SYSTEM ARCHITECTURE FOR EARTHQUAKE, TSUNAMI PREPAREDNESS AND WARNING

Orhan Altan[1], Gerhard Kemper[2]

[1]Istanbul Technical University, Istanbul-Turkey - oaltan@itu.edu.tr
[2]Office for Geotechnics, Geoinformatics and Service, Speyer / Germany - Boden-Umwelt-Kemper@t-online.de

WG IV/8

KEY WORDS: GIS, Remote Sensing, Photogrammetry, Crisis Management, Crisis Preparedness, Early Warning

ABSTRACT:

Humanity is always under the threat of earthquakes. Anatolian peninsula is one of the well-known area which amongst the areas endangered by earthquakes. During the history many dramatic examples have been occurred. In these earthquakes many people either died or have been injured. In addition, lots of damage in this area has been occurred. More west, in the Sea of Marmara, these earthquakes have also initiated Tsunamis which hit the coastline and caused secondary damages. Modern technologies in combination with remotely sensed data in GIS environment open a wide field for assisting in Crisis Management. The most important component of any Crisis Management System is a Crisis Preparedness Plan where especially our disciplines of Photogrammetry, Remote Sensing and Spatial Information Science can contribute in many ways. Crisis Preparedness plays a key role in preventing the population against big disasters. All Crisis Management efforts need an interdisciplinary cooperation to receive a sustainable help for all citizens. In our paper, we aim to highlight the possible contributions of our disciplines by examples of Earthquake- and Tsunami-Risk for Istanbul. Part of the discussed elements are referred to existing applications already installed or under construction around the world, others are taken from own studies in the area of Istanbul. Nowadays Crisis Management System is founded on 3 columns, the Crisis Preparedness Plan, the Early Warning System and the Rescue and Management Action.

1. RISK-LEVEL

Big events like earthquakes and tsunamis do not necessarily cause a high-risk potential. Risk appears in places of human activity where nature is highly active and people e.g. build urban areas. This means that the risk for human live depends on the natural conditions in combination with the activities of the population and their society. There are many places on our planet where we meet high activity and rapid changes of the environment due to earthquakes, volcanisms, tsunamis, weather-disasters and many more. Natural disasters often occur unrecognized in areas apart from the population. Some places however bear a high risk for human live even they are not as intensively used as others do. Population growth and the need for land usable for agricultural or urban settlement force to make use of such risky areas. Due to the history, people have been aware of these risks, however, depending on competition in farming and social factors, they accessed such unsafe areas. Some areas close by volcanoes even produced fertile soils and where attractive for farming. The coastlines are places where fishers work and live, even a high risk for Tsunamis might exist. Today mainly the urban sprawl raised the risk level but also living and working in areas of high risk became a used fact.

Istanbul e.g. was situated in the middle ages on the European side of the Bosporus, which geologically is saver than the southeastern part on the Anatolian peninsula. Today the city covers the coastline along the Sea of Marmara for several 10^{th} of kilometres and is situated now closer to the North-Anatolian fault. In addition, the densities of urban fabric with houses of several layers enhance the risk level. Strong Earthquakes and Tsunamis are disasters that do not appear very frequently. In our fast style of live, we very much like to forget or ignore such risks sometimes being naïve to believe that modern engineering can manage such things. However, there is a need to balance the risk-level for good crisis preparedness and keep the citizens aware on their situation living in a potentially endangered region.

Balancing a risk level is an interdisciplinary task. In the case of Earthquake and Tsunamis, we have to cooperate with specialists as Geologists and Hydrologist and bring them into contact with city planners and decision makers.

2. EARTHQUAKES NEAR ISTANBUL

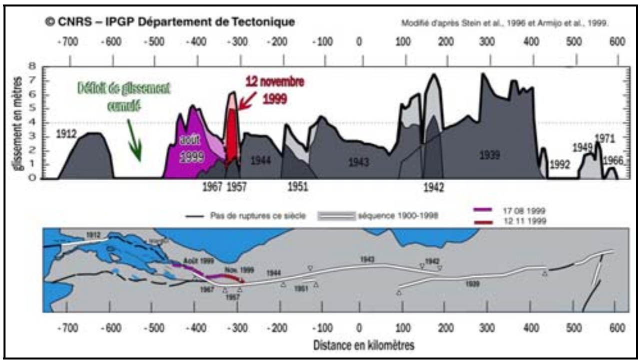

Figure 1. Shift and Tilt dimensions of earthquakes along the north-Anatolian fault since 1939 (upper graphic) and the shift to west of the epicentres (graphic below) [www.jpgp.jussieu.fr, accessed on 1.4.08]

The reason for earthquakes and tsunamis are the movement of geological plates. Some of them move against each, along or over other, cause shift, and tilt stress in the geological structures. The North-Anatolian Fault is one of the biggest and most active tectonically line in the Near East. Big shift and tilt movements combined with an enormous pressure lead to high stress energy in the plates. Beside small movements which usually does not harm, big releases of the plates stress lead to strong and dangerous earthquakes. The entire NW part of Turkey is highly for geological shocks. Monitoring the history of such shocks along this fault show that the epicentres of the earthquakes moved during the last decades from east to west towards the sea of Marmara.

Figure 2: An image from Enric Marti of the Associated Press that was taken for the New York Times on August. "A mosque stood with a few other structures amid the rubble of collapsed buildings in the town of Golcuk 60 miles east of Istanbul". [http://arrowsmith510.asu.edu/Ex-ercises/Exercise3/]

The last strong shock hit Turkey on August 17 in 1999 and caused a dramatic disaster. Measured at 7.4 on the Richter Scale at the U.S. Geological Service in Golden, Colorado, the temblor was centred between Izmit and Bursa, about 80 km east of Istanbul. This was the most powerful earthquake ever to hit Turkey. More than 15,000 people died, 23,000 became injured, and 500,000 finally were homeless. Izmit is situated on the North-Anatolian Fault in the Izmit Bay. This fault leads through the Sea of Marmara just 50 km south of Istanbul's centre and arcs to the southwest towards the Aegean Sea, also well known for a high potential for earthquakes.

Analyzing the Izmit Earthquake, we have to separate the different mechanisms that created the damages. Main shockwaves can shake buildings and destroy them especially such that have been built up illegal ignoring rules for save constructing. Many buildings have been damaged or destroyed by secondary waves, the so-called S-waves. These waves came a few seconds after the primary ones and are usually stronger against buildings. Landslides on the hilly terrain where complete buildings slid down including their foundation have destroyed other houses. The combination of heavy load on the soil, big slope, undercut basis of the hills e.g. by roads and sometimes liquid in the sediments, can lead to a collapse like failure of the sediments and rocks. A similar effect is the liquifiction of ground that even can happen in flat terrain. The saturated soil starts to collapse during shaking and the foundation of buildings sack in or break. Clayish and silty material support such effects especially in combination with high water content.

A Tsunami flew after the Earthquake into the Izmit bay. With a maximum run-up of 2.5 m along the northern coast of the bay and 1 to 2 m on the southern coast, this Tsunami was a relatively small one and mainly flooded the area. However, the Sea of Marmara bids a high potential for creating small and medium sized Tsunamis, which can be even much higher and stronger than the one detected here.

Beside these primary effects of a earthquake, secondary disasters usually aggravate the situation. Broken pipelines, especially gas-lines, cause fires that easily can spread in a partly destroyed city. Industry can create big environmental disasters as seen after the shock by burning oil tanks and running out of petrol. The possibilities of rescue teams are very limited since the access to these areas is difficult. Besides that, criminal activities might start e.g steeling goods from shops. Sometimes the secondary effects are more destructive than the primary ones.

Istanbul is close to this fault and during the Izmit Earthquake, in Istanbul many buildings have been destroyed and 3000 people killed, mainly in the southern part of the Mega city and mainly in so called Gececondo – districts. As mentioned in chapter 1.2, the high dense of urban structure increase the risk-level for the citizens being harmed by geological shocks. Within the last 50 years, Istanbul has grown to a Mega city with more than 16 Mio inhabitants. Rough terrain, forests and the black sea limit the sprawl to the north, so Istanbul expanded to the south on both sides along the coastline of Marmara Sea. The strongest expansion vector leads to southeast and already has met the Izmit bay.

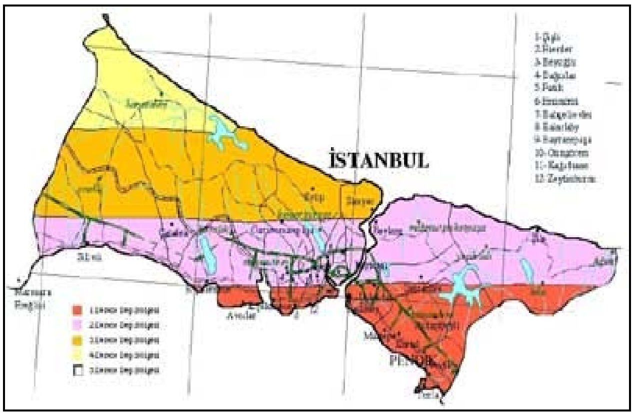

Figure 3. The Earthquake-Map for Istanbul highlights areas where strong shocks have to be expected: the southern part is the most endangered one. [http://www.akut.org.tr]

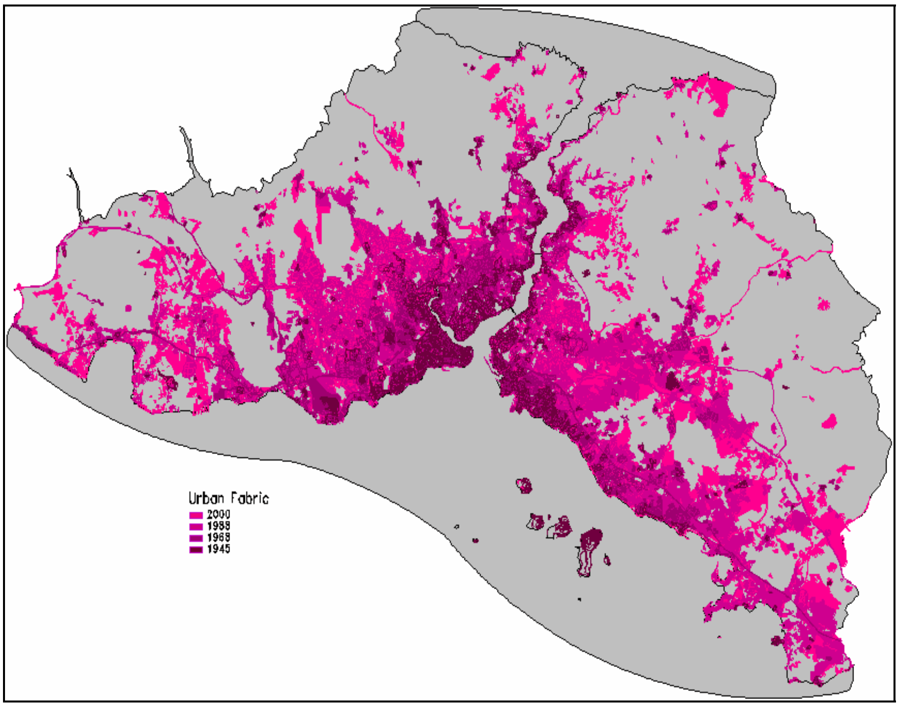

Figure 4. The urban sprawl of Istanbul from 1945 to 2000 represents the high dynamic of this Mega city [Kemper 2005]

Figure 5. Damage from the earthquake 1999, tectonic subsidence, ground liquification and the tsunami. The ship in the foreground thrown onshore by tsunami wave action. [Kandilli Observatory and Research Institute, [www.drgeorgepc.com/ Tsunami1999Turkey.html, accessed on 14.04.08]

Figure 4 shows the urban development towards the more endangered zone for geological shocks. Istanbul's entire coastline along the Sea of Marmara is urban with residential and industrial fabric. This stated the high risk for geological shocks, tsunamis and for secondary disasters. The Earthquake map in figure 4 gives an indication where the highest intensity of shock waves must be expected. The intensity is less in the north and is oriented with the fault-zone in parallel.

The terrain of Istanbul is hilly and especially along the Bosporus are big slopes. There is a big risk for hang-slide as a secondary shock element. The fear for Tsunamis is big since through the history several big Tsunamis have been reported.

The geological survey intensively observes the fault to detect potentially vertical movements. Only the vertical acceleration might initiate a Tsunami. A Tsunami wave grows by approaching the beach. The initial amplitude depends on the shock-intensity, the vertical movement and the water column over the fault.

The path then defines where, with which energy and when a Tsunami runs-up the coastline. The situation along the Bosporus would become critical since the height of the wave can grow by entering this narrow “canyon”. The situation as a funnel might increase the height of the waterfront by factor 2-3. Even Tsunamis are not expected in intensity comparable with the ones in the pacific, reports about Tsunamis in Istanbul demonstrate clearly the destructive power on the coastline.

3. CRISIS PREPAREDNESS PLAN FOR ISTANBUL

Building up a good Crisis Preparedness Plan is the turnkey for any operational Crisis Management System. A Crisis Preparedness Plan needs a highly interdisciplinary work. Usually an inventory of natural and artificial structures and their potential for risk is obligatory and builds its basis. To be effective, they must be part of the city planning. City planning which takes natural risks into account is an important input for the administration. We will show such a potentially run-up analysis of an estimated big Tsunami and the population that would be affected then. Areas detected as risky have to be treated primarily since we must expect the biggest hit of an earthquake or Tsunami there. Organizations that are going to help after the disaster (First Aid, Fire-fighters, Technical Teams…) should be organized without being endangered themselves. GIS Data help to detect paths and roads to enter these areas or to evacuate the people .The ways have to be predefined as well as the chaos by escaping people must be taken into account. Important for the city and the risk managers are information about the stability of the buildings which might be save or even could increase the risk after an earth shock.

To develop a Crisis Preparedness Plan for Istanbul means to cooperate with many disciplines even with assistance of foreign specialists. The integration of all data into a Geo-Server is essential. These data must be prepared in a way that decision-makers can easily access them for the safety of the society. As mentioned before, all data for modelling and management must be combined. In an entire Crisis Management System, this Preparedness Plan delivers the biggest amount of data. A good database is the most important criteria for sustainable city planning with respect to risk management as well as the foundation for strategies and management of disasters. Only such a complete data-collection enables to set up an early warning system and to organize a disaster management. It is important to find acceptance at the population and to practice the behavior in cases of earthquake and/or Tsunami.

4. GEO-SCIENTIFIC RESEARCH

From beginning, the natural disaster potential must be evaluated. Geological and Hydrological survey is a major task for that. Beside the determination of the potential centres of earthquakes, the transport path of the wave-energy must be estimated. In the case of an earthquake, it is the type of geological structures that transport the various waves. In the case of a Tsunami, the bathymetric conditions, the vertical water-column and the run-up-path are of high interest. As mentioned in the chapter before, geological and hydrological might build one of the basic layers in the central database. Remotely sensed data can assist the geologist to detect significant changes from the air or the orbit. Radar-data from Satellites can monitor even very small changes in the terrain that might indicate pressure in the geological structures. Other sensors, like Hyper-Spectral space or airborne scanners, can assist to detect anomalies in the environment, e.g. the emission of thermal heat, gas or other indicators that point out the ongoing activity of the underground. This information can also be part of an early warning system, which will be described later.

For modelling the Tsunami movement, terrain models of the seafloor, the shore and the land behind must be created. Beside classical hydrological methods e.g. via echo sounder, LIDAR technologies using laser with water penetrating wavelength assist perfectly in the off-shore areas for bathymetric measurements. The terrain of the beach but also the terrains behind on elevated areas are important for the run-up simulation. DTM (digital terrain models) and DSM (Digital Surface Models) which include artificial structures as buildings, dams, dikes and others are important to compute reliable hydrodynamic simulations. Especially for Tsunami modelling, the DTM and the DSM are of big importance.

Aerial surveys using airborne cameras and/or airborne Lidar-Sensors are able to deliver a high dense DTM and DSM. The combination is useful because beside the 3D data, interpretation of object’s type and structure is important. These data are the main input for Hydro mechanical engineers to model the run-up of Tsunami waves. In combination with Land-Use Data, risk estimation can be achieved and the generalization of the city into certain risk-levels can be done. Hydrological modelling takes place to estimate the Tsunami wave height and the run-up energy by using the DTM and the DSM. The urban surface has a very complex influence on the hydraulics. Also oblique photogrammetric data can assist to model important objects fully 3D.

Tsunamis cannot be compared with normal waves since the entire water-column covering the shaking ground is accelerated. The energy is extremely high even the amplitude might be only some tenth cm. On the open sea you might even not recognize them but their energy is shown up when they approach the beach. A typical indicator for a Tsunami is the sudden and sustainable falling of the water level where a high front of the Tsunami follows. The height is only one difference; the other is the long ramp on its backside that presses an enormous volume of water onto the beach. Besides that, water can transport material that is then used as so-called “weapons” and increase the destructive force of the wave. Run-up simulation becomes complex when objects or the terrain presses the water into specific directions. As already mentioned, the Bosporus builds a funnel where the water-level can increase several times. The water then runs not perpendicular towards the beach; it runs along the shore and hits the objects from side or even backside, which is extremely dangerous and difficult to be calculated. As better he input data are, as more precise the model can produce results that assist in the further planning.

5. RISK-MAPPING:

To balance the final risk, data of the geoscientific survey and research, hydrological models and land-use data must be combined with the 3D data to achieve a spatial risk-estimation. The combination with demographic data or at least the modelled distribution of such information with urban structural analysis gives a good approximation of a Tsunami Risk-Level as shown below.

The map above was generated using data of the Moland (Monitoring Land-use dynamics) project in combination with demographic data and terrain models classified for Tsunami run-up simulations. Even these estimations are relatively simple and not very precise, it makes the risk level clearly visible. Like that, the area of Büyükcekmece covers residential areas on low-levelled terrain that finally can affect 30,000 people by a Tsunami since they live in the red coloured zone as shown in Figure 6. Such risk maps easily can indicate city planners where risk-factors must be taken into account or at least to define clear rules for constructing objects in these risky regions. Maps as shown above also support the Crisis Management Team to detect sensitive parts of the city and assist them in defining ways to access these areas for helping the people.

Figure 6. Areas of a certain run-up risk for Tsunamis overlaid with land-use data and population density of residential areas. [Kemper 2006]

Many scientists in our discipline use GIS in combination with remotely sensed data and/or aerial photos to extract the land-use and analyze them, commonly in combination with spatial or non-spatial ancillary data. Terrain-models are used for the orthorectification process but as shown above, they can do more. There are various possibilities to contribute to risk mapping out of such data-sources. Risk-maps also help the decision makers to understand the needs for a sustainable planning and support an integrated Crisis management. Crisis Management and the needed reorganisation of a city can find acceptance in the population more easily by presenting these risk-maps than any other arguments can do. Like that, these maps have a big importance to transport political decisions which are needed for a successful crisis management and so finally for a better help for the people.

6. ENGINEERING AND ARCHITECTURE

Concerning the quality of architecture, Istanbul has to deal with difficult “heritage”. This heritage is, the so-called Gececondu areas. These Gececondus are illegally built-up areas with small but also bigger residential buildings. Usually after some years, they were legalized by the city administration. Owners and their relatives, means that they were not built by engineering rules, built-up these houses. Depending on the political situation, especially during election terms, they were legalized later and then often enlarged with additional stories, a extremely critical activity. In most cases, these buildings are weak and not stabile against earthquake shocks. Some building even collapsed without any earth shocks. Often also the foundation of buildings is weak especially if the building where increased. The scientific knowledge in constructing shock-proven buildings is well known in Turkey but has only rarely applied to the real work. To validate all buildings in Istanbul on their stability causes an enormous work. Nevertheless already, the over-planning of the former Gececondu areas takes place, which can be seen as a good chance for planning new residential areas that consider the risk and make live more safety. Actually, there is a big need to get data of the buildings about their static-stability, their use and their internal infrastructure e.g. if there are heavy machines, lifts, gas-pipelines... It is also worth to know how many people in which daytime stay inside the building. Are Emergency exists available and do they really guide to a safer place? To collect these data, field mapping is very limited since it accesses only the outside part of the building. Oblique imaging technologies e.g. pictometry, can assist in same way as they do for home security analysis in other parts of the world. Such images can help engineers and other specialists to validate the static of a building since they enable the view to typical constructive elements of the building.

7. CITY PLANNING

Logically, all information must be integrated in a sustainable city planning. City planners, the Administration and Decision makers are situated at the activity part of the preparedness server. Validating the actual natural and artificial structure and to make use of this information to design a safer city is a sustainable and long lasting work. City planners deal with various information and must build the communication interface between geoscientists and the decision makers. Typically, the city planners have the knowledge (and sensitivity) about what can be modified, what is possible in the legal frame and which is the right way to motivate politicians for investing into a "city for tomorrow". However, as a part of the Crisis Management System, city-planners are strongly depended on the data other disciplines produce. These data are sometimes heterogenic and not compatible for making easy decisions. Besides the traditional developing and planning of urban structures, an entire risk-analysis with its recommendations must become part of enhanced master plans. Other already mentioned disciplines must be deeply integrated here, e.g. Geographers, Computer Scientists and others. Our discipline can perfectly contribute to the GIS application, furthermore 3D data and the animation in virtual reality environment is a highly innovative part, which can contribute perfectly to a sustainable city development. To simulate different planning scenarios in combination with a visualisation of different disasters assists to all people for getting a better understanding of the needs to change existing structures of Istanbul towards a safer city. But city planning is not focused on the inner cities buildings only, also infrastructural objects as roads, bridges, pipelines and dams must become part of a master plan that aims to reduce the risk and showing up ways to access areas in case of a disaster.

8. DATA AND DATA-HANDLING

Dealing with such a big amount of various data needs a powerful sever or at least a server farm with spatial database and geodetic interfaces. Such a centralised data-server is needed for modelling the data and for the management of crises. Spatial Information Sciences make use of GIS running on Server-Farms to handle these data and give access to specialists for analysing and modelling with the data and to produce new datasets. Geo-Data-Server Applications for storing all data use a Geo-Data-Warehouse with a Geo-Portal that manages access to administrative, scientific and public parties. This database also prepares the criteria for sustainable city planning with respect to risk management as well as to assist in founding strategies for the management of disasters. GIS and Computer Scientists of our discipline work since several years on the data handling via Geo-Data Warehouses since we are used to deal with a big data volume and a big variety data-types

Such a complete data-collection enables to set up an early warning system and to organize a disaster management plan. It is important to find acceptance in the population and train common behaviour in cases of earthquake and/or Tsunami. A central server can assist in analysing chaotic situations in cases of a crises. It is important for the Crisis Management plan to take these conditions into account, however this is a difficult analysis which needs assistance of psychologists and other experts.

9. CULTURAL HERITAGE

What is the role of cultural heritage in a crisis management system? Actually, we still can find the famous objects e.g. Hagia Sophia, Blue Mosque and others only partly influenced by Earthquakes or Tsunamis. Their positions are typically on saver places and their construction is already proven by a long historical experience. Beside the fact that we can learn from their construction and placement, we have to keep care about these objects and preserve them since they are part of our cultural root. The urban structure around such objects might increase the risk for them in cases of a earthquake. There is a tradition in photogrammetry to observe, document and analyze cultural objects for their preservation and reconstruction. These new aspects crate a need for closer cooperation with city-planers to plan areas around cultural heritage sites with respect to preservation on our cultural heritage.

10. DECISION MAKING AND ORGANISATION

Today there is still a weak point in all activities; it is the final rendering of the developed concepts and ideas into real activities and master plans. Very often good ideas and concepts get lost due to changes of political parties or by lack of money in the related budget. However, it is much easier for decision makers to start new activities, when the concept is transparent and understandable and meets all aspect in a well-balanced way. Scientists usually have a lack of knowledge how to present the results even they have nice tools to build scenarios and simulations. Too often, we believe that simulations and animations are just toys to attract non-scientists. This technology is able open doors to the administration and by that, it also hands over a key for accessing the public. If the population is aware of the needs for planning and reorganization of the city, rendering of the plans becomes easier and gets apart from political competition. This is sustainable too! Nevertheless funding is an issue that is on a basis that the scientist can hardly influence.

11. RESCUE PLANS

An important issue of the Crisis Preparedness Plan is to contribute to the rescue planning. Crisis preparedness means to simulate the disaster and to adjust the rescue-plans on basis of data in the Geo-Data-Server. The geo-scientific data deliver the modelling e.g. a simulation about possible destroyed infrastructure by shock waves. Other simulation might deliver run-up simulations and their affectivity on the urban structure. Result of these simulations is a spatial dataset (map) that points out where help is needed most urgently. In addition, here the database can assist to plan the best access to these areas. Where are roads to access these places, which hospital is the closest, how to get machines and other material there? Where will the people go when being in panic? Psychological estimations must become part of that since panic people behave not rational. What about infrastructures that can create additional disasters e.g. Gas-pipelines, petrol stations....? It is an important task for computer scientists with the help of geoscientists and psychologists to develop plans for entering and leaving theses areas. This extremely interdisciplinary cooperation might result in a route planner and navigation system on various levels. This "rescue planner" can also be used as a simulator to manipulate some of the input variables to estimate possible improvements that can be done in the city planning. In some cases, also rules have to be defined. A god rescue plan must include the population.

They need guidelines how to behave in a disaster situation and must have training.

12. TRAINING AND WARNING

As mentioned before, there must be an education of the people especially in the most endangered areas. How should they behave, where should they go and how can they assist the rescue teams? In Japan already the children in school learn how to react during an earthquake shock and/or if a Tsunami must be expected. Trained people know when the beach fells more dry than normal that they should access higher terrain or upper floors of stabile buildings.

Figure 7. Tsunami warning board on a beach, [http://www. enchantedlearning. com/subjects /tsunami/ accessed on 18.04.08)

Warning must follow simple signs and be in languages, which local but also foreign people can understand easily. In cases of a disaster, people must be rescued but can become also part of the rescue system. Knowing what to do and knowing how to help people reduces panic and makes the rescue easier. This is a political task mainly to educate and train the people. Part of this training is the sensitization and information of the citizens where the simulations and risk-maps can help. Interactive maps, oblique images and 3D city-models with virtual reality simulations increase the acceptance in the population for learning how to behave and how to assist in these situations.

Part of the training is to understand the alarm signals, either by the natural signatures, as there are pre-earthquake rumours and vibrations, or by the water run-off at the shore. In addition, there must be a common alarm system that clearly indicates what must be expected e.g. an approaching shock within the next seconds or a Tsunami within the next 20 minutes.

13. EARLY WARNING SYSTEM

Bases on such a crisis preparedness system, an early warning system needs additional sensors, automated activities and a perfect communication system. An operational communication, e.g. special channels in the GSM, is essential since wired based communication technologies frequently become damaged by the earthquakes. Radio modem and GSM are the main assistance then and have to be prepared and well applied.

In the warning system, the pre-designed data are needed to set the right alerts at the right time on the right place. Sensors have to communicate with a central organisation, but in some cases a direct access of the warning is more efficient e.g. in Japan, the fast trains are stopped fully automated by an alarm sign and gas pipelines are closed immediately. A prepared alarm-chain has to be activated by the sensors.

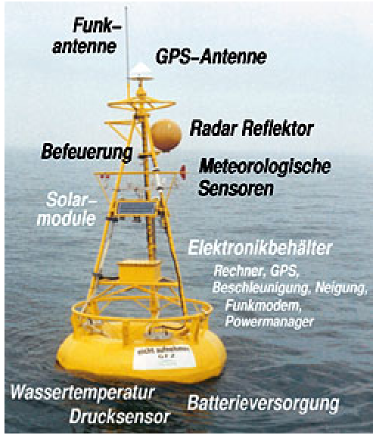

Figure 8. Tsunami Sensors installed close to tectonic fault zones for detecting Tsunami waves when they start, [http://www.forschung.bmbf.de/de/4879.php accessed on 18.04.08)

We have to be aware that theses things have to be tested and trained by the crisis management teams and by the population to know what must be done if a disaster happens.

In 2005, the Tsunami disaster at Bandah Aceh had neither a sufficient alarm system nor the population has known how to behave. A big problem of this Tsunami disaster was the transport of “weapons” by the water. The transported wooden boards, cars, and many other things made even a 2 m flood extremely dangerous and destroyed more buildings than expected by water only. It must be part of an early warning system to get such “weapons” fixed, e.g. grouping cars to blocks, close shops, remove dangerous things inside…

An early warning or forecast system must be based on a good preparedness plan. Early warning is a difficult task for earthquake shocks since the reaction time is extremely short and the activity must be designed as an automatic procedure. For Istanbul also the Tsunami warning needs an automated workflow since the wave can hit the beach already after 10-30 minutes. Early warning surely has limits by these short timeframes, a good preparedness however can give at least a chance to save lives and prepare for a rapid rescue. Forecast is difficult but can assist to set a first alarm level.

14. FORECAST AND ALARM SENSORS

Remote Sensing tools can assist in the forecast and support geologists to detect stress in the rocks that might lead to an earthquake. Radar-sensors in air- or space-borne platforms can detect even small changes in the surface and indicate stress by using interferometric methods. Frequently made observation with this technology give a good temporal monitoring and increase the accuracy.

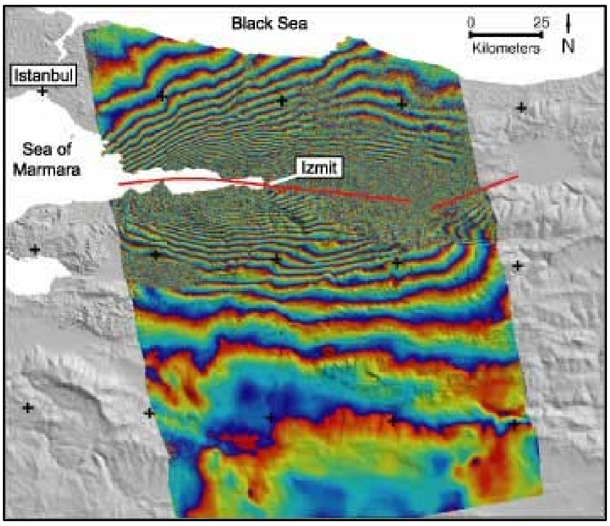

Figure 7. This interferogram was created from two sets of radar data: The first was obtained before the Izmit earthquake, and the second 35 days after [comet.nerc.ac.uk/images, Accessed on 11.04.2008]

Real-time observation needs mechanic or electronic devices. Various innovative sensors have been developed within the last 10 years. Already applied in many areas are seismographs, which detect small rumours and vibrations that might indicate an upcoming shock. Actually, they are useful to set a pre-alarm but it is a forecast only that must be handled carefully. Even the population is trained; every warning creates fears and panics. A forecast that comes too often reduces the responds at the population, a warning that comes not or too late decreases the chance for reacting. In fact, forecast is a difficult balance. Therefore, the main shock must be detected immediately and this measurement then used to start an alarm chain. To detect these shocks-waves, sensors based on acoustic, accelerative or other detectors can clearly identify these accelerations and validate their strength. Not always the P-wave is the most destructive one, usually the S-wave have the mayor effect on buildings. If an earthquake happens with its epicentre 100 km south of Istanbul, the P-wave might arrive within 15 seconds, while the S-wave would approach 10 seconds after then.

Any activity is limited to a few seconds only. This means that a real-time communication is essential in combination with an automated reaction system.

Tsunamis waves run slower and would hit the beach between 15- 30 Minutes after the shock. Sensors to detect Tsunamis waves in the Sea of Marmara are just under installation. They will provide an active warning via radio communication. Even 15 Minutes is a short time, it enables to start a planned alarm-chain and save many lives. Combined with the data of the Crisis Preparedness Plan, this gives the chance to compute where and how strong the Tsunami will arrive and which dimension it will have.

15. COMMUNICATION

A key issue is the communication in cases of disasters. Beside the communication between sensors and the Crisis Centre with its servers, communication is needed to set the alarm and to keep contact with the rescue teams. It must be expected that wired connections can be destroyed. Beside radio transceivers, which are frequently used by emergency teams, GSM can assist with reserved channels beside the normal “traffic”. This keeps the keeps the communication for the Crisis Management going even the other lines might be overloaded. Using cellular networks data-communication can be possible as long as the transmitters are powered. In preparation with a project, this already was designed with the company Turkcell, one of the biggest Cellular Service Suppliers in Turkey. Critically is the powering supply at the transmitter and repeater stations, means at least at important stations a redundant powering system e.g petrol based generator, batteries… must be installed.

We have tested even CB-Radio for transmitting data that works slow but reliable up to 20 km. Satellite communication is another possibility to keep the communication going even far apart from repeater stations.

16. AUTOMATED ALARMING AND ACTIVITY

As discussed before, automated actions are needed to manage as much as possible in a short time. In 25 seconds, there is a chance to stop trains or keep them in the stations, close pipelines to limit fire disasters, put all traffic-lights to red and stop lifts at the next floor. Such activities must be prepared by using the Crisis Preparedness Plan to set up such strategies. They must be properly installed and well tested. The robustness of the alarming communication is extremely important and the immediately respond on that.

Setting the public alarm can be done by different ways, by sirens, radio-information, warning SMS, using the speakers on Minarets and many others, it does not harm to be creative as long as it assists to inform the people. All citizens have to be educated to recognize these alarms and must be trained in reacting without panic in the right way. Personal activity can be in accessing the safest room in a flat, leaving the balcony and, when outside, getting distance to buildings. These relatively small things can save hundreds of lives. The alarm is needed also to prepare the rescue team.

17. CRISIS MANAGEMENT

If a disaster has happened, even the city is well prepared and the alarm system worked properly, still must be expected wounded or killed people, damaged infrastructures and so called secondary fails as burning tanks…. It is very important to have a rapid information system to receive an inventory about the destroyed areas. Knowing where the emergency teams still can cross rivers, how to get access to areas and estimate where the help is mort urgently needed benefits the work.

If a disaster has happened, this crisis must be managed. Even a good Preparedness Plan has existed and the alarm chain had worked, we must be aware that chaos appears due to lack of information. Important is to help the people and to reduce secondary crisis. Getting an overview on the situation and analyzing the needs is extremely important.
Airborne remotely sensed and photogrammetric techniques in combination with orientation systems help in getting new data. Field sensing completes these data and close range application can assist with displacement analysis to validate the grade of damage at buildings.

18. UPDATING WITH IMAGERY

Getting the latest information of the affected area is crucial for managing the rescue teams. Rapid data capturing and processing is a part where our discipline can contribute well. To support the Crisis Management team with new data, aerial survey can contribute perfectly. We have to make use of direct orientation aerial imaging systems to get referenced data as fast as possible. Today push broom scanners but also small, medium and large format digital cameras are often combined with high precision GPS/IMU orientation systems that finally allow rapid and fully automated extraction of orthorectified image data. These techniques are nowadays small and easy to install and can be adjusted to many aircrafts. Any aircraft that makes inspections is able to carry such a system and make images which are more far than documentation only. Modern GPS-IMU systems deliver the parameters for exterior orientation in real-time or after post processing. It means that after landing, the GPS-IMU Data are ready soon and connected with the Image-protocol and a DTM, automated tools in many photogrammetric softwares can create orthophotos automatically without big personal interaction. These data are not that precise as aerotriangulated images are but they enable a rapid updating of the Database on the Server In the last 10 years, many automated tools have been developed, mainly designed for remotely sensed data like satellite images, to extract changes automatically. Using cluster analysis or any other of the many analyzing tools, they can indicate where e.g. destroyed buildings are. Since these operations go also automatically, no personal assistance is needed. Within a few hours, taken imagery and their analysis can be integrated in the Data Server and becoming accessible to the rescue and managing teams. Using space borne data however is limited by the long repetition rate of the satellite platforms. Airborne hyper-spectral sensors however can assist perfectly in getting relevant data because they enable a huge combination of spectral bands that can indicate much more than an image alone can do. They support multiple cluster analysis, which more easily can detect objects or damages of interest even environmental disasters. Producing Lidar Data of the destroyed areas can deliver very dense DSMs, which easily can be validated with the existing DSM data on the server to produce a change map.

It is important to produce data as fast as possible, not as accurate as possible. Also the resolution should only meet the requirements, e.g. images with 30 cm GSD (Ground Sampling Distance) are already excellent for that task.

19. MOBILE MAPPING

The central data-warehouse that is frequently updated needs also ground based information e.g. where hospitals still have capacities, where machines are available to make streets passable, where is the helps most urgently needed. This widens the usability of the central Data-base. It is important that information about operational or damaged infrastructure is supported to the Central Crisis Management for guiding the Rescue Teams. Mobile GIS used as navigation tool can be updated continuously to support the teams with latest information e.g. how to find the last working bridges cross a river and how to access the next hospital. Vice versa, information of the teams can be transmitted to Crisis Management and/or the Server by tracking the rout and digitizing broken roads. This again can indicate if building machines are needed to repair the infrastructure to keep the rescue going. GIS specialists already have developed remotely controlled GIS applications that support the iterative updating of central GI Server. In addition, here the communication is important to get access to the data on the server. GPRS on reserved lines via local cellular providers is a good solution but also radio modems can solve this task. A limit can be the transfer rates, which mean that an intelligent file-sharing system must be implemented. Only updated data should be transferred then and best is in using vector formats. Our discipline has knowledge in these techniques and perfectly can contribute to solve this task.

20. BUILDING OBSERVATION

Beside the immediate updating, also the close range photogrammetry can assist in the damage analysis of buildings days or weeks after the disaster.

After an earthquake one endeavours to construct new houses for the homeless people as quickly as possible or repair the buildings which are to be restored in a short period. This works have to be done very quickly to pretend other disasters or epidemics. During the renovation of damaged buildings, one of the problems is rapid determination of the actual state of these buildings. An insufficient determination of damage results can cause great problems later on during preparation and implementation of the renovation project. After the Izmit Earthquake, many buildings had to be validated to check their stability for further use. The Department for Photogrammetry of the ITÜ surveyed many of them using close range photogrammetric methods to determine their displacements. In cooperation with building-engineers, the stability of the objects were validated and steps for reconstruction defined.

Figure 8. Handheld based Mobile GIS with editing and navigation function can assist in Crisis management for updating the GIS Database and navigate. [Example from GGS-Speyer, 2008]

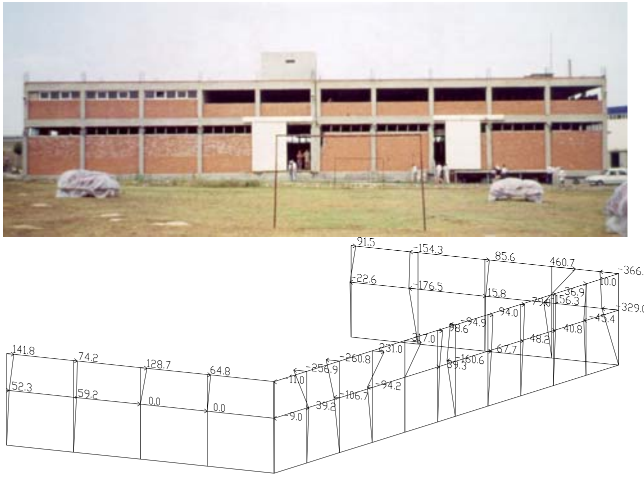

Figure 9. Photogrammetric evaluation of a damaged building in Adana.

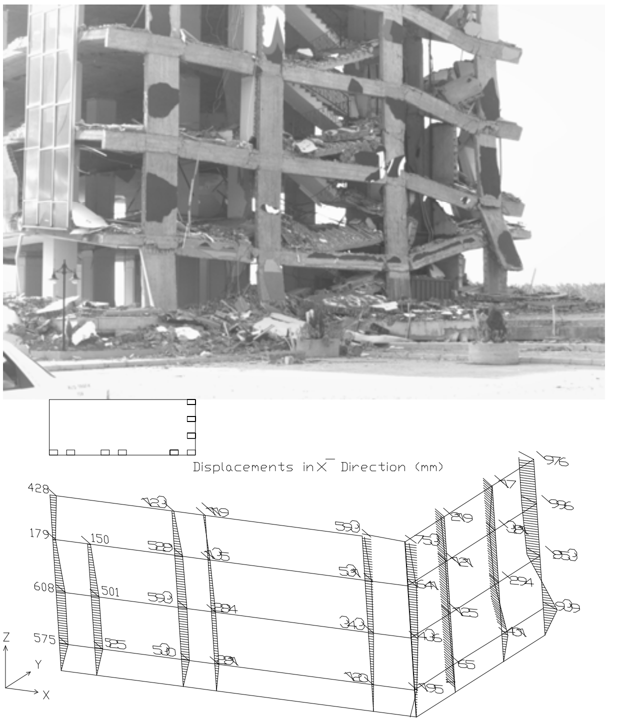

Figure 10. Displacements of a Damaged Building in Marmara Earthquake 1999.

REFERENCES

ALPAR, B. / GAZIOGLU, C. / ALTINOK, Y. / YÜCEL, Z.Y. / DENGIZ, S. (2004): Tsunami hazard assessment in Istanbul using by high resolution satellite data (Ikonos) and DTM. - XXth Congress of the ISPRS, Istanbul.

ALTAN, O., KEMPER, G., LAVALLE, C., DEMICHELI, L., (2002): MOLAND – monitoring land-use changes for the city of Istanbul. International conference of the ISPRS-Commission 7, Hyderabat / India.

CELIKOYAN, M. / ALTAN, M.O. / KEMPER, G. (2004): Accuracy Investigation for a Large-Scale GIS. - XXth Congress of the ISPRS, Istanbul.

GERLACH, F. (2000): Characteristics of Space Imaging's one-meter resolution satellite products. - International Archives of Photogrammetry and Remote Sensing, XXXIII-B1, 128-134.
HEITNER, K.L. (1969): A mathematical Model for calculation of the Run-up of Tsunamis. Pasadena, California

KASANKO, M. / LAVALLE, C. / DEMICHELI, L. / MCCORMICK, N. / NIEDERHUBER, M. (2000): The MOLAND method as a decision-making support tool in urban management. - Second International Conference on Decision making in Urban and Civil Engineering. Lyon, France, 20-22 November 2000.

KEMPER G. / ALTAN, O. / LAVALLE, C. / DEMICHELI, L (2002): Die Landnutzungs-Entwicklung von Istanbul 1945-2000. - Angewandte Geographische Informationsverarbeitung XIII – Agit 2002, Wichmann, Heidelberg.

KEMPER G. (2003): GPS-Datenerfassung für Kartographie, GIS, Überwachung und Fernerkundung. - 5. Sapos-Symposium, Bundesamt für Kartographie und Geodäsie, Frankfurt

KEMPER, G. (2004):. GPS-Datenerfassung für Kartographie, GIS, Überwachung und Bestandserfassung; 1. Anwenderseminar GPS/Sapos, Landesamt für Vermessung und Geoinformation Sachsen-Anhalt, Magdeburg 6.7.04

KEMPER G. (2005): Tools of photogrammetry, Remote-Sensing and Geo-Information-Systems - The world between Developers and Endusers. – Congress on Remote Sensing Arabia, Riyadh 2005.

KEMPER, G. / ALTAN, O. / CELIKOYAN, M. (2005) Tsunami-Gefährdungskarte für Istanbul. – Angewandte Geographische Informationsverarbeitung XI – Agit 2005, Wichmann, Heidelberg

KETIN, I. (1990): Geological Map of Istanbul, Scale 1:50,000, 1 sheet.

LAVALLE, C. / MCCORMICK, N. / KASANKO, M. / DEMICHELI, L. / BARREDO, J.I. (2003): Monitoring and forecasting the dynamics of European urban areas - The territorial approach as key for urban development strategies. - Urbanistica, 121,105-111, 2003.

SPACE IMAGING LLC (2002): IKONOS Products and Product Guide. - 2002. Version 1.1.

YILDIZ TECHNICAL UNIVERSITY (ed.) (2000): International Mediterranean Project – Integration of Ground Truth & Space-borne Sensor Data with a GIS for Coastal Zone Management of the Turkish Mediterranean Coasts. – ESA demonstration Project final Report, MM.XXSF, March 2000.

YOUNG, T. (1994). Towards an international classification of land use. - Consultancy report to United Nations Environmental Programme, Food and Agriculture Organisation (UNEP/FAO)

Kiremidjian, A.S., King, S. 1995. *An integrated earthquake damage and loss methodology through GIS*, VII. International Conference on Soil Dynamics And Earthquake Engineering (SDEE 95), p. 664, (UB: 4B 1252), Boston.

Steinle, C., Bahr, H. P. 1999. Laserscanning for change detection for urban environments, in (Eds: Altan & Grundig) Third Turkish – German Joint Geodetic Days "Towards A Digital Age", Volume I, pp. 147-156, Istanbul, Turkey.

Tazir, T. Z. H., Gavarini, C. 1989. *AMEDEUS, A KBS for the Assessment of Earthquake Damaged Buildings*, Report of the IABSE Colloquium on Expert Systems in Civil Engineering, pp 141-150, Bergamo.

Weindorf, T., Vogle, T., Bahr, H. P. 1999. An approach for the Detection of Damages in Buildings from Digital Aerial Information, F. Wengel et al. (Eds.) Vrancae Earthquakes: Tectonics, Hazard and Risk Milipation, pp. 341-348, Klumer Academic Publishers, Netherland.

Geology and Earthquake Risk, http://www.jpgp.jussieu.fr; accessed on 01.04.2008

Tectonic structures and earthquake risk, http://www.jpgp.jussieu.fr; accessed on 26.12.2004

Newspaper Report in Izmit Earthquake, http://arrowsmith510.asu.edu/Ex-ercises/Exercise3/; accessed on 20.03.2008

Earthquake Risk of Istanbul, http://www.akut.org.tr; accessed on 19.04.2008

Damage of the earthquake, www.drgeorgepc.com/Tsunami1999Turkey.html; accessed on 14.04.2008

Tsunami warning, http://www. enchantedlearning. com/subjects /tsunami/;accessed on 18.04.2008

Tsunami Sensoring, http://www.forschung.bmbf.de/de/4879.php; accessed on 18.04.2008

Radar-Interfreometry, comet.nerc.ac.uk/images; accessed on 11.04.2008