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Title: **The value of integrating information from multiple hazards for flood risk management**

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**Iteration: First review**

The objective of the paper is to present a comprehensive methodology for urban flood risk analysis, integrating pluvial flooding, river flooding and dam failure. The methodology is first presented in general and then applied to a case study. Moreover, the article would provide evidences on how outcomes from flood risk analysis supply better and more complete information to decision makers with regard to flood risk management.

Although the topic is of prime interest in the field of flood risk assessment and management, the paper suffers from some major criticisms that can be summarised as follow:

- Not only the terminology but also concepts are different than those used by the “floods” community; this makes the paper difficult to read for a “floods” experts (on the other hand, the paper is just on flood risk). I guess this is because authors come from the “dam safety” school which is more in line with industrial risk than natural risk’s approach. I am referring, for example, to the meaning authors give to flood risk analysis, evaluation, calculation and management (such a definition is not common in flood risk community), to how authors define “risk models”. Also tools are not very familiar to floods experts (e.g. influence diagram) nor they are explained in the paper. In this regard, I suggest of (i) making the paper coherent with flood risk analysts’ perspective (see e.g. results from the FLOODsite project or Merz et al.: Assessment of economic flood damage, Nat Hazards Earth Syst Sci, 10, 1697-1724, 2010) or (ii) defining and/or explaining in detail all the terms, methods, tools and concepts implemented. Otherwise, the paper is not fully understandable.
- The paper is very complicated as it represents an interesting attempt to model all the chain, from hazard to damage. I appreciate the effort to cover the whole chain. However, maybe because of authors’ expertise, the paper is not very balanced. Aspects related to dam failure are described very in detail, with a level of complexity that makes difficult to non-experts their understanding. Other aspects, like hydraulic analysis and damage estimation, are handled in short; this way, again, it is not possible to understand what they actually do and why. In this regard, I would suggest to make the paper more balanced maybe splitting the article in two papers.
- The discussion on how risk analysis results affect decision makers' choice is handled very shortly. On the other hand the title points just at this aspect. With respect to this authors should make a choice. (i) Changing the title of the paper (that should be very focused on the procedure that is the core of the paper now), leaving out this concept from the abstract and limiting the discussion of the point in conclusions or (ii) do not change the title, reduce the discussion of the procedure and expand the discussion on the value of results that should became the real core of the paper.

For these reasons I suggest re-drafting the paper in order to overcome present shortcomings, before its publication. In the follow, specific comments are provided on the current version of the paper. There could be inconsistencies in them because, as a flood expert, I had several problems in comprehending the paper . I reserve to add more specific comments in a next version if it will be submitted to NHES.

**Specific comments**

## Abstract

It should be rewritten according to the new version of the paper.

## Section 1 and Section 2

General comment: Contents of these sections should be reorganised. Concepts like flood risk, risk analysis, risk evaluation, risk calculation and risk management should be defined before they are used.

Pg. 3306. *"Floods may result from a combination of meteorological and hydrological extreme occurrences (WMO/GWP, 2008). In most cases, floods are additionally influenced by human factors"*.

It's too generic, please specify.

Pg. 3307. The Directive 2008/114/EC is not critical for the paper.

Pg. 3307. *"According to EU (European Union) Floods Directive (EC,2008)"*. The floods Directive should be properly referenced.

Pg. 3307. *"an assessment of potential risks including preliminary flood risk assessments, flood hazard maps, flood risk maps and flood risk management plans for each river basin district"*. Considering FRMPs as part of risk assessment is too much restrictive.

Pg. 3308 *"This paper proposes the use of risk models as they provide a logic and mathematically rigorous framework for compiling information to estimate flood risk"*. What do authors intend with risk models? This should be clarified. For example I consider F-N curve being a risk model, nor the authors do so. So what is authors' approach?

What does "compiling information to estimate flood risk" mean? I estimate flood risk by risk models?!?

Pg. 3308 *"The proposed methodology describes the process for combining all necessary information to estimate, analyze and evaluate flood risk"*. Which is the difference among estimate, analyze and evaluate (see general comment)

Pg. 3308 *"the proposed methodology describes the process for combining all necessary information to estimate, analyze and evaluate flood risk, obtaining an integrated flood risk outcome which includes several sources of hazard, the resulting potential flood events and consequences. This integrated outcome provides better and more complete information to decision makers (e.g. by analyzing flood risk for the current situation and the impact of different risk reduction measures)"*. The added value should be linked to the capacity of including several hazards. Comparing the impact of different risk reduction measures is not the innovative aspect of the procedure.

Pg. 3308. *"Attempts to develop common understanding on risk management concepts and terms among organizations are relatively new (IEC, 2009) or in process"*. I do not agree with this. Debate on flood risk terminology date back to thirties (see Gilber White!). IEC is not the most referenced source in flood risk community. See, instead, the report by the FLOODsite project "Language of Risk".

Pg. 3309 *"However, attention should be paid since there is no univocal relationship between hazard and probability (as probability includes also exposure) neither between vulnerability and consequences"*. It's too generic, please specify.

Pg. 3310 *"In general, potential adverse consequences of flooding can be classified in three categories: consequences for human health; consequences for cultural heritage and economic activity, and, consequences for the environment."*. This is not a general rule, it's authors approach. *"According to this, flood risk may be assessed in terms of societal, economic or ecological risk"*. Several authors would not

agree on considering risk to cultural heritage as an economic risk. Limiting societal risk to human casualties (as it is done in the rest of the paper) is not correct too: it includes several aspects: harms to people, trauma and psychological consequences, loss of human and social capital (see Sue Tapsell publications, among other, for a general review).

Pg, 3310. *“Indeed, these three dimensions are generally evaluated at a different level of detail. Which is this level of detail?”*

Pg. 3310. *“In most cases, ecological risk is not evaluated due to a lack of applications for quantitative risk assessment”*. Many authors would not agree. See results from the Conhaz project for a review.

Pg, 3311. *“As already mentioned, risk is commonly expressed by the following notation: Risk = Hazards×Vulnerability”*. This expression was not discussed before.

Pg. 3311 *“Data and time requirements for these tools are usually more demanding than for other methods, thug their results may pay back by providing significant information and recommendations for decision makers”*. I do not agree. Uncertainty of input data can affect results reliability, leading to unsuitable choices. Complete and quantitative tools can improve or not the decision making process according to how uncertainty is handled and represented/discussed.

Pg. 3311 *“Outcomes from risk modelling can be later used to represent F –N and F –D curves”*. Again I have a problem in understanding what do you mean with risk models.

Pg. 3312 *“In addition, the use of risk models and F –N curves allows to identify main variables and to reduce uncertainty on the analysis”*. Which are these variables? How uncertainty can be reduced?

Pg. 3312. *“In a first level, sensitivity analyses can be conducted to study the relationships between the information used for the risk model and improve their understanding”*. Not clear, please specify

Pg. 3312 *“Different methods can lead to a difference in ranking of importance of model factors”*. Which are these factors? Only reference to models variables was made before.

Pg. 3312 Only methods to reduce epistemic uncertainty are discussed. What about random uncertainty?

Pg. 3313 This terminology is not common in flood risk's community. For this reason, I suggest to put these definitions at the beginning of the introduction (see general comment)

Pg. 3313 *“Depends on the agreed tolerability criteria”*. Who agree on it?

Pg,. 3313 *“Several definitions of flood risk management can be found in the literature. As an example... ”*. Risk management was already defined! This is a repetition of above concepts.

Pg. 3314 *“flood risk governance”*. What risk governance is? No definitions are supplied for this. How does it differ from risk management?

Pg. 3314 *“Among the existing tools and techniques for risk analysis, these can be classified by applicability in terms of risk identification, risk analysis and risk evaluation”*. What do you mean with risk identification? No definitions are supplied for this

Pg. 3314 *“Event trees are particularly applicable for risk identification and analysis but not for risk evaluation”*. I guess that you discuss event trees because they are applied in the procedure but this is not clear for the reader, at this point.

Pg. 3314 *"F–N and F–D curves outstand as effective tools to support risk evaluation"*. How? Why?

### Section 3

General comment: I have a problem in understanding what do you mean with risk models, risk models architectures, etc. I found several inconsistencies along the paper.

Pg. 3315 *"the characterization of the "system" and the definition of the necessary assumptions to analyze the current situation"*. What do you mean with system? What do you mean with assumptions?

Pg. 3315 What do you mean with risk model architecture? Is it the event tree that you mention two lines after? (The event tree is a way of modelling a phenomenon). Is it the influence diagram? Is it the generic scheme? please specify.

Pg. 3316 *"Different risk models maybe used to analyse each flood hazard"*. I do not agree. In my opinion, you need to use different models to analyse hazard, exposure and vulnerability and combine them according to the scenario (e.g. situation A or B) you are analysing. A1, A2 and B are not risk models but the conceptual scheme of the scenarios. Each block of the scheme requires one or more models as you described later.

Pg. 3316 *"results are later combined to obtain total flood risk"*. How? This is not clear in the paper, neither in the follow.

Pg. 3316 *"additional studies or ad hoc estimations may be required to characterize all necessary variables"* What do you mean here with characterize?

Pg. 3317 lines 7-12. According to Fig. 3. models to estimate flood characteristics at the study site are included in system response nodes. Consequences' nodes should include models to estimate economic consequences (e.g. depth-damage curves) and damage to people.

Pg. 3317 *"Table 1 lists overall information that is necessary to develop the corresponding influence diagram"*. Table 1 includes the same information of Figure 3. It's not necessary. In any case, where is the influence diagram?

Pg. 3317 *"the second scheme (risk model A2) shows a generic diagram that can be used to analyze flooding from rainfall events at the river catchment area"*. Is Figure 4 (and Figure 3 and 5) a model, the risk model architecture or a generic diagram? See comment above! I agree that it's a generic diagram but this is not clear in the paper.

Pg. 3317 *"Information for this second diagram will include the aspects listed in Table"*. Table 2 includes the same information of Figure 4. It's not necessary.

Pg. 3318 *"information on loads, system response and consequences are necessary to incorporate input data into the risk model architecture proposed in risk model B (Fig. 5) which results from the combination of risk models A1 and A2, by adding a common initiating event"*. Fig. 5 is not a risk model. How do you combine results? Addition? I understood that results from A1 and A2 are summed in the case of situation A. Which is the difference in this case? In any case, adding results would not be correct.

Pg. 3318 *"the defined influence diagrams are the compact representation of the event tree that includes all possibilities that can lead to flooding"*. Again, I do not understand where you defined them, what do you mean with influence diagram.

Pg. 3318 *“adapting input data to avoid double counting in areas potentially affected by several flood hazards”*. How?

Pg. 3318 *“Figure 6 shows a general scheme of the process for combining results from independent risk models”*. Figure 6 is too generic and does not explain how results are actually combined in the procedure. In any case, the Figure assumes that the output of one model is the input for another one (cause-effect relationship) but it's not always the case in flood risk assessment.

Section 3.8 I agree with statements but I do not understand what do you do in the procedure

Pg. 3320 *“Non-structural measures include a wide range of options such as urban planning, flood forecasting, advanced warning systems, flood emergency plans, aids and insurance, etc.”*. This sentence is not in the correct place. In any case, you have already discussed the point in the introduction.

Pg. 3321 *“prioritization of risk reduction measures based on equity and efficiency principles”*. Such principles should be discussed.

Pg. 3321 *“Different indicators can be found (Bowles, 2004) to analyze and justify prioritization of risk reduction measures. Software tools are also available to analyze and compare risk calculations for several alternatives (SPANCOLD, 2012). These tools define the optimal sequence of risk reduction measures according to different efficiency and equity principles”*. This point is not explain in the follow (i.e. case study). Consider to delete.

#### Section 4

General comment: Sections describing dam failure modes are too detailed with respect to other sections; moreover they are not very clear to non experts. I suggest to make them easier to understand, maybe leaving out some details. Table 13 should be deleted.

Section 4.4.1. According to section 3.1 here you should define the scope of the analysis (e.g. screening, preliminary analysis or detailed study) on which the complexity of the risk model depend. But you do not discuss this.

Fig. 8 and Fig. 11 are not understandable. Please, consider to extend captions.

Pg. 3324 *“Potential consequences are estimated by combining inputs from the two types of flood events (pluvial flooding and river flooding from the natural flow regime of the river), avoiding double counting by considering the maximum number of potential fatalities from both sources of flood hazards for each flood event”*. What about economic damages? How they are combined?

Pg. 3325 *“Concerning the natural flow regime of the river (with a mean annual peak discharge of  $29.3\text{m}^3\text{s}^{-1}$ ), hydrographs from return periods that range from 2 to 10 000 yr are used”*. How?

Pg. 3326 *“Potential economic damages are obtained by estimating direct costs from flooded areas, land-use, reference costs and percentage of damages depending on flood depths.”*. This sentence has not sense for me.

Pg. 3326 *“for buildings with two or more stories without basement”*. Why did you choose this curve? Did you carry out a vulnerability analysis of buildings in the area under investigation?

Pg. 3326 *“Total costs for the Base Case in case of pluvial flooding and the natural flow regime of the river are shown in Table 8”*. Which is the scale of the analysis? Micro (i.e. Individual buildings) or meso (i.e. land use categories)? USACE curves must be implemented at the micro scale. Is this the case?

Pg. 3326 *“risk calculations are performed”*. What do you mean with risk calculation? Combining consequences and probability?

Pg. 3329-3330 *“results on total societal or economic risk do not present significant differences since these values are more influenced by the impact of pluvial flooding in the urban area”*. I do not see this evidence, please explain.

Pg. 3330 *“the relationship between warning times and flood hydraulic characteristics”*. Which is this relationship? Do you mean the lead time? Please explain.

Pg. 3332 line 4. Why do you consider the dam lifespan? Are you assuming that non structural measures will last for the entire lifespan?

Section 4.1.11 This discussion should be linked to case study results. This is not the present situation. It's too generic.

### Bibliography

I did not check the bibliography at this stage of the review. I reserve to do this in a second time.

### Tables

Tables 1 and 2 are redundant. Should be deleted.

Table 6: 0.369 should be replaced with 0.396. It is not clear what 0.604 and 0.369 refer to.

There are two tables 9. They are not explicative in any case.

Table 11: It is not clear how these values have been selected. What do they refer to?

Table 13 should be deleted.

### Figures

Figure 1: It is not clear. Why are there steps?

Figure 4: Which is the difference between “Hydrographs and peak flow discharges” and “Flood characteristics at the river course”?

Figure 5: It is not clear how model A1 and A2 are combined

Figure 6: It is not explicative of the procedure

Figure 14-15-16-17: Why are there steps? Please discuss