The CEDIM Forensic Earthquake Analysis Group and the test case of the 2011 Van earthquakes

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SUMMARY:

The Center for Disaster Management and Risk Reduction Technology (CEDIM, www.cedim.de) has embarked on a new style of addressing disasters, known as Forensic Disaster Analysis. It combines the development of a comprehensive understanding of disasters with real-time analysis. Time-critical comprehensive analysis includes the impact (seismology, socio-economic losses, aid and shelter), comparisons with recent historic events, social vulnerability, reconstruction and long-term impacts on livelihood issues.

The M7.2 Van Earthquake (Eastern Turkey) of 23 October 2011 served as a test case for the aforementioned forensic approach. Our team consisted of two seismologists, three engineers, a social scientist, an economist, an earthquake reporter and a meteorologist. Four reports were produced: one immediately after the event on the situation (24.10); a situation up-date (25.10); one addressing shelter issues, in comparison to previous Eastern Turkish Earthquakes (26.10); and a comprehensive overview report (02.11).

Keywords: CEDIM, Forensic Disaster Analysis, Van Earthquake

1. INTRODUCTION

The Center for Disaster Management and Risk Reduction Technology (CEDIM, www.cedim.de) embarked on a new style of addressing disasters, known as Forensic Disaster Analysis. The notion has been coined by the Integrated Research on Disaster Risk initiative (IRDR, www.irdrinternational.org/) launched by the International Council for Science (ICSU) in 2010. It combines the development of a comprehensive understanding of disasters with real-time analysis. Comprehensive analysis includes the impact (seismology, socio-economic losses, aid and shelter), comparisons with recent historic events, social vulnerability, reconstruction and long-term impacts on livelihood issues. The methodology undertaken by CEDIM differs from the FORIN methodology, as the time-critical component of the analysis focusses on near real-time conclusions where information may be sometimes scarce or unclear.

Time-criticality is important given the initial hypotheses (with little information after the first day) on loss evolution, and implications can be tested in the following days; this process significantly speeds up our understanding of earthquakes within their respective socio-economic contexts. For example, issues relevant to reconstruction can be identified at an early stage, given a comparison with previous earthquake experience of the region. During this critical window, media can also be fed with science-based information that can help promote mitigation and preparedness measures. Additionally, user interest by emergency services, the tourism industry, economic cooperation agencies and relief agencies is high at this initial stage.

2. THE CEDIM FORENSIC DISASTER APPROACH

The goal of the CEDIM Forensic Disaster Approach is to understand how natural hazards become disasters or do not become disasters. This requires event-based in-depth analysis of natural disasters and the related complex interactions and cascading effects in and between the natural, social, economic and infrastructure systems. The dissemination and communication of such information is also extremely important, as it must be easy to understand for government officials and stakeholders, yet still science-based.

2.1. What Tools are required?

Many components are required in order to undertake a holistic forensic disaster analysis. A wide spectrum of expertise is also required as well as the interactions between different components such as weather impacts in the region on shelter following an earthquake. It can be seen that an interdisciplinary team of scientists is essential for such analysis, which is one of the strengths of CEDIM, combining Karlsruhe Institute for Technology and GeoForschungszentrum Potsdam research groups in meteorology, hydrology, economics, social science, social media, case-based reasoning, geophysics and seismology, civil engineering and natural earth system disaster science.

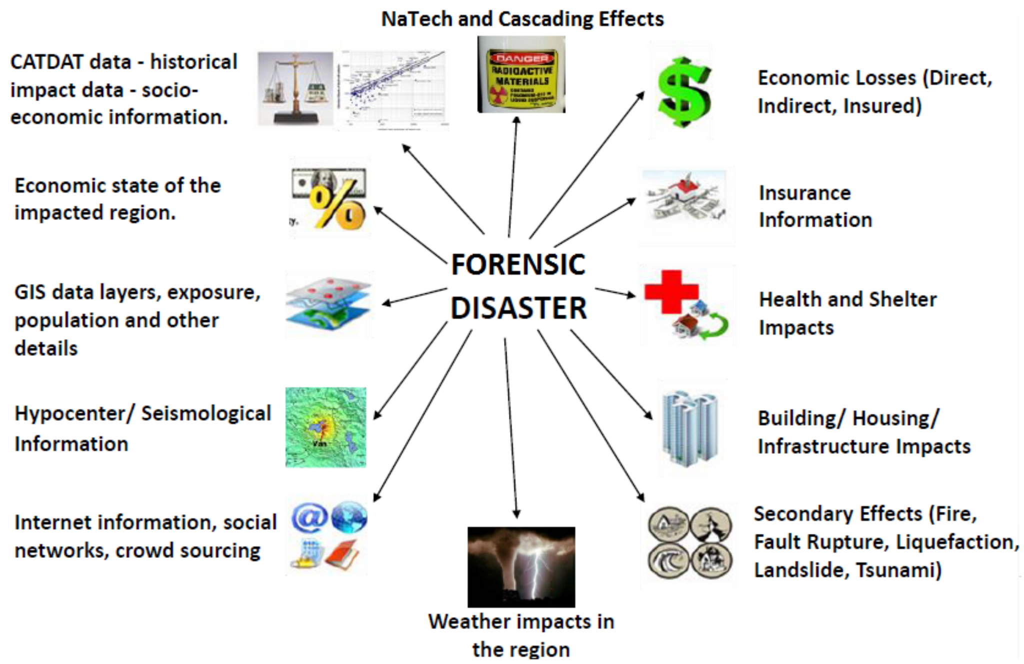

Figure 2.1. The key components to be discovered within the near real-time from a disaster

The forensic approach requires (a) availability and use of global multi-level databases (e.g. CATDAT) regarding previous earthquake losses, socio-economic parameters, building stock information etc.; (b) leveraging platforms such as Earthquake-report.com (Daniell and Vervaeck, 2012b), EERI Virtual Clearinghouse, Relief-web, amongst others where information is organized; and (c) modern crowd sourcing with rapid information from the field. With this, a multi-disciplinary team of scientists from seismology, earthquake engineering, social sciences and economics can analyse and synthesize these data and generate a portrait of the disaster, with the aim of revealing the main characteristics and causes of loss, the conditions and role of relief operations, the short and long-term impact on a regional and national scale, as well as boundary conditions and hints on the reconstruction process.

There is also a need to interact with the people at the location of the event, including disaster response groups, experts and engineers, in order to gain credible information and insights into the ground conditions. This data is essential as although information exchange is becoming faster and data is becoming easier to obtain, there is no substitute for ground level experiences and observations. Thus, further work on networking will be undertaken for future disasters.

2.2. The targets, questions and methods to be addressed and undertaken from Forensic Disaster Analysis

The forensic disaster analysis will be applied to hydrological (floods, tidal waves etc.), meteorological (storms, hail, heatwaves etc.) and geophysical (earthquake, tsunami, volcanic eruptions) events where it is deemed that there is a catastrophic element to the socio-economic systems impacted upon by the disaster. This pertains to the concept of risk and not hazard. A good example is the M8.6 earthquake of Sumatra in April 2012. This quake had a high hazard but very low risk and therefore would not be suitable for analysis.

Criteria to invoke a forensic analysis are different for each disaster type (hydrological, meteorological, geophysical) given different lead-up times, historic impacts and return periods. There will always be a component of team availability and unexpected disasters which may invoke the forensic analysis, but criteria based on historic loss impacts, such as that of the CATDAT Dark Red rating (Daniell et al., 2012a) for earthquakes based on absolute and relative socio-economic impacts from the CATDAT Damaging Disaster Databases (Daniell et al., 2011b), could be used as the base criteria for invoking the CEDIM Forensic Disaster Analysis team.

There are a few targets to be addressed from such an analysis, including:-

- Assessing losses in a structured and strategic way
- Monitoring the course of disasters and identifying options for loss, recovery, loss reduction.
- Identification of interactions of disaster-determining phenomena and the socio-economic context of loss.

There are also a number of specific questions that need to be addressed as part of an analysis:-

- What are critical factors that contribute to loss of life and damage/failure of infrastructure, and impact the economy, in large-scale disasters?
- What are the critical interactions between hazard, socio-economic systems and technological systems?
- What were the protective measures and to what extent (including the residual risk of such systems) did they work?
- Can we predict patterns of losses and socio-economic implications for future extreme events from simple parameters: hazard parameters, historical evidence, socio-economic conditions?
- Can we predict implications for reconstruction from simple parameters?
- To what extent can remote sensing be utilised in a useful way within the hours after a disaster?

These targets and questions will be examined using a few different methods, including near real-time assessment and analysis of losses. Rapid disaster loss estimation has grown significantly in the past few years due to the need for aid groups, governments, media and the insurance industry to know the impacts of a disaster. Additional methodologies will include work on comprehensive analysis of buildings, infrastructure and socio-economics, and analysis of protective systems, including building codes, regulation and insurance.

Much work has been undertaken at CEDIM in the past few years looking at socio-economic impacts of disasters (Kreibich et al., 2010; Kunz et al., 2011; Daniell et al., 2011c) as well as socio-economic indicator and vulnerability indices (Hiete et al., 2009; Daniell et al., 2010; Khazai et al., 2010; Daniell, 2011a). In addition, work on analysis of shelter issues using historical background, comparisons of losses with previous and comparable events (CATDAT etc.) and analysis of current and past reconstruction practice will be undertaken within the context of applicable forensic disaster analyses.

2.3. First Test Cases and Exercises

A number of disasters have been approached in a forensic way by CEDIM before 2011, including work on the Haiti 2010 earthquake (Daniell et al., 2011e), the Elbe 2002 floods (Thieken et al., 2007) and hailstorms (Kunz et al., 2011). Since the start of 2011, a more concerted effort has been made towards forensic disaster analysis work, including a partnership with www.earthquake-report.com providing in-depth socio-economic information from each damaging earthquake worldwide. The cases and exercises in 2011 have been included in the following table.

Table 2.1. Test Cases and Exercises within CEDIM groups in 2011

Date (2011)	Topic	Tasks Undertaken
January	River Floods in Germany	Identifying the interfaces between the different disciplines in the Forensic Disaster Analysis Team
February	Christchurch 2011 earthquake	Economic loss estimation in near real-time and detailed analysis for RBNZ with regard to disaggregation losses and economic impacts (RBNZ, 2011)
March	Tohoku earthquake	Complex forensic disaster analyses in near real-time including loss estimates and statistics on the municipality level for the capital returns, consultancy and insurance sectors. (Daniell et al., 2011d; Khazai et al., 2011) Daily weather forecast for the Tohoku region (direction and velocity of a possible radioactive cloud). Earthquake slip distribution and seismological work.
May	Grimsvötn Volcanic Eruption	High resolution weather forecast maps for the Icelandic area within a few hours.
October	Earthquake in the Van/Ercis Region (Turkey)	Complex forensic disaster analysis in near real-time (4 reports as shown in this paper) Climatological overview of the Van/Ercis region

3. THE TEST CASE OF THE VAN EARTHQUAKE, TURKEY

The M7.2 Van Earthquake (Eastern Turkey) of 23 October 2011 served as a test case for the aforementioned forensic approach. A timeline of the disaster and a summary of the key outputs will be presented. The time-criticality of such analysis should not be understated, and the methodology uses existing data to formulate hypotheses and key questions/problems that need to be solved within the timescale of hours.

3.1. The Initial Process to produce the first report

For the 23rd October 2011 Van earthquake event, alerts of major earthquake activity came first from Earthquake-report.com, including tweets, increase in logins from Turkey and data from KOERI, SARBIS, EMSC and USGS. The full process leading to the initial report can be seen in the diagram below. There was much difference in initial hypocenter information from different agencies, making losses difficult to calculate. This type of problem is common and given that the hypocenter location is the most significant parameter for loss information, the estimates from ELER, PAGER, WAPMERR, CATDAT-EQLIPSE showed a large range of losses.

After the email alert was sent, given the level of the disaster an initial report was compiled by F. Wenzel and checked overnight by J. Daniell and was published on the following morning. Within hours of the process being instigated, other members of CEDIM were emailed to check their availability for input. The first report consisted of the event situation, some extra information on the seismology of the area, rapid earthquake loss estimates from various sources and the socio-economic status of the region, summarizing and using Earthquake-report.com collected data.

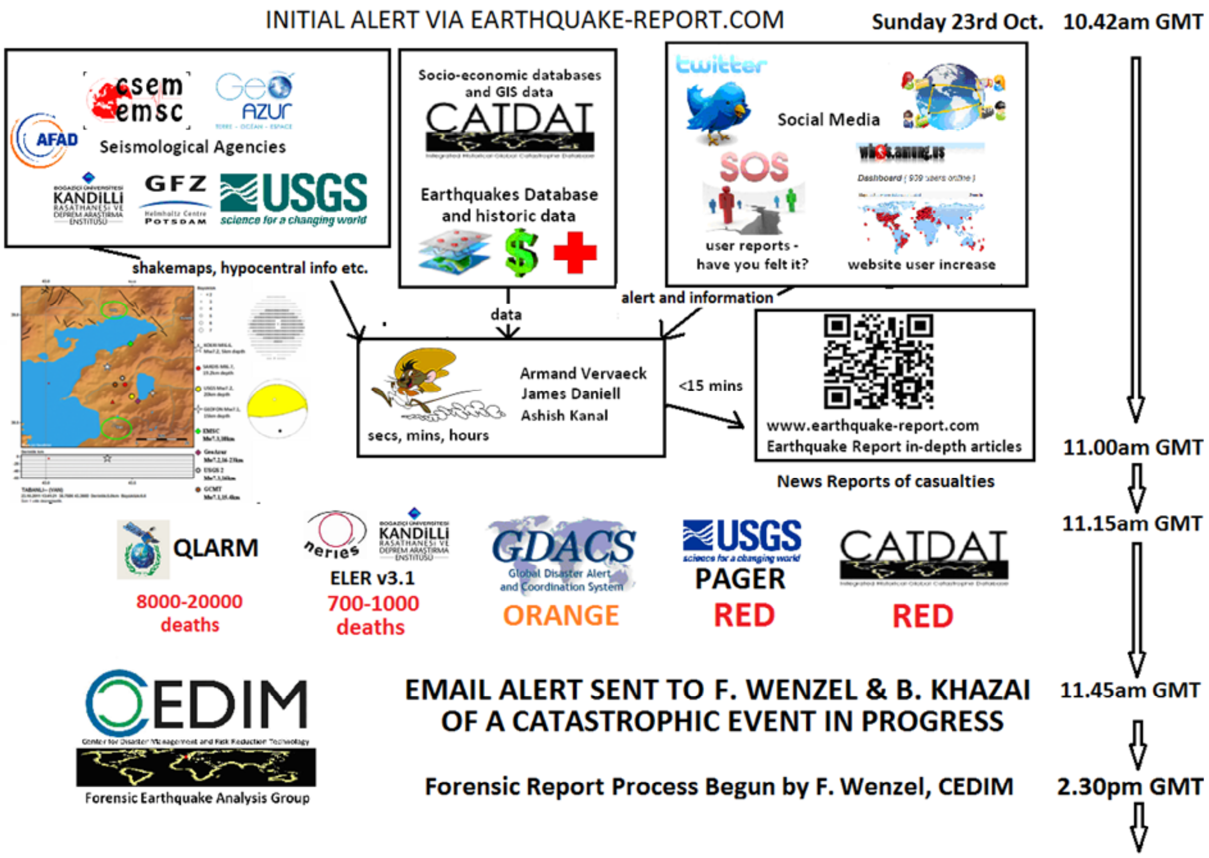

Figure 3.1. The initial process used in this instance for the production of the first report

3.2. The Outputs from the Van Test Case

Our team consisted of two seismologists, three engineers, a social scientist, an economist, an earthquake reporter and a meteorologist. Four reports were produced:-

(24.10) 1st Report - Wenzel, Daniell - seismology, initial loss analysis, setting.
(25.10) 2nd Report - Daniell, Wenzel, Khazai, Kunz-Plapp, Vervaeck, Mühr - comprehensive report on losses (insurance, socio-economics, seismology, weather etc.), and a situation update.
(26.10) 3rd Report - Khazai, Daniell, Kunz-Plapp, Wenzel, Vervaeck, Mühr - Shelter Impact dedicated report and continued work on losses, including shelter prognosis, in comparison to previous Eastern Turkey Earthquakes.
(02.11) 4th Report - Daniell, Khazai, Kunz-Plapp, Wenzel, Mühr, Markus, Vervaeck, Erdik – A comprehensive report (27 pages), including much additional socio-economic loss analysis, comparison with historic East Turkey earthquakes, and social vulnerability.

These reports are all available for download from the CEDIM website: www.cedim.de. Given the short time available to produce reports and the limited impact of the earthquakes (644 dead versus around 19,000 dead in Tohoku), the decision was made after the 4th report to only undertake additional work and research through the work of J. Daniell on earthquake-report.com, and to revisit the impacts in 2012 when more details had become available.

3.3. The Van Earthquake Test Case

The Van earthquake in 2011 hit at 10:41 GMT (13:41 Local) on Sunday, 23rd October 2011. It was a Mw7.1-7.3 event located at a depth of around 10 km with the epicentre located directly between Ercis (pop. 75,000) and Van (pop. 370,000). Much difference in the original hypocenters was seen, with a preferred result from KOERI. From then on, the CEDIM Forensic Analysis Group (using a team of seismologists, engineers, sociologists and meteorologists) and www.earthquake-report.com has reported and analysed on the Van event. In addition, many damaging aftershocks occurring after the main event were analysed, including a major aftershock centered in Van-Edremit on 9th November 2011, which caused many additional losses. The epicentral region was probably exposed to 0.4-0.5g, with Van exposed to 0.15g and Ercis exposed to about 0.2g.

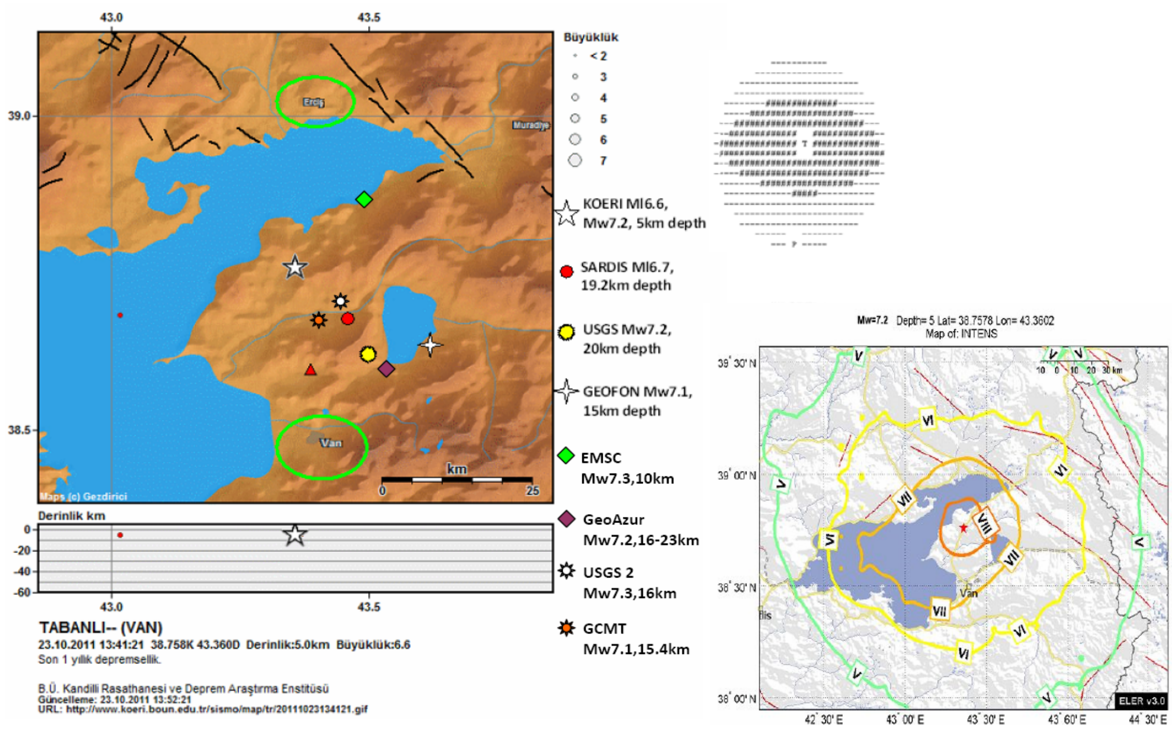

Figure 3.2. Hypocentral information from various agencies placed on the KOERI hypocenter map, including the fault mechanism (thrust fault) and the intensity map as calculated by ELER. (modified from KOERI, 2011)

The Van earthquake occurred in one of the poorest regions of Turkey, which had an extremely different socio-economic status from the western provinces in the country. The Van Province has much inequality between the rural and urban centres, with an average HDI (Human Development Index) similar to that of Bhutan or the Congo. The province of Van has around 1.035 million people as of the last census; however, it was estimated that as many as 1.35 million could live in the province (Van City has an official population of 370,000; yet over 600,000 are estimated to live there).

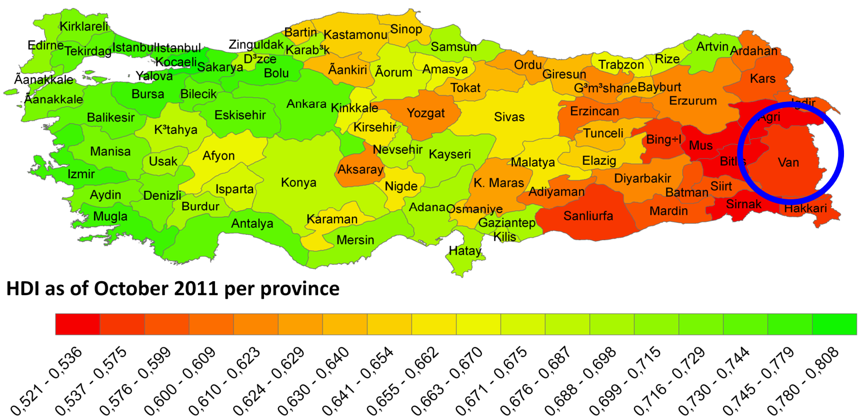

Figure 3.3. Human Development Index in each province from CATDAT, as of October 2011.

From the CATDAT Damaging Earthquakes Database, major earthquakes such as this one have occurred in the year 1111, 1267, 1715 and 1896, causing major damage and having magnitudes around 6.5-7. In the year 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 damaging and casualty-bearing earthquakes again 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. Comparative earthquakes have been studied to examine the relative impact of this quake.

Table 3.1. Comparable earthquakes in Eastern Turkey in recent years (CATDAT Damaging EQ Database)

Year	Event	Deaths	Injured	Homeless	Affected	Buildings Uninhab.	Buildings Damaged	Tents	Temporary Housing
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	N-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
2011	Van-Ercis	604	4201	250000	700000+	28532	55000	>50000	>25000

Given the elevation of the Van area, it was necessary to consult the work of B. Muehr on worldwide weather predictions. It was seen that in the days after the disaster, snow and rain fell in the area around Van (pink = snow, greens and blues = rain). Historical data also showed that the average minimum was expected to be about 2 degrees Celsius at night and 7 degrees Celsius during the day.

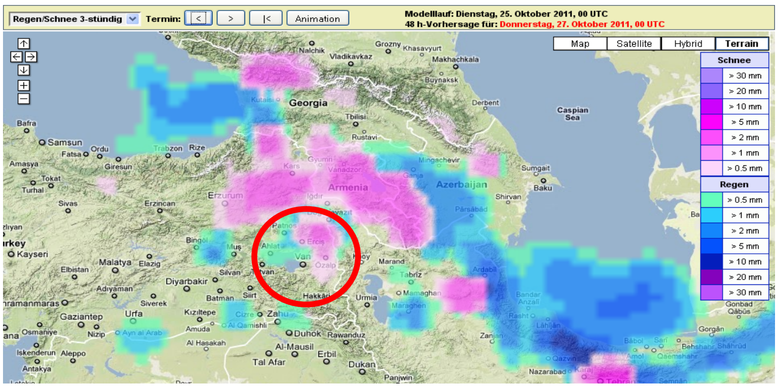

Figure 3.4. Modelled snow and rainfall for Thursday, October 27th 2011. Source: Bernhard Muehr, KIT.

Many different building failures were seen as a result of this earthquake:- Soft storey collapse occurred 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 storeys collapsed in some cases around the urban centres of Ercis and Van. Pancake collapse, where the columns of each level fail, occurred. As observed after the 1999 Izmit earthquake, many of the concrete floors did not remain intact within the collapse structures. In addition, weak column-beam connections and weak building materials such as understrength concrete had a huge impact on the building damage ratios. Poor detailing (insufficient anchorage, confinement etc.) and short columns were commented on as also being problems.

People in rural areas live typically in one storey buildings with tin roofs where there is only a small chance for fatalities, even in the case of heavy damage or collapse. Cattle were held in buildings with heavy concrete roofs and lots of livestock deaths were registered. The pictures in the KOERI reports show villages that seem to be quite devastated, but, as said, not too many fatalities. In terms of 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 were weak first storey collapses (soft storey collapse) as well as pancake collapses that were seen. 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. 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. In Van and Ercis rapid growth occurred during the past 10 years, related to several causes: business due to Iraq war, and intensive trading with Iran. Ercis is essentially a new city.

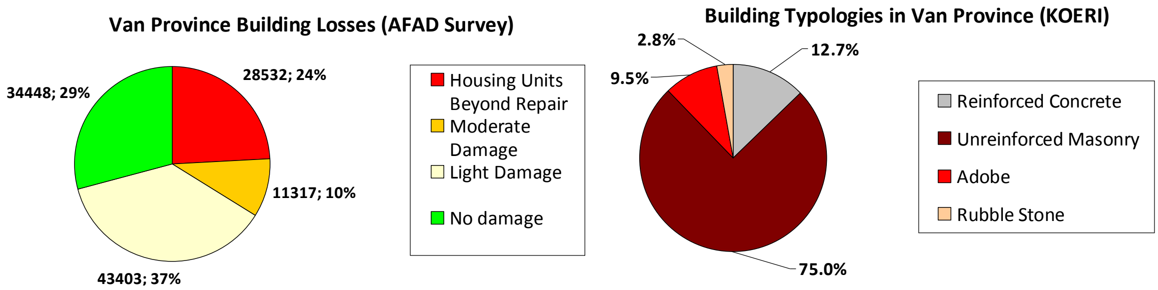

Figure 3.5. Van Province building losses (left), Building typologies in Van Province as per KOERI (right)

The earthquakes are estimated to have caused 604 deaths (23 October) and 40 deaths (9 November), mostly due to falling debris and house collapse. In addition, between 1.5 billion TRY to 4 billion TRY (approx. 800 million USD – 2.2 billion USD) is estimated as total economic losses, with a median of 1.1 billion USD. This represents between 25% to 66% of the provincial GDP of the Van Province (approx. 3.3 billion USD), as of 2011. Other estimates of 1.2 billion USD direct losses, with 0.3 billion USD indirect losses, have been made in Erdik et al. (2012 (March)). For Van Province (Ercis and Van cities), which was much more affected by this quake, for the 64,081 buildings registered, 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), final insurance losses totalled between $30-70 million.

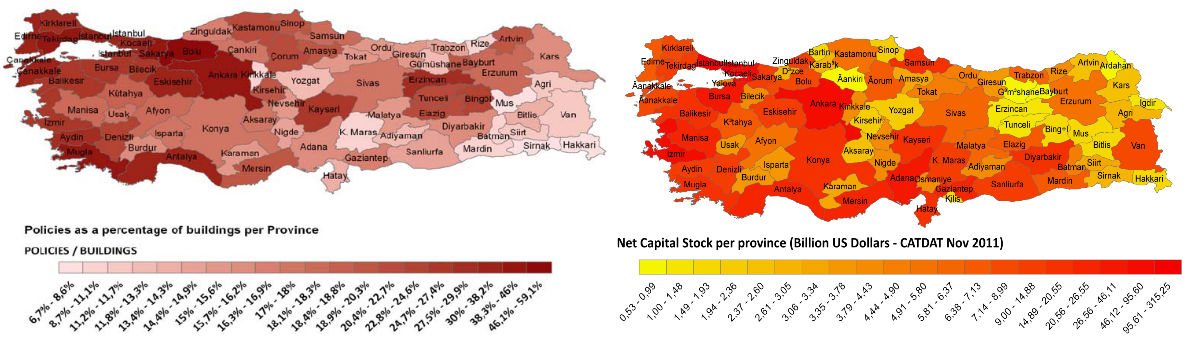

Figure 3.6. TCIP (Insurance) policies as a percentage of buildings per province (left); Net capital stock per province from CATDAT (right)

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 as there is an average household size of 7.6 people in Van province we assumed 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 but is generally lower than 7.6 in the urban centre.

Table 3.2. Shelter (Homeless) estimations as of 2nd November 2011 by CEDIM

Estimation (no. people)	Homeless (uninhab. bldgs)	Homeless (damag. bldgs)	Total
Lower bound (destroyed)	125400	0	125400
Historic (destroyed+0.33xdamaged)	125400	58436	183836
High bound (destroyed+1xdamaged)	125400	177049	302479

The estimation of homeless people due to damaged but habitable buildings is more difficult, as there are more factors influencing this number, including 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, and cold weather conditions. From historical experience, it is known that approximately half of the inhabitants of damaged buildings are homeless for at least for a short time. The age distribution of Van Province is very different from many other locations in Turkey, with a median age around 20 years old. This young and resilient attitude may have helped post-disaster and allowed trapped people to survive longer.

Given that the final total of 28,532 housing units beyond repair and approximately 260,000 homeless was the final total, it correlated well to the study done (200,000 via housing, and 60,000 from supply aspects). There were many good news stories that came out of this earthquake, including that modern construction typically survived and there was a rapid and efficient response by Turkish relief forces. The medical personnel number and search and rescue level increased in the days after the earthquake, as shown below. A few lucky circumstances reduced losses, including that the time of event was a Sunday afternoon, the long duration slow energy release of the earthquake was less damaging for new buildings built to withstand many cycles of loading, and the epicenter was not closer to Van.

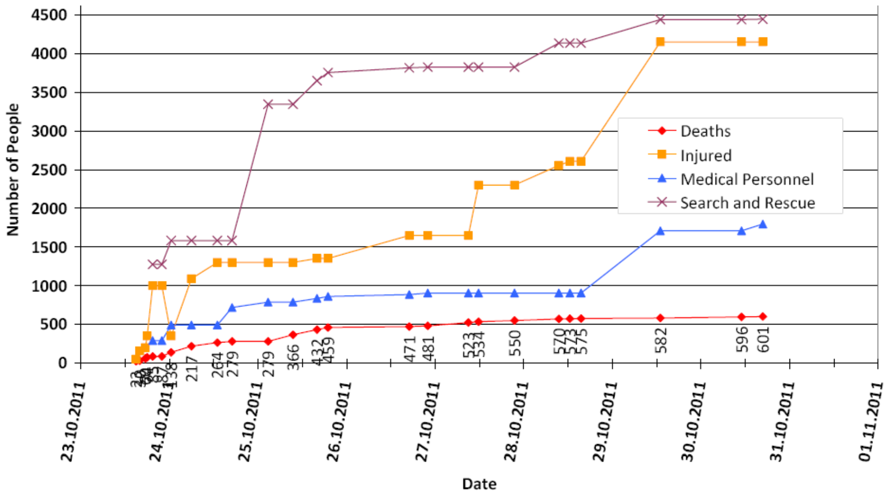

Figure 3.7. Disaster progression in reported casualties, medical personnel and search and rescue staff on-site.

4. CONCLUSION

The development of the CEDIM Forensic Disaster Analysis Group allows for greater multi-disciplinary in-depth analysis of disasters in near real-time to be undertaken and released to the public. The production of rapid analysis of losses to life, property, technical, economic and social systems, combining with existing sources such as Earthquake-report.com, allows for the establishment of a socio-economic context of disastrous events. In addition, work on the comparisons to similar historic events allows for additional knowledge to be disseminated.

The reports produced, such as the work shown in the test case of the Van Earthquake of 23rd October 2011, will be attuned to agencies such as Civil Protection agencies, UN Organizations (OCHA relief web), International Relief Organizations, Scientific and Professional Organizations (EERI), Development Organizations and Industry (Insurance, Tourism, global-scale manufacturing etc.), in order to provide useable post-disaster information. In addition, learning through the rapid post-disaster analysis, it is envisaged that many new research areas will be discovered. Future work by the CEDIM Forensic Disaster Group includes developing a network of interest people and groups to cover more perils (man-made etc.), emphasising insurance and other economic aspects, knowledge management, re-visiting forensic disaster analysis sites and processes, and enhancing stakeholder interaction.

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