Response to reviewers' comments:

Dear referee,

Thank you very much for your valuable comments. I have tried to response to all of them base on scientific and logical reasons and hope it will meet your expectation.

Best regards,

Authors

Referee 1:

1) The output is a qualitative ranking of the susceptibility of the area to ground motion amplification phenomena. The Authors should stress that is a kind of level-1 or grade-1 microzonation study according to international standards and guidelines. More detailed studies are needed in high-risk areas and should be based on numerical modelling of site effects (i.e, physically based procedures which cannot be replaced by influencing
criteria methods).
*R: Yes, the research is conducted based on first level seismic microzonation procedure.

" The purpose of this paper is to develop a model for evaluation of local seismic amplification based on direct characteristics of relevant criteria. Firstly, selected criteria were weighted using AHP method by interviewing 10 experts, next criteria were converted into fuzzy sets, then fuzzy membership functions (MFs) were produced, finally WLC method and fuzzy inference rules were applied to produce a level - 1 susceptibility map of local seismic amplification for a study area."

2) My biggest doubts concern the criteria selected for the procedure. "consolidation and strength": consolidation should be replaced by stiffness (in terms of shear wave velocity or shear modulus) while the strength (i.e. soil resistance) is not pertinent; the resistance should influence the slope stability or the resistance to liquefaction not the amplification phenomena. The "particle size distribution" does not affect the amplification phenomena: the stiffness of soil is the controlling factor not the particle size: a coarse-size if loose soil can be softer than a consistent over consolidated fine grained clay ! The "depth of groundwater" is not pertinent for amplification effects, it only controls the possible occurrence of soil liquefaction in loose sandy soils.

*R: This study tries to propose a method in dealing with uncertainties. As you mentioned, there not a clear procedure of considering all influencing criteria to produce susceptibility level of local seismic amplification. Here what we are trying to say is how we can consider all criteria in a logical procedure. We know it is not a perfect way, but still give ideas to people in this field of study to work on each influencing criteria by its own and improve the model.

The criteria were selected based on an extensive literature review. In order to be able to come up with the idea of influencing criteria on susceptibility level of local seismic amplification, we have to consider the effect of geology, geomorphology, topography and bedrock on this phenomena. We have to make separation among all influencing criteria to be able to solve our problem based on fuzzy theory. According to this theory we can handle uncertainties. As, you said regarding liquefaction and groundwater level. We are not 100 percent sure that the groundwater level will not have any effect on amplification coefficient of an area. Then, we have to come up with the idea that it may have an influence, event it is minor effect. Therefore, fuzziness can solve this problem as seen in the paper.

Yes, I understand consolidation/stiffness is the controlling factor, but still there is an effect of particle size on the local seismic amplification, which is considered through fuzziness of each criterion. Threofre, we have main controlling factors/criteria (main criteria with high weights) and minor criteria (with low weights) based on AHP method. Furthermore, sub-criteria for each criterion that are weighted based on Fuzzy Logic method, as seen in Figure. 1 spatial soft soil has fuzzy membership of 1, while hard rock has fuzzy membership (FM) of 0. It means spatial soil (unconsolidated soil and sediment) has more effect on amplification factor and areas with this type of soil will be highly amplified.
Figure 2 shows the effect of grain size on amplification factor by itself (alone). Fine grain (clay) sediment has FM of 1, while coarse grain sediment (boldder) has FM of 0.3.

Let's see collateral effects on amplification factor:
- Unconsolidated fine grain sediment (unconsolidated clay) = 1 * 1 = 1
- Unconsolidated boldder = 1 * 0.3 = 0.3
  As seen above if we are dealing with unconsolidated clay the amplification factor will be 1, while in unconsolidated bolder the amplification factor will be 0.3.

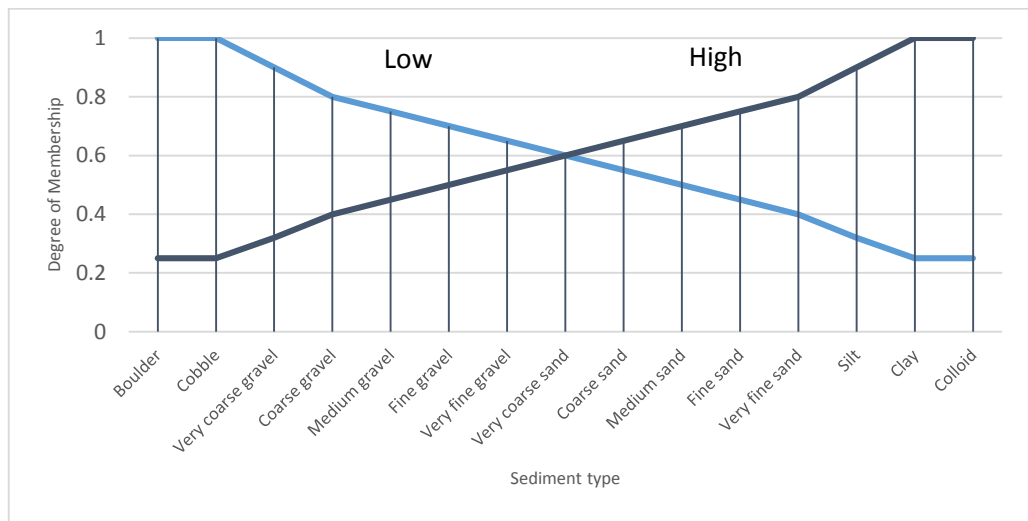Figure 1. Fuzzification of stiffness and strength of soil and sediment

Figure 2. Fuzzification of grain size criterion

In terms of groundwater level, as seen in Figure 3, it is the main factor in effecting liquefaction susceptibility, but it can still effect on local seismic amplification factor.
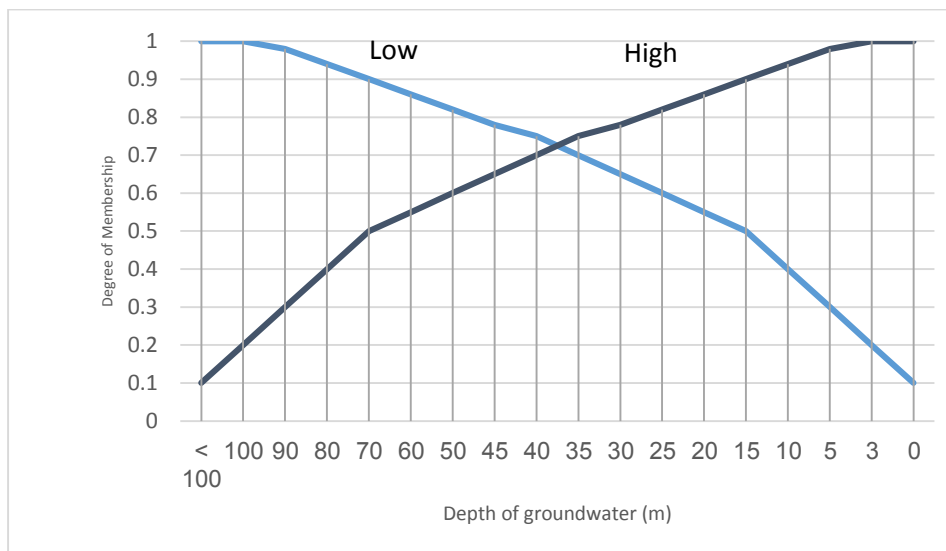

Figure 3. Fuzzification of depth of groundwater

3) In table 1 is not clear the difference between morphology of bedrock and topography of bedrock (even if, as I understand, they are considered as minor criteria). I strongly suggest to remove these factors or better define them.

*R: Morphology of bedrock defines the shape of bedrock. It can be like bowl, cylindrical, semi-spherical, conical, or even invers conical and semi-spherical as a result of revers faults.

Topography of bedrock is very similar to the topographic irregularities, it all says about roughness or smoothness areas and elevation changes.

4) Specific comments 1) It is not clear how the output of model is compared with experimental resonance frequencies. In terms of amplitude of HVSR peak with levels of shaking map ? Please describe better this validation phase.

*R: Predominant frequency ranges from 1.36 to 10.53 Hz, and amplification factor ranges between 1.33 and 4.77. These findings indicate that soil type in Bam city is mainly stiff, and amplification factor is relatively large. There is a high frequency zone from the north and northwest to the southeast of Bam where amplification factor trends to large values. However, in west and southwest of the city, fundamental frequency is low and amplification factor exhibits smaller values compared to other parts of the city.

Predominant frequency (Figure 4a and b) has been divided to 5 classes including: very low, low, moderate, high and very high. These 5 classes overlay the output of the model which has 5 classes that renege from very low to very high susceptibility levels. By comparing these two maps an error matrix will be created and overall accuracy of the output of the model will be calculated.
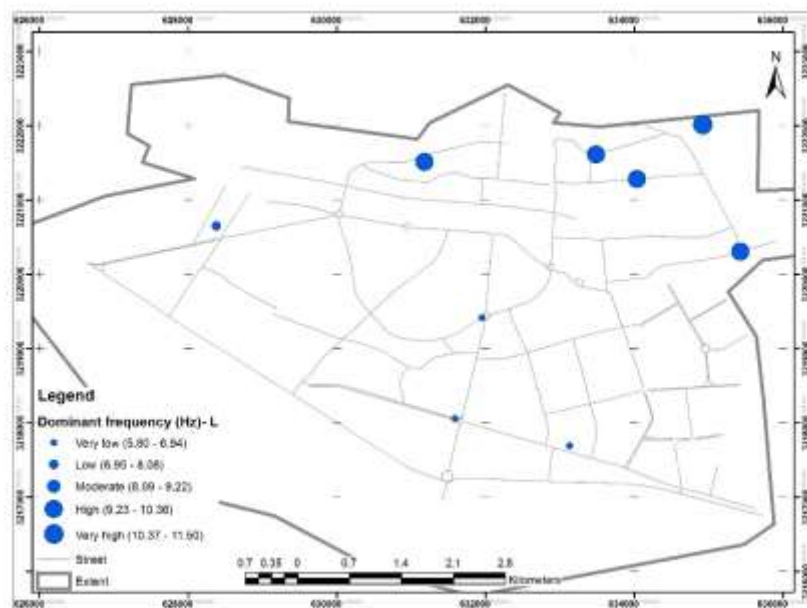
a)
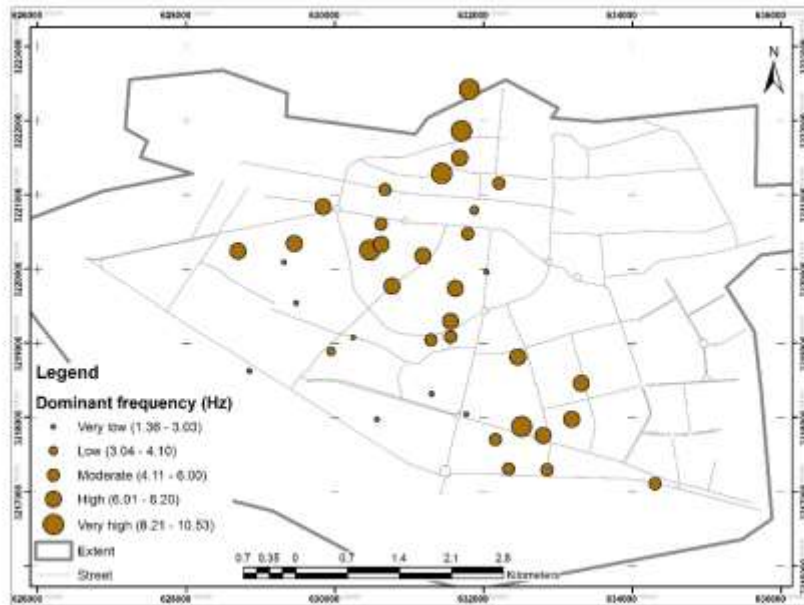
b)

Figure 4. Control data: Dominant frequency by Lashkaripour (a) and by Motamed et al (Motamed et al., 2007) (b) using Microtremor field measurement.

5) Pag. 3: at the state of art, I don't believe that SSHA methods can be used for microzonation: source and path parameters are still quite significant to define. PSHA assessments at regional scale (at outcropping rock) and site response modelling at local (urban scale) are the most adopted procedure almost worldwide.
*R: I have revised this section based on your comments as shown below:
Probabilistic Seismic Hazard Analysis (PSHA) (Cornell, 1968) has been used to assess ground-motion hazards from earthquakes (Atkinson et al., 2015;Petersen et al., 2016). This method depend on "the length of the causative faults and depth of the earthquake", which are generally unknown thus causing uncertainty in assessing ground-motion of earthquakes (Wang et al., 2017). In deterministic seismic hazard analysis (DSHA) (Campbell, 2003;Atkinson and Boore, 2006) the lack of relevant ground-motion attenuation relationship for specific geographic areas can cause uncertainty in applying DSHA for assessing ground motions of an earthquake (Wang et al., 2017). Scenario-based seismic hazard analysis (SSHA) (Panza et al., 2012) applies ground-motion simulations of a scenario earthquake using specified source, path and site parameters, however the parameters needs to be defined significantly. By conducting many simulations, earthquake variability of different sources, ground-motion propagation characteristics, and local site effects can be considered. Therefore, uncertainties using SSHA are quantified explicitly (Wang et al., 2017), although this method is still under development. Therefore, PSHA assessments at regional scale and site response modelling at local scale are the most adopted procedure almost worldwide.

6) Typing 3) Pag. 11: "microtremor" instead of "microtremore
*R: I have revised the word.

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Referee 2:

First of all, the paper need a strong revision of the English by an English mother tongue. Second critical point, authors should avoid to repeat the same concepts too many times just by using slightly different sentences.

R: I have revised the text and removed repetition from different sections. The paper was reviewed by a mother tongue editor to make it as clear as possible.

Third, very important point. Authors talk about seismic microzonation of ground shaking amplification. This concept is not clear to me. Do they mean "seismic site response"? This is a crucial point that needs to be clarified. In addition, in the discussion section, authors suddenly introduce the concept of "susceptibility amplification" (line 469). Susceptibility is different from seismic site response! Authors need to clear state these concepts in the entire paper.

R: The aim of this study was to develop a new method based on thematic layers, AHP and Fuzzy logic theory for producing a qualitative output which can rank the susceptibility of the area to ground motion amplification phenomena.

I have revised the concept based on Aucelli et al. (2018) paper and applied the same terminology as they proposed " modelling of local seismic amplification susceptibility ". This concept have been used throughout of my paper.

Aucelli et al. (2018) proposed a method for producing susceptibility index to local seismic amplification in Isernia Province, Italy based on geological and geomorphological properties of studied areas. This research mostly followed an evidence based approach to estimate susceptibility level of local seismic amplification in the area, although they have not considered the use of multi-criteria decision-making methods (MCDM) in weighting and combining the influencing criteria which is the aim of conducting this research.

Fourth critical point, the method section is 12 pages long whereas the discussion and conclusion section is just 3 pages! This discrepancy is incredible! Methods section include too many repeats of the same concepts (e.g., authors said several time that they interviewed 10 experts!).

R:This is right, but I had to go through a series of different steps in this section to make it as clear as possible. Each step had its own result which I could bring them to the results and discussion section of the paper, but it will make a huge separation between data preparation and fuzzification of each criterion. I had to keep this two parts together to make a good image in readers mind.

R: I have tried to get rid of repetition through the paper.

In additiond, discussion and conclusion section needs to be more detailed.

R: I have read several papers and tried to discuss the findings of this research via a critical approach.

In this study, we have focused on the site effect and local geology properties of a site that have a massive influence on local seismic amplification susceptibility in the study area. To deal with related uncertainties in preparing seismic microzonation, the most important criteria were selected, weighted and then fuzzified. Criteria with high uncertainty degree such as distance of active fault to the site, depth and magnitude of the probable earthquake were not considered because there was no possibility to exactly find out where and how an earthquake will be triggered. Therefore, only the criteria with known location (x and y) and known characteristics were taken into consideration.

Furthermore, to deal with uncertainties Fuzzy Logic is a suitable approach as we can define membership function of the effect of each criterion in the amplification of ground shaking by interviewing 10 experts and obtaining expert's knowledge. This can result in realistic output regarding the behavior of each criterion in ground shaking calculation.

The newly developed model uses AHP and Fuzzy Logic (Zadeh, 1965) to deal with complexities and uncertainties in data analyses in weighting the criteria and fuzzifying the sub-criteria of each criterion. Although, in studies for evaluating seismic microzonation in Bangalore (India) (Sitharam and Anbazhagan, 2008), Dehli (Mohanty et al., 2007), Haldia (India) (Mohanty et al., 2007), Erbaa (Turkey) (Akin et al., 2013) and Al-Madinah (Moustafa et al., 2016) only AHP method was applied to weight the criteria, and none of these studies considered weighting of sub criteria for each criterion even using other methods.

Few researchers have considered direct properties of influencing factors in assessing ground shaking amplification. Even, in evaluating seismic response developed models such as SiSeRHMap v1.0 (Grelle et al., 2016) and GIS Cubic Model (Grelle et al., 2014), the researchers have applied only lithodynamic, stratigraphic and topographic effects as influencing factors. Furthermore, Aucelli et al. (2018) suggested a method for producing susceptibility index to local seismic amplification in Isernia Province, Italy, and they have considered geological and geomorphological properties of studied areas. Although, they have not considered the use of multi-criteria decision-making methods (MCDM) in weighting and combining the influencing criteria which is the aim of current study. The current research considers direct properties of each criteria and tries to manage uncertainties in criteria and sub-criteria of each criterion via weighting and fuzzification process using experts' knowledge and the use of direct properties of criteria. These processes can be extended in more details, which are subject to more investigation in the future.

Fifth point, most of the figures are very hard to read. Quality of figures should be increased. Several other comments are listed in the attached file.

R: Quality and size of all figures were increased as seen below.