We are aware of this limitation and initially considered adding another dataset to include coastal floods. However, no dataset is currently available with the same RCP projections and structure as the one used for the other hazards, which would make it difficult to provide a consistent and uniform quantitative analysis. For these reasons, we chose a cleaner approach, maintaining consistency across hazards. Among the two options, we agree that discussing the projected impacts of coastal floods and storms based on relevant literature is the most suitable approach.

In the reviewed manuscript, we discuss the future projections of coastal floods and windstorms in Section 4.2.2. Moreover, in Lines 418-422, we specified that these hazards

reveal to be important from literature review and we made there already a link to their future projections discussed from literature review. Conclusions, now are modified to also include some info about these hazards.

Comment:

Related to the previous comment, the inclusion of TC impacts seems to be rather confusing, primarily due that no historical impacts of TCs on Europe's infrastructure were presented before. The literature review only mentions the impacts of TCs worldwide, such as in the paragraph about the findings from Verschuur et al. 2023 regarding damages to port infrastructure worldwide (L 280ff). Therefore, I would recommend excluding TCs from the study, or at most refer to them in one or two sentences.

Answer:

Thank you for the constructive comment. We agree and we excluded TC from the analysis.

Comment:

The results for RCP2.6 and RCP8.5 are reported in the Appendix but only briefly mentioned at the very end of the results. Thus, the sentence "*Results for RCP2.6 and RCP8.5 are reported in the Appendix A and discussed in the main text*" (L 149) is misleading.

Answer:

We revised the sentence in line 167-168.

Comment:

Time ranges (e.g. L 197ff, 387ff, 402ff): For the reader it is impossible to set the different time ranges in context to each other. Furthermore, it leads to additional text and distracts the reader's attention. A 52y overlapping window is not recommended; this time span is uncommon and the overlap is less useful when comparing changes in exposure over time. I propose using only a few comparable time ranges, ideally non-overlapping ones. Only when unavoidable, the authors should provide explanation why they deviate. Below, are some examples where the text should be improved:

- The time range of 2010-2018 used for the GDIS dataset should be aligned with the other time ranges of the study (e.g. a division of the 30y windows); the same applies to the DRMKC data, ranging from 2010-2022 (L 387).

- The findings about the exposure to future heatwaves/wildfires include once the changes based on 30y non-overlapping and on 52y overlapping windows (page 20 and 21). Please use only one (non-overlapping) time window.
- It seems that the time range for mid- and end-of-century spans 52 years, so line 169 is misleading.
- L 157 is misleading, too. It refers to the baseline period as a 41y timespan (1965-2005).

Answer:

Thank you for your helpful comment. We acknowledge that the use of different time windows throughout the manuscript may have caused confusion for the reader. The inconsistency in time periods arises from data-related constraints, which were not sufficiently explained in the original manuscript.

In the revised manuscript, we clarify the time windows used for the GDIS and DRMKC database analyses and explain why they differ. Regarding the future projections, after performing a sensitivity analysis and checking the consistency of the data and results, we decided to use 30-year non-overlapping time windows for the EMF calculations.

We revised the text to clarify the rationale behind these choices:

- **Past event databases (GDIS and DRMKC):**

We reviewed the text speaking of ‘recent events’ and not ‘past events’. This is coherent with our objective, that is to review transport-related events from the last decade/ fifteen years, making use of all available information. The GDIS dataset covers events until 2018, while the DRMKC database includes events up to 2022. While this results in slightly misaligned time windows (2010–2018 vs. 2010–2022), we believe including all relevant data from the most recent years improves the completeness of the analysis.

We acknowledge that this was not clear in the original text. We have modified Section 2.1 to specify that the aim is to map recent events, with a focus on the last 15 years (L97–98). Moreover, we clarified that the DRMKC analysis is based on the period 2010–2022, as this dataset provides the most up-to-date information till 2022 (L128–129).

- **Future projections:**

We modified our future projections EMF analysis considering, non consecutive, non overlapping 30-years windows. The results are now presented as comparison

among two future scenarios 2040-2069 and 2070-2099 respect to the historical conditions (1980-2009).

With the review, we found that 30-years is a long enough period to assess the statistics and deal with the extremes in our analysis. The numbers are lower compared to the initial version, but the take-home messages stays the same. Moreover, in this way, all the projections results are more consistent also with the yearly exposed elements analysis showed in the barplots.

Comment:

The statement in line 234f is only partially supported by Table 3 - the table does not provide a quantification over a longer time range as stated in the corresponding sentence. The authors should find literature to support the statement of line 234f. The same applies to Table 4 (L 294-296) and Table 5 (L 357f).

In my opinion the text part about landslides triggered by flash floods and preceding droughts should be set more into context to roads and railways (L 367-371). Furthermore, the last sentence of the text part is just an explanation of processes described in previous sentences, thus, it can be taken out.

Answer:

We added references of relevant literature to strengthen the argument and support the statement in Table 3 (Table A1 in the updated manuscript) (L 253-254), Table 5 (now Table A3) (L 375-377) (the tables are now in the Appendix).

Comment:

Overall, the authors should try to make the manuscript more concise by removing redundant information and ensuring that the explanations support the messages of the text. Some of the previous comments are already related to this issue. Below, are some further examples where in my opinion the text contains redundancies or is too detailed, mainly focusing on Section 3.2.:

- It is sufficient to mention examples of indirect and non-monetary losses just once, as done when cited Bednar-Friedl et al. (2022) or Eneir et al. (2010). In the subsequent text, repetition of these examples should be avoided. If necessary, they could be referred to as non-monetary losses and indirect impacts
- L 401 - 404: I think both sentences can be condensed into one sentence.

- L 438 - 442: Also, here make it more concise, e.g. (L438f) the increase in the ensemble mean is similar across all transport modes, thus it is sufficient to report only a range with 30.8% (waterways) - 37.9% (airports).
- L 469 - 472: Try to include the second finding about road exposure to the previous sentence since all three network types face similar strong exposure
- L 479ff: It seems to be redundant to L475f

Table 6 would benefit from some adaptations (same as for Table A5 and A6): The authors should consider using Q10 and Q90 (instead of Q20 and Q80), since they report only the former in Section 3.2 and Figure 6. Also, the total number of ensemble members used to calculate the median values and percentiles should be provided in the table.

In addition, underline the finding that the Mediterranean region will face the strongest increase in number of heatwaves and wildfires across Europe by mentioning Figure 7 and 9 (L 458f). This would support both the paragraph and the corresponding sentence in the discussion that reflects this result (L 562f).

Answer:

Thank you for the feedback. We worked on improving the flow of the text in Section 3.2 to make it more concise and focused.

Here is the main summary of the revisions:

- We revised the results section on future projections, where we discuss the bar plot (yearly exposed elements). The text is now less technical and more consistent with the rest of the manuscript, reducing redundancy and highlighting the main results more clearly.
- We added a sentence about the Mediterranean region (L435-436).
- We updated Table 6 (now Table 4) , showing the Q10 and Q90 values, along with the number of elements considered. The table has been completely revised to better explain the information and statistics, including a clearer caption.
- Overall, the text is now more concise. However, we decided to keep some repetitions—such as when referring to non-monetary effects—as we believe they effectively emphasize an important message that should stand out in the manuscript.

Discussion

Comment:

While the study solely focuses on infrastructure exposure, it would benefit from discussing briefly the aspect of vulnerability at least in this section. For instance, how the TEN-T network is specifically designed to withstand more frequent and intense climate extremes.

Answer:

We revised the introduction to provide more context and relevant references on risks and vulnerabilities (L44–52). The increasing frequency and intensity of climate extremes represent new challenges for which the TEN-T network was not originally designed. Interest in this issue is growing, so now it is a topic taken into account for the planning of long-term investments. A central aim of this work is to emphasize this lack of preparedness and to highlight the challenges it poses for the resilience of the network. We slightly modified the Section 4.1 to better convey this message, we believe that also with the new version of the Conclusion, it is well conveyed.

Subsection 4.1: The authors should try to adapt parts of the second last paragraph to fit better to the topic of this subsection, namely past events. In addition, the text about the future impacts should be moved to the subsequent section.

We modified the section in lines L606–611 to better explain our reasoning. We acknowledge that it was not clear that the literature review focuses on recent extremes, covering a window of the last 15 years. We want to emphasize that even in recent years, we are already experiencing new impacts due to the increasing frequency and intensity of extremes.

Subsection 4.2: The paragraph about drought impacts is not linked to the analysis of future exposure, furthermore, it contains explanations about drought impacts which should not be part of discussion.

We modified lines 572–580. The discussion of the drought index is included in this paragraph because it describes the index used in the analysis of future exposure. This part is important, as it explains the link between the specific drought index, based on soil moisture drought, and its impact on transport infrastructure.

Subsection 4.2.1 need to be better linked to examples of compound events from the literature review (e.g. co-occurrence of wildfires and heatwaves in Sicily).

That is a good point, thank you. We have added, for each example of a compound event in Section 4.3.1, a reference to the respective table of impact case studies.

Conclusions

Comment:

I would recommend revising this section completely. The additional work can improve how readers perceive the study since most of them will read after the abstract the conclusions to get an impression of the study. Thus, it should be concise and well-devised. For instance, in its current form the section lacks a summary and assessment of the study's key findings.

Answer:

We revised the Conclusion section to add summary and assessment of the key's study findings.

Minor comments

- Comment:

Table 1: The caption should be moved to the top of the table, as well as the text with the references to global climate and impact models.

Thank you for noticing it. We moved the caption and the text with references on the top of the table.

- Consistent writing of “en route”

We reviewed the text.

- Figures in the appendix (A1 – A4): their information should try to be condensed and presented more clearly. Readers might find it difficult to detect the differences between these figures. For instance, it might improve the quality of the figures by representing adjacent events of the same hazard types by one symbol with a size according to the number of events it represents

The reported information, the extreme events from GDIS dataset, is the same in all figures; the differences lie only in the positions of the respective transport modes (airports, ports, inland waterways). Presenting all transport modes in a single figure was confusing, so we split them into multiple figures, one for each

mode. This approach also helps stakeholders focusing on a specific transport mode to easily identify the relevant information. We acknowledge that this was not clearly explained and will clarify it better in the text.

- Table A3: the same sentence appears twice: “*The initial package of as much as 2.25 billion could be complemented by other sources like the EU’s solidarity fund, von der Leyen said.*” and the table caption should refer to Greece

Thank you so much for noticing it, we reviewed the text and the caption.

- L 9: missing whitespace

We modified the text.

- L 69: abbreviated RCP without entire name at first mention, same as for GDIS dataset L 77

We reviewed the text, L80 of updated manuscript.

- L 21: is number from EEA 2023

Yes, we moved the citation in the second row.

- L 41f missing word after “;”

We modified the text in line L43-44 of the updated manuscript.

- Make figures colorblind friendly
- We tested the figure’s palette in online colorblind friendly website.
- Figure 8: similar red tones should be avoided, and the black error bars are barely visible

Thank you for the comment. We try some other combinations, but we feel this palette is appropriate, since it is also on the styles of the maps. We decided to keep this layout.

- Figure 5: Merge both plots as they refer to the same information
- Thank you for the comment. Although the plots contain the same information, we believe it could be useful for stakeholders to have both.
- Years for in-text citations are occasionally missing, please have a look at the NHESS guidelines for citations, e.g. L 111
- We reviewed the citations.
- Lange et al. 2020b is the same as Lange et al. 2020a

Thank you for noticing it. We reviewed it.

Refereere 2

Dear Reviewer,

We would like to thank you for your constructive feedback and careful review. Your comments were very helpful in guiding us to improve the manuscript, particularly by refining the title to make it more impactful, adding more context on risk assessment, and enhancing the figures.

Please find below our point-by-point responses (in bold) to each of your comments.

Comment:

The authors may consider reformulating the title to make it more engaging and assertive. At present, the use of a question reduces the impact of the message in the paper. A more direct and declarative title could better reflect the findings and relevance of the study, while also capturing the attention of the reader more effectively.

Answer:

We appreciate your suggestion regarding the title. Although we initially preferred the use of a question, we agree that a more assertive formulation would more effectively convey the main findings. We changed the title in: 'Europe's transport infrastructure is not ready to face climate change'.

Comment:

While the manuscript provides a valuable compilation of bibliographic references related to individual extreme climate events—particularly in the case study sections—there appears to be a gap in terms of broader scientific framing. Specifically, the references are largely concentrated on the documentation of specific events (e.g., floods, heatwaves) and their impacts, but there is limited engagement with the wider scientific literature on climate risk assessment for transport infrastructure. This includes theoretical or conceptual discussions on vulnerability and resilience, as well as methodological references supporting the use of multi-hazard models and exposure metrics like the Exposure Multiplication Factor (EMF). Furthermore, the transition from observed events to model-based future scenarios would benefit from clearer referencing to studies that have addressed similar downscaling and ensemble techniques. Overall, the manuscript would be strengthened by a more explicit literature review that connects recent empirical findings with the methodological and conceptual framework guiding the projections.

Answer:

Thank you for this insightful comment. We agree that the manuscript would benefit from a stronger connection to the broader scientific literature on climate risk assessment for transport infrastructure.

We modified the Introduction incorporating relevant theoretical and conceptual literature on vulnerability, resilience, and climate risk frameworks in transport systems (L44-52). In this context, we referred also to the IPCC definition of risk to better connect our analysis and methods to larger methodological and conceptual framework.

The importance of multi-hazard analysis and the rationale under the use of the Exposure Multiplication Factor (EMF) metric, with proper references, are reported in the *Methods* section (lines 177–185). We cited there others paper that use the same framing and same data.

Comment:

Acronyms and technical terms (e.g., RCP6.0, EMF) are not always introduced or defined clearly upon first use. Ensuring consistent definition and explanation would make the manuscript more accessible to non-specialist readers.

The manuscript oscillates between formal and informal tones in isolated comments and segments. Standardizing the scientific tone and avoiding colloquial or overly informal phrasing.

There are some suggestions:

Line 25: Please define the acronym used in this emissions scenario to ensure clarity for all readers;

Answer:

We revised the manuscript defining the acronyms (L80).

Line 116: Are there existing studies or references supporting these events? Consider adding them to strengthen the discussion;

Yes, the studies and references supporting the use of this database and events definition are reported in lines 177-179 of the revised manuscript.

Line 117: Please rephrase the last paragraph into a bullet list to improve readability;

Thanks for the comment, we reviewed it and rephrased in bullet points (L117-128).

Line 118: Consider clarifying the resolution used for impact models by specifying it in latitude × longitude format;

We specified it as: “ 0.5° × 0.5° (approximately 55 km × 55 km at the equator)” in line 135.

Line 135: The introduction to Table 1 should appear before the table to improve logical flow and readability;

Thank you for pointing this out, we updated it (L141).

Line 137: Please elaborate or rephrase for precision;

We reviewed the text in lines 149-160, to give more information about raw data and sensitivity analysis.

In the initial dataset, heatwaves and droughts are recorded as affecting entire grid cells, whereas wildfires, tropical cyclones, and floods are expressed as the fraction of the grid cell exposed to the extreme event. For these latter hazards, a threshold is required to convert the fractional exposure into binary data and ensure consistency across the dataset. We classify a grid cell as affected by wildfires, tropical cyclones, or floods if more than 0.3% of its area is exposed. This relatively low threshold was selected because these hazards are often highly localized; using a higher area percentage would have excluded a substantial number of events.

Line 138: Consider explaining the overlapping time periods “2049 to 2075” as they may confuse the readers;

After checking the consistency of the data, we changed the exposure analysis to use 30-year non-overlapping time windows. This point was also raised by another reviewer, and we agree that using non-overlapping time windows is more appropriate for easier interpretation of the results.

Figure 3: Please avoid using grey tones in the graphical elements, as they visually overlap with the background text and reduce readability;

Thank you for the comment. We have updated Figure 3 and Figure 4 to replace grey tones with more distinct colours to improve readability.

Figure 4: Please consider increasing the primary units on the y-axis to improve readability. The current scale makes it difficult to clearly interpret the number of reported events per country;

Thank you, we adjusted the primary units in Figure 4 to make it more readable.

Figure 5: Please consider using a more contrasting color palette to improve readability.

Thank you for the suggestion. We modified Figure 5 using a more contrasting colour palette to improve the readability.

Referee 3

Dear Reviewer,

I would like to thank you for your valuable feedback and constructive review. Your comments have been very helpful in improving the context of the paper, particularly by encouraging us to provide more information on risk assessment for transport infrastructure and to cite key references such as the IPCC risk definition. We also refined the manuscript, especially in the Discussion and Conclusion sections, by improving the flow of the text and ensuring a more coherent and consistent narrative structure.

Please find below our point-by-point responses to each of your comments.

Comment:

The paper addresses a very relevant and urgent issue – the impact of climate change on transport infrastructure in Europe – which makes it of great interest to both policy makers and the scientific community. The topic is of great relevance, given the increasing climate-related disruptions to transport systems across Europe.

Answer:

Thank you for your positive comment on the relevance and urgency of the topic.

Comment:

The manuscript would benefit from the following improvements:

- Since the paper addresses climate change impacts, it would be important to clarify in the Introduction or Methods section why exposure definitions from the IPCC frameworks are not adopted or cited in the paper.

Answer:

Thank you for the comment. We modified the Introduction incorporating relevant theoretical and conceptual literature on vulnerability, resilience, and climate risk frameworks in transport systems (L45-52). In this context, we referred to the IPCC definition of risk and clarify how the current analysis relates to it, since we focus on the hazard and exposure components.

Comment:

- It is recommended to cite some papers that address the topic of climate risk analysis for the infrastructures such as airports (e.g.

<https://doi.org/10.1016/j.cliser.2024.100536>; <https://doi.org/10.1007/s11069-021-05066-0>)

Answer:

Thank you for the interesting references. We added them in the Introduction section, lines 48-49 of the revised manuscript.

Comment:

- It is recommended to streamline the Discussion section, which currently appears fragmented. A more coherent narrative structure would improve the clarity and interpretation of the results.

Answer:

Following this suggestion, and those of the other reviewers, we revise the Discussion section, to be more concise and with a better narrative structure.

Comment:

- It is suggested to integrate the "Challenges and future work" section in the Conclusions.

Answer:

Thank you for the suggestion. We totally revised the conclusions, integrating the 'Challenge and future works'.