Reply to Anonymous Referee #1

The authors thank for the feedback. We appreciate the comments and valuable discussions on this manuscript. The comments and replies are provided as follows.

1. The common procedures for DSHA and GM-selection were applied in the case studies for six Taiwan sites (cities). The review comments are listed as followings: 1. Based on the DSHA results, all the controlling seismic sources of the six study sites are the area sources. However, the criteria for assigning the locations (hypocenter or the rupture plane) of the earthquake scenarios of the area sources were not provided. For example, the controlling magnitudes of the study sites b and c (Kaohsiung city and Taichung city) are Mw6.5 and Mw7.3, respectively, but, the RSs are similar to each other as shown in Figures 4. It means that a shorter source-to-site distance was assigned to the site b than that to the site c. What are the criteria for assigning the locations (hypocenter or the rupture plane) of the earthquake scenarios (the worst-case?)? It should be noted that the area source models (Cheng et al., 2007) were developed for PSHA, and might not be adequate for the DSHA. In this paper, the upper-bound magnitude of area-source zone C, Mw7.1, was used for the DSHA scenario, however, the magnitude of Mw7.1 came from a historical event occurred in the subduction zone with a focus depth more than 70km. This paper may not assign a more likely earthquake scenario for the DSHA, even for the worst-case. Similar questions can be found on the other study sites.

Reply: There was indeed a mistake about the DSHA calculation of Kaohsiung city, which has a controlling source Zone G with a maximum considered earthquake of M6.5. Therefore, the response spectra based on DSHA computation scheme for Kaohsiung city should be smaller than that of Taichung city, instead of the similar trend as pointed by the reviewer. The updated computation of DSHA-based response spectrum and recommended ground-motion waveforms for Kaohsiung city will be provided in the revised manuscript.

Also thanks for pointing out that the maximum magnitude M_w 7.1 of area source C came from a historical subduction event. Nonetheless, the seismic zonation used in this study (from Zone A to Zone T) is categorized as shallow crustal regional source following previous researchers' work (i.e., Tsai 1986; Cheng et al. 2007). The maximum earthquake magnitude reflects a combined effect of regional seismology regarding historical earthquakes, focal mechanism, and source zonation, etc. Thus, the maximum magnitude of these seismogenic zones (e.g. M7.1 for source C) is adopted as the worst-case scenario during DSHA calculations. The worst-case scenario was used for identifying the earthquake scenario considered in DSHA analysis; for each area source considered, the closest source-to-site distance is assigned accordingly, as listed in the updated Table 3 below. More discussions on the worst-case scenario for each study city will also be provided in the revised manuscript.

Table 3 (updated). Summary of the Site's Coordinates, along with Respective Controlling Seismic Sources for Each Site in DSHA Computations

City	Latitude (^{o} N)	Longitude (^{o} E)	Controlling source	Maximum magnitude	Closest source-to-site distance (km)
Taipei	25.05	121.50	Zone C	7.1	2
Kaohsiung	22.63	120.32	Zone G	6.5	2
Taichung	24.15	120.68	Zone E	7.3	2
Chiayi	23.47	120.44	Zone F	7.3	2
Hualien	23.98	121.56	Zone O	8.3	2
Pingtung	22.02	120.75	Zone L	7.3	2

2. The DSHA spectra are similar to each other for most of the study sites; however, the earthquake records from the GM-selection are quite different (I was surprised by these results). For example, the RSs of the Taichung and Chiayi cities are the same. But, the GM-selection results are different. More discussions on this or providing of other detail conditions of the GM-selection would be helpful.

Reply: Thanks for this valuable comment. In the procedure described in this study, ground-motion time histories are selected according to a quantitative measure, the mean squared error (MSE), which evaluates how well a time history conforms to the target spectrum. The DGML search engine used in this study searches the NGA database for ground-motion waveforms that satisfy the general criteria (i.e. $5.5<M_w<8$, $0<R_{rup}<30$ km) and then ranks theses records in an order of increasing MSE. It means that the ground-motion waveform that matches the target RS best has the lowest MSE and will be ranked No. 1. To be more specific, the MSE is defined using the following equation (Wang *et al.* 2015):

$$MSE = \frac{\sum_i w(T_i)\left\{\ln\left(Sa^{target}(T_i)\right) - \ln\left(f \times Sa^{record}(T_i)\right)\right\}^2}{\sum_i w(T_i)} \quad (1)$$

where T_i denotes considered spectral periods, $w(T_i)$ denotes a weight function that allows for assigning weights to different period ranges so that the periods of more interest can be emphasized in the ground-motion selection process, f represents a scale factor to linearly scale the whole ground-motion time history. More detailed condition on how ground motions are selected will be added in the revised manuscript. It should be also noted that the MSE does not vary too much in some cases. For example, as highlighted in the following Figure 1, the MSE ranges from 0.023-0.035, indicating that the selected scaled ground motions are almost equally good and compatible with the target response spectrum. Therefore, in this study, we intentionally select some other ground-motion waveforms if some of them have been recommended in the other study cities. As a result, different GM selection results are recommended for the Taichung and Chiayi cities although they have the similar target response spectra. We expect, by doing so, more flexibility and options could be provided for time-history analyses in engineering practice. It should be also mentioned that although different ground motions are selected for various sites, they are statically consistent and compatible with the corresponding DSHA spectrum.

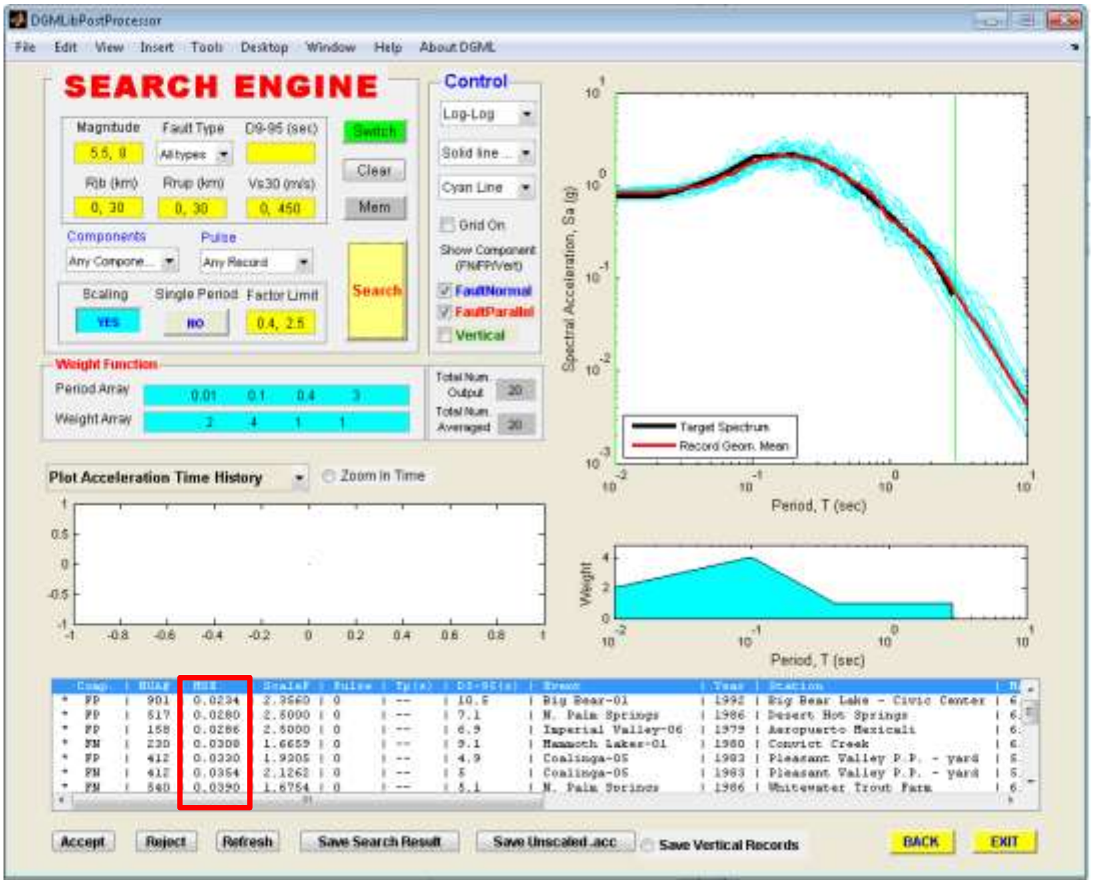

Figure 1. The screenshot of the database's interface. The red box highlights the column that reports the computed MSEs of selected ground-motion records.

3. Furthermore, it seems that the RSs (as shown in Figures 4) of the study sites were generated from the "attenuations for the hanging-wall and rock sites (Lin et al. 2011)", not the ones shown in Table 2 (for hanging-wall and soil sites). I suppose that this minor mistake is not important, but a correction of Table 2 will be better and appreciated. And, do you think the specific hanging-wall attenuations are good for the area sources? It's questionable for the cases with very short distance.

Reply: Thanks for pointing out the typo and meaningful discussion. The attenuation adopted in this study is indeed for the hanging-wall and rock sites, and thus Table 2 is updated as follows. For the second concern, we agree that the worst-case scenarios considered in this manuscript may not be the hanging wall case. However, since the Lin et al. (2011) model is the only available regional-specific response spectral attenuation model for shallow crustal earthquakes to the authors' best knowledge, this hanging-wall attenuation model is then adopted in the current study with reasonably conservative results provided. Besides, to avoid possible saturation at short distance in the attenuation model, each seismogenic area source was defined with assumed depth as 2 km.

Table 2 (updated). Summary of the Coefficients of the Local Ground Motion Models used in This Study (Lin et al. 2011)

Periods (s)	c_1	c_2	c_3	c_4	c_5	$\sigma_{\ln Y}$
PGA	-3.279	1.035	-1.651	0.152	0.623	0.651
0.01	-3.253	1.018	-1.629	0.159	0.612	0.647
0.06	-1.738	0.908	-1.769	0.327	0.502	0.702
0.09	-1.237	0.841	-1.750	0.478	0.402	0.748
0.1	-1.103	0.841	-1.765	0.455	0.417	0.750
0.2	-2.767	0.980	-1.522	0.097	0.627	0.697
0.3	-4.440	1.186	-1.438	0.027	0.823	0.685
0.4	-5.630	1.335	-1.414	0.014	0.932	0.683
0.5	-6.746	1.456	-1.365	0.006	1.057	0.678
0.6	-7.637	1.557	-1.348	0.0033	1.147	0.666
0.75	-8.641	1.653	-1.313	0.0015	1.257	0.652
1	-9.978	1.800	-1.286	0.0008	1.377	0.671
2	-12.611	2.058	-1.261	0.0005	1.497	0.706
3	-13.303	2.036	-1.234	0.0013	1.302	0.702

References:

Cheng, C. T., Chiou, S. J., Lee, C. T., and Tsai, Y. B.: Study on probabilistic seismic hazard maps of Taiwan after Chi-Chi earthquake, J. GeoEngineering, 2, 19-28, 2007.

Lin, P. S., Lee, C. T., Cheng, C. T., and Sung, C. H.: Response spectral attenuation relations for shallow crustal earthquakes in Taiwan, Eng. Geol., 121, 150-164, 2011.

Tsai, Y. B.: Seismotectonics of Taiwan, Tectonophysics, 125, 17-37, 1986.

Wang, G., Youngs, R., Power, M., and Li, Z.: Design ground motion library: an interactive tool for selecting earthquake ground motions, Earthq. Spectra, 31, 617-635, 2015.

Reply to Anonymous Referee #2

The manuscript is presenting a procedure for selecting the acceleration time histories from the New Generation Attenuation database for six cities in Taiwan needed for either earthquake resistance design or assessing the seismic performance of existing structures.

1- In page 3 the second step for DSHA is to define the Mmax and closest distance to each fault, how the author did assign the distance between source and sites of interest? I did not see any location for the maximum magnitude earthquakes assigned to each fault line or area.

Reply: The authors thank for the comments. In this study, the seismic zonation for DSHA (from Zone A to Zone T) is categorized as shallow crustal regional source following several previous work carried out by local researchers (i.e., Tsai 1986; Cheng et al. 2007). The maximum earthquake magnitude represent a combined effect of regional seismology regarding historical earthquakes, focal mechanism, and source zonation, etc. Thus, Mmax and closest distance of these seismogenic zones (e.g. M7.1 for source C) are adopted as the worst-case scenario throughout DSHA calculations. For each area source considered, the closest source-to-site distance is added in Table 3 in the revised manuscript, as follows:

Table 3 (revised). Summary of the Site's Coordinates, along with Respective Controlling Seismic Sources for Each Site in DSHA Computations

City	Latitude (^{o} N)	Longitude (^{o} E)	Controlling source	Maximum magnitude	Closest source-to-site distance (km)
Taipei	25.05	121.50	Zone C	7.1	2
Kaohsiung	22.63	120.32	Zone G	6.5	2
Taichung	24.15	120.68	Zone E	7.3	2
Chiayi	23.47	120.44	Zone F	7.3	2
Hualien	23.98	121.56	Zone O	8.3	2
Pingtung	22.02	120.75	Zone L	7.3	2

2- There is no information about the fault style or fault type for each fault line or area which could be important in selection criteria.

Reply: Comments appreciated. We added fault type for each line source in Table 1 in the revised manuscript. The area sources are shallow crustal regional sources following previous researchers' work (i.e., Tsai 1986; Cheng *et al.* 2007).

3- Lines 66-67, simple method does not mean accurate estimate and with new updates of DSHA and PSHA it is easy to resolve the transparency issue.

Reply: Comments appreciated. We fully agree that new updates and generations of DSHA and PSHA allow for transparency for both methods. Therefore, we rewrite Lines 66-67 as follows: "Compared to the complicated probabilistic approach, DSHA is an analysis accounting for a worst-case scenario in terms of earthquake size and location. Specifically, DSHA utilizes the maximum magnitude and shortest source-to-site distance to evaluate the ground motion intensities under such a worse-case scenario. The basic steps are listed as follows … "

4- Why did the author not use PSHA or Neo-DSHA (Magrin et al. 2016 and references therein) in the estimation of the target response spectra, since they are incorporating sets of earthquakes scenarios and the resulted RSs will cover a wide range of possible scenarios than only on worst-case scenario used by this study? The long period part of the RSs might be dominated by far field sources which can be easily tackled by incorporating sets of scenarios. Keep in mind for PSHA weights in a logic tree were commonly determined by a large group of experts instead of "the author's experience and judgment".

Reply: Thanks for the suggestions. Actually there are quite a few PSHA studies for Taiwan, including several ones the authors previously conducted (i.e. Wang, J.P. Huang, D., et al. 2013; Cheng *et al.* 2007). In this study, we intended to perform a deterministic study which allows for full consideration of the worst-case scenario for several study sites in Taiwan. We also thank the reviewer for pointing out the concern about long period part of the response spectra, which may be indeed dominated by a far field seismic source, i.e. a subduction source around Taiwan. However, in the current ground-motion selection practice, ground motions selected from the most comprehensive Next Generation Attenuation (NGA) database managed by the Pacific Earthquake Engineering Center (PEER) are all recorded from historic shallow crustal earthquakes, which have substantially different characteristics with those recorded from a subduction earthquake. To the authors' best knowledge, development of the subduction earthquake database by PEER is still ongoing and the database is yet released. In this regard, we focus on the short to moderate period of response spectra in the current study to avoid unnecessary confusion induced. `

5- Lin et al.(2011) attenuation model is not the only available local model for Taiwan, so why the authors employed only one model rather than carrying out a sensitivity analysis in order to better assess the epistemic uncertainty?.

Reply: Comments appreciated. We know that there are indeed some other local GMPEs such as Lin and Lee 2008. However, considering the above mentioned one is particularly for subduction earthquakes, we do not incorporate it in the ground-motion selection process since ground motions in the NGA database are all from shallow crustal earthquakes. Also, the worst-case scenario is used throughout the current for identifying the earthquake scenario in DSHA analysis. Thus, we do not induce the epistemic uncertainty in this concern.

6- Lin et al (2011) have developed different attenuation relations based on source characteristics and site effects, what is the basis for the selection of the attenuation relation being used i.e. the hanging-wall and soil sites relation, for estimating the RSs for the six cities, do all the sites are located on the hanging wall? "Chi-Chi earthquake records are used in developing the hanging-wall/footwall attenuation relation" see Lin et al (2011). Please explain this in the proper place in the manuscript.

Reply: Thanks for the meaningful discussion. The attenuation adopted in this study is indeed for the hanging-wall and rock sites (ref. Table 2 in the revised manuscript). We agree that some of the study sites may not be located on the hanging wall. However, the hanging-wall attenuation is adopted in the current study for the consideration of worst-case scenario for DSHA and reasonably conservative results.

6- The authors used Lin et al. (2011) attenuation relationship in order to predict the response spectra for periods ranging from 0.01s - 5s, but in table 2 and the response spectra figures, the author present periods only till 3 seconds.

Reply: Comments appreciated. In this study, we focus on periods ranging from 0.01 s to 3 s for seismic design of low to median rise buildings, with an emphasis on buildings lower than 30 stories. We do not really fit the target response spectrum over a broad range (e.g. from 0.01 s – 5 s) and expect by doing so, the fitting error may be significantly increased. It is also worth mentioning that in contemporary practice of ground-motion selection, sets of time histories are also commonly selected based on a target conditional mean spectra, which provides realistic spectral shapes for scenario earthquakes. Researchers identified that fitting the entire uniform hazard spectrum (UHS) over a wide range may be overly broad and thus overly conservative for a single earthquake, because the UHS represent a combination of multiple scenario earthquakes.

7- How did the authors decide the scaling factor range? Please explain in the manuscript.

Reply: Ground motion scaling is actually a topic subjected to intense debate over the past decades, since researchers recognized that improper scaling of a record can lead to bias estimates of structural responses (Luco and Bazzurro 2007). However, it was also reported that if the record is scaled multiple well-established target parameters (e.g. Arias intensity, PGV), ground motions can be scaled by a reasonable factor and still can result in unbiased estimates of responses for structural/geotechnical systems. Therefore, in this study, we follow the general practice of the developer of the Design Ground Motion Library (DGML), with the range of the scaling factor specified from 0.4 to 2.5 (Wang et al. 2015).

More discussion on this point is added in the revised manuscript in Lines 153-160: "….but has been subjected to intense debate over the past decades. Previous researchers pointed out that improper scaling of a record can lead to bias estimates of structural responses (Luco and Bazzurro 2007). For example, if an excessive range of scale factors is applied, the selected ground motion suite might result in drastically biased distribution of the other ground-motion characteristics, such as duration, Arias intensity, that cannot be represented by the target response spectrum. Therefore, we follow the general practice of the Design Ground Motion Library (DGML) and assign a relative narrow range of scale factors (0.4-2.5) throughout the selection procedure in this study (Wang et al. 2015)."

8- The authors described the duration of the ground motion and fault style as casual parameters whereas they are very important for the selection of proper time histories.

Reply: The authors fully agree that ground-motion duration and fault style are quite important in the selection process, so described in the original manuscript "Other causal parameters, such as the category of fault types or the range of duration parameters, are not particularly specified". The authors used "causal" that means indicating a cause, instead of "casual" that means trivial/unconcerned parameters.

9- In Figure 4 the response spectra for the first 5 cities are almost the same, do the authors expect big differences in the selected time histories if yes, why?. Is it ok to use one RS for the 5 cities?

Reply: Thanks for the comments. The principle of deterministic seismic hazard assessment (DSHA) is to incorporate the worst-case earthquake scenario, that is, the maximum considered earthquake (MCE) occurred at the closest source-to-site distance. This so-called worst-case scenario reflects a combined effect of regional seismology regarding historical earthquakes, focal mechanism, and source zonation, etc. Thus, the maximum magnitude of these seismogenic zones (e.g. M7.1 for source C) is adopted as the worst-case scenario in the calculation. As can be seen from Table 3 in the revised manuscript, several studies sites are governed by similarly large MCE, which can result in similar spectra shape for different study sites.

10- Lines 224-225 "First, the adopted local GMPE was developed with 42 earthquakes, 85% of which are not associated with the Chi-Chi earthquake, its foreshocks and aftershocks (Lin et al., 2011)" this is not correct because in that study 44 local earthquakes and 8 earthquakes from outside Taiwan were used and about 81% of which are not associated with Chi-Chi event. I do not know if the authors recognised that about 52% of the records used to develop the attenuation relations of Lin et al. (2011) are coming from Chi-Chi 1999 earthquake and its aftershocks.

Reply: Thanks for the valuable comment. The statement about the usage of local ground-motion record in the initial submission was indeed a mistake. We removed such an argument and rewrite it in the revised manuscript in Lines 244-248:" It somewhat comes to as a surprise that the motions of the local earthquake were "out-performed" by non-local motions in matching the response spectra with local ground motion models. This might be due to two reasons. First, apart from the Chi-Chi earthquake, most events used for developing the local GMPE are not included in the NGA database. The second reason is that the employed searching process does not specify more weights or preferences to local earthquakes…."

11- In the table4 there are two Chi-Chi earthquakes (i.e. 1989 and 1999), in the text, the authors used only Chi-Chi earthquake without any additional information about the year or magnitude, it is better to be more specific.

Reply: Comment appreciated. We actually specify year, magnitude and fault rupture mechanism of each event in Table 4 in the original submission.

12- Line 221 "Why Chi-Chi earthquake's motions are not selected?" this title does not consist with what is mentioned in Table 4, where Chi-Chi, 1999 earthquake has been selected for Taipei (with basin effect) and Pingtung cities.

Reply: Comment appreciated. We modified the subtitle 4.4 in the revised manuscript to "Why local earthquake's motions are not selected for all cases?"

13- Lines 229 and 230 “The second reason is that the employed searching process does not specify more weights or preferences to local earthquakes” actually the selection of local earthquake records will be better since they intrinsically contain the correct path effects which can affect the experienced ground motion at the site of interest.

Reply: The authors agree that local ground motions may contain intrinsic correct path effects at the site of interest. However, the principle of current ground-motion selection practice is searching for time history record sets in the database on the basis of the similarity of a record’s response spectral shape to a design response spectrum over a user-defined period range. Ground-motion time histories are ranked according to a quantitative measure, the mean squared error (MSE), which evaluates how well a time history conforms to the target spectrum. In such a case, local earthquake records are not always selected and recommended for the study sites because they might not perfectly conform to the target spectra.

14- Lines 233-235 are unclear, please re-write.

Reply: Comments appreciated. We rewrite the statement in the revised manuscript in Lines 248-253:” As discussed previously, the search criterion are only associated with the spectral shape, as well as seismological parameters such as magnitude, distance, site condition, etc. The search engine searches the database and ranks the records based on a quantitative measure: the mean squared error. With this in mind, as long as the size of the database is sufficient, it is not surprising that a non-local ground motion can be found better matching the target spectra.”

References

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