Nat. Hazards Earth Syst. Sci. Discuss., 2, C1528–C1544, 2014
www.nat-hazards-earth-syst-sci-discuss.net/2/C1528/2014/

Natural Hazards and Earth System Sciences
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Discussions

Interactive comment on "A GIS based urban flood risk analysis model for vulnerability assessment of critical structures during flood emergencies" *by* R. Albano et al.

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Received and published: 15 July 2014

Response to Reviewer Comments Journal: NHESS Article: A GIS based urban flood risk analysis model for vulnerability assessment of critical structures during flood emergencies (doi:10.5194/nhessd-2-2405-2014) Authors: R. Albano, A. Sole, J. Adamowski and L. Mancusi MS No.: nhess-2014-67 MS Type: Research Article First Contact: Eng Raffaele Albano, albano.raffaele@tiscali.it 15/07/2014

Dear Editor, Referees,

We would like to express our gratitude for having accepted our paper in NHESSD and to have provided very useful and constructive comments of our work. In the following sections, you will find our replies to all the comments of each referee.

In the attached PDF file you will find the improved version of the paper, based on the comments of the Referees.

In this response letter, we provide the page and/or line numbers where we made changes to address the comments of the reviewers.

Kind regards,

Raffaele Albano, Aurelia Sole, Jan Adamowski and Leonardo Mancusi.

Anonymous Referee #2

General Remarks:

a) The paper describes a method for vulnerability assessment but probability of flood events are not estimated thus the title should be modified (a flood risk analysis model must include probability and consequences).

Response: A new title is provided on the basis of the comments of this Referee and the Anonymous Referee n.1 (see specific remarks n.1 of Referee 1): A GIS Based Model to Estimate Flood Consequences and the Degree of Accessibility and Operability of Strategic Emergency Response Structures in Urban Areas

b) The abstract should be modified. "The proposed model is unique in that it provides a quantitative estimation of flood risk...". Flood probability is not considered, I would recommend using "estimation of flood vulnerability". "This information can be used...to prioritize..." No detailed description on how to prioritize risk reduction measures based on results from this method is provided in the paper.

Response: The abstract and the rest of the paper have been modified in order to standardize the terminology. In the conclusion the authors have proposed how to improve the model developed in this study, in order to analyze the risk of floods, and not

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only to estimate the consequences of one flood event (p.33 l.13-16). The model can support the maximization of the benefit of limited investments trough the prioritization of the decisions on flood mitigation strategies that should be planned. In this light, the model identifies the structures and infrastructures whose maintenance of performance, in terms of connectivity or operability, could be essential in order to facilitate assistance to victims and rescue activities, and could support decision -makers in order to highlight the areas that need priority interventions (e.g. p.4 l.31-33 p.32 l.3-10; p.33 l.5-9).

c) The terminology should be standardized. Check terminology on flood risk (see Floodsite project, Language of risk, 2005; or ISO 31000, 2009). The terms 'analysis', 'evaluation' and 'assessment' are frequently used in the paper but referring to 'estimation' (e.g. page 2411, l.12, "the assessment of loss of life", while section 2.1.1. is entitled "Loss of life estimation"; page 2414, "Road closure evaluation" vs. page 2432, "Road closure estimation"). In addition, the terms 'method' and 'model' are used indistinctly (e.g. page 2413, l.17, "the adopted method models"; page 2411, l.1, "this phase of the model"). Please note that a 'method' is not a 'model' and vice versa. I would recommend to clarify this aspect.

Response: This is an interesting observation regarding the paper. The authors have now carefully read the suggested papers, and this has provided a very useful opportunity to check the terminology and standardize it. The standardization of the terminology has been performed in all parts of the paper and, in this light, a new title for the paper has been provided. In addition, new titles have been given for the various steps of the model (p.5 fig.1). The new terminology has also allowed the authors to clarify the aim of the paper in accordance also with the major revision n.1 of anonymous Referee n.1. The authors think that the new terminology and, hence, new Keywords of the paper are more accessible in the scientific database (p.1 l.33).

d) Overall description of the method in Section 2 is found along with information and hypotheses for the case study analysis (see page 2411). More distinction between overall methodology and case study description should be made. Information on the case study should be included only in Section 3.

Response: This observation is in direct contrast with the major remark n.2 of the first anonymous referee. As mentioned earlier, we decided to follow the suggestion of reviewer 2. However, the authors have introduced in section 2 (methodology) more details about information on data and aspects of the methodology (e.g. depth-damage curves) that were implemented and used in the model for other case studies and, in the "case study section", the authors have described in detail the choices adopted for the specific case study presented in the paper. For example, the authors highlight that it is useful to implement the model with a micro-scale map of the urban system (p.11 l.6-7), and then in the case study section the authors describe what kind of city map was used for the specific case study (p.23 l.10) (the same for the occupancy type map and population data (p.23 l.1-4)). The authors have also now made a distinction between the methodology presented and the model application. The part related to the application of the model ("2. case study") incorporated the specific information and data used for the case study. In contrast, the methodology section reports some of the information and choices utilized to implement the model justifying the choices adopted.

e) I would recommend reconsidering the structure of Section 2 based on the phases established in Figure 1 (phase III is described in section 2.1 and phases IV and V in section 2.2).

Response: The authors have reconsidered the structure of section 2, introducing section "2.1 Data Acquisition and Harmonization" and "2.2 Definition of the flood scenario" (p.6; l.1 and l.9).

f) I would recommend including a simple example (case study or theoretical example) to estimate impedance, reliability and influence indexes for a system with several “origin-destination” pairs and paths. The case study does not provide enough information/results about this phase.

Response: The estimation of the index introduced in equations (1-4) is now better

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explained, and some simple examples are described and represented in fig. 5-6-7 (p.15-19). In the results section, the results of the influence index are described (p.29 l.10-16), together with additional comments on the results in the results section (p.28), and presented in Fig.13.

g) In general, several parts of the manuscript would benefit from re-drafting and editing (some paragraphs are difficult to understand; e.g. page 2412, l.15-18; page 2416).

Response: These sections and the rest of the paper have been re-drafted on the basis of the referees comments.

Specific comments:

1.The term “critical structure” has to be explained in the paper. How a structure is classified as “critical” or “non-critical”?

Response: The term has now been substituted with "Strategic"(for emergency management), as in the title.

2. “Within this context, a flood risk analysis model was developed in this study that is based on GIS, and integrated with a model that assesses the degree of accessibility and operability of strategic emergency response structures in an urban area. . .” Please clarify the outcomes of the study: method or model/method including the use of 2 models. . .

Response: The outcomes of the paper are the implementation of a model that is applicable in a real case study in Italy. The authors have also now made a distinction between the methodology presented and the model application. The part related to the application of the model ("2. case study") incorporated the specific information and data used for the case study. The methodology section reports some of the information and choices utilized to implement the model justifying the choices adopted.

3. Check reference: Jonkman and Kelman, 2005.

Response: We have used now only Jonkman at al., (2005) as suggested by the anonymous referee #3, (p.1 l.41).

4. [Page 2407, l.2-4] Check references

Response: The authors have reported a citation that is more suitable for this part of the paper, (p.2 l.4), as suggested by the Anonymous Referee n.3, see specific remarks n.2.

5. The term 'whole life' has to be explained.

Response: The authors have clarified the term introduced by Sayers at al. (2013) (see reference p.37 l.15-16) with an example taken from Sayers at al. (2013) (p.2 l.5-13).

6. The term 'residual damage' has to be explained.

Response: The term residual damages is no longer used. This part has been redrafted on the basis of the comments of anonymous referee n.1 (p.2 l.26-27).

7. "in an efficient way". How do you consider the degree of efficiency of the analysis?

Response: "in an efficient way" was deleted. This part has been redrafted on the basis of the comments of anonymous referee n.1 (p.3 l.4-9).

8. "The proposed model for flood risk assessment in urban areas provides a comprehensive and quantitative evaluation of direct damage to inform decision-making in terms of loss of life and structural and economic damage"... The model does not provide flood probability thus it cannot be defined as flood risk assessment. The term 'comprehensive' can be used in flood risk analysis when both risk components are estimated (probability and consequences).

Response: All the terminology has been standardized as mentioned in the general remarks (c). The authors have used the terms "consequence estimation". For this specific comment see p.4 l.5-

9. “The proposed model can aid in prioritizing the decisions. . .” This aspect is not later described in the paper. How decisions can be prioritized?

Response: The proposed model can aid in prioritizing decisions on flood mitigation strategies that should be planned. These could support the maximization of the benefit of limited investments, by choosing the highest priority one for emergency service based on the definition of a hierarchy among the various structures and infrastructures by identifying those structures and infrastructures whose loss of operability and accessibility could cause vulnerability in the entire system and problems with the performance of rescue activities and victim assistance (p.4 l.31-33; p.32 l.3-10; p.33 l.6-9).

10. Renumbering section 2 based on phases shown in Figure 1. (2.1. Phase I, 2.2. Phase II, 2.3. Phase III- GIS Direct impact assessment. . .)

Response: The authors have reconsidered the structure of section 2, introducing section "2.1 Data Acquisition and Harmonization" and "2.2 Definition of the flood scenario" (p.6; l.1 and l.9). So phase I corresponds to sect. 2.1 now, phase II to sect. 2.2, and so on.

11. The term ‘assessment’ includes analysis and evaluation.

Response: The term ’assessment’ has been substituted by estimation.

12. The term ‘flood severity’ is not introduced in section 2.

Response: Now the authors have introduced this on p.6 l.25-27.

13. References to the case study should be included in Section 3. Description of the method in Section 2 should be more general.

Response: This part has been deleted here and included in Section "3.1.2" (p.23 l. 30-31 and p.24 l.1-5).

14. Definition of Flood Wave Arrival Time not clear. The flood wave arrival time is independent of being during the day or at night. On the contrary, warning times in case

of flooding may differ. Please explain the two components of the vector unit flow rate and definition of the DV parameter.

Response: p.7 l.16-21: The outputs of the hydrodynamic model were processed to derive the information required for the analysis (e.g., Flood Wave Arrival Time, Peak Unit Flow Rate, etc..). Using GIS scripts, a Flood Wave Arrival Time (Twv), i.e. the time of occurrence of the flood wave, grid was obtained. In addition, the two components (x-coordinate and y-coordinate) of the vector unit flow rate were combined to obtain the maximum "Peak Unit Flow Rate" values (m2/s), (i.e., the flow discharge for each linear meter of cross-section).

p.8 l.25-30: The warning time, that is the function of the Twv, at night is defined as a time period 15 minutes lower than the warning time during the day, such as in Escuder-Bueno et al. (2011). If there is no warning time or data is not available, the available warning time is estimated from the difference between the time of occurrence of the first-notice-flow and the first-damage-flow, such as in Escuder-Bueno et al. (2011).

15. The DV parameter was proposed by Graham in 1999 (USACE).

Response: This can be seen on p.7 l.22. We have introduced "proposed by Graham in 1999".

16. The use of the fatality rates proposed in the SUFRI project is suggested in this paper for the case study (since it has been previously applied in Italy). This should be included in Section 3. Is it possible to use other fatality rates for life-loss estimation? If so, then this section should give general guidelines on how to estimate loss of life, providing the example of the fatality rates from Escuder-Bueno et al. as an example in Section 3.

Response: Of course, there are several methods to estimate loss of life and, hence, fatality rate, but we have described and justified the approached implemented in the presented model (p.8 l.9-30).

17. The fatality rates proposed in Escuder Bueno et al. (2012) are classified in 10 categories (not 7). Check reference.

Response: p.8 l.15-18:There are 10 fatality rates proposed by Escuder-Bueno et al. (2012), but in the model, seven categories have been implemented because the categories C8, C9, and C10 are useful only in the case of a dam-break event (Escuder Bueno et al., 2011).

18. “The methods were based. . .” I would suggest avoiding the use of past tense.

Response: This can now be seen on p.10 l.10.

19. Please clarify the term “content-structure value ratio”.

Response: This has now been done on p.10 l.26-28: "content-structure value ratio, i.e. the ratio between the unitary value of the content and the unitary value of the building structure".

20. Move content to Section 3.

Response: Table 3 is an essential example to understand the methodology utilized. The authors have now highlighted what kind of map is useful to implement the occupancy type (p.11 l.6-7) and, then, have introduced table 3, and in the case study section have described the source and type of zoning map (urban city map at a scale 1:5000 taken from SIT Puglia Database, 2001) utilized to estimate the occupancy type (p.23 l.10).

21. Please describe the different phases of a flood event as it is assumed in the paper (the terms “emergency phases” and “pre-event phase” are used in page 2413 and 2414, respectively; also “emergency response phase” in page 2417).

Response: In p.3 l.25-26, the authors have explained the meaning of the emergency phase (i.e. during and immediately after a flood). This is also reported in other parts of the paper (e.g. p.5 l.14).

22. I would suggest avoiding the use of first-person narrative.

Response: This has been changed (p.13 l.2).

23. Check the use of the term 'residual damage'. Residual damage (or residual risk) generally refers to existent damage or risk that cannot be reduced by structural and non-structural risk mitigation measures.

Response: This has now been changed in damages (p.13 l.8).

24. "Degree of inoperability of a path" and "reliability" are two related but opposite terms. Please clarify relationship between terms.

Response: The name of the indexes have been improved in order to improve the readability of the paper. The new name of the index cited by the Referee is "inverse (connectivity) reliability" (p.15 l.10) (see also p.5 Fig.1).

25. Equation 1 is presented before explaining "od" (origin-destination).

Response: This has been addressed (p.15 l.20-22).

26. The term "index" is used in lines 1 (referring to impedance index), 5, 6, 9, 11, and 17. Please review the description of all indexes.

Response: The term indexes are always preceded by the name (e.g. inverse reliability index, impedance index, and so on).

27. Please describe the role of the proposed Classification A, B and C in the method and its connection with the indexes described in section 2.2.2.

Response: The role of the influence index is to estimate the degree of influence among the elements of the system considering the degree of connectivity, accessibility, and the role of each in the system in the emergency phase (see p.20 l.11-14). In this light, the influence index is based on the weakness index, the population at risk in each census area in which the element (e.g. roads, buildings) is located. Indeed, the influence

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index takes into account the role of each element in the system in the emergency phase. In this light, the components such as buildings or communication networks were subdivided into categories A, B and C (see p.20 l.20-22).

28. Systemic vulnerability is defined as the maximum value among the structural damage and the influence index. Why is life-loss not considered as direct loss? Traditional direct loss analysis includes life- and economic-loss. Please clarify index units. “Since it highlights the maximum risk”. . .What does it mean? Please clarify whether it refers to maximum flood damage (risk would include flood probability).

Response: The life-loss is considered as direct loss. The loss of life is estimated by the model. The systemic vulnerability index, now "maximum impact index", takes into account the direct damage to buildings and infrastructures and the population affected. Indeed, Eq 5, the influence index (whose value is incorporated in the maximum impact index), as in Pascale et al. (2010), is modified by introducing a correction factor that takes into consideration the population affected by the event, calculated previously in Sect. 2.3.1. The roads and the buildings at risk located in the census area with higher numbers of population at risk have higher values of the influence index, for the same value of weakness index and the same functions in the systems in the case of an emergency (p.20 l.15-21). The systemic vulnerability index, which we now call the "maximum impact index", is the higher value between the direct and indirect consequences estimated respectively by step III and IV in fig. 1 p.5.

The choice of taking the higher value between the direct and indirect consequences is justified by the evidence that the summation of the indirect impact index, which represents the influence impact in the system (Sect. 2.4.2), and direct damage, described in Sect. 2.3.2, could cause an underestimation of the maximum impact value due to a flood event: the ratio between the potential maximum value of the summation of the direct and indirect impacts and the estimated impact value is lower than the ratio between the potential maximum value that could be estimated with this methodology, i.e. value 1, and the maximum value, estimated by this methodology, between the direct and indirect impact values, previously described (see p.21).

The index ranges between 0 (no impact), and 1, the highest impact within the system. (p.20 l.13-14)

29. Include Results in section 3 (3.1 Data; 3.2 Results).

Response: See now the title of the sections: p.22 l.29: "3.1 Data" and p.24 l.7; "3.2 Results".

30. I suggest using “flooded area” instead of “risk area”

Response: This has been addressed (p.26 l.10-11).

31. “the highest probability of loss of life” Do you mean highest fatality rate?

Response: The right term is "highest fatality rate": See p.26 l.13.

32. “We made the assumption that the first notice peak corresponded to the first damage flow. . .” Then, is the warning time equal to zero?

Response: Yes. The warning time, that is a function of the Twv, at night is defined as a time period 15 minutes lower than the warning time during the day, such as in Escuder-Bueno et al. (2011). If there is no warning time or data is not available, the available warning time is estimated from the difference between the time of occurrence of the first-notice-flow and the first-damage-flow, such as in Escuder-Bueno et al. (2011) (p.8 l.25-30).

33. “There is no public education. . . despite the low flood severity due to low values of the Peak Unit Flow Rate” This paragraph is difficult to understand. The existence of public education, risk communication, etc. is a characteristic of the urban area that may inform on the level of flood severity understanding of the population at risk and it is not related to flood severity values of the analyzed flood scenario.

Response: The authors have re-written this part (p.26 l.23-32).

34. "...1 fatality due to low population density". It would be interesting to analyze the scenario with seasonal variability (higher population at risk) with the aim of comparing results for both situations.

Response: The validation is based on an event that occurred in March, where there is no seasonal variability. However, In Italy the months, with seasonal variability, is, July-August, where there can sometimes be a lower probability of occurrence of a flood disaster event. Anyway, a majority of the people at risk are in the down-flow area, near the sea. Further, the area characterized by the highest fatality rate, estimated by the model, shown in the area colored in red in Fig. 10, is the first zone affected by water flow. The comparison between historical data of loss of life between 2000 (AVI project, 2000) with the estimated degree of loss of life (via the model), represented in Fig. 10 in categories from low to high, is justified by the fact that during the event of March 1 2011, there was no loss of life. Therefore, it has been more important to validate, with the historical data, in a spatial way the degree of potential loss of life in the system (p.26 l.12-32).

35. Quantitative results (or summary of results) regarding population at risk, fatality rates, impedance and influence index values for the case study are not included.

Response: The authors have now provided more evidence in the results section with quantitative validation (p.28 l.2-11), and spatial validation with more observation points (p.29 and figs.11-13-14) and historical data of past events (p.26 l.12-32).

36. "the innovative aspect ...is to provide a quantitative estimation of flood risk" Combination of flood probability and consequences is not considered in the manuscript. The case study has been analyzed for a unique flood scenario.

Response: The risk has now been substituted by consequences (p.32 l.18).

37. Write all references in alphabetical order.

Response: This comment has been addressed; see p.34-37.

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38. Categories C8, C9 and C10 are missing in Table 1.

Response: p.8 l.15-18: There are 10 fatality rates proposed by Escuder-Bueno et al. (2012), but in the model, seven categories have been implemented because the categories C8, C9 and C10 are useful only in the case of a dam-break event (Escuder Bueno et al., 2011).

39. Show results in MEuro.

Response: A typo error has been corrected in table 5. The value in the table is expressed in Euro.

40. How population at risk or life-loss is included in the definition of the influence index? Please clarify.

Response: Eq 5, the influence index, as in Pascale et al. (2010), has been modified by introducing a correction factor that takes into consideration the population affected by the event, calculated previously in Sect. 2.3.1. The roads and the buildings at risk located in the census area with higher numbers of population at risk have higher values of the influence index, for the same value of the weakness index and the same functions in the systems in the case of an emergency (p.20 l.15-19).

41. Include units (SI) of the DV parameter. Check references (LSM shown in the title and DHS in figure caption). DV values were proposed by Graham (1999).

Response: The authors have changed the figure into a table (p.8 tab.1) in order to convert the values in International System of Units, and have cited DHS, which used the image from LSM.

42. Divide Figure 3 into two figures (one for each graph).

Response: This comment has been addressed: the figures are now Fig.2 and Fig.3.

43.Please define acronyms (IRPI, AVI. . .)

Response: It is defined in the references. See p. 34 l.9-13.

44. Loss of life is represented using three qualitative levels (low, medium and high) but the method describes quantitative life-loss estimation (by using fatality rates).

Response: The comparison between historical data of loss of life between 2000 (AVI project, 2000) with the estimated, by the model, degree of loss of life, represented in Fig. 10 in categories from low to high, is justified by the fact that during the event of March 1 2011, there was no loss of life. Therefore, it could be important to validate, in a spatial manner, the degree of potential loss of life in the system (p.26 l.12-32).

45. Systemic vulnerability estimation (figure 9) or systemic vulnerability evaluation (figure 1). Check the use of 'evaluation'/'estimation' in the paper.

Response: We have used "maximum impact estimation", see p.32 l.2.

Other comments:

1. p.2407 l.9: Delete "It can be seen that"

Response: Addressed: See p.2 l.13

2. p.2407 l.12: with particular attention on emergency management

Response: Addressed: See p. 2 l.16

3. p.2407 l.20: in case of emergency

Response: Addressed: See p. 2 l.26

4. p.2410 l.1: Delete "In this manner"

Response: Addressed: See p.4 l.31

5. p.2410 l.1-5: In Sect. 2, the overall GIS framework is outlined. In Sect. 3, the validation and results on a real flood event are described. In Sect. 4, results are provided, and, overall discussion and conclusions are provided in Sect. 5.

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Response: In section 2, the overall GIS framework is outlined, in section 3 the application and results of the proposed model on a real flood event are described, and an overall discussion and conclusions are provided in section 4. (p.5 l.1-4)

6.p.2411 l.6: Replace incidents by events

Response: Addressed: See p.7 l.7

7.p.2412 l.5: multiplied. . .times

Response: Multiplied doesn't make sense (p.8 l.10)

8. p.2412 l.7: The fatality rates proposed in the SUFRI project (Escuder-Bueno et al., 2012) were adopted. . .

Response: Addressed: See p.8 l.10-11

9. p.2412 l.13: C1 to C10

Response: p.8 l.15-18: There are 10 fatality rates proposed by Escuder-Bueno et al. (2012), but in the model, seven categories have been implemented because the categories C8, C9 and C10 are useful only in the case of a dam-break event (Escuder Bueno et al., 2011).

10. p.2413 l.13: Replace demonstrate by show

Response: Addressed: See p.10 l.23

11. p.2413 l.22: Figure 3 shows the depth-damage curves used in this case study.

Response: Figure 2. Structural depth-damage curves implemented in the model (Source: Department of Water Resources Division of Flood Management 2008). (p.11 l.10-11) Figure 3. Content depth-damage curves implemented in the model (Source: Department of Water Resources Division of Flood Management 2008). (p.12 l.2-3)

12. p.2414 l.20: consider

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Response: Addressed: See p.14 l.4

13. p.2414 l.25: Replace utilized by use

Response: Addressed: See p.14 l.9

14. p.2414 l.26: Replace less by lower

Response: Addressed: See p.14 l.10

Please also note the supplement to this comment:
http://www.nat-hazards-earth-syst-sci-discuss.net/2/C1528/2014/nhessd-2-C1528-2014-supplement.pdf

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