Estimating seismic casualty in Khyber Pakhtunkhwa Province, Pakistan

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Abstract: Earthquake casualty assessment is essential to planning for a disaster and facilitating good decision making at the provincial and national levels for any earthquake disaster management body. Evaluations produced from earthquake loss models give basic vital tools to provincial and national crisis management cell. Estimation from loss models is vital for medical groups and organizations giving emergency services to aid their readiness and reaction capacities. Alleviation and proactive measures are essential for reducing human casualties. Subsequently the more we think about conceivable catastrophe levels from a future earthquake, the better society can get ready for and react to earthquake. The most serious outcome of earthquakes is the potential colossal loss of human life. No less than 75 nations endured such loss amid the most recent century. The amount of fatalities in Pakistan from 1900 to 2013 from earthquakes goes to an aggregate of 142,988, which makes the nation seventh in the arrangement of nations with most earthquake deaths.
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1. Introduction

The Destructive earthquakes generally lead to great loss of life. The amount of seismic casualties caused by the Kashmir Earthquake (October 2005) is surprisingly large. On-site investigation and many studies suggest that seismic casualty were mainly attributed to building collapse, which kills the trapped if they are not rescued in time. At present, life loss relief is still of top importance for earthquake disaster reduction. The main task of emergency rescue during the early period after quakes is to rescue those trapped in ruined buildings, by making good use of all possible conditions. It appears very necessary to assess seismic casualties, especially the trapped, so as to give a quantitative reference for rescue action to be taken. Previous assessment methods in this field have several shortcomings as follows: (a) After-effect: the development of casualties during rescue period has not been taken into account. (b) Only some, not all, of the factors that influence seismic casualties are considered. (c) The humanist factors, in particular the psychological and physical factors of humans themselves, are seldom involved. To atone for these shortcomings, a model developed by Zhao Zhengdong and Zheng Xiangyuan (2001) is used to carry out the dynamic assessment of casualty for Kashmir earthquake.

KPK is located in the north-west of Pakistan (figure 1). The province consists of 24 districts with approximate estimated total population over 25 million (FBS Pakistan, 2012).

Ahmad et al. (2010) carried out the causality assessment for un-reinforced masonry building of Mansehra and concluded that total injuries of 2294 ±459 people and fatalities of 29±6 will be expected for the exposure of 50 years.

2. Background

Some previously developed casualty models are briefly discussed.

The number of casualties is proportional to the building damage due to earthquakes (Nunez, 2000).

Casualty models normally use the relationship between casualty and structural damage for earthquake casualty assessments (Seligson and Shoaf, 2003).

Jaiswal et al. (2009) proposed an empirical model for the USGS known as PAGER that can be used for casualty estimation where the relationship of shaking intensity, based on past history is used to determine the casualty rate for many developing countries including Pakistan.

Kythreoti (2002) used a similar approach where the mean fatality ration (MFR) and mean injury ratio (MIR) were associated with the mean damage ratio (MDR). Data from the past earthquakes were used to develop MIR and MFR. Again, data on damage due to earthquake is required to develop new MIR and MFR for the study region.

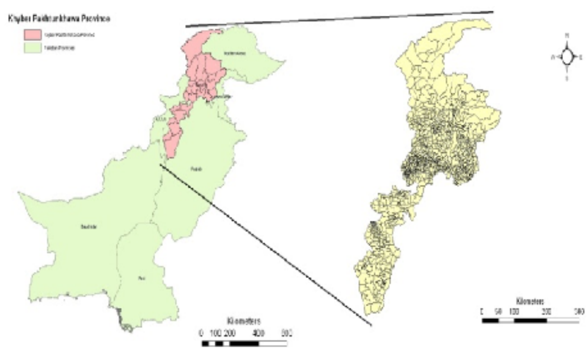

Figure 1. Study Area –Khyber Pakhtukhawa (KPK) Province Pakistan

Rojahn and Sharpe (1985) proposed a casualty model known as "The Applied Technology of Council of California (ATC-13) Casualty Model". It uses the simple relationship between degree of damage and casualty. The greater the damage, the higher will be casualty. It also considers casualty due to non-structural damage like falling of roof tiles.

The above methods use simple relationships between shaking intensity and casualty. However, casualties are affected by multiple parameters such as building damage, population occupancy trends, number of entrapped occupants and rescue capability at various levels. A more comprehensive casualty model is given by Coburn and Spence (2002) as well as HAZUS (NIBS, 2002) model.

HAZUS Casualty Model (NIBS, 2002)

Federal Emergency Management Agency (FEMA) under the umbrella of National Institute of Building Sciences (NIBS) developed a methodology adopted in HAZUS (NIBS, 2002) where the casualties are divided according to the severity and are associated with a structural damage factor. The data used in HAZUS are based on various building types in the US.

HAZUS casualty rates are the casualty rates (fatalities and injuries) given in their manual for various building types. This manual is developed by carrying out extensive research by many engineers in US keeping in view the structural aspects of buildings and social aspects of population. The building stock in the study region such as Pakistan and other developing countries like Haiti, India and Iran are quite different from the building stock in the US and other developed countries. Therefore, data are required from developing countries to develop relationships between fatalities, injury severity and damage factors.

Another Casualty model which is given by Coburn and Spence (2002) is discussed in the following section.

Casualty Model by Coburn and Spence (2002)

Coburn and Spence (2002) have proposed a casualty model where the effects of response times and search rescue efforts are taken into consideration. The fatality calculations involve appropriate factors based on population of buildings, occupancy, entrapment rate and also involves the effects of rescue and preparedness levels, which makes it more suitable for determining the effects of search and rescue levels of a community. Similarly, the method gives the number of severe, moderate and light injuries that can be used in the planning of response/rescue and medical aid for a community.

3. Socio-Economic Vulnerability of Study Region

Socio-Economic Vulnerability will increase the entrapment rate M3.

Social vulnerability of KPK

According to FBS (2012) In KPK 30% of population is below this group (1-10) which is quite high as compared to western countries. This group is very vulnerable to earthquake shaking and building collapse as this age group is inside house most of the time and has no knowledge to respond to earthquake (So, 2009 and So, 2008). Social vulnerability also changes from district to district. For example percentage of age group (1-10) is 36% for Kohistan as compared to 30% in Abbottabad as given by FBS(2012).

For this we need age group table for KPK which is obtained from FBS (2012).

Economic vulnerability of KPK

Economic vulnerability is considered because a low income community with household size of eight residing in rural areas of Kohistan district with two rooms will be more vulnerable to be trapped and injured than a community of high income people with household size of five residing with 4-5 rooms in urban area of Abbottabad. This can be calculated from FBS(2012). The socio-economic vulnerability is shown in Fig 2.

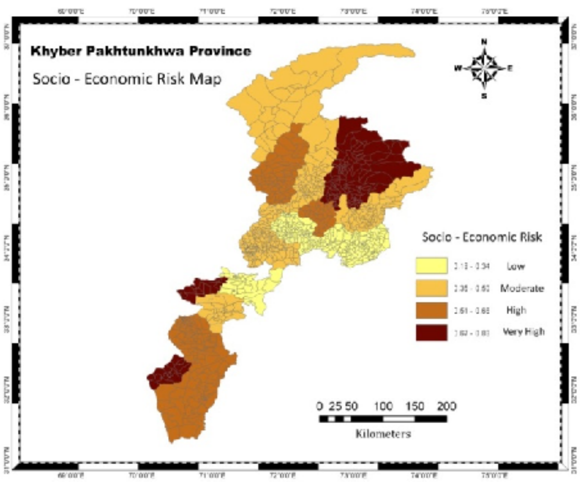

Figure 2 Socio-economic risk map of the study region.

4. Dynamic Assessment of Casualty

Coburn and Spence (2002) model give value for M5 (mortality post collapse) which are empirical based on past earthquake data from Europe due to which it may underestimate the value of M5 for Pakistani conditions which are different from Europe and these values cannot be directly used without modifying them. A more comprehensive method is given by (Zhao Zhendong, 1998) which is discussed as follows.

The injury state of the trapped person develops under certain conditions, which include the initial injury state, geographical location, trap surroundings. A function given by equation 1 (after Zhao Zhendong, 1998) is used to express such development:

$$C(t) = (C_o^{\frac{1}{n}} + S_o t)^n \qquad (1)$$

Where: C_0 = index of initial injury ,C_0 = [0,1], S_0 = geographic location.

S_0 = [0.004, 0.1], depending upon geographic location.
n = trap surroundings, n = [1.0,3.0], the higher value it is, the worse trap surroundings the trapped will has.
Extreme hot or cold temperature, rainfall, fire break and after shocks can increase this factor.

Through two-dimensional and three-dimensional parameter analysis (Zhao Zhendong,1998), it can be shown that among three factors S_0, C_0 and n, S_0 affect the value of C(t) the most.

It has been pointed out that, in case that the Initial Injury Index C_0 is given, the geographic location S weighs more than the trap surrounding n. So distribution of geographical location S needs to be analyzed. It is obvious that the trapped of each injury rank C_m are in different geographical location, favorable or not. The value of S_o is assigned using first the geographic location with most severe being land slide area. Second the ease of escape is considered. Narrow roads and densely populated area will increase the value of S. For Pakistani conditions the following values are selected.

S_1= 0.005 ,S_2 = 0.008 ,S_3 = 0.015 ,S_4 = 0.03 ,S_5 = 0.07

S_1 = Urban Plain Area, S_2 = Rural Plain Area, S_3 = Urban Hilly Area,S_4 = Rural Hilly Area,
S_5 = Land Slide Area

It should be noticed that the above five divisions of S are not equal, for the influence of S on C is nonlinear.

A sample Calculation of M_5 for Reinforced Concrete Frame structure (RCF)

Initial Casualty Matrix C_0

This matrix depends upon three factors.

1. Initial injury distribution at collapse

2. The difficulty in cutting the material of one structural type differ from that of the other. Therefore, each type of structure has an initial casualty matrix of its own.

3. Void formation after collapse. The formation of void spaces as the supports fail and the debris settles may allow trapped victims to survive (Macintyre et al, 2005).

Initial Casualty Matrix C_0 for RCF
We define initial Casualty Matrix for RCF as follows.

Slightly Injured = C_1[0.4-1.0], Moderate Injured = C_2[0.85-1.0], Seriously Injury = C_3[0.95-1.0]

This is based on previous Chinese earthquake records on RCF (Zhao Zhendong, 1998).

Since S_0, C_0 are now known we can draw Table 1, by using n = 1.6. Finally we determine value of M5 for RCF for KPK and compare it with Coburn and Spence (2002) model.

Table 1 Changing of light Injury Index C for RCF using $C(t) = (C_0^{1/n} + S_0 t)^n$. Here n=1.6

	C_1(light injury)				
T	S_1	S_2	S_3	S_4	S_5
3hrs	0.42	0.43	0.45	0.51	0.66
6hrs	0.43	0.46	0.5	0.62	0.97
12hrs	0.47	0.51	0.62	0.88	1
24hrs	0.54	0.64	0.88	1	1
2day	0.7	0.92	1	1	1
3day	0.88	1	1	1	1
4day	1	1	1	1	1
5day	1	1	1	1	1

The rescue rate for Pakistan is not known. However global rescue data is available (YU Shizhou et al, 2012) which is given in Table 2.

Table 2. People rescued successfully in different times (after YU Shizhou et al, 2012)

Time in hours	% of people rescued successfully
3	25
6	50
12	70
24	90
48	100

Applying the rescue rate given in Table 2 te get Table 3 which gives the value of M5 required for RCF.

Table 3. Percentage of people residing in RCF, successfully rescued in different times.

	C_1(light injury)				
T	S_1	S_2	S_3	S_4	S_5
3hrs	0.25	0.25	0.25	0.25	0.25
6hrs	0.25	0.25	0.25	0.13	0
12hrs	0.03	0	0	0	0
24hrs	0	0	0	0	0
2day	0	0	0	0	0
3day	0	0	0	0	0
4day	0	0	0	0	0
5day	0	0	0	0	0
Total saved	0.53	0.5	0.5	0.38	0.25
M5	0.47	0.5	0.5	0.62	0.75

Similarly using the same procedure, value of M5 for moderate and serious injury can be calculated which is shown in Table 4. and Table 5.

Table 4. Percentage of people residing in RCF successfully rescued in different times.

	C_2 (moderate injury)				
	S_1	S_2	S_3	S_4	S_5
M5	0.89	0.89	0.92	0.99	0.99

Table 5. Percentage of people residing in RCF successfully rescued in different times.

	C_2 (serious injury)				
	S_1	S_2	S_3	S_4	S_5
M5	0.99	0.99	1	1	1

Comparison of post collapse mortality with Coburn and Spence (2002) model

For RCF structure, minimum value given by Coburn and Spence (2002) model is 0.7 and maximum is 0.9.
Now according to current methodology Minimum value of RCF will be governed by S1.
According to global data compiled by Coburn and Spence (2002), injury distribution in RCF is bi-modal with 40% lightly injured, 20% moderate injured and 40% seriously injured.
M5 for whole region can be calculated using Eq.(2) (proposed by Zhao Zhendong, 1998).

M5 for whole region = Injury Distribution of light injury at collapse x value of M5 for light injury + Injury Distribution of moderate injury at collapse x value of M5 for moderate injury + Injury Distribution of severe injury at collapse x value of M5 for severe injury (2)

Hence M5 for S_1 = 0.4 x 0.47 + 0.2 x 0.89 + 0.4 x 0.99 = 0.762
Maximum value of RCF will be governed by S5.
Hence M5 for S_5 = 0.4 x 0.75 + 0.2 x 0.99 + 0.4 x 1 = 0.898
The comparison of the two is shown in Table 6.

The reason for difference of values between two models is that Coburn and Spence (2002) model utilizes data from European earthquakes which has slightly better rescue rate than global average.

Table 6. Comparison of M5 values for RCF.

	M5 value of RCF predicted by Coburn and Spence (2002)	M5 value of RCF predicted by Coburn and Spence (2002)	Difference
Minimum	0.7	0.76	8%
Maximum	0.9	0.898	-0.22%

Similarly defining C_o for UBM as follows.

Slight Injury = $C_1[0.2,0.3]$
Moderate Injury = $C_2[0.4,0.6]$
Serious Injury = $C_3[0.7,0.9]$
Using the same procedure it can be shown that value of M5 for UBM = 0.6.
Similarly for different set of Co the value of M5 for adobe = 0.5 and for RCI = 0.75

5. Fatalities and Injuries in study area

Seismic Hazard Assessment of KPK and building inventory development

Seismic Hazard Assessment (SHA) and building inventory of KPK has already been carried out. (Khan and Qureshi (2014)).

Building Vulnerability Relationship
GESI (2001) curves for collapse state are used.

Number of Collapses in 50 years
Using GESI (2001) curves, the total number of collapses are determined for the study region and is shown in Fig.3

M1(Population per building)
M1 is determined from Census data 1998 and updated from FBS(2012)

M2(Occupancy Trend)
M2 is determined using Equations developed by Jaswal et al. (2009) based on employment status. These equations are modified for study region.

M3(People trapped by collapse)
The values given in HAZUS manual are used. These values are modified for study region.

M4(Injury Distribution at Collapse)
Taken from Coburn and Spence (2002) model

M5(Mortality Post Collapse)
Determined using dynamic assessment of casualty.

Fatalities in study area
Fatalities in the study area are determined using Coburn and Spence (2002) and is shown in Fig.4.

Injuries in study area.
Light Injury = Injury not necessitating hospitalization.

Moderate Injury = Injury requiring hospital treatment.

Severe Injury = Life threatening cases needing immediate medical attention.

This breakdown of injuries aid medical community to deal with the earthquake disaster.

Injuries are shown in Fig. 5, Fig. 6 and Fig.7.

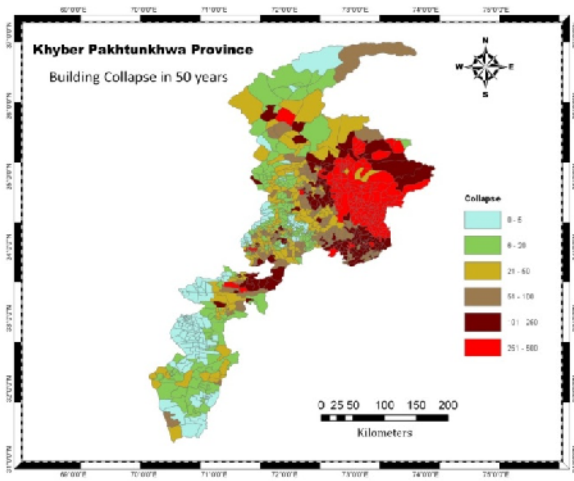

Figure 3 Number of collapsed buildings in the study region in 50 years.

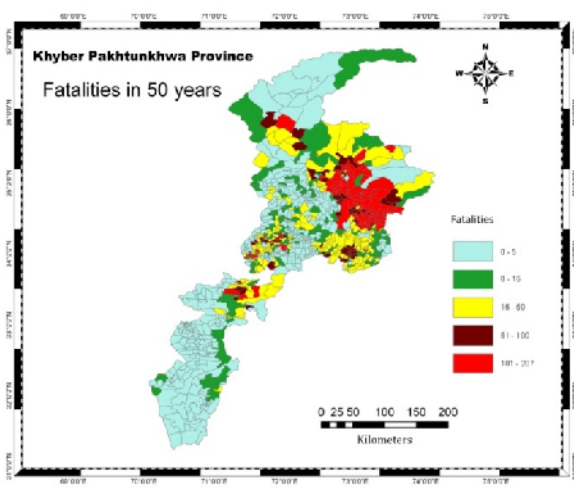

Figure 4 Fatalities in 50 years.

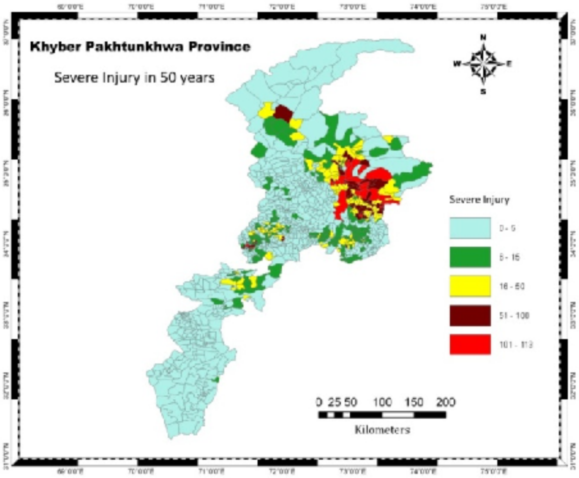

Figure 5 Severe Injury in 50 years.

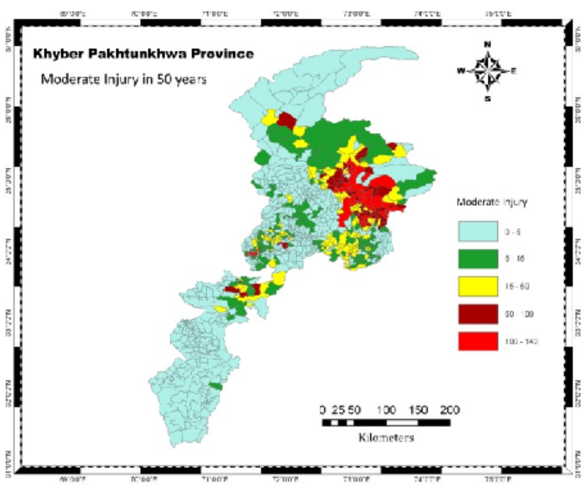

Figure 6 Moderate Injury in 50 years.

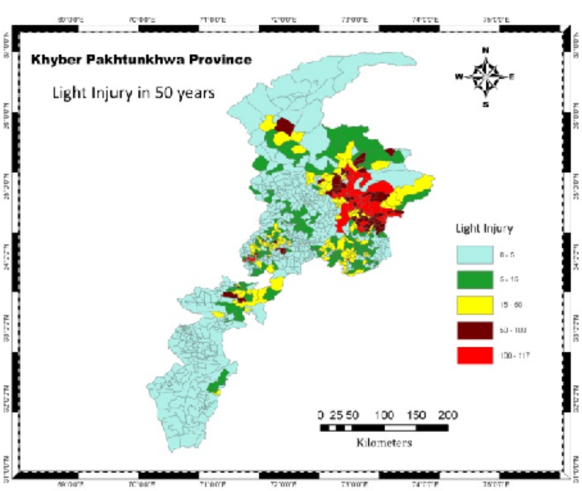

Figure 7 Light Injury in 50 years

Conclusion

In this paper casualty assessment of KPK was carried out using Coburn and Spence model (2002) and it was found that total fatalities expected in the study region are 20904 and total injuries 35420 for 50 year return period .

Some additional factors like socio-economic vulnerability which are not considered by Coburn and Spence (2002) (and can affect final casualty measure) are calculated for study region.

Life vulnerability analysis (dynamic) is different from structural vulnerability analysis (generally static). A key link is often ignored by previous assessment methods, i.e., the injury development, which is directly related to the timely and effective rescue activity and dissemination of disaster prevention knowledge. The injury development of trapped victims was studied in detail for different geographic locations in the study area.

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