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Interactive Comment

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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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: PhD 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 #1

Major remarks:

1. The scope of the paper is not quite clear to the reader. In the introduction, the authors bring up a range of flood risk analysis tools, including direct damage models and infrastructure disruption methods. The authors note that these 'traditional standard based approaches' (what does this mean?) fall short. The reasons that are proposed why they fall short include the fact that 'dependences and interdependences' are not included. The authors seem to focus on the fact that road networks and dependencies need to be analysed properly, and see it as their main aim to provide a new methodology that does include such things. However, if we read the rest of the paper, the authors present a very integrated approach to flood risk assessment (which is interesting). The result section mainly highlights the quantitative results for direct damage and fatalities, and the results for roads and emergency operations are not covered to great quantitative detail. In addition, the authors state that they focus on direct effects of floods. However, road closure and network effects are textbook examples of indirect effects. I suggest that the authors provide a more clear scope to their introduction, that should make clear what the current status of integrated risk assessments are (e.g., the HAZUS-MH and Multi-Coloured-Manual models include many of these steps – why are

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they not enough?) and what this paper is adding. They should stick to definitions and risk assessment literature as is outlined for example in Meyer et al., 2013 and Merz et al., 2010. For clarity, I would suggest to combine the last two paragraphs of the introduction, which now both state the main aim of the paper but in a different way. This would help the reader to grasp better what the paper is doing.

Response: On the basis of the definitions and risk assessment literature, as is outlined for example in Meyer et al. (2013) and Merz et al. (2010) (p.4 l.10-15), and on the basis of the comments provided by this referee, the authors have clarified on p.5 that the paper is focused on total (the authors have used the terms maximum, i.e. the higher value between the direct and indirect consequences estimated respectively in step III and IV in fig. 1 p.5., as justified in p.21 l.20-30 and p.22 1-3) impact estimation, i.e. the direct and indirect impact, in the emergency phase of a flood event. The authors have also clarified in the abstract that the majority of the current damage loss models do not properly analyze the road network connections and dependencies within the systems. As such, losses of the roads could cause important damage and problems to emergency services in case of flooding. On the basis of this, the authors have clarified that the paper is focused on the integration of a direct impact estimation model with an indirect impact estimation model, based on the premise that the impact of a flood event on individual elements of strategic infrastructure or single nodes in network systems may influence the system as a whole in the emergency phase of a flood. Hence, the authors have now mentioned in the introduction that the paper does not concern all the wide range of indirect impacts (p.4 l.10-12), but rather that it aims to investigate the relationships of spatial accessibility and functional/operability failure (i.e. the performance to guarantee victim assistance and rescue activities) in a complex urban system during an emergency phase. Finally, the authors have reported in the results section of the paper a more detailed description of the results of the estimation of the accessibility and operability model (p.29 l.10-26 and Fig.13-14). Finally, the authors have clarified the terms 'traditional standard based approaches' 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).

2. I suggest combining sections 2 and 3. For the reader it is very difficult to understand the methods and framework (section 2) without having any information on the case study. For example: can the depth-damage curves that are used (section 2) be applied to the Italian case-study (section 3)? What are the land-use and population data (section 3) that are used to make the fatality risk functions and direct damage estimates (section 2)?

Response: These observations are the opposite of the major remark of the second anonymous referee (in “d”). We decided to maintain the section about the methodologies ("2. Overall Framework"), separated by the section about the application of the model ("3. Case Study"), following the advice of referee #2 in order to respect the structure of a typical journal article composed of an introduction, methodology, application and results, and conclusions. However, we have introduced, in section 2 (methodology), more details regarding information on data and aspects of the methodology (e.g. depth-damage curves) that were applied in the specific case study, or could be implemented and used in the model for other case studies. 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.8), 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 authors have now clarified in the paper that the depth-damage curves implemented in the model are taken from USACE (Department of Water Resources Division of Flood Management, 2008), and which are also proposed in the ’SUFRI’ Methodology (Escuder Bueno et. al, 2011). They are more precautionary than the one proposed by Luino et al. (2003) for Italy (p.11 l.2-7). The authors have highlighted in the results that there is an underestimation of the model in the estimation of direct economic damage (but have justified why (p.28 l.2-11)). Therefore, the use of curves taken by Luino et al. (2003) could produce an additional underestimation of the direct economic damage that could be related only to the depth-damage curves utilized.

3. The quantitative estimates and validation of the results deserve more attention. The authors currently provide some maps, but no tables of total estimates. On page 2423 they state that 'The validations performed by comparisons with the case study illustrate the reliability of the model'. However, this is not backed by the data. Is this based on Figure 8 alone? More evidence should be provided here, and a clearer validation of the results should be attempted.

Response: The authors have 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.14-23).

Specific remarks:

1. The concept of 'vulnerability' as used in this paper should be described. The authors use it in a very different way than the damage models they are citing – usually, vulnerability is seen as the susceptibility of the exposed elements (e.g. depth-damage functions represent vulnerability). In this paper, it is seen more as a measure of total impact, I feel, which is OK, but should be made clear.

Response: The authors have provided a new title, also on the basis of the comments of Anonymous Referee 2, that highlights that the final result of the model is a measure of maximum impact (p.21 l.19-30), i.e. the higher value between the direct and indirect consequences estimated respectively in step III and IV in fig. 1 p.5.

2. Abstract: add a sentence that makes clear how current approaches fall short, and how this study contributes.

Response: The majority of the currently available approaches do not properly analyze road network connections and dependencies within systems, and as such a loss of roads could cause significant damages and problems to emergency services in cases of flooding. The proposed model is unique in that it provides a maximum impact estimation of flood consequences on the basis of the operability of the strategic emergency structures in an urban area, their accessibility, and connection within the urban system of a city (i.e., connection between aid centres and buildings at risk) in the emergency phase (p.1 l.18-20).

3. p. 2406, l. 21: twice 'significant'

Response: The authors have deleted this sentence with the citation and have focused explicitly on floods citing Jha et al. 2012 (p.1 l.36-38).

4. p. 2406, l. 20-22: focus explicitely on floods (not 'disasters' in general) and provide some global literature, e.g. Jha et al. 2012 (see below).

Response: The authors have deleted this sentence with the relevant citation and have focused explicitly on floods citing Jha et al. 2012 (p.1 l.36-38).

5. P. 2407, l. 6: what is the 'traditional standard approach'? Please explain..

Response: This term was introduced by Sayers at al. (2013) (p. 2 l.8-13).

6. P. 2407, l. 13-14: it's HAZUS, not HAZUM. Jongman et al. 2010 does not exist (it's Jongman et al. 2012) and is in any case not the correct reference for the Damage scanner model. Check for the correct base reference. And why capitalize all damage model names?

Response: The new reference for the Damage scanner model is Klijn et al., (2007), (as suggested also by the third anonymous referee, see specific remarks n.3), and now not all damage model names have been capitalized as before. This is addressed in p.2 l.19-23.

7. P. 2407, l. 17-23: this section is very vague. What exactly do you mean? If you mean that most damage models (based on depth-damage) don't account for indirect effects, that is correct. So that means that you will take indirect effects into account, right? But in several places you emphasize that you provide a framework for direct risk assessment, how does that match?

Response: As discussed in comment 1 of the major revision, the paper is focused on maximum impact estimation in the emergency phase and, hence, takes into account direct and indirect (for emergency service) impacts due to a flood event. This section, as well as the entire introduction, was revised on the basis of the referee's comments (p.2 l.17-30).

8. P. 2408, l.2-3. Damage models DO evaluate the degree of physical damage to roads and infrastructure.

Response: The authors have clarified that the cited papers on accessibility of road networks have not estimated the degree of physical damage of road networks and buildings due to natural events (p.3 l.1-6); instead, the cited flood damage model evaluated the degree of physical damage to roads and infrastructure.

9. P. 2408, l26 onwards: here you start describing what the added value of your paper is. However this is not clear. Is it that you base your model on '[. . .] an accessibility and reliability analysis of the road network'? At this point, you should make very clear what you do; to what extent you look at direct and indirect effects; what the results will be; and why it is better than what is already out there (which you described earlier)

Response: The authors have clarified that the majority of the current damage loss models do not properly analyze the road network connections and dependencies within the systems. The latter approach does not take into account the dynamic nature of the urban system with its interconnections and relationships among elements, and hence the performance of strategic structures and infrastructure in case of emergency. Hence, indirect damages in the field of emergency management are not considered in these currently available consequence estimation models. For example, the inaccessibility of inundated roads during emergency management activities could cause indirect damage to the operability of strategic structures such as hospitals or fire stations. In light of this, the proposed model for consequence estimation in urban areas provides a quantitative evaluation of direct damage, to inform decision-making in terms of loss of

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life and structural and economic damages, that is useful in order to support an innovative methodology for investigating the relationships of spatial accessibility and functional/operability failure (i.e. the performance to guarantee victim assistance and rescue activities) in a complex urban system during the emergency phase. Concurrently with the occurrence of physical and functional damage to urban areas, the operability of the strategic emergency structures, their accessibility and connection within the city, or in general the urban area, is an important priority in emergency management. The proposed model does not aim to estimate all the wide range of indirect impacts that may have effects on time scales of months and years (i.e. macro-economic effects or long-term barriers to regional development (Merz et al., 2010)). Instead, the model focuses on how the impact of a flood hazard on individual elements of strategic infrastructure or single nodes in network systems may influence the system as a whole (Meyer et al., 2013) in the emergency phase of a flood. The present framework, integrated in a GIS (Geographic Information System) framework, aims to estimate the direct and indirect damage of a flood event in order to understand the strengths and fragilities of a particular urban area. The scope is to define a hierarchy between the various structures (e.g., hospitals, fire stations, town halls, schools, industries, etc..) and infrastructure (e.g., main roads, secondary and local roads, bridges, etc..) through the identification of those structures/infrastructure whose operation and efficiency are critical in emergency management. The proposed model can aid in prioritizing the decisions on flood mitigation strategies that should be planned. This could support the maximization of the benefit of limited investments by selecting the highest priority ones for emergency service (see p. 4 of the attached paper).

10. P. 2409, l. 5: what do you mean with ‘dependencies and interdependencies’?

Response: The authors have now used the terms dependencies and not interdependencies. In relation to this section of the paper, in p.4 l.2-5, the authors have discussed the meaning but it is also presented in the rest of the paper in a detailed way.

11. P.2411: I would suggest making the hydrological modelling a separate section.

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Interactive Comment

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Right now it is unclear to the reader what kind of data you used (which discharge, how you computed the '1/30' etc. Also the population and loss of life should have more details. Following my earlier remark (see 'major remarks') I think the methods and data sections should be combined, so you can clearly state which census data you used, which population data, etc.

Response: The authors have added a subsection to Sect. "3.1 Data", called "3.1.2 Hydrological and Hydraulic characterization of the simulated scenario", where we address the issues raised by the reviewer in comment 11 (p.23 l.23-31 and p.24 l.1-5).

12. P.2412, l.3: which population data? Source?

Response: In the methodology, the authors have now suggested how to manage the population data (p.8 l.4-7). In the case study section, the authors have now highlighted that the population data is aggregated at the census area level. The source of population data is ISTAT, National Institute of Statistics, 2001, (p.23 l.3).

13. P.2412, l.11 onwards: which socioeconomic indicators? How is flow velocity incorporated? How does this matter in your case study?

Response: The DV parameter incorporates the flow velocity (p.7 Tab. 1). DV is essential to estimate the flood severity that is one of the parameters in Tab.2 (p.9 Tab.2), in which the socioeconomic indicator is explained and utilized for the categorization C1-C7 (p.9 Tab.2). In the case study, the authors described the situation in Ginosa, i.e. no public education on flood risk, risk communication, and lack of coordination between emergency agencies and authorities, in order to describe the parameters, (i.e. flood severity, warning time and so on), used to perform the estimation of the loss of life in the model (p.26 l.20-32).

14. Section 2.1.1: which land-use data is used? What source? What's the case study?

Response: In the case study, the available land use map is taken from the SIT Puglia database (2011), and is at a 1:5000m scale (p.24 l.4-5).

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15. Section 2.2.1: so, roads are only closed to emergency vehicles because other vehicles block the road? This implies that emergency vehicles can actually operate at water depths of 1 metre, i.e. depths below the height of a car. Is this true? And valid?

Response: The curves implemented in the model are used when incoming flow depths are lower than the vehicle height, shown in the lower part of the graph in Fig. 4. When the incoming flow depth is greater than the vehicle height, the roads are considered to be always inaccessible. This choice is justified by the possible presence of emergency vehicles that can work in worse conditions than cars (e.g. firefighter trucks, ambulances, small boats, and so on). As such, the methodology aims, on the one hand, to give more importance to closure for vehicle transport that is a frequent phenomena in urban areas as highlighted in Albano et al. (2014), Gruntfest (2000) and Gruntfest and Ripps (2000) (see reference p.34-37) and, on the other hand, aims to be precautionary and independent of the type of vehicles available in a specific scenario in the analysis (p.14 l.11-18).

16. I think multiple elements are missing in the equations 1 to 4.

Response: These equations have been checked together with the name of the indexes to improve the readability of the paper (p.15-19).

17. Section 2.2.2 is overrepresented in the methodology section (which may not be bad) but is not much reflected in the results section. All output indicators that are defined in equations 1 to 4 do not come back as results in the end. Why is that? If they are not relevant, can't you leave them out?

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

18. P. 2421, l. 14-27: so flow velocity is not incorporated. What does this this mean for

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the fatality estimation? Isn't it a factor there? Also for this section: how is inundation calculated? Is there an assumption on breach locations or levees?

Response: Flow velocity is not incorporated only for direct damage to buildings, but is incorporated in the loss of life estimation. (p.7 l.16-27) The scenario utilized for the application of the model is a simulated event that has a return time period closer to the real event of March 1 2011, which occurred in Ginosa, Italy. The maximum discharge of the chosen event, i.e. March 1st 2011, can be assimilated to an event with 30 years return time, estimated using the VAPI method, which is recommended by local authorities (e.g. the Basin Authority of Puglia Region) in Southern Italy (Claps et al., 2005). (p.23 l.24-29) Regarding how inundation was calculated, the hydraulic simulations of flood scenarios were performed using a 2D commercial flood model. For this case study, the Mike Flood model was used since it was deemed to be the most appropriate model for this area as highlighted in Sole et al. (2012), who calibrated the model in the area using the Digital Elevation Model of the study area, which includes cross sections of the river embankment extrapolated from laser scanner data. The geometry of hydraulic mitigation structures, like levees, is taken by the field survey effectuated by the Basin Authority of Puglia, and the assumption utilized in this study is the overtopping of the levees. The friction coefficient of the flooded area is evaluated by the land use map at a scale of 1:5000, which is available on the online database of the Puglia Region (SIT Puglia database, 2011). (p.23 sect. 3.1.2).

19. Section 4: some basic results are missing: how many people are modelled and observed to be affected? What is the mortality ratio? What is the modelled damage? It would be great to have a general results table.

Response: The authors have 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.14-23).

There have no reports about observed number of affected people, so this information was not included. However, the total loss of life estimated by the model corresponds to less than 1 fatality due to the low population density of the area as well as the low percentage of people at risk. In the event of March 1st 2011, there were no reported fatalities. The validation of the model in terms of loss of life, due to the low numbers of estimated and observed numbers of loss of life, was integrated with a validation, in spatial terms, on historical data (AVI project, 200): historical data on loss of life for floods has highlighted that a single flood event in Ginosa prior to the year 2000 resulted in casualties. The largest number of victims was found to be in the area highlighted as most prone to fatalities according to our application shown in Fig. 10 (p.27 l.1-6).

After the March 1st event, the total amount of money requested on the basis of a self-estimate by the citizens of Ginosa to the Italian Government for the damages to their proprieties due to this flood event was around 6,501,741 € (source: "Ordinanza ministeriale del 5 luglio 2012 n. 4024"), in comparison to the 4,736,125 € estimated by the model as direct economic damages. This discrepancy could be justified by the evidence that the model does not take into consideration the damage caused by pluvial contribution to the flood event (the model simulates only the river flood event). Indeed, the number of buildings affected by the flood estimated in the model is about 63% of the number of buildings affected by the real event (about 1000 buildings). It should be noted that it is not possible to complete a validation on the other elements (i.e. roads, railways, agricultural areas) involved in the flood event due to a lack of available data from the real event. However, it is possible to make a spatial comparison with photos recorded at 10 observation points throughout the city (Figures 11-13-14), as was done in this study (p.28 l.2-15).

20. P. 2423, l.15-20: what validation results? Figure 8? How does this support the outcomes?

Response: The authors have 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.14-23).

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Please also note the supplement to this comment:
http://www.nat-hazards-earth-syst-sci-discuss.net/2/C1515/2014/nhessd-2-C1515-2014-supplement.pdf

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