

ANSWER TO REVIEWERS

Journal: NHESS

Author (s): Contreras-Jara et al.

Manuscript ID: egosphere-2025-4016

Title: "Indirect Costs of Floods: A Case Study of Highways Road Users"

Iteration: First review

Reviewer #1

#	Comment	Answer
R1-1	<p>The manuscript presents an integrated framework to estimate Expected User Costs (EUC) for highway networks affected by flooding. The approach combines hydrological and hydraulic modelling, bridge and road vulnerability models, and static traffic assignment to quantify indirect impacts on users in terms of increased travel time and fuel consumption. The method is applied to the "Aconcagua Bajo" watershed in Chile, and EUC is computed across return periods from 2 to 100 years. The topic is timely and important, particularly because quantifying indirect economic impacts on road users remains insufficiently addressed in flood-risk literature. The explicit inclusion of fuel consumption in the EUC metric is a notable and useful contribution.</p> <p>The manuscript is scientifically relevant and addresses an important gap by estimating user-based indirect flood losses. However, several aspects of the structure, clarity, and methodological transparency require improvement before publication.</p>	<p>We thank Reviewer 1 for the positive assessment of the manuscript and for the constructive comments that have helped improve its clarity and methodological transparency.</p>
R1-2	<p>clarity and Structure: The narrative often anticipates methodological elements that are described in detail only later. The overall structure (methodology vs. case-study description vs. results vs. discussion) could be reorganised to follow a more conventional and reader-friendly flow.</p>	<p>The manuscript has been reorganized to follow a more conventional flow. The new structure is described in response to comment R1-15</p>
R1-3	<p>replicability: Some essential modelling details are missing or only partially provided (e.g., input data sources, flood-depth selection per road segment, functioning of vulnerability models). Providing these details is crucial for transparency and reproducibility.</p>	<p>The modelling details flagged in this comment have been addressed individually in the responses to comments R1-8, R1-9, and R1-10, where the exact data sources and URLs, the flood depth selection criterion, and the description of the vulnerability models have been clarified and incorporated into the revised manuscript</p>
R1-4	<p>key modelling assumptions: several strong assumptions (e.g., traffic assignment minimising travel-time only, constant capacity for flooded roads, threshold probabilities for interruption) require clearer justification and references.</p>	<p>The modelling assumptions highlighted in this comment have been addressed as follows: the travel time cost and fuel consumption cost components of the traffic assignment are clarified in the response to R1-11; the 15% traffic</p>

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		<p>interruption threshold is justified in the response to R1-14. Regarding the assumption of constant road capacity under flooding, this is valid within the scope of the study, which evaluates a fixed maximum flood depth scenario for each return period. The analysis does not consider temporal variability of flood depth during an event; therefore, capacity and interruption states are treated as static conditions associated with the peak flood scenario. This assumption has been acknowledged in the revised Discussion section (lines 463- 462):</p> <p>“The traffic assignment model assumes constant road capacity and static interruption states for each flood scenario, based on the maximum flood depth for each return period. Temporal variability of flood depth during an event, which could result in variable capacity and transient interruption states, is not considered in the present study.”</p>
R1-5	Overall, I recommend major revision to strengthen structure, clarity, and methodological completeness.	All specific comments have been addressed individually in the responses incorporating clarifications on structure, data sources, modelling assumptions, and methodological transparency into the revised manuscript. The improved structure is explained in response to comment R1-15.
R1-6	Conceptual clarity & definitions Line 89 (Risk-receptor consequences): The definition is unclear. Please clarify what is meant by risk-receptor consequences within this framework, or provide a reference.	<p>We change the paragraph to clarify the term as follows (line 91 – 92):</p> <p>“Consequences comprise three factors (Gouldby and Samuels, 2005): exposure, vulnerability, and the potential affection on people or damage to infrastructures.”</p>
R1-7	State of the art & motivation Line 108: The statement “Engineers face challenges in estimating traffic reassignment...” requires a supporting reference. Several works in the hybrid flood-risk modelling literature could be cited.	<p>Supporting references were introduced. The following change is included between Lines 111-113:</p> <p>“Engineers face challenges in estimating traffic reassignment and road user costs as a proxy for the expected annual damage (EAD) in flooded highway networks (Pregolato et al., 2017b; Hackl et al., 2018; Zhang and Alipour, 2019, 2020; Qiao et al., 2023; Rebally et al., 2026).”</p>
R1-8	Data and replicability Line 143: “The traffic assignment model uses road and traffic data obtained from national road and traffic surveys...”	<p>The road and traffic datasets used are publicly available. We introduce a paragraph with explicit references and data sources in lines 400-404 as follows:</p> <p>“The traffic assignment model uses road and traffic data obtained from national</p>

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	Please specify the exact datasets, source years, and URLs if publicly available, to ensure replicability.	road and traffic surveys conducted yearly by the Chilean Ministry of Public Works (MOP): the National Road Network geodatabase (MOP, 2020a; available at http://www.mapas.mop.cl/), its dimensions and characteristics (MOP, 2020b), and the National Traffic Survey 2019 (MOP, 2020c; available at https://vialidad.mop.gob.cl/plan-nacional-de-censo-vial/). All datasets are freely accessible online.”
R1-9	Road-flood overlay and hydraulic outputs Line 163: When overlaying flood maps with the road network, each segment may experience varying flood depths. Please clarify which water-depth value is used for computing vulnerability and speed reduction (e.g., maximum depth along the segment? average? depth at centroid?).	The flood maps produced by HEC-RAS 2D represent the maximum flood depth at each pixel for each return period. When overlaying these maps with the road network, the flood depth assigned to each segment corresponds to the maximum value recorded along that segment, which represents the most restrictive condition for traffic operability. This criterion was clarified in lines 179-182 as follows: “The flood maps represent the maximum flood depth at each pixel for each return period. For each road segment, the maximum flood depth along the segment was extracted from these maps and used as input to the traffic interruption probability model (Eqs. 5 and 6) and the speed reduction model (Eq. 7), as it represents the most restrictive condition for traffic operability”
R1-10	Vulnerability models Lines 165–167 (Contreras-Jara et al. 2018): Equations (5) and (6) provide the calibrated probability of interruption, but a brief qualitative description of the underlying model is needed for readers unfamiliar with the reference. For example, explain in a sentence whether it is an empirical fit derived from controlled experiments, traffic data, or physical modelling.	A brief description of Eqs. (5) and (6) was included in the revised manuscript in lines 206–201. “The traffic interruption probability model for flooding, given by Eqs. (5) and (6) for light (Pint-light) and heavy (Pint-heavy) vehicles respectively, were used to estimate road vulnerability. Contreras-Jara (2018) calibrated Eq. (5) and Eq. (6) for Chilean conditions using reliability principles. The models estimate the probability of traffic interruption in terms of the flood height (h, m).”
R1-11	Traffic modelling Line 173: The sentence mentions speed, traffic volume, and travel time, but not fuel consumption. Since fuel consumption is essential for EUC, clarify how FCC is computed, linking clearly to Section 7.5.	The term FCC is wrong. The actual term is f_v (line 264). We erase the text “....and fuel consumption costs (FCC)” The value was obtained from the reference MDS (2020). It is included in section 4.4.3, line 425.
R1-12	Hydraulic modelling Section 5.2:	We confirm that the same DEM was used in hydraulic modeling. The

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	<p>The DEM resolution of 12.5 m is used in hydrological modelling; confirm explicitly whether the same resolution is used in HEC-RAS 2D hydraulic simulations.</p>	<p>following change is included in lines 343 to 345:</p> <p>“The same ALOS PALSAR digital elevation model (12.5 × 12.5 m resolution, JAXA 2011) used for hydrological modelling was used as terrain input for the HEC-RAS 2D hydraulic simulations.”</p>
R1-13	<p>Also clarify whether road elevations (crest level, crown elevation) are known or assumed based on DEM.</p>	<p>Road surface elevations were extracted from the ALOS PALSAR DEM (12.5 × 12.5 m) at the centerline of each road segment. Given the DEM vertical resolution, deriving more precise road elevations from this source is not feasible; this limitation has been acknowledged in the revised manuscript at Line 372 – 374:</p> <p>“Road surface elevations were obtained from the ALOS PALSAR DEM (12.5 × 12.5 m, JAXA 2011), extracted at the centerline of each road segment. Given the vertical margin of error of the DEM, more precise road surface elevations cannot be derived from this source”.</p>
R1-14	<p>Traffic interruption thresholds Line 300: “The limit values of Pint-light and Pint-heavy of 15% were defined.” This choice is unclear. Please explain why 15% was selected, whether this threshold is standard in the literature, and how sensitive results are to this assumption.</p>	<p>The 15% threshold is derived from the calibration range of the speed reduction model by Pregolato et al. (2017a, b), which is valid for light vehicles up to $h = 0.3$ m. A justification was included in lines 219 – 221:</p> <p>“In the flooded links, the limit values of $P_{\text{int-light}}$ and $P_{\text{int-heavy}}$ were set at 15%, consistent with the upper calibration limit of the speed reduction model of Pregolato et al. (2017a, b) for light vehicles at $h = 0.3$ m. The same threshold was applied to heavy vehicles using Eq. (6), yielding a flood depth limit of $h = 1.0$ m.”</p>
R1-15	<p>Structure and flow The manuscript currently mixes theory, methodological detail, and case-study information across sections. I strongly suggest adopting a clearer structure:</p> <p>(i) Methodology (all models, equations, thresholds), (ii) Case-study description (all input data and site characteristics), (iii) Results (hydraulic outputs, exposure, vulnerability, network costs), (iv) Discussion and limitations. This would significantly improve readability.</p>	<p>We change the paper structure as follows (third level titles are omitted):</p> <ol style="list-style-type: none"> 1 Introduction 2 Flood risk in highways networks <ol style="list-style-type: none"> 2.1 The flood risk concept 2.2 Flood risk in highway networks modeling 3 Methodology for estimating the road network flooding risk <ol style="list-style-type: none"> 3.1 General description of the procedure 3.2 Workflow 3.3 Step 1: Hazard modeling 3.4 Step 2: Road network exposure modeling 3.5 Step 3: Road network risk modeling

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		4 Case study and application: Road Network of Aconcagua Basin 4.1 Study area 4.2 Flood hazard modeling 4.3. Road network exposure to floods 4.4 Road network risk modeling 5 Results discussion 6 Conclusions