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Research Article

ENGINEERING-SEISMOLOGICAL ASPECTS OF EARTHQUAKE SCENARIO DEVELOPMENT ON THE EXAMPLE OF TASHKENT, UZBEKISTAN

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ABSTRACT
For the purposes of disaster preparedness and optimization of mitigation measures, it is advisable to use more than one scenario describing possible impacts from different credible earthquakes. Along with preparation of a set of probable earthquake damage scenarios also maps of seismic microzoning of urban territories should be used presenting maximum expected seismic input for every point of the territory under study. Besides, it is advisable to take advantage of probabilistic approach to make it possible seismic risk assessment.

Keywords: *Seismic Risk, Seismic Hazard, Earthquake Scenario, Seismic Intensity, Potential Earthquake Focus, Engineering-Geological Conditions, Seismic Fluctuations*

INTRODUCTION
Analysis of longterm seismic hazard for Tashkent based on the present day seismological knowledge shows that the maximum of ground shaking expected on the territory of the city from future earthquakes is estimated at the level of intensity VIII. This level of seismic hazard implies initial seismic input without consideration of local soil conditions, which are to be taken into account at the stage of seismic microzoning. The first map of seismic microzoning of Tashkent was developed in 1964-1965. The map divided the city into zones of intensity VII, VIII and a small area of intensity more than VIII. The next version of the map, revised after the earthquake of 1966 and put into practice in 1971, divided the territory into two zones of intensity VIII and IX about the equal size. According to the map of seismic microzoning of Tashkent being now in force, refined in early eighties on the base of complex of engineering-seismological and geotechnical investigations and authorized by the State Committee on Civil Engineering in 1986, the territory of the city, depending on local soil conditions, is divided into two zones of intensity VIII and IX (Figure 1). All the maps of seismic microzoning of the city mentioned above were developed in the conventional deterministic manner implying that initial seismic input for the every point of the territory of the city is the same and equal to intensity VIII, and corrections increasing the intensity level up to IX were made due to influence of site effects. Thus, the values of intensity VIII and IX presented on the map of seismic microzoning show design seismic input, corresponding to maximum expected level of seismic hazard in Tashkent, to be considered by earthquake engineers for the buildings under design, construction or restoration on the territory of the city (Tyagunov *et al.*, 1999)**.**

Study Area
Having considered all these earthquakes and compared their possible effect on the territory of the city, for the scenario purposes a potential earthquake was selected with magnitude 6.1 located underneath the-city. The selected potential earthquake relates to Tashkent flexural-ruptured zone coinciding with the territory of the city. This zone belongs to Karzhantau fault, which is responsible for more than 20% of strong earthquakes in Tashkent region and represents real seismic threat for the city.

MATERIALS AND METHODS
Research Method
For scenario purposes, an earthquake should be selected capable to produce on the territory of the city seismic effect close to upper estimates of the long-term seismic hazard. Therefore, those source zones were considered which could generate earthquakes producing on the territory of the city ground shaking corresponding to intensity VII-IX (MSK). In addition, probability of earthquake occurrence was taken as the second aspect of analysis. Thus, selection of variants of potential earthquakes for scenario purposes was conducted using two main criteria: first, possible destructive force on the territory of the city close to

the upper estimations, and, second, greatest probability of such an event.

At the first stage of investigations all the zones were considered capable to cause on the territory of the city ground shaking corresponding to intensity VI-VII. The selection of hazardous zones was carried out with formalized methodology described below (Plotnikova *et al.*, 1999).

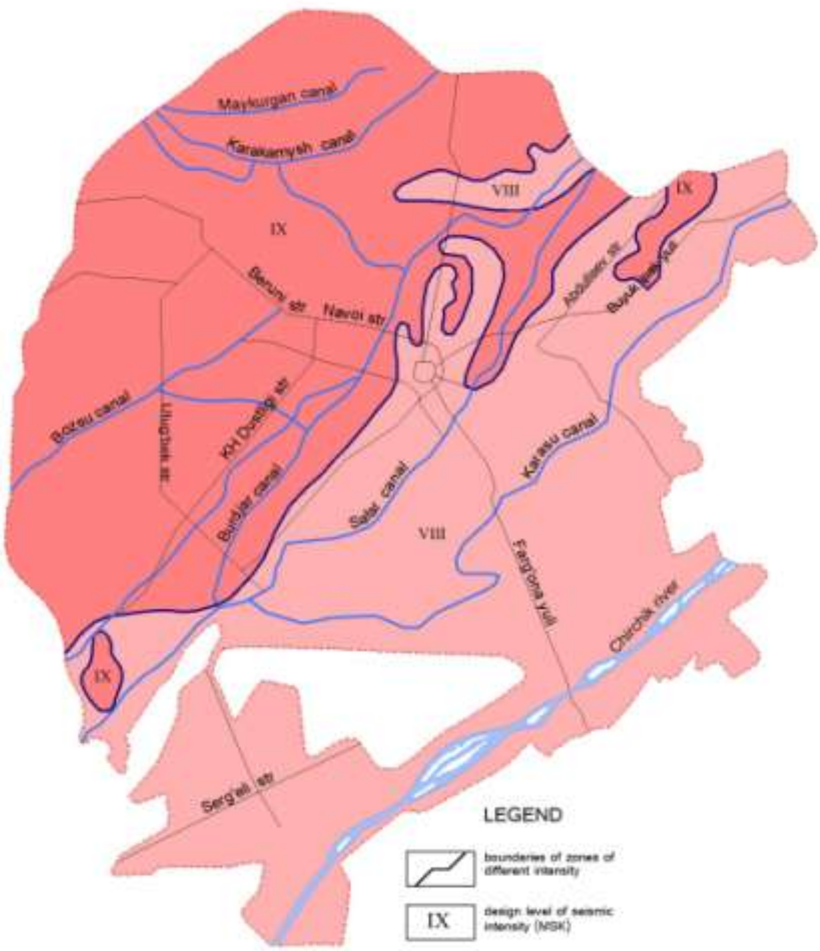

Figure 1: Current map of seismic microzoning of the city of Tashkent

Using model of Artikov-Ibragimov (Artikov *et al.*, 2012), relating ground shaking intensity level with earthquake magnitude and hypocentral distance, and taking into account peculiarities of the region and macroseismic data obtained from analysis of consequences of past earthquakes, we calculated for the specified intensity level the corresponding values of limiting epicentral distances R in dependence on earthquake magnitude M, which are presented in the table below (Table 1).

Table 1: Calculated values of limiting epicentral distances relating intensities and magnitudes

R	**M=6.0**	**M=6.5**	**M=7.0**	**M=7.5**
Rm(I=VI-VII)	60	113	135	250
Rm(I=VII)	42	77	91	165
Rm(I=VIII)	15	34	40	72

Then on the map of M_{max} of the territory of Uzbekistan we inscribe circles of calculated radiuses R=R„, centered at Tashkent. Correspondingly, as zones of potential hazardous earthquake sources those areas were considered, being captured by the circle of radius R_{m0} and having magnitude no less than M_0.

Using such a methodology seven hazardous source zones were selected (Figure 2), capable to generate earthquakes producing on the territory of Tashkent ground shaking of intensity VI-VII.

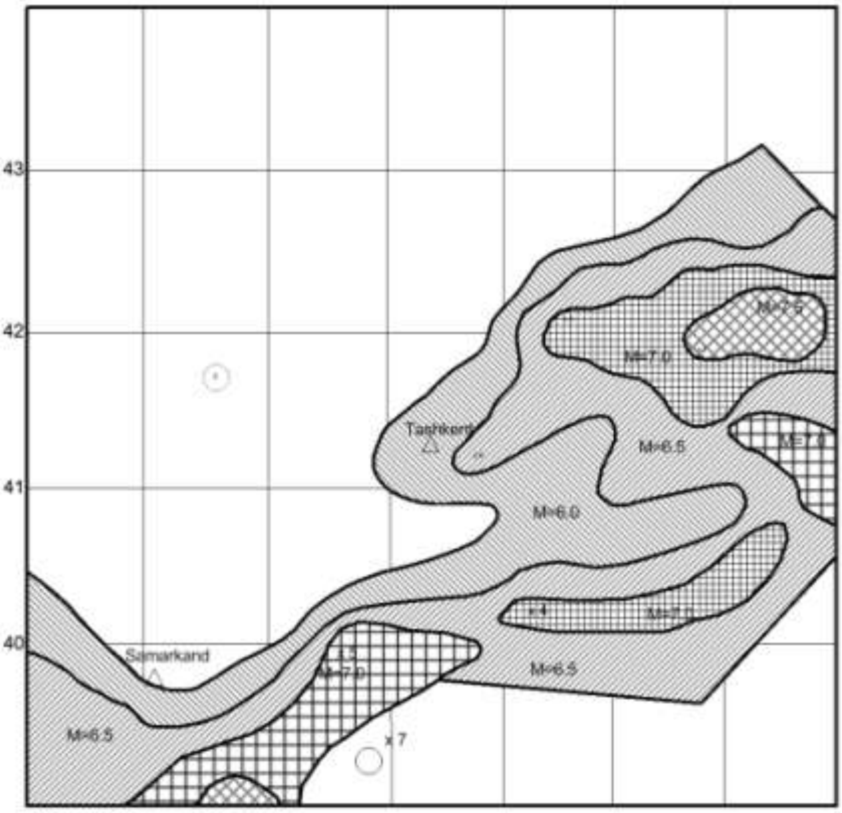

Figure 2: Map of M_{max} and potential earthquake sources
LEGEND: x7 - Potential earthquake sources

At the second stage of the procedure used for selection of scenario earthquake for each of the seven considered zones probabilities of occurrence of earthquakes of specified magnitude for the period of 50 and 100 years were calculated. In the table below (Table 2) the calculated values of probability of ground shaking corresponding to different intensity level expected on the territory of Tashkent from each of the seven considered source zones for the period of 50 and 100 years are presented (Artikov *et al.*, 2016)..
For each of the considered zones potential hazardous sources of earthquakes were selected. Then for the seven selected earthquakes theoretical isoseisms were constructed and possible seismic effects on the territory of Tashkent were evaluated taking into account damping of seismic energy with the distance as well as influence of ground conditions. Parameters of those considered earthquakes and their possible effect on the territory of the city are presented in the table below (Table 3).

Table 2: Probabilities of ground shaking in Tashkent from considered hazardous zones

Intensity	**Probability the period of 50 and 100 years,%**	**Zones**						
		1	2	3	4	5	6	7
VI-VII	P(50) P(100)	7 13	0 1	1 2	4 7	2 4	25 42	43 68
VII	P(50) P(100)	0 0	0 0	0 0	0 0	0 0	12 23	24 42
VIII	P(50) P(100)	0 0	0 0	0 0	0 0	0 0	3 5	4 7

Table 3: Parameters of potential earthquakes and their effect in Tashkent

Zones	Coordinates of the epicenters	Magnitude	Depth, km	Distance from Tashkent, km	Intensity (MSK) in Tashkent
1	41.90N; 71.70E	7.5	25	210	VI-VII
2	41.70N; 67.50E	7.5	30	160	VI-VII
3	42.05N; 70.55E	7.0	15	130	VI-VII
4	40.25N; 70.15E	7.0	15	140	VI-VII
5	40.00N; 68.65E	7.0	20	150	VI-VII
6	41.25N; 69.75E	6.5	15	35	VI-VII
7	41.27N; 69.23E	6.1	10	0	VIII-IX

So, at further stages of the study by all the blocks this event was considered as the scenario earthquake and it served as a base for analysis of seismic influence on the city to diagnose if the city is prepared for such an event and to learn what should be done to mitigate possible seismic disaster.

RESULTS AND DISCUSSION

Results of Application of Estimation Method

Taking into consideration attenuation of seismic energy with the distance and influence of local ground conditions the distribution of seismic effects resulting from the scenario earthquake within the boundaries of the city was estimated. Change in site intensity due to influence of local soil conditions was determined from consideration of such factors as:

- Type of soils composing upper part of the ground cross-section;
- Thickness of the stratum;
- Seismic properties of soils and their seismic response;
- Level of underground water;
- Possibility of manifestation of seismogeological effects.

According to these evaluations, a map of seismic effects' distribution from the scenario earthquake was compiled (Figure 3). On the map zones with expected intensity VII, VIII and IX (MSK) were identified as well as areas with probable manifestation of seismogeological effects falling within the zone of intensity IX. Analysis of the map shows the following distribution of seismic effect from the scenario earthquake: approximately, 20 % - intensity VII, 40 % - VIII, 30 % - IX, and about 10 % - zones with probable manifestation of seismogeological effects, including 8% - ground failure in the nature of liquefaction and 2 %- slope phenomena (landslides, rockfalls). Additionally, for the purposes of dynamic analysis of buildings and lifeline facilities located in different zones of the scenario macroseismic field, artificial accelerograms were modeled corresponding to different level of seismic intensity - VII, VIII and IX. Thus, seismic input presenting influence of the scenario earthquake on buildings, structures and infrastructures was given in the form of both MSK intensity values and accelerograms.

Using these estimations of possible seismic influence in Combination with data on inventory of buildings (classified into vulnerability classes) and lifelines, damages to buildings and infrastructure were estimated and then a comprehensive scenario was prepared, revealing vulnerable points of the city. Thus, at the second phase of the case study the scenario prepared would be considered as a base for development of the risk management plan.

At the phase of development of disaster mitigation plan it is important to keep in mind that in the context of the methodology used in the framework of the case study any scenario depends heavily on the model of seismic event selected as a scenario earthquake.

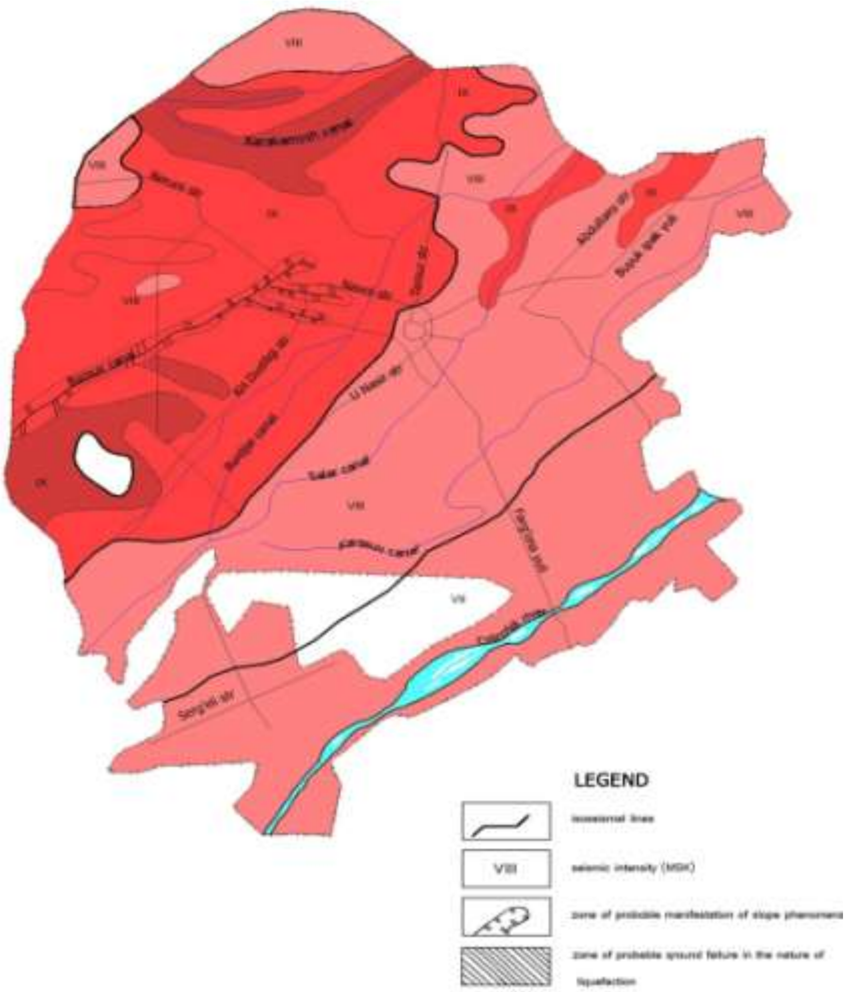

Figure 3: Ground shaking intensities and seismic effect distribution in Tashkent resulting from the scenario earthquake

As it was shown above the hypothetical scenario earthquake used for assessment of possible impacts on the city of Tashkent and damage scenario preparation was selected considering two criteria: first, possible destructive force on the territory of the city, close to the upper estimations of probable seismic effect expected in Tashkent, and, second, greatest probability of such a destructive event. However, broadly speaking, the selected scenario earthquake is not an event corresponding to greatest probability of occurrence. It should be considered only as one particular earthquake in Tashkent. And other seismic events of different magnitude, location, return period, not considered in the case study would produce different seismic influence, different consequences and different scenario. For example, as a variant of credible scenario earthquake could be taken any of strong events of the long seismic history of the region, in particular Tashkent earthquake of 1966.

In our case, using probabilistic approach only at the stage of scenario earthquake selection, at the subsequent stages we used the earthquake selected for the purposes of scenario preparation in the deterministic manner. So, in the framework of the case study seismic risk in the strict sense of the word was not estimated. However, to improve methodology of revealing of vulnerable points of urban areas, and, accordingly, to increase efficiency of an action plan, it is worthwhile, along with preparation of deterministic earthquake scenarios, to take advantage of probabilistic methodology of assessment of seismic risk as it stands. For these purposes a probabilistic map of seismic hazard for the territory of the city should be developed, taking into consideration the totality of hazardous potential sources, distribution of probable earthquakes of different magnitude in space-time domain, as well as using the same approach to evaluation of attenuation of seismic energy with the distance and influence of local soil conditions. On the base of such a map, it would be possible to prepare a map of seismic risk distribution, combining estimations of seismic hazard and vulnerability of the exposure at risk. In addition, in our opinion, development of such probabilistic maps of seismic microzoning of urban territories should be considered as an important part of seismic risk management plan, making it possible to indicate priority directions for the development and implementation of disaster mitigation measures.

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