Global J. Environ. Sci. Manage., 3(4): 447-456, Autumn 2017
DOI: 10.22034/gjesm.2017.03.04.010

CASE STUDY

Debris management after earthquake incidence in ancient City of Ray

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Received 15 December 2016; revised 7 March 2017; accepted 2 May 2017; available online 1 September 2017

ABSTRACT: Ancient City of Ray, located at the southern urban part of Tehran province, is one of the best recognized civilization sites in the world. In this study, the past earthquake incidence in Ray was reviewed using hazards united states tool as a geographic information system-based natural hazard analysis tool. hazards united states tool was chosen to estimate the damage on structural and non-structural elements during various earthquake scenarios with magnitudes of 4.5, 6 and 7.5 on the Richter scale in Ray City. Earthquake magnetitudes of 4.5, 6 and 7.5 would severely damage 49, 72 and 82% of buildings, respectively. The number of casualties was estimated to be in the range of 558 to 2220 people. It was also computed that 93, 197 and 331 km^3 of debris would be produced at 4.5, 6 and 7.5 Richter earthquake, respectively. Subsequently, Arc-GIS was used to find out the best route from the affected areas to the temporary disposal locations and to allocate the required number of heavy equipments and manpowers for debris disposal planning. A set of factors, including diversity of the existing wastes, separation of the recyclable wastes, and allocation of the best place and route for debris disposal in the shortest time and with the shortest distance in the street network, were presented and considered in the analyses. Finally, it was concluded that debris management is not only a logistic activity, but also it is an inseparable part of the post-accident recovery process.

KEYWORDS: *Building debris; Earthquake; Hazards United States (HAZUS); Pathfinding; Temporary repositories.*

INTRODUCTION

One of the most-challenging issues after earthquake accidents is the problem of dealing with the earthquake debris. Lack of prepardness or insufficient information about the facilities, the potentials of the region, and the composition of the generated debris will in first place delay the relief efforts, induce public dissatisfaction, and leave irreparable environmental, economical and social impacts in long term. Although debris managers are concerned about the related environmental issues, pre-accident planning and prepardness for an earthquake have not received enough attention in Iran (Raffee *et al.,* 2008). In this regard, planning must be done in respect of the laws and environmental guidelines which would facilitate the debris removal during an accident (Edrissi *et al.,* 2013). Estimation of the debris generated by an accident is a complex task because numerous variables should be taken into account and the assessment range can vary from a small amount of debris to thousands of tonnes (Pramudita *et al.,* 2012). Selecting a landfill site for earthquake wastes is important because if it is not wisely chosen

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Note: Discussion period for this manuscript open until December 1, 2017 on GJESM website at the “Show Article”.

beforehand, cleaning of the city's passages will be delayed during the critical conditions following the accident. At the time of a natural disaster, it is likely that a place for temporary stacking of the debris and wastes is needed, which could be due to some problems such as full burial sites and insufficient removal/transportation equipments (Karunasena *et al.,* 2012; Zhou *et al.,* 2015). Using temporary stacking sites reduces the costs of debris removal and waste cleaning (Cochran and Townsend, 2010). In fact, the debris are transfered twice; once from the accident area to the temporary stacking site and then from there to the final burial site (Hekimoglu *et al.,* 2013). Rodríguez *et al.* (2006) studied and designed earthquake emergency routes in the United States. Their report analyses the behavior and destruction of the buildings in previous earthquakes and the related guidelines for designing them. Subsequently, they studied different methods for vulnerability assessment and for estimation of building damages with an emphasis on roads, soil behavior and site impact (Rodríguez *et al.,* 2006). The effects of earth's movements, soil liquefaction and slip on the transportation system were considered simultaneously. Hu and Sheu (2013) discussed the economic damage caused by an earthquake, including the damage inflicted on the bridges and the delay in travelling. Inui *et al*. (2012) considered San Fernando Bay to study the site impacts on bridges and discussed a 7.0 magnitude earthquake scenario in Hayward Fault as a basis for studying the effects of (vertical/horizontal) displacement and acceleration. Fujino and Noguchi, (2009) presented a method for estimation of destruction debris and evaluation of available options for debris management in Tokyo. Nouri *et al.* (2011) studied the utilizable methods for controlling the generation of destruction debris in building sites. They concluded that some parts of administrative and educational buildings used as storage for hazardous and flammable materials are susceptible to many disasters. More recently a new citizenship HSE model is developed for schools and kindergartens in Tehran to minimize the hazards of incidences in educational centers (Karbassi *et al.,* 2016). Wang and Hu, (2010) estimated the amount of generated destruction debris using a statistical model. Brown *et al.* (2013) studied the debris generated by destruction and construction focusing on the mass balance of the elements in a separation program. Karta *et al.* (2004) attempted to study the analysis of generation sources, estimating the destruction and construction debris, as well as the process of debris management in Greece. Ozdamar *et al.* (2014) presented a path-finding model for transportation of equipment's in a crisis. Omidvar *et al.* (2014) employed a creative solution to solve the model and compared the efficiency of the model with the data obtained from the Izit earthquake in Turkey. In another study, it was suggested that the main challenge in an evacuation operation is that most often the exit routes are not sufficient in number and capacity to support the sudden surge in traffic (Stepanov and Smith, 2009). They stated that the capacity of the transportation network in a crisis is usually insufficient to support the transportation demand during evacuation. The direct and indirect costs calculation in national scale and the interactions between private sectors were studied by Tam *et al.* (2006). Most studies calculate the costs of damage to the buildings and highway networks but they fail to demonstrate how different systems influence each other by damage intensification (Askarizadeh *et al.,* 2016). Leem and Rhee (2010) used the shortest-path algorithm (SPA) for evacuation path determination after incidents such as earthquakes, storms or chemical explosions.

This study takes the overlap of the evacuation path and the roads into consideration. Some researchers have tried to find the optimized path for the debris transport from the viewpoint of network design (Jenelius *et al.,* 2007). Moreover, Stepanov and Smith *et al.* (2009) examined the design and analysis of the evacuation routes in transportation networks and proposed a method for finding the best route. Chang *et al.* (2012) also tried to formulate the emergency evacuation problem and the rebuilding of the rescue and relief network. Limited efforts have been done for estimation of post-earthquake debris. TELES, RISK-UE and RADUIS are some of the models presented for prediction and estimation of vulnerability to earthquake. In this paper, it is attempted to estimate the volume of building debris following the earthquake using the Tehran earthquake damage estimation system (TEDES) software designed based on HAZUS model. Since this model relies on a variety of data and variables, it can be used as a suitable model for assessment of debris volume, estimation of casualties, and reduction of city vulnerability to earthquake (Gulati B., 2006). Considering the likeliness of disaster repetition, pre-crisis preparedness can be crucial in minimizing the potential losses. This study was conducted to present a comprehensive plan to manage the disposal of debris caused by an earthquake in Ray where is extremely vulnerable to earthquake. The available documents imply that, throughout the history, Ray has been ruined by earthquakes for several times. Although most of the seismic data for Tehran and Ray in the 20th century has been collected, now there is no date for the first 30 years. Unlike historical earthquakes, Tehran and Ray have not been faced a massive earthquake from the end of the 19th century. However, there have been some earthquakes that seriously terrified the people. This study has been carried out in historical city of Ray of Iran in 2016.

MATERIALS AND METHODS

Ancient city of Ray, located in Tehran province, is one of the oldest cities in Iran and the world. The history of residence in Ray dates back to 3000 BC. With an area of 2293 km^2, Ray City is located at the southeast of Tehran with the geographic coordinates of 35.5770° N and 51.4625° E and elevation of 1062 m (meters) above sea level. Environmental changes due to the existence of polluting sources, such as industrial factories and installations, have increased the earthquake risk and probability of a crisis outbreak. Population growth in the south border of Tehran has worsened the vulnerability of this area. North and South Ray faults as well as Kahrizak and Pishva faults can be named as the major faults in Tehran and Ray. Soil amplification coefficient in some regions of District 20 in Tehran is high, and especial attention should be paid to prevention of increasing high-rise buildings and population establishment in this area to reduce the risks. Earthquake and unexpected incidents are followed by other incidents, such as fire and explosion, which can be prevented by pre-planning.

In this study, a geographic information system-based natural hazard analysis tool (HAZUS) was applied to estimate both the potential post-earthquake damages and the extent of earthquake-induced debris at Ray region. Having this in mind, the on-site impacts caused by earthquake were estimated using attenuation relationships and probability of damage occurrence based on fragility curves. 3 steps are required to run HAZUS analysis. For instance, the data related to earthquake scenarios, target sites and final processing are necessary to run HAZUS analysis. The data about structure of systems (load-bearing brick or masonry walls, columns of stone, woods, stone, woods, iron or steel beams, glass) number of flood for building, age of buildings, soil type (clay, silt, sand, gravel, poor graded), as well as the location of faults in Ray were collected. In earthquake engineering topics, those parts of a building which are resistant to gravity, earthquake, wind and other types of forces are called structural components (columns and pillars, all types of roofs, primary and secondary beams, bracings and foundations). Details of structural components are usually analysed and designed by structural engineers. Non-structural components are all components and common things inside a building such as false ceiling, windows, wood, glass, office supplies, furniture, electrical equipment, lamps and chandeliers. Non-structural components are not usually analysed by structural engineers but architects, mechanical engineers, electrical engineers or interior designers specify their type and characteristics.

Three earthquake scenarios were proposed under three magnitudes (4.5, 6 and 7.5 on the moment magnitude scale). The mentioned earthquakes are assumed to occur by activation of Ray faults. Considering the attenuation equation, the effects caused by earthquakes with magnitude of M at a point in distance of R from the earthquake center depend on earthquakes tectonic focus, soil characteristics, and finally seismic waves' path. In the present study, attenuation equations of Bozorgnia and Campbell (1994) were applied to determine the earthquake magnitude. They used worldwide acceleration records of earthquakes with magnitudes of 4.5 to 7.5 torques for modelling of strong ground motion as Eq. 1.

$$\begin{aligned}\ln(\mathrm{PGA}) = \\ -3.511 + 0.903\,\mathrm{M_w} - 1.328 \ln\sqrt{\mathrm{R}^2 + [0.148\exp(0.65\,\mathrm{M_w})]^2} \\ + (1.126 - 0.113 \times \ln(\mathrm{R}) - 0.956\,\mathrm{M_w}) \cdot \mathrm{F} \\ + (0.95 - 0.170\ln(\mathrm{R}))\mathrm{S_{SR}} + 0.406 - 0.221\ln(\mathrm{R}) \cdot \mathrm{S_{SR}}\end{aligned} \quad (1)$$

Where, $M \leq 7.5$, then $\sigma_{Ln(PGA)} = 0.887\text{-}0.0693$ M, a and if $M > 7.5$, $\sigma_{Ln(PGA)} = 0.39$

M_W is moment magnitude scale;

F represents a parameter affected by fault type so as for inverse and pressure faults F=1;

R represents nearest distance < 60 km;

SSR stands a parameter influenced by site location as SSR=1 for soft site, and SSR=0 for sedimentary site; and SHR stands a parameter influenced by site location as SHR=1 for metamorphic and crystalline rocks, and SHR= 0 for sedimentary sites according to Eq. 2.

$$Y = A_1 \exp(A_2 M)\,(R + A_3 \exp(A_4 M))^{A_5} + A_6 S \quad (2)$$

Coefficients of experimental-theoretical ground motion relation in different periods of time for the vertical constituent and the location from stone or soil, in 10 periods from time zero to time 3 seconds, for the earthquakes with magnitudes of $M_W = 4.5$ to $M_W = 7.5$ and distance of $r_{ib} \leq 150\ km$ are presented Eq. 3.

$$\begin{array}{ll} A_1 = +0.040310 & A_2 = +0.417341 \\ A_4 = +0.651000 & A_3 = +0.001001 \\ A_5 = -0.351120 & A_6 = -0.035853 \end{array} \quad (3)$$

Cumulative damage probability is calculated with the help of below mentioned equation. The parameters namely median spectral displacement and beta is obtained from given values in HAZUS technical manual for different building types. Standard normal cumulative distribution function is obtained from z-distribution table of function (0.1). Output is presented in 3 levels: slight, moderate, and extensive damage of buildings in Eq. 4.

$$P(d_s \mid S_d) = \varphi\left[\frac{1}{\beta_{ds}} \times \ln\left(\frac{S_d}{\bar{S}_{d,ds}}\right)\right] \quad (4)$$

Where, $P(d_s \mid S_d)$ is the probility of reaching the slight damage state for a given peak building response (S_d), $\bar{S}_{d,ds}$ is the median value of spectral displacement at which the building reaches the threshold of the damage state, βds is the standard deviation of the natural logarithm of spectral displacement for damage state (ds), and φ is the standard normal cumulative distribution function.

According to the results from TEDES software and Eq.4, the statistical analysis and classification of buildings in Ray city are carried out based on type of structure (metal, concrete, and masonry), number of floors, and age of buildings or their construction quality. Decision on number of classifications and their quality is on the employer and his/her consultants. For each type of building, three frangibility functions are provided for three levels of slight, moderate, and extensive damage to building. These functions express the percent of buildings fit into each level based on severity of the earthquake. HAZUS technique has been applied to predict and estimate the debris left from earthquake. It provides estimations for 2 types of debris: 1) Structural debris including elements of reinforced concrete or steel, and 2) Smaller debris including bricks, irons, glasses, woods, plastics, etc. Debris estimation could be carried out using two methods: a) General occupancy class, and b) Specific occupancy class.

The debris for each sampled building is in relation with the situation in different phases of earthquake damage and its weight is computed according to tone per a thousand square foot. The other step for calculating the debris is to combine the debris of different regions and different buildings.

To calculate the weight of the debris from non-structural or structural elements, Eqs. 5 and 6 were applied on the basis of ton per a thousand square feet.

$$EDF_s(j.k) = \sum_{i=2}^{5} P_s(i.k) \times DF_s(j.i.k) \quad (5)$$

$$EDF_{ns}(j.k) = \sum_{i=2}^{5} P_{ns}(i.k) \times DF_{ns}(j.i.k) \quad (6)$$

Where, j is represents kind of the debris; if $j_=1$, then the debris is from bricks, woods, glasses, etc.; and if $j_=2$, then the debris is from elements of steel or reinforced concrete,

i represents the level of damage ranging from 1 to 5,

k represents type of the building ranging from 1 to 36,

$DF_s\,(j.i.k)$ represents the amount of debris of type j for building of type k when damage level is i,

$P_s\ (i.k)$ represents the probability of being in damage level i for building of type k,

$EDF_S\,(j.k)$ represents the debris of type $j_=1$ produced by damage to building of type k, and

$EDF_{ns}\ (j.k)$ represents the debris of type $j_=2$ produced by damage to building of type k.

The above-mentioned values show the percentage of expected debris of type i produced by structural or non-structural damage to building of type k. On the event that the values of $SQ(k)$, $W_s\ (j.k)$, $W_{ns}\ (j.k)$ are given through the statistics, percentage of expected debris can be obtained using Eq. 7.

$$DB(j) = \sum_{k=1}^{36} \begin{bmatrix} EDF_s(j.k) \times W_s(j.k) \\ +EDF_{ns}(j.k) \times W_{ns}(j.k) \end{bmatrix} \times SQ(k) \quad (7)$$

$W_s\ (j.k)$ is weight of structural debris of type j per a thousand square feet,

$W_{ns}\ (i.k)$ is weight of non-structural debris of type j per a thousand square feet, and

SQ(k) is square foot of debris pertaining to building of type k per a thousand square feet.

The bare-lands of Ray were suggested to be used as disposal location for construction debris. Following an earthquake, debris from buildings should be brought to depot location in shortest time via the shortest direction. The consideration which have a prominent role in selection of evacuation routes based on their significance are: 1) sustainability and invulnerability of the buildings nearby the route networks, 2) low population density in the blocks near the route networks, 3) absence of unsafe facilities. Generally, any increase in the size of resident population nearby the route networks can reduce the feasibility for efficient evacuation. It means that, the routes with higher population density are less appropriate for optimization measurements. Existence of tunnels or bridges at the vicinity of evacuation routes can be very dangerous. Therefore, the routs with tunnels or bridges were highly prevented or at least, the routs with the least qualification for making the bridges or tunnels safe were selected in this article. Moreover, the routes for debris evacuation were modelled through network analysis. In addition to the main route networks (motorways) and main directions, a particular network consisting of underline sub-routes was considered to facilitate reaching from main routes to the determined places. To appoint the best way to carry the debris to the suggested places through the shortest distance in the shortest time, both the short pass and short time analysis were conducted. In this regard, gravity center in each region and the depot location were supposed to be as destination. It is so important to consider the motion speed assigned to various kind of directions when rendering the short pass analysis. The average speed limits in most of the main streets and highways in Tehran are announced to be 40 km/h and 80 km/h. The initial network system was adjusted with the help of specialists who were fully familiar with the place using the objective Judgment Analysis method. Consequently, the routs prioritized for debris disposal were defined based on 3 criteria as: need of the district, net area of the region, and impact of the old urban texture. Obviously, crucial paths' length at every region could be function of the whole area as presented by parameter B in Eq. 8.

$$B = L_{c.r}\ G_n^{-1} \tag{8}$$

Where, $L_{c.r}$ represents the length of crucial path, and G_n represents the gross area of the district.

Necessity of the region is known to be function of its vulnerability. In order to quantify the mentioned criterion, C was defined according to Eq. 9.

$$C = T_{db}\ G_n^{-1} \tag{9}$$

Where, T_{db} stands for the total number of damaged buildings, and G_n stands for the net area of the district.

Evidently, the extended old urban texture at each district can raise the length of those routes prioritized to be reopened immediately. To specify the effects of old urban texture, Z was described according to Eq. 10 in which Ut signifies the area of old urban texture in each district in percentage.

$$Z = C \times (1 + 2 \times \mathrm{Ut}) \tag{10}$$

Casualties are estimated based on the amount of damage to all types of buildings. According to this plan, the victims are classified into three qualitative levels of the homeless, wounded and dead people. These levels are ascribed to the level of physical damage to the building and their correlation is expressed by tables with coefficients of casualties for any type of building and damage. In each level, numerical coefficients are defined for casualties. These coefficients, like damage functions, have been pre-defined and saved Eq.11.

$$Ks = Dn \times M_1 \times M_2 \times M_3 \times (M_4d + (1-M_4d) \times M_5) \tag{11}$$

Where, Ks is casualties, Dn is number of collapsed buildings, M_1 is number of people in each building, M_2 is condition of building in terms of the number of residents during earthquake, M_3 number of people trapped in collapsed buildings, M_4d is rate of casualties after collapse of buildings, and M_5 is casualties after collapse (rate of the wounded people who die after collapse and before receiving first aids).

RESULTS AND DISCUSSION

In HAZUS analysis, volume of debris generated by an earthquake with a moment magnitude of 4.5 on Ray faults is estimated at about 93 km^3. As a result of this earthquake, 49% of the buildings will be damaged, over 558 people will be killed, 2500 people will be injured and 7000 will become homeless. The number of casualties and percentage of damaged buildings in Ray earthquake scenarios is given in Table 1. Vulnerability assessment results show that 10, 15 and 24% of the buildings will be severely, moderately and slightly will be damaged, respectively. The volume of debris generated by an earthquake with a moment magnitude of 6 on Ray faults is estimated at over 197 km^3. By this earthquake, 72% of the buildings will be damaged and about 2060 people will be killed, 5120 people will be injured and 13,000 will become homeless. Vulnerability assessment results show that 21, 24 and 27% of the buildings will be severely, extensively damaged in the area of study, respectively. The amount of debris at various Richter magnitudes is given in Table 2. The volume of debris generated by an earthquake with a moment magnitude of 7.5 on Ray faults is estimated at about 331 km^3. By this earthquake, 82% of the buildings will be damaged, 2,220 people will be killed, 5,500 people will be injured and 15,120 will become homeless. Vulnerability assessment results show that 25, 27 and 30% of the buildings will be severely, extensively damaged in an area of study, respectively.

In order to evacuate and temporarily reposit the structural debris, the arid land sites situated at the Ray City were determined (Fig. 1). In selection of the routes, it was attempted to choose the safest

Table 1: Quick estimation of the number of casualties in Ray earthquake scenario

Scenarios	Peak ground acceleration	Cumulation damage probability	Damaged buildings (%)	Deaths	Injuries	Homeless
4.5 M_W	455	moderately	49	558	2500	7000
6 M_W	1400	extensively	72	2060	5120	13000
7.5 M_W	1627	extensively	82	2220	5500	15120

Table 2: Total amount of debris caused by Ray earthquake scenario

Scenarios	First type/ structural debris in km^3	second type / non-structural debris in km^3	Total debris in km^3
4.5 M_W	68	25	93
6 M_W	133	64	197
7.5 M_W	205	126	331

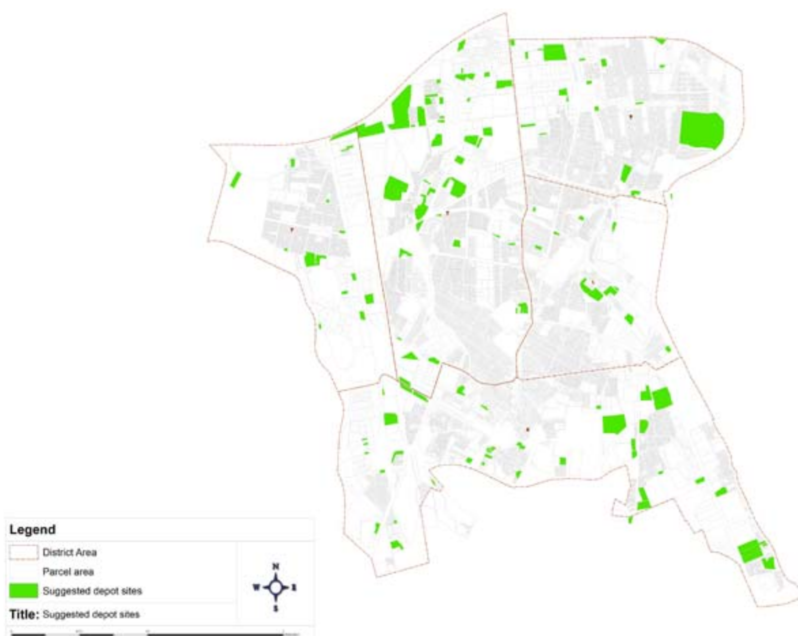

Fig. 1: Distribution of depot locations for the debris in Ray City

and fastest routes. The maximum amount of time to arrive at the target sites is 32 m and the longest displacement is 18.61 Km. Considering the extents and limits of debris removal, and cleaning and reopening of the routes, the routes must be as short as practically possible. Therefore, the centers of gravity in the regions of Ray City were chosen as the starting points (Fig. 2) and their coordinates were recorded by a GPS device to be analyzed in the GIS environment. The required maps were modified and prepared in different layers using auto-map software. In this way, the geographical system database was saved in different layers and it was used with the aid of GIS analysis for three major analyses: a) Finding the best route, b) Locating the nearest site, and d) Determining the service range.

Management of structural debris and wastes is a relatively new concern for municipalities. Knowing that the data and useful information on debris management are insufficient, the data obtained in this regard can be an important source of feedbacks for the estimation of the amount of debris and wastes and the experiences gained can be used for better preparedness, facilitation of the reconstruction operations, and aid operations with less costs during a natural disaster in future. According to the data from Tehran Disaster Mitigation and Management Organization (TDMMO), 200 m^3 debris would be generated as per complete destruction of one residential unit and the demolition tonnage for the buildings in Ray city is predicted to be ranged from moderate to heavy. Considering the time required for loading and transportation between the cleared areas and the selected depot sites, each truck would be able to perform 8 services per 24 h to carry 50 m^3. This should be taken into account in estimating the required equipment for debris evacuation. The required equipment for earthquake scenarios has been estimated and presented in Table 3.

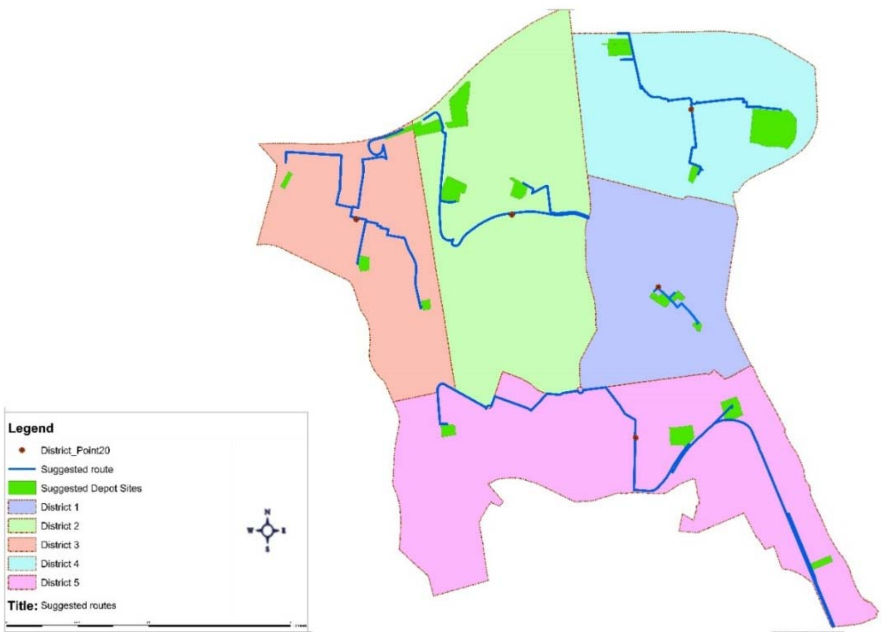

Fig. 2: Debris evacuation routs in Ray City

Table 3: Necessary manpower for debris removal in the Ray earthquake scenarios

Job	Necessary manpower to remove 18 km^3 of debris	Necessary manpower for 93km^3 of debris in 4.5 M_W scenario	Necessary manpower for 197km^3 of debris in 6 M_W scenario	Necessary manpower for 331km^3 of debris in 7.5 M_W scenario
Driver	8	39	83	140
Driver assistant	5	24	52	87
Assessor	2	9	20	35

Table 4: Necessary equipment for debris removal in the Ray earthquake scenarios

Equipment type	Necessary equipment for removal of 18km^3 of debris	Necessary equipment for 93km^3 of debris in 4.5 M_W scenario	Necessary equipment for 197km^3 of debris in 6 M_W scenario	Necessary equipment for 331km^3 of debris in 7.5 M_W scenario
Truck	9	44	93	157
Mini loader	2	9	20	35
Loader	4	19	41	70
Bulldozer	3	14	31	52
Dumper	3	14	31	52
Hydraulic excavator	2	9	20	35
Fuel tanker	15	74	156	262
Crane	10	49	104	175
Passenger car	4	19	41	70
Motorcycle	6	29	62	105

Table 4 demonstrates the necessary equipment for the most potential earthquake scenarios (4.5, 6 and 7.5 magnitude earthquakes on Ray fault).

The data given in Tables 3 and 4 indicate of the significant number of required manpower and machineries. It is concluded that the existing capability is about 5.78% of the real needs.

CONCLUSION

In order to facilitate the debris removal operation and management, due measures should be done to reduce the total costs and response time. For instance, the costs of debris removal and evacuation should be predicted in advance and appropriate methods of finance must be brought out. The volume of debris and the required machinery for its transport to a proper place must be computed well before an incident. It is very vital to find suitable locations for disposal of demolitions. Also, it is very vital to force the owners of vulnerable buildings to strengthen the structures of their building before any incidence occurrence. An appropriate regulation should be developed for handling the hazardous waste after earthquake occurrence. Estimating the composition of debris before any incident can help mangers to come up with the appropriate machinery needs. Municipality of Ray City should come into contract with the owners of heavy machineries well before any incident. The contract may provide some tax reduction to the owners of heavy machineries during the years before earthquake incidence and in turn they help the municipality to transport debris on free charges. Finally, it is proposed to improve the capacities of the existing TEDES for the fast estimation of losses caused by earthquake upon occurrence and to simulate earthquake scenarios. This would aid prioritization of building improvement operations at various parts of the town and give a chance to the crisis managers for more efficient decision making.

ACKNOWLEDGEMENT

This study was supported by Tehran Urban Planning and Research Center. Authors also wish to express their gratitude to Dr. Pour Moosavi for his valuable information and assistance during this work.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

ABBREVIATIONS

A	Coefficients of correlation
B	Net area
G_n	Net area of the district
C	Total area
DB	Ton per debris
Dn	number of collapsed buildings
DRSC	Debris removal specialized committee
EDF	Indicated the debris of type
Eq.	Equation
GIS	Geographic information system
GPS	Global positioning system
h	Hour
HAZUS	It is a geographic information system-based natural hazard asnalysis tool
RADIUS	Remote autheritication dial in user service
	Damage area effect
j	Demolition
K	Building types

Km	Kilometer
Km^3	Cubic Kilometer
Km/h	Kilometers per hour
ks	Casualties
$L_{c.r}$	Length of the critical route
m	Meter
m^2	Square meter
m^3	Cubic meter
M	Magnitude
M_4d	Rate of casualties after collapse of buildings
Mw	Moment magnitude scale
P	Demolition possibility
R	Distance
SHR	Site affected parameter so as for rocks
SPA	Shortest-path algorithm
SQ	Square foot of debris
SSR	Site affected parameter so as for soft
T_{ab}	Total damaged building
TEDES	Tehran earthquake damage estimation system
TDMMO	Tehran Disaster Mitigation and Management Organization
Ut	Percent of damaged area
Z	Weight Damage area effect
%	Percent

REFERENCES

Askarizadeh, L.; Karbassi, A.R.; Ghalibaf, M.B.; Nouri, J., (2016). Management of post-earthquake construction debris in Tehran Metropolitan. Int. J. Environ. Sci. Tech., 13(2): 639-648 (**10 pages**).

Brown, C.; Milke, M.; Seville, E., (2011). Disaster waste management: A review. Waste Manage., 31(6): 1085-1098 (**14 pages**).

Campbell, K.W.; Bozorgnia, Y., (1994). Empirical analysis of strong ground motion form the 1992 leaders, California, earthquake. Bull. Seismol. Soc. Am., 84(3): 573-588 (**16 pages**).

Chang, L.; Elnashai, A.S.; Spencer, B.F., (2011). Post-earthquake modelling of transportation networks. Structure Infrastructure Eng., 8(10): 893-911 (**9 pages**).

Cochran, K.M.; Townsend, T.G., (2010). Estimating construction and demolition debris generation using a materials flow analysis approach. Waste Manage., 30(11): 2247-2254 (**8 pages**).

Edrissi, A.; Poorzahedy, H.; Nassiri, H.; Nourinejad, M., (2013). A multi-agent optimization formulation of earthquake disaster prevention and management. Europ. J. Oper. Res., 229(1): 261-275 (**15 pages**).

Fujino, Y.; Takada, T., (2009). Risk assessment, management and monitoring of infrastructure systems. Season 13-resource recycling concrete: Present and future, Japan, 4:233-253 (**20 pages**).

Gulati, B.; (2006). Earthquake risk assessment of buildings: applicability of HAZUS in Dehradun, India. Unpublished M.S. Dissertation, Faculty of geo-information science and earth observation, Netherlands.

Hekimoglu, Y.; Esen Melez, I.; Canturk, G.; Erkol, Z.; Canturk, N.; Gokhan Dizdar, M.; Oguzhan Melez, D.; Nuri Guler, O., (2013). Evaluation of the deaths secondary to entrapment under the debris in the Van earthquake. Egyptian Journal of Forensic Sciences, 3(2): 44-47 (**4 pages**).

Hu, Zh-H.; Sheu, J-B., (2013). Post-disaster debris reverse logistics management under psychological cost minimization. Transport. Res., Part B: Methodological, 55: 118-141(**24 pages**).

Inui, T.; Yasutaka, T.; Endo, K.; Katsumi, T., (2012). Geo-environmental issues induced by the 2011 off the Pacific Coast of Tohoku Earthquake and tsunami. Soils Foundations, 52(5): 856-871 (**32 pages**).

Jenelius, E., (2007). Approaches to road network vulnerability analysis. Licentiate thesis in infrastructures with specialization transport and location analysis. Royal Institute of Technology, Stockholm, Sweden.

Karbassi, A.R.; Shahpasand, M.; Rajabi, A.A.; Ghafari, H.A., (2016). Development of new citizenship HSE model for schools and kindergartens of Tehran Metropolitan City. Int. J. Human Capital Urban Manage., 1(1): 19-30 (**12 pages**).

Karunasena, G.; Amaratunga, D.; Haigh, R., (2012). Post-disaster construction & demolition debris management: A Sri Lanka case study. J. Civil Eng. Manage., 18(4): 457-468 (**12 pages**).

Leem, Y.; Rhee, S., (2010). An efficient dissimilar path searching method for evacuation routing. KSCE J. Civil Eng., 14(1): 61-67 (**7 pages**).

Nouri, J.; Mansouri, N.; Abbaspour, M.; Karbassi, A.R.; Omidvari, M., (2011). Designing a developed model for assessing the disaster induced vulnerability value in educational centers. Safety Sci., 49(5): 679-685 (**7 pages**).

Omidvar, B.; Golestaneh, M.; Abdollahi, Y., (2014). A framework for post-earthquake rapid damage assessment of hospitals. Case study: Rasoul-e-Akram Hospital, Tehran, Iran. Environ. Hazards, 13(2): 133-160 (**28 pages**).

Ozdamar, L.; Tuzun Aksu, D.; Erguneş, B., (2014). Coordinating debris cleanup operations in post disaster road networks. Soc. Econ. Plann. Sci., 48(4): 249-262 (**14 pages**).

Pramudita, A.; Taniguchi, E.; Gul Qureshi, A., (2014). Location and routing problems of debris collection operation after disasters with realistic case study. Procedia Soc. Behav. Sci., 125: 445-458 (**14 pages**).

Rafee, N.; Karbassi, A.R.; Nouri, J.; Safari, E.; Mehrdadi, M., (2008). Strategic management of municipal debris aftermath of an earthquake. Int. J. Environ. Res., 2(2): 205-214 (**10 pages**).

Rodríguez, G.; Alegre, F. J.; Martínez, G. (2007). The contribution of environmental management systems to the management of construction and demolition waste: The case of the Autonomous

Community of Madrid (Spain). Resour. Conserv. Recycl., 50(3): 334-349 (**16 pages**).

Stepanov, A.; Smith, J.M., (2009). Multi-objective evacuation routing in transportation networks. European J. Operation. Res., 198(2): 435-446 (**12 pages**).

Tam, V.W.; Tam, C.M., (2006). A review on the viable technology for construction waste recycling. Resour. Conserv. Recycl., 47(3): 209-221 (**13 pages**).

Wang, C.Y.; Hu, S.R., (2008). A study on emergency evacuation and rescue network reconstruction for natural disasters with multi-class travel behavior constraints, J. East. Asian Soc. Transport Stud., 6: 4269-4284 (**15 pages**).

Zhou, C.; Liu, X.; Wang, Z.; Yang, T.; Shi, L.; Wang, L.; Cong, L.; Liu, X.; Yang, J., (2015). Marine debris surveys on four beaches in Rizhao City of China. Global J. Environ. Sci. Manage., 1(4): 305-314 (**10 pages**).

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HOW TO CITE THIS ARTICLE

Askarizadeh, L.; Karbassi, A.R.; Ghalibaf, M.B.; Nouri, J., (2017). Debris management after earthquake incidence in ancient city of Ray. Global J. Environ. Sci. Manage., 3(4): 447-456.

DOI: 10.22034/gjesm.2017.03.04.010

url: http://gjesm.net/article_25212.html