Forensic Earthquake Analysis Group

"Comparing the current impact of the Van Earthquake to past earthquakes in Eastern Turkey"

CEDIM Forensic Earthquake Analysis Group – Report #4
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TABLE OF CONTENTS

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1 Introduction and Setting

The Van earthquake in 2011 hit at 10:41 GMT (13:41 Local) on Sunday, October 23rd, 2011. It was a Mw7.2-7.3 event located at a depth of around 10 km with the epicentre located directly between Ercis (pop. 75,000) and Van (pop. 370,000). The province of Van has around 1.035 million at the last census. The Van province is one of the poorest in Turkey and has much inequality between the rural and urban centers with an average HDI (Human Development Index) around that of Bhutan or Congo. The earthquake is estimated to have caused around 700-1000 casualties (601 currently as of 2nd November 2011; mostly due to falling debris and house collapse), and around 1 billion TRY to 4 billion TRY (approx. 555 million USD – 2.2 billion USD) in total economic losses. This would represent around 17 to 66% of the provincial GDP of Van.

From the CATDAT Damaging Earthquakes Database, major earthquakes such as this one have occurred in the year 1111 causing major damage and having a magnitude around 6.5-7. In the year 1646 or 1648, Van was again struck by a M6.7 quake killing around 2000 people. In 1881, a M6.3 earthquake near Van killed 95 people. Again, in 1941, a M5.9 earthquake affected Ercis and Van killing between 190 and 430 people. 1945-1946 as well as 1972 brought again damaging and casualty-bearing earthquakes to the Van province. In 1976, the Van-Muradiye earthquake struck the border region with a M7, killing around 3840 people and causing around 51,000 people to become homeless.

The HDI (Human Development Index) in the affected region (Van, Hakkari, Bitlis, Mus) is among the lowest in Turkey. Please note that this is the 2009 definition of HDI and not the current UNDP 2nd version. HDI is a combination of literacy rate, life expectancy and GDP (per capita). In the Van area (0.630), the HDI is equivalent to Bhutan, India or Congo, as compared to the average HDI of Turkey which is 0.810, equivalent to Brazil, Peru or Colombia. This reflects the rural character of the region, the fact that civil conflict prevailed for decades, and points to reduced local capacities for disaster preparedness including hospital and other medical resources.

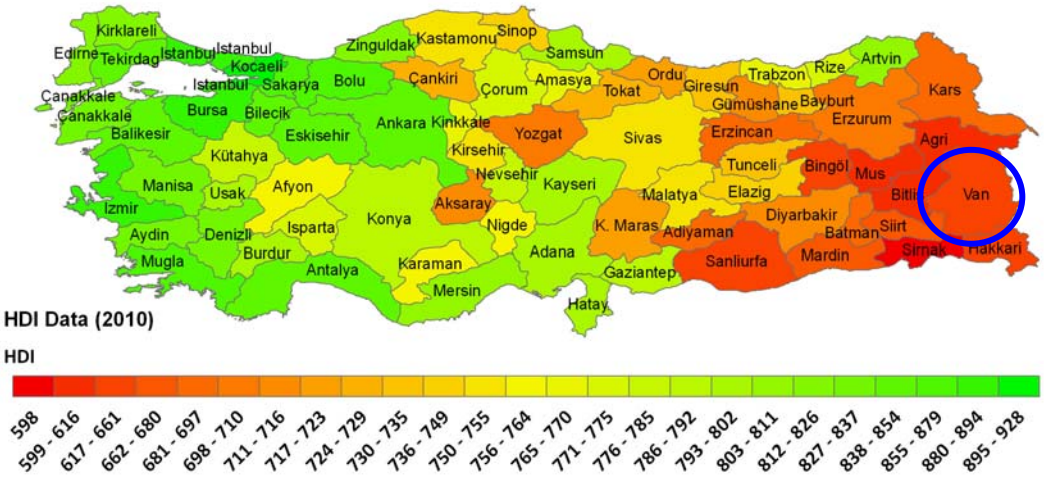

Figure 1: Human Development Index of Provinces in Turkey, showing one measure of coping capacity

Van Province has an official population of 1.035 million (as of 31.12.2010, ABPRS) with a very low population density corresponding to 54.3/km^2. Compared to other provinces, the average household

size is relative high (between 7 and 8 persons). It has 539,619 residents living in cities, and a village population of 495,799.

The official population of Van City was 367,000 in 2010 as per the Address Based Population Registration System (ABPRS), but values of 500,000 and 600,000 have been estimated by government sources. The Ercis part of the province has Ercis City (approx. 77,000) and many other settlements. (Urban=78,397, Rural=66,832). Based on the available Census data 1985, 1990, and 2000 the population of Van province increased substantially during from 1985 to 2000, both cities at least doubled their number of inhabitants during the last 25 years.

Table 1: Population changes from census information for the cities of Van and Ercis from 1985-2010 (Data Source: State Institute of Statistics, Turkey)

City	1985 Census	1990 Census	2000 Census	2009-12-31 Registered	2010-12-31 Registered
Van	110,653	155,623	284,464	360,810	367,419
Erciş	36,582	40,481	70,881	74,858	77,065

See the social vulnerability section below for a further insight into the dynamics of the Van province in terms of reconstruction issues.

2 The Impact of the 2011 Van Earthquake

2.1 Ground Motion and Seismology

The Van earthquake in 2011 hit at 10:41 GMT (13:41 Local) on Sunday, October 23rd, 2011. Estimates of the hypocenter range from Mw7.1 to Mw7.3 and from 5 to 20km from different agencies. This corresponds to a seismic moment release difference of 2 times. The earthquake released its energy by thrust motion on an EW trending fault. Faults of an earthquake of this size extend typically for 60 to 100 km length. Although the epicenter is located in the North Anatolian Fault Seismo-tectonic Zone, the fault motion suggests that the event belongs to the broad Bitlis-Zagros Fault Zone, where thrust mechanisms dominate.

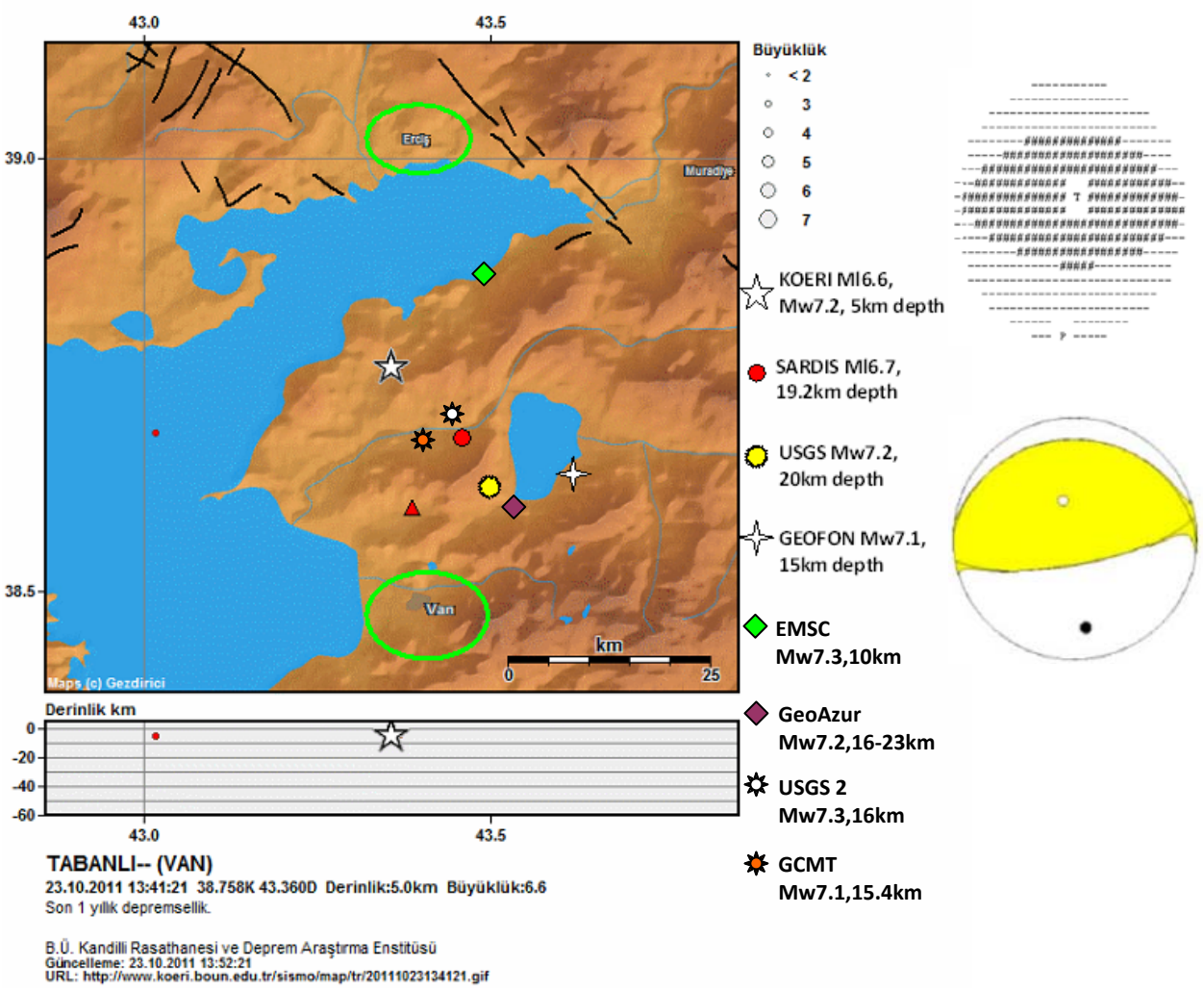

Figure 2: Hypocenters as determined from various agencies as compared to the large population areas of Van and Ercis (base picture courtesy of KOERI)

Ground motion estimates have been published by Kandilli Observatory and Earthquake Research Institute (KOERI, http://www.koeri.boun.edu.tr/) as well as Earthquake Engineering and Research Center Middle East Technical University (EERC-METU, www.eerc.metu.edu.tr). KOERI shows that the seismic hazard before the event, mimicked the location of the earthquake to cause large ground motions. In the epicentral area they reach values of 60% of gravitational acceleration (0.6g) and peak ground velocities of 50-60 cm/s. This would be beyond standard code levels. The different

hypocenters from various agencies are shown on the following diagram. The KOERI hypocenter appears to correlate best to the damage seen.

Both the Van and Ercis cities are built on the shores on Van lake which suggests soft soil conditions for the cities, possibly soil liquefaction along the shore of the lake causing greater ground motions and this aggravating factors for building collapse and ground failure.

EMS intensities are estimated as above VIII within an area with 25 km diameter as per KOERI. However, these values are computed, not measured and must still be validated by field observations of the Turkish strong motion networks. Strong motion measurements and macroseismic intensity observations of the epicentral area are still not available. The Strong Motion Data Base of Turkey: (http://kyh.deprem.gov.tr/ftpt.htm) provides data from 22 stations most of them at large distances beyond 100 km. The strong motion data is initially reported by EERC-METU. The closest stations are:-

Muradiye (No. 6503, hypocentral distance 49.1 km) PGA=179 cm/s^2

Malazgirt (No. 4902 hypocentral distance 94.5 km) PGA=56 cm/s^2

Bitlis Merkez (No. 1302 hypocentral distance 112.8 km) PGA=102 cm/s^2

Agri Merkez (No. 0401 hypocentral distance 122.8 km) PGA=18.3 cm/s^2

The relatively high value at Bitlis, where also much damage has been reported may be caused by the EW extension of the ruptured fault.

KOERI shows estimates of PGA values modelled with ELER, including soil effects, but using a point source instead of an EW elongated rupture. Epicentral PGAs are estimated as 550 cm/s^2; this should be essentially the value for Van and Ercis. The KOERI model is compatible with records of the Strong Motion Data Base of Turkey between 50 km and 120 km.

The ground motion at Muradiye and Bitlis was below the Turkish Design Spectra even for soft soil conditions (KOERI report 31.10.2011). In the epicentral area between Van and Ercis PGA values are estimated as 550 cm/s^2, three times higher than at Muradiye. The used ground motion prediction equation includes a 35% chance that the values exceed 750 cm/s^2. It is thus conceivable that ground motion, at least locally, exceeded code level.

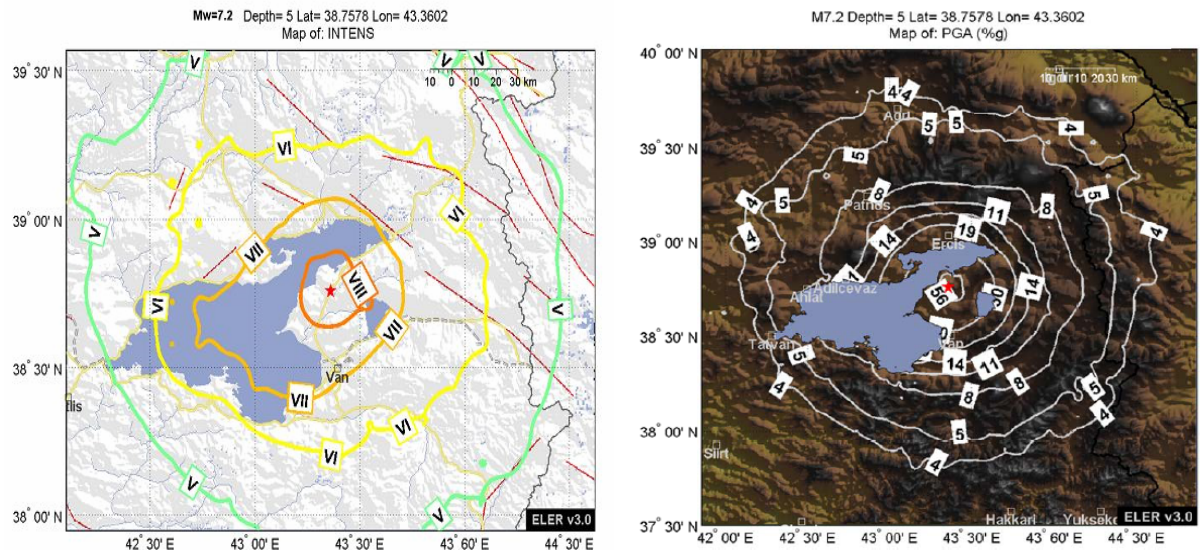

Figure 3: Courtesy of KOERI (http://www.koeri.boun.edu.tr/) – Intensities (EMS) (Left); PGA (%g) (Right)

For those interested in reading about the dynamics of the active tectonic features of the Eastern Mediterranean region and the Eastern Anatolia fault systems at play, we recommend reading "Seismotectonics of the Van Region" and other seismic hazard data created by KOERI at Bogazici University. Link provided at the end.

Aftershock Sequence

As of 31st October 2011, the affected area is still hit with continuous aftershocks. There have been over 1792 aftershocks greater than magnitude 2. Over 7 of these have been greater than magnitude 5, including a M5.6 and M5.9 soon after the quake, a M6.0, 10 hours after the earthquake, and a M5.7 which caused much additional damage including collapsed houses. This sequence of events has kept people on the streets with reports of many more people leaving their homes. As can be seen below, felt aftershocks have been distributed over a large area, meaning that most of the Van Province population has been significantly affected.

In many historical earthquakes, aftershocks are the main reason for people staying out of their homes, combined with the fear of buildings collapsing until proper assessment is done. In this earthquake, like the 2011 Japanese earthquake, the aftershock sequence has produced a larger than normal number of people to leave their homes who do not have severely damaged or destroyed housing. People are staying outside of their homes warming up in the heat of a campfire and covered with sheets.

The number of aftershocks between each magnitude bound are as follows: M2-3: 716 ; M3-4: 913 ; M4-5: 108 ; M5-6: 7; M6-7: 0. The approximate aftershock distribution can be seen in the last report.

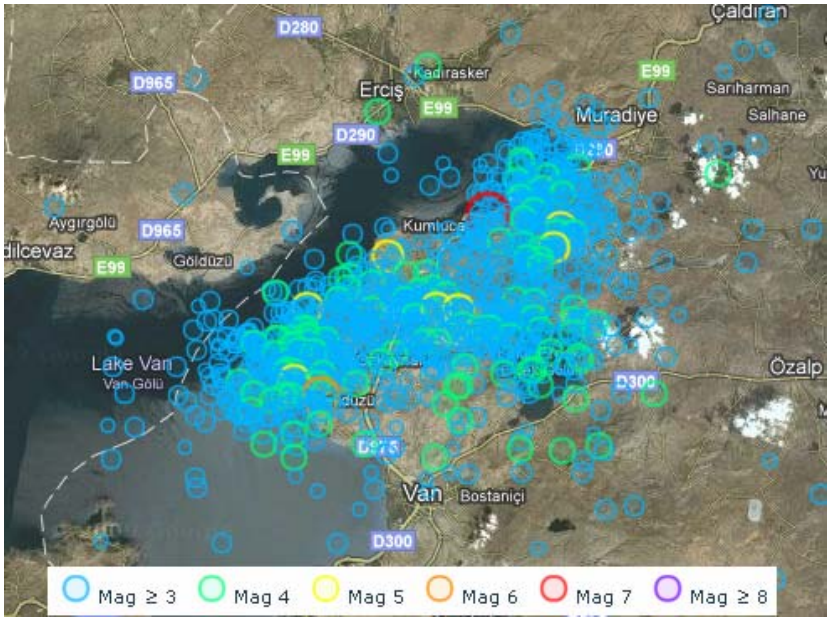

Figure 4: Aftershock distribution from EMSC representing 1128 aftershocks over M>3 as of 2nd November 2011 (Courtesy: EMSC, http://www.emsc-csem.org/Earthquake/202/Earthquake-M7-2-Eastern-Turkey)

2.2 Building and Lifeline Impacts

Ercis was the most heavily hit, with statistics coming out that from the 12 of 13 boroughs on the 1st November 2011 that 5497 households have been severely damaged and in addition 9060 households became damaged. This was out of 18,424 households (Hurriyet, 2011). This could mean that around 30% of buildings in Ercis are damaged beyond repair.

A further indicator for this statement is that Atalay stated that 5000 containers are required for temporary housing in villages, 2500 containers are required in Van City, whereas 9000 containers are required in Ercis. The housing has been stated that it will only be "allocated to the families whose houses have been destroyed or unsafe".

As of the 31st October 2011 reported from Turkish Red Crescent, from the 43,548 buildings that have been examined, 2309 have collapsed, 11,847 have been severely damaged or are uninhabitable. 17,923 houses have been slightly or moderately damaged. In addition, 11,469 buildings have been undamaged. A group of almost 200 staff has been undertaking preliminary assessment of the damaged buildings.

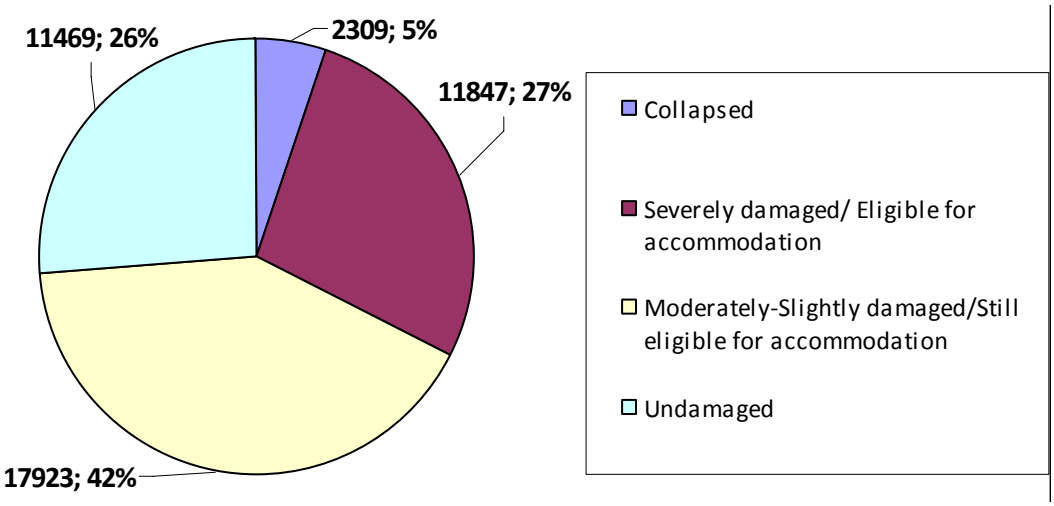

Figure 5: The current statistics of building damage as determined by different damage classes (TCRS details)

In addition to a ground survey, DLR has also done remote sensing work on the Eastern Turkey earthquake. Due to cloud cover however, damage assessment is difficult.

In the Van City, the natural gas system (building collapse on a system regulator), water supply system (pipeline damage), the power and communication systems (general interruptions) were all affected, however were reported to be functional again within 24 hours after the earthquake. The Van-Ercis road was also reported to have been damaged in the form of road collapse and cracking.

Figure 6: Soft storey collapse (left, gazetevatan.com); Pancake Collapse (central, fotogaleri.ntvmsnbc.com); Rural damage (right, gaztevatan.com)

Soft storey collapse regularly occurs in Turkish apartment buildings with the bottom storey having a higher storey height than the storeys above it, providing extra height for shops or for carparking. Concrete frame buildings with concrete flat slabs of three to seven stories collapsed in some cases around the urban centers of Ercis and Van.

Pancake collapse can occur where the columns of each level fail. Pancake collapses of the lower part and of the entire building and so-called outspread multi layer collapses can be seen in photos provided. As observed after the 1999 Izmit earthquake, many of the concrete floors did not remain intact within the collapse structures. Large voids in upper stories when only partly collapsed, but mostly very dense collapse structures lead to many casualties. This is the most fatal type of collapse with approximately 10x more injuries occurring in a total collapse, than in other forms of buildings beyond repair.

In addition, weak column-beam connections and weak building materials such as understrength concrete have had a huge impact on the building damage ratios. Lack of code enforcement may also have played a role, however more details are needed before commenting further. The 1998 (enforced essentially from 2000 onwards) and 2006 updates of the Turkish earthquake code have been integrated into modern buildings. Before that 10 other updates of various forms occurred for Turkish earthquake-resistant codes, however, not many in Eastern Turkey were enforced. From the CATDAT system, the building practice factor (a function of corruption, building practice, enforcement etc.) in this part of Eastern Turkey has a rating of 3.7/10, meaning that a reasonably high amount of non-code enforcement is expected. The seismic code index on the other hand is 8.5/10, indicating one of the best standards in the world for the relative hazard, when enforced.

Prof. Mustafa Erdik, Head of KOERI, has discussed some of his impressions from the 3 days he was in the field.

Rural damage: People live typically in one storey buildings with tin roofs where this is only a small chance for fatalities even in case of heavy damage or collapse. Cattle was held in buildings with heavy concrete roof, lots of losses. The pictures in the KOERI reports show villages that seem to be quite devastated, but as said not too many fatalities.

Urban damage: Many modern buildings did quite well but typically older ones collapsed. The typical damage forms are well documented in the KOERI reports on the web. There have been weak first storey collapses (soft storey collapse) as well as pancake collapses that have been seen.

Duration of Shaking: The duration of shaking was quite long (40 seconds as compared to typically 20 seconds for a Mw7 event); this is more devastating for old buildings. Prof. Mustafa Erdik believes that, although bad for old construction, this type of energy release, rather than a shorter more intense release may have helped the more modern building stock.

Rapid Growth: He confirmed that in Van and Ercis rapid growth occurred during the past 10 years, related to several causes: Business due to Iraq war, intensive trading with Iran. Ercis is essentially a new city.

There are many favourable conditions that have come out of this earthquake however, including that modern construction typically survived and rapid and efficient response of Turkish relief forces.
At the same time a few lucky circumstances reduced losses:

- Time of event was a Sunday afternoon
- Long duration slow energy release of the earthquake which was less damaging for new buildings built to withstand many cycles of loading
- Epicenter not closer to Van

Table 2: Building Stock Information as per KOERI report (KOERI, 1st November 2011)

	Van(Total)	Ercis	Muradive	Merkez
Number of Buildings	78,000	10,700	3,600	35,200
Reinforced Concrete	12.7%	27%	5%	5%
Unreinforced Masonry	75%	63%	81%	82%
Adobe	9.5%	8%	12%	9%
Rubble Stone	2.8%	2%	2%	4%

2.3 Economic Impacts

Total economic damage is estimated in the low single-digit billion USD from EQECAT CatWatch mimicking the PAGER model estimate (as reported on in the past CEDIM reports). Although this is 1/10th of the 1999 Izmit earthquake, it also should be noted that this earthquake is in a region around 4 times poorer (GDP-based) than Izmit.

The GDP of Mus, Hakkari, Van and Bitlis together (4 provinces) was in the order of 8.66 billion TRY back in 2008. Of these, Van Province represents about half of the 8.66 trillion TRY (equivalent to around 10.9 trillion TRY in 2011 via inflation). The equivalent is 6.132 billion USD (2011). 21.3% was Agriculture, around 15.8% was industry and 62.9% was services. Due to the economy of Turkey changing significantly from 1995-2010, much change has occurred in the region creating many economic uncertainties for analysis.

The Van Province GDP can be assumed to be around 3.3 billion USD (2011). Generally such disasters have taken around 15-33% of provincial GDP in the past, and using a factor system to calculate this in the Van Province, around 500 million-1.25 billion USD is a reasonable estimate. Outlier estimates suggest a higher range up to 2.2 billion USD. Van is one of the poorest regions of Turkey. In the rural areas, sheep and cattle farming is a common form of income.

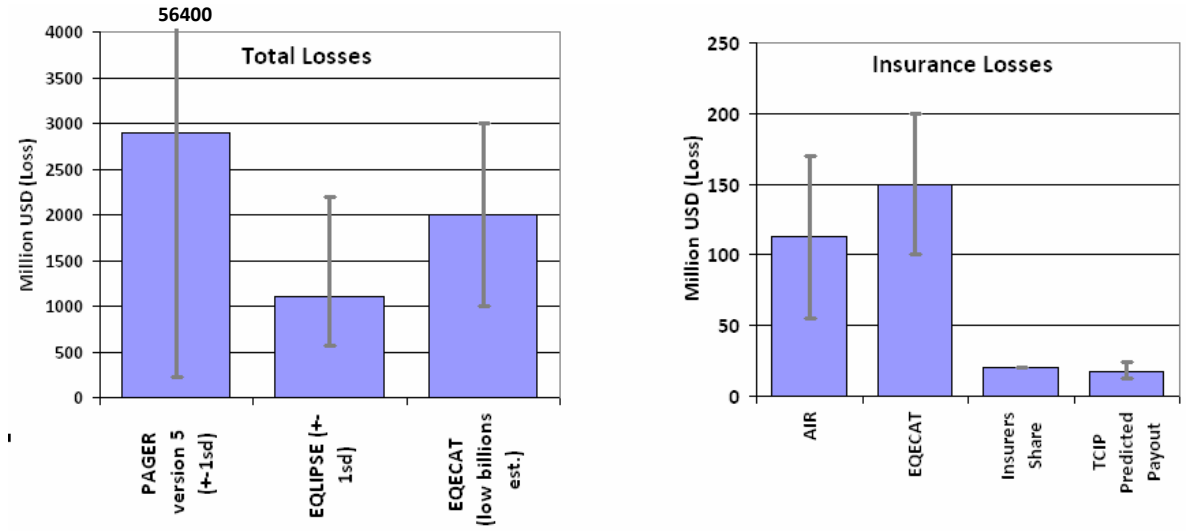

Figure 7: Economic Loss Estimates from various agencies (left); and Insurance Loss estimates from various agencies (right)

Economic Aid

As of the 2nd November 2011, the government campaign for national aid has resulted in 63.45 million USD; 50 million USD of this total has been donated by Saudi Arabia. More can be found at ReliefWeb.

2.4 Insurance Impacts

EQECAT has brought forward an insured loss estimate of around 100-200 million USD through their models which would also fit in reasonably well. AIR estimated insured losses between 55 million USD and 170 million USD. Other Turkish estimates believe that private insurers will only pay out around 20 million USD. The TCIP payment would most likely be around 31 million TRY (around 17.2 million USD).

An important tool to mitigate losses via insurance is available with the Turkish Catastrophe Insurance Pool (TCIP, www.tcip.gov.tr). It has been established after the 1999 Izmit earthquake by Decree Law No.587 "Decree Law Relating to Compulsory Earthquake Insurance" the same year and started being operational in 2001. It is a compulsory insurance for private residential buildings in municipalities and offered by 29 insurance companies in Turkey. As any insurance it redistributes losses in space and time and thus mitigates the regional and temporal impact, but also stipulates code compliancy for modern buildings.

The number of sold policies was at 2.43 million in 2001 (19% of the insurable buildings), fell after this but grew again constantly since 2003 with fewer policies in the past two years. The average national insurance penetration is around 20% with notable differences across the regions and provinces. For instance the TCIP 2009 annual report indicates a 32.5% penetration in the Marmara Region, but only 13.7 in the East Anatolian Region.

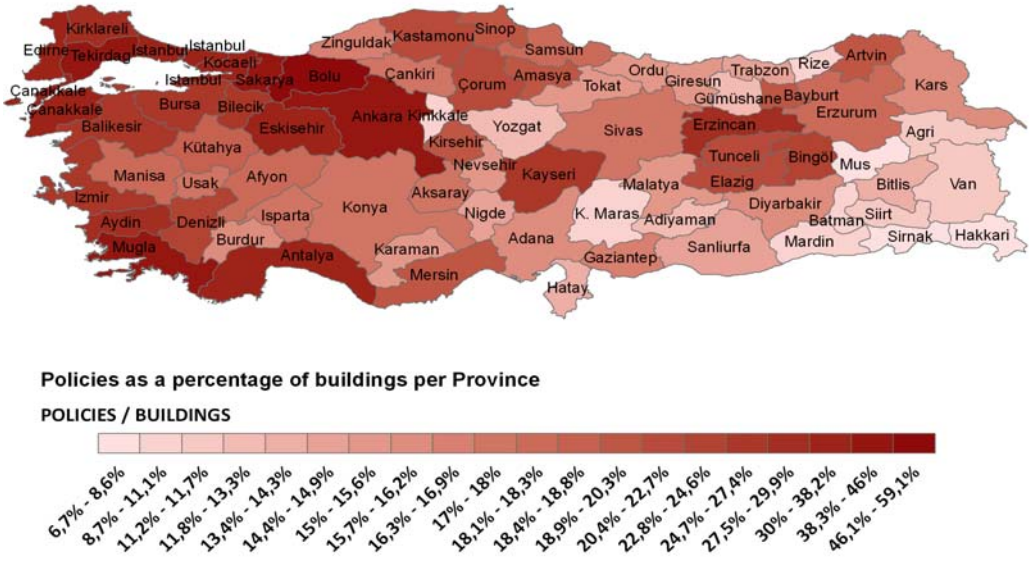

Figure 8: Policies as a percentage of buildings per province in Turkey (data from TCIP)

The latest data from the Turkish Insurance Compensation Pool showed that in Bitlis there are 28,919 houses/buildings, of which 4047 have insurance (around 14%). The premium each year is 411,433TRY (228,000 USD). For Van Province (Ercis and Van cities) which is much more affected by this quake, for the 64,081 buildings, 7312 of them have TCIP insurance for earthquakes, **equivalent to 11.4%** with a 814,670TRY (453,000 USD) premium. Based on the 814,670 TRY premium (there is approximately a 400 million TRY (222 million USD) exposure).

Hakkari which was also affected has 16,314 houses/buildings with a much lower takeout of 1399 buildings; only 8.6%, with 144,469 (80200 USD) TRY premium.

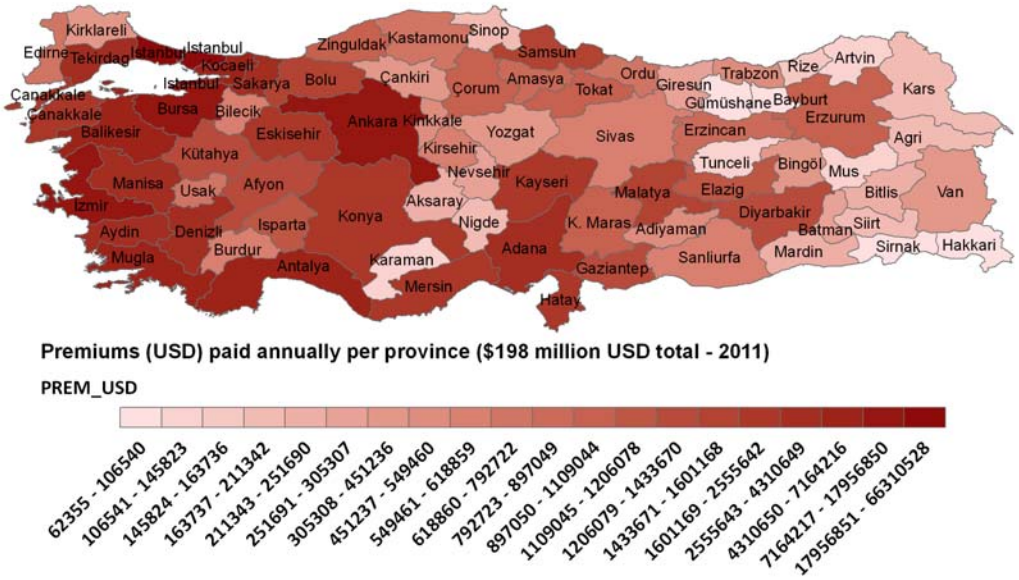

Figure 9: Premiums (USD) paid annually per province (data from TCIP)

In summary the TCIP insurance scheme does contribute significantly to loss mitigation, even in the Eastern Anatolian regions.

2.5 Fatalities, Injured and Hospital, Rescue Impacts

Shortly after the earthquake, several source parameters were provided by seismic network operators. Moment magnitudes were approximately equal, but epicentres differed by about 25 km between GFZ, EMSC, USGS and KOERI. No information on uncertainties was provided by the network operators. The USGS location was closest to the city of Van so that initial estimates by PAGER and WAPMERR generated fatality predictions that were an order of magnitude too high. KOERI put the epicentre 30 km North of Van and predicted fatalities with its ELER v3.1 loss estimation tool at between 700 and 1000 seems to very much be a realistic estimate at this point of body counting.

The current number of fatalities stands at 601, with more expected. Most people have died due to falling debris and building collapse. As of current statistics, 2309 buildings collapsed and 11387 buildings were severely damaged. To find and extricate survivors trapped in such structures as shown above in the building damage section, well trained urban search and rescue (USAR) teams are needed. Over 4400 search and rescue personnel were on hand including over 1000 within hours of the disaster occurring. But even with good equipment, rescue work can be very time consuming and dangerous where “solid structures” i.e. concrete slabs are present. Thus, the exact position of the trapped persons must be located to enable fast and direct access. 188 people were pulled from the wreckage alive.

Compared to the 1999 Izmit earthquake, the number of collapsed buildings and casualties was much lower. Therefore, no foreign USAR teams were formally invited by the Turkish government. Azerbaijan however has sent 140 SAR staff as part of their aid package. The Turkish Disaster and Emergency Management Presidency (AFAD) reported that 18 search dogs were sent to the region. Considering the challenges of the dense collapse structures, more search dog teams would have been useful for better search efforts. Training and equipment of the national teams has much improved in the last years, so much so that the search and rescue tasks could be handled by the national teams. As of 31st October 2011, the approach moved from search and rescue to recovery and reconstruction.

The following diagram shows the progression of the reported death and injury toll from this disaster as well as the number of medical personnel and SAR staff.

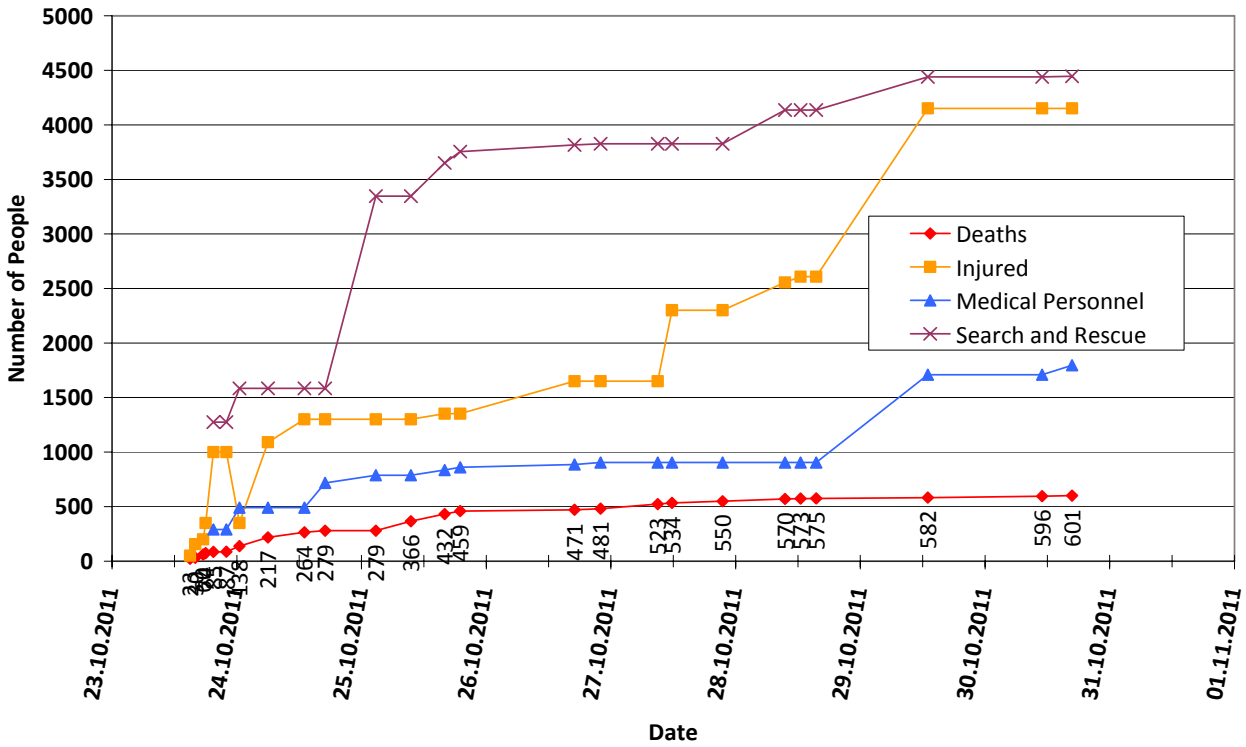

Figure 10: Deaths, Injured, Medical Personnel and Search and Rescue trends as collected from earthquake-report.com via AFAD

Hospital capacity is also an issue at play in this case. The hospital in Ercis was badly damaged in the earthquake according to reports from earthquake-report.com, with medical tents being deployed instead of using the hospital. With 179 hospital beds per 100,000 capita in Van Province as of 2007 (1851 total beds in the province) and over 4152 people injured, this puts a strain on the local medical situation given that people would have been inhabiting most of the beds when the earthquake hit. According to a disaggregation by ITU, they believe 95 of the deaths, 350 injured to have occurred in Van City, 169 deaths, 750 injured from Ercis, and 337 deaths, 3052 injured from other locations. This still needs to be confirmed.

The hospitals in the Van Province did not receive major damage according to a report from KOERI.

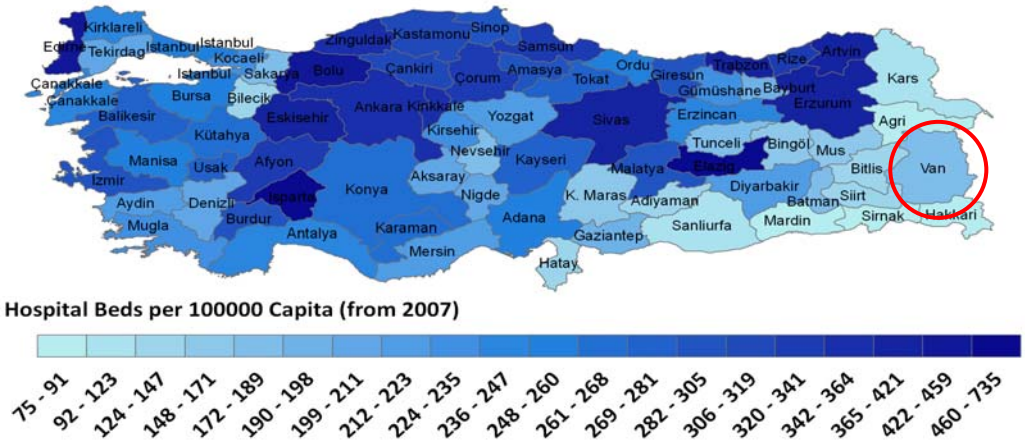

Figure 11: Number of hospital beds per 100000 capita (from 2007) – data from TURKSTAT

Nevertheless, search and rescue activities started very quickly and also the medical care situation was set up very quickly and effectively by the Turkish Red Crescent Society and other Turkish Relief Organisations. Apart from moving patients (already in-patients at the time of the earthquake) to hospitals in Ankara and Erzurum, eleven mobile hospitals were installed 3 days after the earthquake, and blood donations were provided from hospitals in neighbouring provinces.

30 field tents were set up for public services and psychosocial trauma support on the 4th day after the earthquake, however psychosocial workers were also there beforehand on the previous days. According to the Turkish Red Crescent Society, psychologists and social service specialists were assigned to the disaster affected regions to provide psycho social support for the victims who lost their beloved ones and for the victims who have experienced post-traumatic stress disorder. Plans for children and women are also being developed, and trained community leaders such as teachers and religious leaders were integrated in psycho-social support.

"Religious officers and leaders cooperated with the Turkish Red Crescent personnel on setting up prayer tents and placing burial rituals and a religious ritual for those, who lost their lives as a result of the earthquake" (TRCS, 2011).

2.6 Shelter and Homelessness

The TCRS has stated that as of 31st October 2011, they are providing shelter for 147,470 victims. Through analysis below, CEDIM believes there could be around 183,000 people seeking shelter.

It was stated yesterday by the Turkish government (Atalay), that 16,500 container houses are going to be built as part of the shelter phase before permanent reconstruction occurs. Ercis district and city needs 9000 and Van City requires 2500. The remaining villages are going to need 5000 container houses. The containers generally hold 4-8 people. The Mevlana container houses are generally made of steel/metal and have 2 rooms, bath, toilet and kitchen facilities. They are also connected to all facilities (power, water and waste) and are insulated. 16,500 houses indicates that between 65,000 and 130,000 could be long-term homeless.

Many relief items (including approx. 80,000 pieces of warm clothing) had been distributed in the first three days after the earthquake to the people by authorities, organizations and charitable people. However, because the number seeking shelter is around 148,000, these were possibly not sufficient for the number of people that were seeking support and shelter, as not only the people whose houses have been demolished were out of their houses, but also the majority of the people at the affected area passed their day and night on the streets next to their houses.

The number of shelter seeking population may be as high as 300,000 people (see estimation of homeless people below). Especially in the first days after the earthquake the shortage of tents, coupled with the approaching winter worsened the situation. A full report on the weather conditions in Eastern Turkey has been compiled by Bernhard Muehr at KIT (http://www.wettergefahren-fruehwarnung.de/). International aid was accepted on the 27th October 2011. International assistance was only wanted in the form of tents, blankets, prefab houses and containers and/or money.

The figure below shows the increasing number of tents and blankets, and the same pattern can be seen for other relief items not shown in the diagram: sleeping bags, catalytic ovens, 65 prefab houses and the 2300 prefab Mevlana container houses.

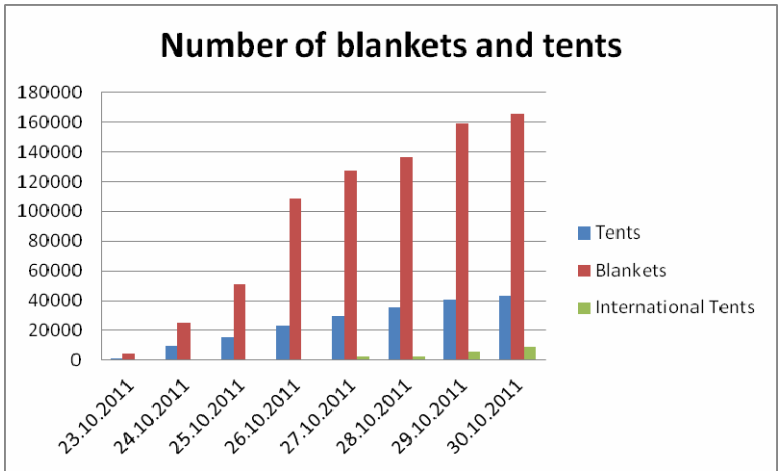

Figure 12: Number of blankets, tents and international-provided tents for the 8 days after the earthquake.

Emergency food (food parcels, baby food) came in very quickly, but did not reach all regions immediately. Several mobile kitchens and bakeries were set up and ingredients for typical regional food were dispatched. From the third day after the earthquake it was reported that 3 meals a day were served in the shelters.

Homeless estimation

In the Turkish reconnaissance, a slightly different system to the usual "Miyamoto International" red, yellow, green tag system has been reported. Buildings beyond repair (red and some orange) were counted, as well as buildings damaged or slightly damaged (some orange and green tagged).

As of 2nd November 2011, 14,156 buildings containing an estimated 16,500 households are uninhabitable. For the estimation of homeless people we assumed that all people from severely damaged/destroyed households became homeless, and with an average household size of 7.6 people in Van province we assume that at least 125,400 people became homeless due to the earthquake. In rural conditions, the average household can be up to 10 people in some parts of Van Province and is generally lower than 7.6 in the urban centres.

The estimation of homeless people due to damaged but habitable buildings is more difficult, as there are more factors influencing this number:-

- fear of aftershocks, further collapse
- the interruption of gas, water and energy supplies
- already displaced populations seeking aid
- people seeking aid who are not earthquake-affected.
- Cold weather conditions

From historic experience it is know that approximately half of the inhabitants of damaged buildings are homeless for at least for a short time.

However, if we take into account the factors above and assume 100% of damaged households seek shelter, then an upper bound to the homeless would move to 300,000. This is ignoring the possible unofficial population of Van being higher than the official figures in ABPRS (possibly up to 45% higher). It must be stressed that this methodology is very dependent on the current reports of households in collapsed and damaged buildings.

Table 3: Homeless as calculated from uninhabitable buildings and damaged buildings.

(no. of people)	Homeless (uninhabitable buildings)	Homeless (damaged buildings)	Total Homeless
Estimation lower bound (destroyed)	125,400	0	**125,400**
Estimation (historic average) (destroyed + 0.33x damaged)	125,400	58,436	**183,836**
Estimation higher bound (destroyed + 1x damaged)	125,400	177,079	**302,479**

For the people seeking shelter when their houses are not collapsed, dependent on the extent and sort of lifeline disruption, people have to weigh the advantages and disadvantages of leaving or staying. An outage of the sewage system may be deemed liveable if adequate water supply remains to ensure hygiene levels or the outage of electric power mainly affects services for storing and preparing food.

In Van City the natural gas system, water supply system, the power and communication systems were all affected, however were reported to be functional again within 24 hours after the earthquake (AFAD). Thus, it is likely that given the harsh climate more people in habitable buildings (non-damaged structures and utility services) remained. Yet, other factors such as anxiety of aftershocks may have led these persons to evacuate.

Furthermore, the number of dislocated persons should be distinguished from the actual number of persons who are likely to seek shelter. People are not equally vulnerable to disasters and not all of the displaced will be dependent on public emergency shelter assistance. For example in Van, the large percentage of children in the population (40% of the population is 14 years and younger) may have been a decisive factor for their parents to seek shelter for their families.

Figure 13: DLR – Center for Satellite Based Crisis Information – Tent City in Ercis Before (left) and After (right) (DLR, 2011)

One important research question to improve the assessment of gaps and needs for public shelter following disasters is to identify patterns of vulnerability and inequality in homeless persons seeking shelter. Surveying 18 key studies in post-earthquake shelter 11 factors were reduced in determining the evacuation behavior as seen below.

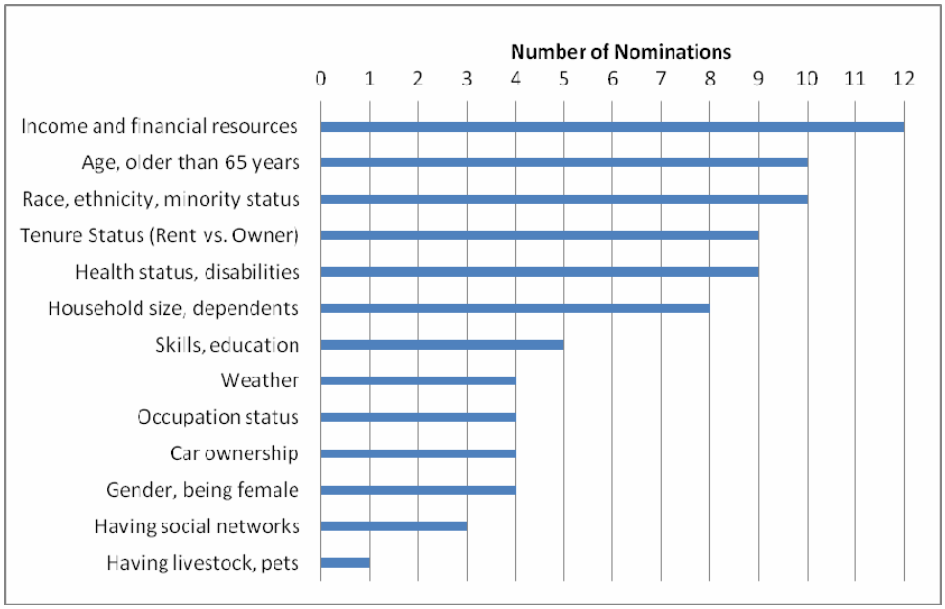

Figure 14: Number of nominations found for indicators in the 18 studies surveyed (Khazai et al., 2011)

2.7 Education, Cultural and Religious impacts

The ministry of education announced (24.10.2011) many schools in the area collapsed or have been seriously damaged. As no children were at school on Sunday, apart possibly those attending boarding schools a particularly high death toll may have been avoided. There have been reports however of teachers and students being killed. School collapses are a notorious problem, as seen in the 1999 Izmit earthquake and more recently in the 2003 Bingöl event.

Collapses of schools remains a critical issue in Turkish earthquakes and requires full attention of government agencies in the future. Had the event occurred on Monday morning instead of Sunday afternoon an additional drama were likely.

Schools and Universities will remain closed until the 14th November. Prefab housing will be used in placed of unsafe/uninhabitable classrooms in many cases.

Reports of three mosques being damaged in Ercis have occurred. Minaret damage was widespread through the villages, as well as two minarets being collapsed in Van, Mus and Ercis. In addition, the museum and its collection was damaged in Van City.The Culture and Tourism Minister Ertugrul Gunay stated that there were cracks in glass enclosures and objects with fractures. There were also some cracks in the structure, however not to any serious extent.

3 Comparisons of the Van Earthquake with recent historic East Turkish Earthquakes

3.1 Comparison Loss Tables from Historic Earthquakes

The October 23, 2011 earthquake in Van can be seen to have some comparisons with other previous recent Turkish Earthquakes (see tables below). Some good additional work has been produced by AFAD, METU, earthquake-report.com and KOERI in terms of some of the other damaging earthquakes to have hit the region.

Table 4: Selected CATDAT Damaging Earthquakes Database Median Data – Provinces affected and hypocentral information

Date, UTC Time	Magnitude, Depth	Main Cities Affected	Primary Province	Other Impacted Provinces/Countries
23.10.2011, 10:41	**7.2Mw, 5-20km**	**Van, Ercis**	**Van**	**Hakkari, Mus, Bitlis**
19.08.1966, 12:22	6.8Mw, 17km	Varto	Mus	Bingol, Erzerum
22.05.1971, 16:44	6.7Ms, 4km	Bingol	Bingol	Elazig
06.09.1975, 09:20	6.7Ms, 39km	Lice	Diyarbakir	Bingol, Elazig
24.11.1976, 12:22	7Mw, 9km	Muradiye	Van	Agri, Hakkari, Iran, Armenia
30.10.1983, 04:12	6.6Mw, 16km	Narman-Horasan	Erzurum	Kars, Agri, Artvin
13.03.1992, 17:18	6.6Mw, 26km	Erzincan	Erzincan	Gumushane, Bayburt, Tunceli
01.05.2003, 00:27	6.3Mw, 14km	Bingol	Bingol	Tunceli, Elazig, Diyarkabir

Table 5: Selected CATDAT Damaging Earthquakes Database Median Data –Health and Building Aspects

YEAR	Event	Deaths	Injured	Homeless	Affected	Buildings Destroyed/ Uninhabitable	Buildings Damaged	Tents**	Temporary Housing**
2011	**Van-Ercis**	**601***	**4201***	**150000***	**700000+***	**14156***	**17923***	**52000***	**16500**
1966	Varto	2517	1420	108000	217000	20007	n/a	n/a	11140
1971	Bingol	995	1900	45000	88665	5617	6726	9035	tbc
1975	Lice	2385	4500	5000++	53372	8149	8453	4144	5805
1976	Muradiye	3840	15000	51000	216000	9552	10175	5000	10000
1983	Narman-Horasan	1400	1137	25000	130000	3241	7092	5473	3000+
1992	Erzincan	652	3850	95000	322000	4783	13385	27250	16000
2003	Bingöl	177	530	45000	245000	5367	12073	14000	tbc

***data still being updated – refer to earthquake-report.com for latest updates,** size of temporary housing and tents differs, and also includes temporary housing and prefab housing in many cases built.**

3.2 Loss analysis diagrams

A “loss score” for each of the 8 earthquakes is derived based on the weighted sum of several indicators of disaster impact in terms of physical damage (destroyed buildings) and human loss (death, injuries and homeless) and is shown in the Figure 4. A score of 1 shows the highest disaster impact in terms of the indicators used and a score of 0 the least. Using the latest information about loss figures from the 2011 Van-Ercis event, it can be seen that this event ranks as the third most damaging earthquake when compared with similar events in eastern Turkey in the past 50 years.

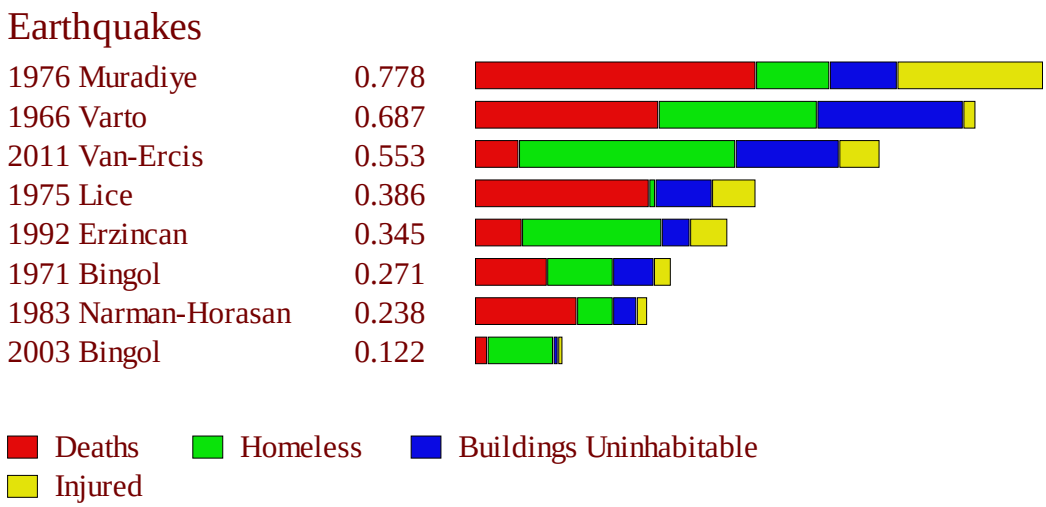

Figure 15: Loss score for historic earthquakes in eastern Turkey

When an earthquake strikes, the physical impacts of the event are aggravated by the socio-economic characteristics of the threatened populations. The Human Development Index (HDI) is used as a composite statistic and initial proxy for capturing the coping capacities and vulnerabilities of the provinces affected by the historic events. HDI is a comparative measure of life expectancy, literacy, education and standards of living for countries worldwide. The UNDP Disaster Risk Index builds (DRI) on HDI, and uses HDI as a first step for measuring human vulnerability and coping capacity. HDI has the added advantage that is commonly used a “headline indicator” with which decision makers are already very familiar. HDI values were compiled for each of the provinces and trended in time from 1966 to 2011 (Daniell, 2011). The HDI values for the primary province and secondary provinces affected by each earthquake in the year that the earthquake occurred were summed up using earthquake intensities in each of the provinces as an influence weight. These percentages came from the relative impact of the disaster in each province. i.e. if around 75% of the damage and fatalities occurred in Province 1, and 25% in Province 2, a rating of 0.75 was given to Province 1 and 0.25 given to Province 2.

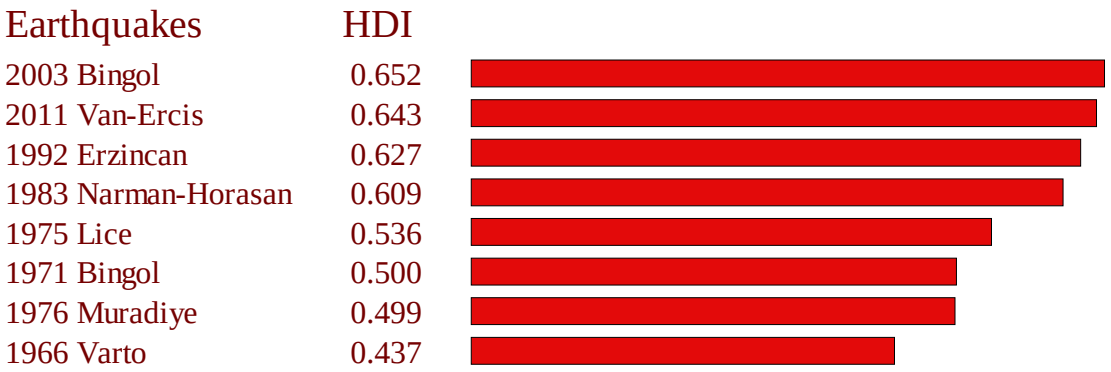

Figure 16: Ranking of the HDI score in each of the provinces affected by the historic earthquakes in eastern Turkey similar to the 2011 event

Figure 17 shows a scatterplot with the Earthquake Loss Score shown on the vertical axis and HDI scores on the horizontal axis. The earthquakes in the bottom right have the least physical impact corresponding to higher capacities in the affected community according to the HDI values at the time of the earthquake occurrence, while the earthquakes in the upper left have the highest physical impacts corresponding with relatively lower capacities in the affected communities. It can be seen that the 2011 event has an impact greater than all but the 1966 Varto and 1976 Muradiye of the Eastern Turkey earthquakes in the last 50 years.

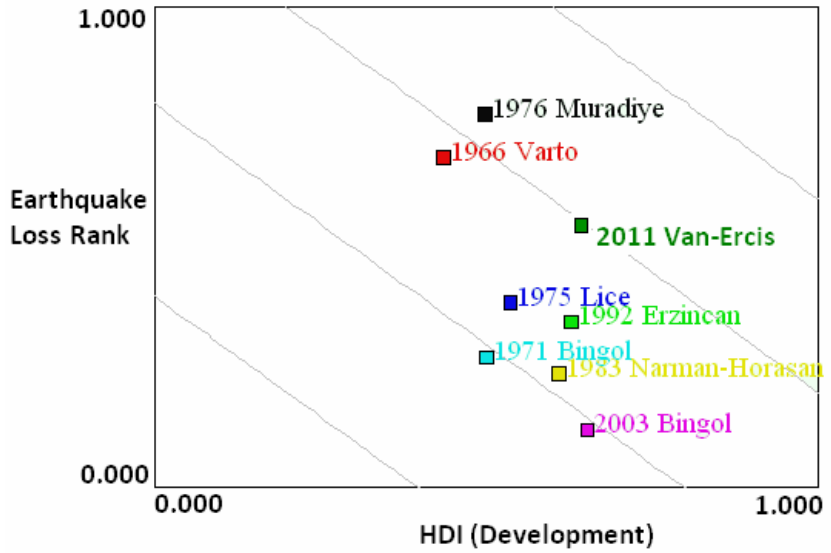

Figure 17: Scatterplot of Earthquake Physical Loss vs. HDI score for each of the provinces affected by the historic earthquakes in eastern Turkey similar to the 2011 event

4 Social Vulnerability, Reconstruction and Long-term impacts for livelihood Issues

"Reconstruction can be an opportunity to address longer-term livelihood vulnerability within poor communities and households, and to empower the most vulnerable" (Practical Action, 2011). The future trajectory and velocity of reconstruction after the Van-Ercis earthquake can be glimpsed from trends in some similar events in the past in eastern Turkey. Looking at the reconstruction policy of 8 eastern Turkey earthquakes, several lessons can be drawn which are listed below. Particularly, attention should be paid to events that occurred during the late fall/early winter where the reconstruction policy was to resettle the dislocated people or to accelerate the reconstruction policy by providing prefabricated homes in order to avoid homelessness during the harsh winter conditions.

Resettlement: Most displaced persons do not want to relocate and wanted to remain close to their original homes. Examining these 8 events, a typical trend is that existing settlements were preferred and new houses were built generally on the same location. After the 1983 Narman-Horasan earthquake villagers were relocated to nearby towns not damaged by the earthquake for the cold winter until the reconstruction of new villages could begin in the spring. This decision was taken so that people could benefit from the land and services in the town, sewage, roads, electricity, schools, mosques, etc., and because of the available empty housing in the town centers or within the immediate vicinity. Relocation was carried out with negotiations with village leaders, however, the attitude of the villagers was divided. As it turns out In the 1983 Narman-Horasan earthquake temporary shelters built by local means were put up as close as possible to the original houses of victims or any land belonging to the families (e.g., victim's gardens, village commons, agricultural land and any other convenient open spaces). 60% of villagers wanted to remain close to their original land and only 15% wanted government relocation. The remaining 25% either wanted independent local resettlement or settlement in other cities.

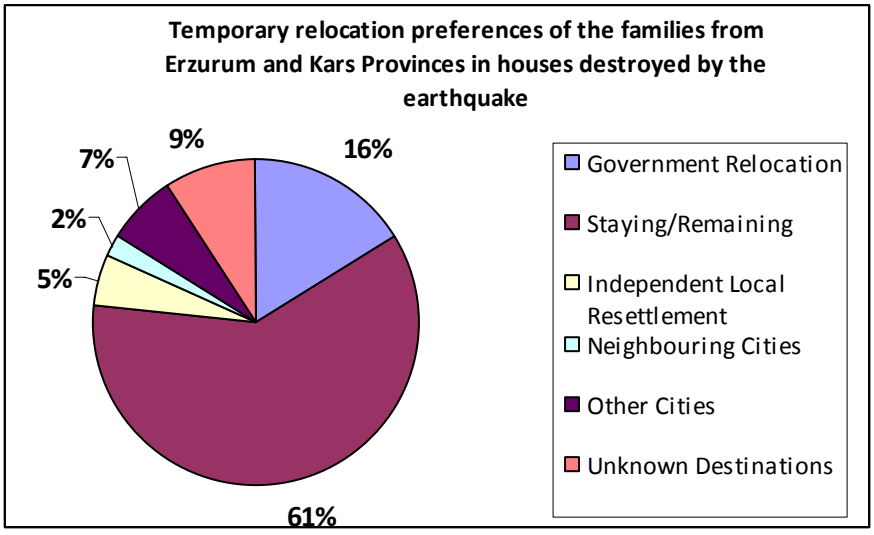

Figure 18: Temporary relocation preferences of the families from Erzurum and Kars Provinces in houses destroyed by the 1983 earthquake

Similarly, the decision to relocate Lice after the 1975 earthquake 2 km south (due to the risk of rockfalls from the old site) proved to be very unpopular with its residents, and was made without their participation. The town of Lice was planned for an eventual population of 20,000 (twice the

pre-earthquake total). The new site did not possess climatic shelter from the hillside, has taken valuable agricultural land out of use and was initially without water supply. The new choice of flat site may have been influenced by requirements of prefab houses. The Government policy of relocating families to other parts of Turkey after the 1976 Muradiye earthquake was interpreted by some critics as being politically motivated. It appears that few families took up the offer which consisted of removal costs, provision of new land and initial grant of livestock.

Accelerated Reconstruction: In the past reconstruction programs have revealed an emphasis on houses as the physical capital rather than housing as the arena of social and economic life. After the 1983 Narman-Horasan earthquake prefab houses were imported from Ankara after people were placed in tents and empty buildings in and around the town centers. A considerable stock of prefab housing existed in Turkey as no major event had occurred in Turkey since the 1976 Van event. The capacity of the Turkish Government to build prefab houses so rapidly (54 days, 1568 units) was an achievement but conversely the houses had many deficiencies: climatic and cultural unsuitability, no provision for animals, they were too small and they did little to generate work. Essentially, they reflected an urban middle class set of values in sharp contrast to rural values and priorities. As in Lice in 1975, the Government adopted a policy to provide prefabricated housing, with plans to build 10,000 units. Prefab Housing construction started 4 months later after the 1976 Muradiye earthquake as building work was not possible during the winter months. No attempt was made to provide resources for training local builders in earthquake resistant construction of traditional buildings. As Turkey has not had a major earthquake like Izmit 1999 in the last decade a considerable stock of prefab housing may exist, however past events show that accelerating the reconstruction process to provide prefabricated housing may backfire if these ignore climatic, material and cultural conditions.

Rebuilding: The Van-Ercis earthquake like other historic earthquakes in the region is a test of poor quality of local structures and local building methods. An improvement in the local building materials and methods of construction both for repairs and for new buildings is more desirable than the relocation of the villages and towns (Training and education programs). The great damage was caused by factors frequently cited in earthquake literature: inadequate materials, improper methods of construction, lack of repair of previous damage and inadequate foundations. Improvement in the local building materials and methods of construction both for repairs and for new buildings is more desirable than the relocation of the villages and towns. In these past events no efforts were made to train people in construction methods to make permanent houses earthquake resistant later. Without enough understanding of locally adaptable earthquake resistant construction techniques, financial incentives and education in new skills, the future vulnerability of the area will remain high.

Migration, Trade and Cultural Issues: Long-term physical recovery of the communities in the area is inevitably linked to migration. In May 1984 after the the Narman-Horasan earthquake the Libyan Government announced that 150,000 workers from Turkey would be employed. Among the consequences of such a decision are that the skilled construction workers may go abroad and the local male labour force will decrease. This should be balanced against the fact that the rate of the migration to bigger cities in the West is already very high and may increase in the future. The aspiration to live in bigger cities is higher among young people. Van Province has a long history

marked by many different cultural influences being on the Armenia, Iran, Syria, Azerbaijan border with a long history of Kurdish influence, which will not be discussed further in this report.

A societal driver influencing the reconstruction activities is the growing urbanization and the in-migration from the rural regions in the region. Even though agriculture (livestock and farming) is still the primary source of income for the majority of rural people in this region, civil war (1984-1999) and economic crisis have resulted in the migration of a significant number of people from rural areas to urban centers. The war in Iraq and rapid increase in trade with Iran also saw rapid new development and growth of border cities such as Van. In 2008, trade between Turkey and Iran was at 10 billion USD, increasing tenfold from the year 2000 (Pupkin, 2010). Preparing a rural-urban migration policy, development of a risk-sensitive city master plan and introduction of urban redevelopment projects will be some important next elements in the reconstruction planning of this event.

Another issue in the border region that sets the wider context for the relief and reconstruction efforts is the fact that Turkey hosts at the moment appr. 7.700 of Syrian refugees in Hatay province in the South of Van. On October 30th, seven days after the earthquake, the AFAD reported that they will "continue assisting the Syrian citizens without interruption", and "that relevant institutions and organizations are continuing to provide shelter, food, health, security, social activities, education, religious services, interpretation and other services in the temporary shelters."

Buying Livestock: Compared with the previous post-disaster situation in Eastern Turkey, there seemed to be less demand on space for livestock and the storage of hay after the 1983 Narman-Horasan earthquake since the Government Meat Cooperation and private entrepreneurs bought up the animals. *Buying animals or agricultural land will have the top priority and in reality minimum household investments actually goes into improving quality of construction***.**

A significant number of livestock were killed in this earthquake. Many stables and livestock quarters in the recent earthquake collapsed under the weight of concrete roofs.

Table 6: Selected CATDAT Damaging Earthquakes Database Median Data –Livestock Losses

YEAR	Event	Cattle Dead	Sheep/Goats Dead
2011	**Van-Ercis**	**Unknown**	**unknown**
1983	Narman-Horasan	7483	22864
1992	Erzincan	11000	
2003	Bingöl	288+	1374+

5 Conclusion

The CEDIM Forensic Earthquake Analysis Group has presented their 4th report on the 2011 Van earthquake which struck on the 23rd October 2011 with a Mw7.1-7.3 and a depth of around 10km. The impact of this earthquake has not been seen in this region of Eastern Turkey for at least the last 35 years (Varto 1966 and Muradiye, 1976). The economic and casualty impacts are relatively low considering the size of the earthquake and ground motion by world standards. However, shelter and building damage numbers are high and have influenced the large nature of the disaster.

In earthquakes of this size, the decisions made for reconstruction are very important and are detailed above as compared to past earthquakes. The impact of the number of livestock killed by concrete roofs, and also the destruction of rural housing will have major consequences for the rural sector. The following is a summary of some of the current conditions and findings that have been made in this report:-

- The current death toll of 601 and injury toll of 4152 was caused primarily from building collapses in urban centers via pancake collapse and soft storey forms. Falling debris also caused casualties. The efficient response of the Turkish government is to be commended in the medical and SAR field. There were only a few fatalities in rural areas as most buildings were one-storey with tin roofs.
- Around 150,000 to 180,000 people are expected to be homeless as a result of this earthquake, with the around 14,000 uninhabitable buildings. Provisions for temporary housing are that 16,500 containers will be setup – 9000 in Ercis, 5000 in villages and 2500 in Van City. The cold winter weather will play a major role in the choices of where the occupants shelter.
- The GDP of the Van Province is approximately 3.3 billion USD. Expected losses are around 15-66% of the provincial GDP at around 500 million to 2.2 billion USD. The total insurance loss is expected to be around 40-100 million USD, with the contention being to the lower bound of the range.
- 14,156 buildings either collapsed or were severely damaged, and 17,923 buildings were moderately or slightly damaged at this point in the preliminary assessment by ground teams, with many older buildings not withstanding the number of cycles due to the long duration of the earthquake (40 seconds as compared to a usual 25 seconds for such an earthquake). Modern construction on the other hand fared quite well.
- Rapid growth has occurred in Van and Ercis over the last 25 years with intensive construction shown. With the median age of people being less than 20 years old in Van Province, this also has major and complex issues for the recovery of the area.
- Businesses are beginning to return to normal in Van City, and schools and universities will hopefully reopen on the 14th November.
- Many favourable conditions occurred which reduced fatalities including that the time of event was a Sunday afternoon, the epicenter was not closer to Van but in between Ercis and Van, and also the long duration, slow energy release.

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