Exercise 6E. Earthquake risk assessment estimation.

Expected time:	3 hours
Data:	data from subdirectory: RiskCity exercises/exercise06E/data
Objectives:	In this exercise we will demonstrate a method for the calculation of the range of buildings that might be collapsed or partially damaged by earthquakes under different earthquake intensity classes. We do this by making use of a vulnerability table, which gives a relation between earthquake intensity and degree of damage for a number of building types. We will not deal with the determination of the actual earthquake hazard, and calculate the degree of ground shaking under different earthquake scenarios and local soil conditions.

Input data

The following data are used in this exercise.

Name	Type	Meaning
Elements at risk		
Building_map_1998	Raster	Buildings of the city
Building_map_1998	table	Table containing information about: type, landuse, dimension of the building; number of people during day/night.
Mapping_units	Polygon and table	Polygon map of the mapping units (basic units for risk assessment), and associated table containing information on the number of buildings for different building types.
Earthquake data		
Damage	Script	Script file that will be used to calculate the earthquake loss for different scenarios
Other data		
High_res_image	Raster	High resolution image of the study area.

Depending upon the earthquake intensity and the building strength, a building may get damaged during an earthquake ranging from fine cracks in plaster to the total collapse of the building. Earthquake intensity is expressed in various scales. One the most used one is the Modified Mercalli Intensity (MMI), which gives pre-defined classes of earthquake effects on buildings, people and the environment, on a scale from I to XII (See also session 3E of the Guide book). Based on damage surveys carried out for historical earthquakes a relation has been established between MMI and the degree of damage to buildings. The degree of damage is related to the strength of a building, which again is related to the construction materials and construction types. We have a vulnerability table for the following building types (See also session 4 of the Guide book). The vulnerability table is shown on the next page.

- Adobe, Field Stone, Wood and other scrap materials (**AD**)
- Brick with Mud (**BM**)
- Brick with Cement (**BC**)
- Reinforced Concrete Frame with Masonry having three or less stories (**RCC3**)
- Reinforced Concrete Frame with Masonry having more than 3 stories (**RCC4**)

In the table, the vulnerability of the various types of buildings is expressed as the percentage of buildings that have collapsed or are partially damaged for different MMI classes and Peak Ground Acceleration (PGA) classes. The values in the table are given in percentages.

Building type: adobe + field stone masonry buildings (AD)

MMI	VI	VII	VIII	IX
PGA (%g)	5-10	10-20	20-35	>35
Buildings collapsed (%)	2-10	10-35	35-55	55-72
Buildings partially damaged (%)	5-15	15-35	35 - 45	45 - 28

Building type: brick in mud (BM)

MMI	VI	VII	VIII	IX
PGA (%g)	5-10	10-20	20-35	>35
Buildings collapsed (%)	0-6	6-21	21-41	41-61
Buildings partially damaged (%)	3-8	8-25	25-28	28 - 39

Building type: brick in cement (BC)

MMI	VI	VII	VIII	IX
PGA (%g)	5-10	10-20	20-35	>35
Buildings collapsed (%)	0-1	1-5	5-18	18-38
Buildings partially damaged (%)	0-11	1-31	31-45	45- 62

Building type: reinforced concrete with 3 or less floors (RCC3)

MMI	VI	VII	VIII	IX
PGA (%g)	5-10	10-20	20-35	>35
Buildings collapsed (%)	0-2	2-7	7-15	15-30
Buildings partially damaged (%)	0-4	4-14	14-30	30-60

Building type: reinforced concrete with 4 or more floors (RCC4)

MMI	VI	VII	VIII	IX
PGA (%g)	5-10	10-20	20-35	>35
Buildings collapsed (%)	0-2	2-8	8-19	19-35
Buildings partially damaged (%)	0-4	4-16	16-38	38-60

We will estimate the total number of buildings for each building type in the city and we will apply the vulnerability values for each intensity class. We will then also do the same at the level of the mapping units. Applying the vulnerability at individual building level is not correct. The values indicate the percentage of a group of buildings with the same characteristics that might collapse or be severely damaged. It doesn't indicate the percentage of each individual building. Therefore it can only be applied at an aggregated level, such as mapping units, or at the entire city level.

Estimating the number of buildings for each building type

We need to calculate the number of buildings of the different building types (AD, BM, BC, RCC3 and RCC4). In the table **Building_map_1998** we can observe that the buildings are originally divided into six classes: Adobe (AD), Brick in mud (BM), Brick in cement (BC), Fieldstone (FI), Reinforced concrete (RCC), and

Wood and other scrap materials (WO). First of all we need to reclassify them according to the building types described used in the table at page 6E-4. Basically we have to group the adobe, the field stone and the wood constructions into one class (AD) and we have to split the reinforced concrete buildings into two classes according to the number of floors (RCC3 and RCC4).

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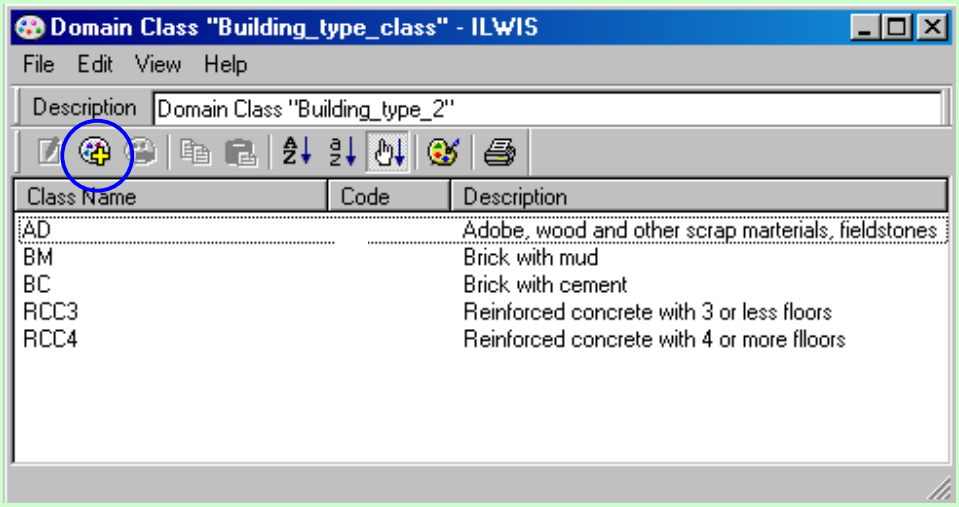
- Open the domain **Building_type** and check the building types and their codes; they are the ones used in the table/map **Building_map_1998.**
- In order to reclassify the building types we need to create a new domain; go to *file / create / domain* and chose *class.* Call it **Building_type_class** and fill the domain window as it appears in the figure below. To add a new class, click the icon with the blue circle.



- Open the table **Building_map_1998.** create a new column using the following expression:

BT:= IFF((building_type="AD") or (building_type= "FI") or (building_type="WO"), "AD",IFF(building_type="BM", "BM", IFF(building_type="BC","BC", IFF((building_type="RCC") AND (Nr_floors <= 3), "RCC3","RCC4"))))

IMPORTANT: chose in the column properties window the domain **Building_type_class.**

This formula contains 4 nested IFF statements. In the first IFF statement we group the 3 building types Adobe, Fieldstone and Wood together under the Class Adobe (as we don't have vulnerability values for the other two classes). If the building type is Brick in mud or Brick in cement, we leave it as it is. In the last IFF statement we divided the reinforced concrete buildings in those with less than 4 floor and more than 3 floors.

- Check the use of brackets in the formula. Can you explain why there are 4 closing brackets at the end?.

We created a column with the new classification of the building types. At this point we can calculate the number of buildings for each building class. Since we will deal with the total number of buildings and we will calculate quite some columns, we will make a new table and we call it **Building_type_class**.

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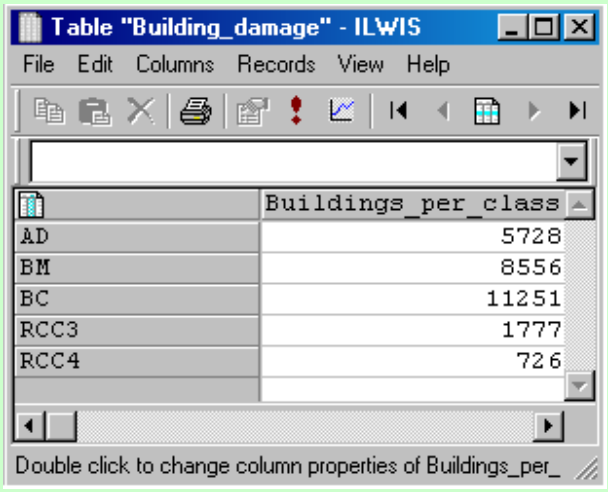
- Open the table **Building_map_1998** and create a new column with the number of buildings for each building class. Go to *columns / Aggregation* choose: *Column* : **BT**, *Function* : Count, and *Group by* **BT**. Output table: **Building_type_class**. Call the new column **Buildings_per_class**.
- Open the new table **Building_type_class**. At the end the table should appear as in the figure below.



- What is the total number of buildings? Instead of doing the calculations manually, it is better to visualize the statistics pane; go to *View* and chose *Statistics Pane.*

Using vulnerability tables for the entire city

In the table shown above, the percentage of building-damage for different earthquake intensities (in MMI) and for five building types in the city is given. This data in this table were obtained from an NGO (NSET-Nepal). In the table two types of damage grades are given which were defined in the following way:

- Collapsed buildings
- Partly damaged buildings

Damage – intensity relationships for buildings are cannot be predicted very precise, because the amount of damage depends on many other factors (See session 4 of the Guide book). In the damage matrix table, the damage grades are not given with a single percentage value but as a range showing minimum and maximum percentages.

Regarding the procedure for applying the vulnerability curves to the RiskCity dataset, the following four types of columns for each earthquake intensity class (from VI to IX) will be created in GIS in order to calculate the number of vulnerable buildings:

- Partial damage min (Minimum probable number of buildings having partial damage)
- Partial damage max (Maximum probable number of buildings having partial damage)
- Collapse min (Minimum probable number of buildings having total damage)
- Collapse max (maximum probable number of buildings having total damage)

From the vulnerability table given above there are many different possibilities for combining the information: for different Intensities (VI, VII, VIII and IX) and for partial or complete collapse minimum and maximum values are given. We will only calculate here one scenario: minimum percentage of collapsed buildings in an earthquake with Intensity IX. The percentages related to the minimum buildings collapsed expected in this scenario are:

Building type	Min expected Buildings collapsed	(0 – 1)
AD	55%	0.55
BM	41%	0.41
BC	18%	0.18
RCC3	15%	0.15
RCC4	19%	0.19

(check these values by comparing them with those in the vulnerability table)

Now we can calculate the number of buildings collapsed for each of the building classes according to these percentages.

- Open the **Building_type_class** table and add an empty column called **IX_collapse_max.** Assign it a value domain, *value range* between 0 and 1 and *precision* 0.01. Fill the new column with the correct values we extracted from the table, according to the building classes (Ex. AD = 0.55)
- Multiply the column **Buildings_per_class** by the column **IX_collapse_min** by typing in the column command line the following expression: **IX_tot_collapse_max:=Buildings_per_class * IX_collapse_max**
- Visualize the *Statistics Pane* and read in the sum row the total number of buildings collapsed for this scenario. How many building are expected to collapse? How many Adobe buildings? How many buildings in brick with mud
- Now do the same steps for MMI classes VI, VII and VIII. Read the total values from the table and write them down. How many buildings might collapse in Intensities VI, VII, VIII and IX? Write the results in the table below.

	VI	VII	VIII	IX
Nr of Buildings Collapsed max				

Using a script for building loss estimation for mapping units

In the previous section we only calculated the maximum number of buildings that could be severely damaged for the entire study area.

However the risk assessment can also be done at a lower aggregation level. As mentioned before we cannot use the vulnerability values at the level of individual buildings. Therefore we will use the mapping units as the basic units for the risk assessment. We have already calculated the number of buildings in the 5 building types (AD, BM, BC, RCC3 and RCC4) per mapping unit.

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- Open the table **Mapping_units** and check the contents of the columns. What does **Nr_AD** mean?
- Display the map **Mapping_units** with the attribute: **Nr_AD**. Which pattern is visible?

To calculate the minimum and maximum number of buildings that might be severely or moderately damaged for all earthquake scenarios, would take a long time to do manually and can be better done in a script. We have prepared a script for that already. The script contains only two lines:

Script: Damage

```
Tabcalc Mapping_units %1_%2_%3:=(Nr_AD*%4)+(Nr_BM*%5)+(Nr_BC*%6)+(Nr_RCC3*%7)+(Nr_RCC4*%8)
%1%2%3:= MapAttribute(mapping_units,mapping_units.tbt.%1_%2_%3)
```

Parameters:

%1 = Intensity (VI, VII, VIII, IX)
%2 = Collapse or Partial
%3 = Max or Min
%4 = the value of damage for Adobe building (Nr_AD)
%5 = the value of damage for Brick in Mud buildings (Nr_BM)
%6 = the value of damage for Brick in Cement (Nr_BC)
%7 = the value of damage for RCC buildings with less than 4 stories (Nr_RCC3)
%8 = the value of damage for RCC buildings with more than 4 stories (NR_RCC4)

NOTE: you need a raster map of mapping units in order to run the second line of the script.

In the script, the eight required parameters are identified by the symbols %1 %2 … %8. The script function "tabcalc" is a function that creates a new table or a column in an existing table; in this case we will create a new column in the table **Mapping_units.** For more information on scripts check the ILWIS help and search for "script syntax". %1_%2_%3 indicates the name to be assigned to the new column. This is composed of the three first parameters %1 (intensity), %2 (Collapse or partial damage) and %3 (Max or Min). So in case you want to calculate the maximum number of partially destroyed buildings under Intensity VII, you have to use: VII Partial Max.
According to the input parameters that are provided by the user, the parameters %1, %2 etc. will be replaced with actual text. The first line in the script creates in the table **Mapping_units** the columns of the expected collapsed/damaged buildings for each class. The second line creates an attribute map from the columns created in the first line.

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- Use the script **Damage** and run it using the various parameters from the vulnerability table. For example:

Run damage VI collapse max 0.1 0.06 0.01 0.02 0.02

You can also create a script which serves as the input script for the script **Damage** and which will contain all scenarios.

We will concentrate on the calculation of the number of buildings that might be heavily damaged (collapse or unrepairable) under earthquake intensities VI , VII, VIII, and IX .

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- Create a script **Damage_input** and write the input for all scenarios in the following way:

Run damage VI collapse max 0.1 0.06 0.01 0.02 0.02
Run damage VI collapse min 0.02 0 0 0 0
Run Damage VII collapse max 0.35 0.21 0.05 0.08 0.07
Run damage VII collapse min 0.1 0.06 0.01 0.02 0.1
Etc.

- Run the script **Damage_input** by typing the following command on the command line:

  Run damage_input

- Display the results in a table below. Compare the results with those that you calculate for all buildings in the city?

- You can also display the resulting maps that were generated with the script Damage. Open for example the map IXcollapsemax, which is the "worst case scenario" for the city. Which areas have the highest losses?

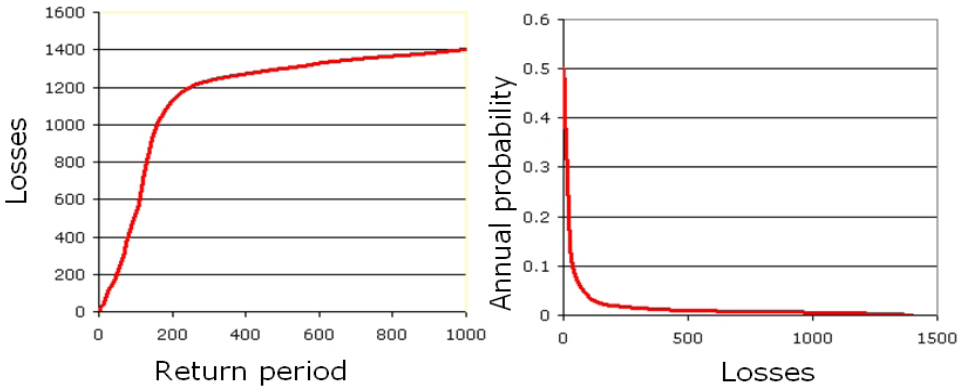
	VI	VII	VIII	IX
Collapse max				
Collapse min				

Generating risk curves

On the basis of studies on the earthquake catalog of the region and with the help of models for the calculation of earthquake attenuation, it has been determined that the various intensities occur with the following return periods:

	VI	VII	VIII	IX
Return period	10	25	50	100

The risk can be represented as a curve, in which all scenarios are plotted with their return periods or probability and associated losses. Such a risk curve is also called the Loss Exceedance Curve (LEC). The left graph has the advantage that it is better visible which return periods have the largest contribution to losses. The right curve can be used directly to calculate the Average Annual Losses (AAL). This is done by calculating the area under the curve (also Guide Book, session 6.5.5).



Two ways to represent a risk curve. Left: Plotting losses against return period. Right: plotting losses against annual probability.

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- Create the Risk curves, and plot the values for the 4 earthquake intensity scenarios in the graph. Do it for the minimum and maximum number of expected collapsed buildings.

☞ **Advanced Task**

- Up to now we calculated the estimated minimum and maximum number of collapsed buildings for each intensity scenario. Try to calculate by yourself the minimum and maximum number of expected partially damaged buildings.

Question:

We have now assumed that the entire city will have the same earthquake intensity under the same earthquake scenario, which is a particular earthquake with a certain magnitude occurring at a particular distance from the city. Is this a correct assumption? What should we have done to improve this result?