Prof. Dr. Mustafa Erdik Interview: Tracing the Evolution of Earthquake Modeling in Türkiye

20 December 2024, Friday

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Summary

Prof. Dr. Mustafa Erdik, a distinguished academician in Earthquake Engineering, and a member of T-Rupt's Board, discussed the evolution of earthquake hazard and risk modeling in Türkiye. He highlighted key milestones such as the 1980 probabilistic seismic hazard assessment and the 1999 Kocaeli earthquake risk assessment. He emphasized the role of EU projects and the Earthquake Hazard Assessment associated with the 2018 Turkish Earthquake Design Code, in advancing these models. Technological advancements, including GIS, fast computing, and AI, have significantly improved data analysis. Key contributions include the development of catastrophe models and the importance of resilience in infrastructure. Challenges in code implementation and retrofitting of buildings with inadequate earthquake performance were also discussed, along with the need for public awareness and education.

Müge Tavşanlı: Professor Mustafa Erdik, thank you for sparing this time for us today.

Your work has been pivotal in shaping our understanding of earthquake hazards and risks in Türkiye.

To start, could you share with us some of the earliest efforts in earthquake hazard and risk modeling in Türkiye? How have these efforts evolved over the years?

Prof.Dr. Mustafa Erdik: Well, thank you for inviting me to share my experiences on both issues, the hazard part and the risk part itself.

Essentially, the concept of earthquake hazard, particularly the probabilistic earthquake hazard, began globally in 1966 with Professor Alan Cornell. Interestingly, Cornell was involved in the design and construction of the Alibeyköy Dam in Istanbul, where he wrote his seminal paper. This marked the initiation of probabilistic earthquake hazard assessment, starting essentially in Istanbul.

The United States Geological Survey (USGS) was the first to adopt this probabilistic approach, developing their initial PSHA (Probabilistic Seismic Hazards Assessment) maps in 1976, which were finalized in 1990. During my visit to USGS in the late 70s, I collaborated with their staff, including Dr. Ted Algermissen and Dr. Walter Hays. Given the similarities between Türkiye's tectonics and California's, we explored how to apply probabilistic earthquake hazard assessment in Türkiye. My first study on this was published in 1980. That was in line with most studies in the world. In fact, it was prior to what has been done in Japan. It was about the same time in Italy.

In Türkiye, early efforts were more deterministic, based on past experiences. Significant activities began after the 1939 earthquake in Erzincan, leading to the development of earthquake hazard maps for earthquake-resistant design. The first official probabilistic hazard map of Türkiye was developed in 1996, with subsequent advancements driven by European Union projects like GSHAP, SESAME, SHARE, NERA, and SERA. These efforts culminated in the 2018 Turkish Earthquake Code. In this context, a team led by Prof. Dr. Sinan Akkar was formed around three to four years earlier to develop the official earthquake hazard map we use today, funded by TCIP and AFAD. Later on, there were other attempts, especially in Europe, and there is the Europe Hazard Map 2020, which includes Türkiye as well.

So activities in this area are making significant progress. However, as with earthquake risk, the focus has shifted towards managing uncertainties rather than just the data itself. While tectonic and earthquake data have remained relatively stable over the years, our methods for managing uncertainties have greatly improved, and many contributions are being made in this regard.

Müge Tavşanlı: It's fascinating to hear about the evolution of earthquake hazard assessment in Türkiye. Moving on to the risk aspect, could you elaborate on the first attempts at earthquake risk assessment in Türkiye and how they have progressed?

Prof.Dr. Mustafa Erdik: The first probabilistic earthquake risk assessment in Türkiye was part of the IDNDR (International Decade for Natural Disaster Reduction) project by the United Nations, which ran from 1990 to 2000. I was on the executive board of this program, which initiated the RADIUS

project to assess risk in major cities. Izmir was included in this project, and the first earthquake risk assessment and mitigation plan for Izmir was developed in 1999, just before the Kocaeli earthquake.

The 2020 Izmir earthquake validated our 1999 risk map, as the highest risk areas we identified coincided with the most damaged areas. Following the 1999 earthquake, global interest in earthquake risk assessment grew. The US Red Cross commissioned us to prepare an earthquake risk map for Istanbul in 2000, followed by a comprehensive risk assessment developed with JICA's assistance and the Istanbul Metropolitan Municipality's leadership. This risk assessment was updated in 2009 and 2019.

Globally, the GEM Foundation developed a comprehensive earthquake risk map, and Türkiye participated in the EU's risk assessment projects. Several of our colleagues contributed to the SERA project. In 2020, the latest version of the European risk map was released. Our efforts also include risk assessments in several cities in the Aegean region of Türkiye. Additionally, through a NATO project, we conducted earthquake risk assessments in Bishkek, Kyrgyzstan, and Tashkent, Uzbekistan.

Recent efforts have expanded to risk assessments in various international projects in the Caucasus and the Middle East, sanctioned by the European Union and OECD. As a result, we have developed earthquake risk maps for Cyprus, Armenia, Georgia, Lebanon, Jordan, Pakistan, Iran, and Türkiye. Advances in technology and techniques have significantly improved our ability to manage uncertainties in risk assessment.

One of the most notable recent studies is the CatMod platform, promoted by T-Rupt, which has evolved into comprehensive risk assessments. As I mentioned earlier regarding hazard assessment, the biggest challenge in risk assessment is managing uncertainties. Every step of the risk assessment process involves numerous uncertainties, which can sometimes compound. Effectively handling these uncertainties requires significant expertise in statistical and probabilistic methods.

Müge Tavşanlı: Thank you for sharing these insights, Professor Erdik. It's clear that both hazard and risk assessments have come a long way in Türkiye, contributing significantly to our understanding and preparedness for earthquakes.

We haven't talked about the technological part of it. What technological advancements have significantly impacted earthquake hazard and risk modeling in Türkiye?

Prof.Dr. Mustafa Erdik: Well, it's both technology and the advancement of science. They go hand in hand in improving risk and hazard assessment in Türkiye and globally. One significant advancement is the introduction of university graduate courses on hazard and risk assessment, including probabilistic risk assessment.

Another major advancement is the development of GIS technologies and the emergence of fast computers. The advent of fast computing has also been crucial. Nowadays, we use techniques like Monte Carlo simulation, which require significant computing power that wasn't available 10 or 20 years ago. Artificial intelligence has also started to play a role in various aspects of risk assessment.

Crowdsourcing for data acquisition via the Internet and the use of remote sensing data and satellite information have greatly improved the quality of data and analysis. These technological advancements have enhanced our ability to manage and analyze data, leading to better hazard and risk assessments.

Müge Tavşanlı: Thank you. What are some of the key contributions of Turkish researchers, including your own, to the field of earthquake hazard and risk modeling? How do you see the future of such modeling in Türkiye evolving?

Prof.Dr. Mustafa Erdik: Well, I've already mentioned some of my contributions, so I won't repeat them. However, many young researchers and professors are making significant strides in this field. For instance, Prof. Dr. Sinan Akkar from T-Rupt has developed a state-of-the-art routine for CatMod, which can be extended to both hazard and risk assessments.

Other notable contributors include Prof. Dr. Ayşegül Aşkan and Prof. Dr. Zeynep Gülerce, who have published excellent papers on PSHA. On the structural and risk side, Prof. Dr. Altuğ Erberik and Prof. Dr. Ufuk Yazgan have done extensive work on fragility analysis. There are many others whose names I might have missed, but these are some of the key figures driving advancements in this field.

Müge Tavşanlı: Thank you again. What were the key highlights and takeaways from the World and European Conferences on Earthquake Engineering? Especially the most recent ones.

Prof.Dr. Mustafa Erdik: Earthquake engineering conferences have been held for decades, but recently they have become more like conventions. While you listen to presentations, the sessions are about 15 minutes, and sometimes there's no time for questions. The main benefits are networking, seeing what projects are ongoing, and exploring potential collaborations.

Key topics that have gained importance include resilience—how structures, cities, and systems recover and return to normalcy after an earthquake. This concept is crucial for both UN activities and new construction materials and technologies. Protecting critical infrastructure, such as hospitals, police headquarters, and government offices, is also a major focus. Seismic isolation techniques are being studied to ensure these facilities remain operational after an earthquake.

These conferences foster cooperation among researchers dealing with similar issues, opening new avenues for research.

Müge Tavşanlı: Excellent, your answer naturally leads us to our next topic: building codes. The Turkish Building Earthquake Design Code was last updated in 2018. Can you discuss the most significant changes in this update and how they have impacted building practices in earthquake-prone regions?

Prof.Dr. Mustafa Erdik: The preparation of building codes in Türkiye and Europe differs from the United States. In the US, codes are prepared by professional engineers, while in Türkiye and Europe, they are mostly prepared by professors. The 2018 Turkish code is a combination of the ASCE-SEI code from the US and the EC8 code from Europe, incorporating the best aspects of both.

The 2018 update introduced performance-based design, new seismic hazard maps, site response studies, building importance categories, structural regularities, ductility requirements, retrofit requirements, and attention to non-structural elements. It also included a new subchapter on seismic isolation.

However, having a good code and implementing it are two different things. The challenge lies in implementation. Efforts are underway to simplify some aspects of the code to make it more prescriptive and easier to apply and check. The code is excellent, but the real issue is its implementation.

Müge Tavşanlı: I agree. My next question concerns enforcement. What measures are being taken to increase the earthquake performance of older buildings that were constructed before the latest building codes were implemented?

Prof.Dr. Mustafa Erdik: Well, that's a very good question. This is a key aspect of mitigating earthquake risk in big cities in Türkiye. As we've seen in recent earthquakes, many buildings suffered damage that could have been avoided if they had been built according to the earthquake code. Our primary goal is life safety, followed by ensuring buildings remain in repairable condition. If a building collapses, it not only fails to protect lives but also cannot be repaired.

Currently, several techniques are being employed to retrofit older buildings. These include adding shear walls, strengthening connections between walls, floors, and ceilings, and adding braces to increase structural strength. We can also increase ductility through column jacketing using fiber-reinforced polymers (FRPs) or reinforced concrete or steel jackets. Reducing the building's mass and using seismic isolation techniques can also help.

However, these methods often require vacating the building, which poses significant social challenges. Families need to be relocated, and the building must be reoccupied and refitted after retrofitting. To address this, external retrofitting techniques are being used, especially in cities like San Francisco, Los Angeles, and Japan. This method allows retrofitting without entering the building, which is particularly useful for historical buildings in Istanbul. Retrofit of a historical building is a

very expensive and long-term affair, because you have to secure permissions from the boards of antiquities and monuments, so that what you are doing is compatible with the original structure. Whereas if you strengthen the building or if you retrofit the building by using structural members from outside, and if they are removable, then things are much easier. In consequence, external retrofitting is less intrusive and can be removed after the earthquake if needed.

While the knowledge and techniques for retrofitting are well established in Türkiye, the main challenges for widespread and expedient applications are the capacity and the financial constraints.

Müge Tavşanlı: Last year, we experienced Kahramanmaraş earthquakes. What lessons have been learned from the February 2023 earthquake sequence, and how are these lessons being integrated into future earthquake preparedness and mitigation strategies?

Prof.Dr. Mustafa Erdik: That's a valid question. What we have learned, or rather re-learned, is the importance of strict enforcement of building codes. This includes checking both the design and the construction of buildings. While construction is somewhat monitored, design checks are often inadequate. Some buildings failed due to design flaws, not construction issues.

We also need resilient infrastructure and lifeline systems. Our infrastructure, especially roads and bridges, performed well compared to those in Japan or the United States, but there's always room for improvement.

The biggest issue in the Kahramanmaraş earthquakes was the loss of life, primarily due to pancake collapses of soft-story buildings. These collapses are difficult to survive or rescue from. As such, the prioritization and the retrofitting soft-story structures is crucial.

We should also avoid construction in liquefaction-prone areas, designating them as green spaces instead. Community and volunteer networks played a vital role, and their importance cannot be overstated. We have seen good examples of it, but there needs to be more so we need to pay attention to that.

Finally, earthquake insurance is essential. While it doesn't save lives, it alleviates the financial burden on the government. Proper earthquake insurance can help people to fix or rebuild their homes. The lack of professional and third-party liability insurance was evident, especially for facilities like hotels. Ensuring such insurance could prevent unsafe hotels from operating, ultimately saving lives.

Müge Tavşanlı: What role does public awareness and education play in earthquake preparedness, and what initiatives are currently in place in this regard?

Prof.Dr. Mustafa Erdik: Public awareness and education are important, but there are limits to their effectiveness. If you live in a safe house, taking precautions can help save lives. However, if your

house is not safe, these precautions may only help in minor earthquakes, not major ones. It's crucial to understand these limits.

For example, in Japan, it is reported that students sometimes run from garden to inside the school building, to go under desks during an earthquake, which may not always be the best action. People should use reasoning rather than automatic responses. Training is essential, but the first step should be pressuring the government to ensure safe housing.

There should also be campaigns on earthquake basics, focusing on community efforts rather than individual actions. Drills are necessary to prepare communities for what to do after an earthquake, how to seek assistance, and where to take injured people. Structural safety, such as securing furniture, is also important.

School-based earthquake programs are vital. The TCIP, in collaboration with the Ministry of Education, is working on these initiatives to raise awareness among the next generation. However, they should also be given the means to protect their homes physically.

Müge Tavşanlı: Thank you.

Can you share any memorable experiences or breakthroughs from your career that have significantly impacted the field?

Prof.Dr. Mustafa Erdik: I've mentioned some, but a few memorable experiences stand out. Between 1990 and 2000, I was part of the UN IDNDR project and prepared a study in 1995 on earthquake risk in the Marmara area and Istanbul. Then, we conducted the RADIUS project in Izmir, and I was awarded the UN SASAKAWA award, becoming the first Turkish person to receive it.

Another memorable event was working on earthquake risk assessments in Bishkek and Tashkent, the first such studies in ex-Soviet republics. This NATO project, in collaboration with USGS, earned me the NATO Summit award. I was fortunate to be in the right places at the right times, in receiving recognition for these efforts.

Müge Tavşanlı: What advice would you give to young researchers and engineers interested in earthquake hazard and risk modeling?

Prof.Dr. Mustafa Erdik: I always advise young researchers to build a strong foundation in earthquake science, engineering, seismology, and probability. Experience with related software is crucial. OpenQuake and Capra (The Central American Probabilistic Risk Assessment) are widely used and open software tools.

Knowledge of GIS systems so that they can display their findings, machine learning, artificial intelligence, and crowdsourcing techniques is also essential. Understanding remote sensing techniques like Lidar and InSAR is beneficial for hazard and risk assessment. Familiarity with coding languages like Python, R, and MATLAB is important.

Attending conferences and joining professional organizations is vital, the road is open for them. When I started, we didn't have the internet, so I spent a lot of time in libraries. METU (Middle East Technical University) had a good library, but then again, it was not as good. So I used to go to a lot to Britain and sit in the Oxford, Cambridge and Imperial College libraries to get books, literature and data. Even taking photocopies at that time, was very difficult, so I would write down things. Today, access to information and tools is much easier, allowing young researchers to excel globally.

Müge Tavşanlı: Thank you, Professor Erdik, for sharing your invaluable insights with us today. Your expertise and thoughtful answers have been incredibly enlightening. We deeply appreciate your time and contribution.

About Prof. Dr. Mustafa Erdik;

Prof. Mustafa Erdik has had a distinguished career in earthquake engineering and modeling. He began his academic journey with a degree in civil engineering from the Middle East Technical University in 1970, followed by a Master's and Ph.D. from Rice University, completed in 1975.

Prof. Erdik's involvement in earthquake studies began early in his career. After completing his Ph.D., he worked as a staff engineer in Houston, Texas, and then as a visiting scientist at the US Geological Survey in California. He returned to Türkiye and started his academic career at the Middle East Technical University, where he served as the director of the Earthquake Engineering Research Center from 1980 to 1987.

In 1988, he joined Boğaziçi University and established the Department of Earthquake Engineering in 1989. He also served as the director of the Kandilli Observatory and Earthquake Research Institute, contributing significantly to earthquake hazard and risk assessment.

Prof. Erdik has been a member of the Board of Directors of T-Rupt since its establishment.

Prof. Erdik has been involved in numerous international projects and has published extensively on earthquake preparedness and risk mitigation. Prof. Mustafa Erdik's key contributions and work in earthquake modeling and engineering:

- Istanbul Earthquake Rapid Response and Early Warning System:

Prof. Erdik played a pivotal role in developing this system, which aims to provide rapid response and early warnings for earthquakes in Istanbul. This system is crucial for minimizing the impact of earthquakes on the city's population and infrastructure.

- Structural Health Monitoring:

He has been involved in the structural health monitoring of several UNESCO World Heritage Sites, including Hagia Sophia and the Süleymaniye Mosque. These projects help ensure the preservation and safety of these historic structures during an earthquake.

- Global Earthquake Model (GEM):

Prof. Erdik has contributed to the Global Earthquake Model, an international collaborative effort to develop a comprehensive and openly accessible model for assessing earthquake risk worldwide.

- Publications and Editorial Work:

He has published numerous articles and reports on earthquake preparedness, hazard assessment, and risk mitigation.

- Significant Awards and Honors:

(2018) Science Award, Turkish Scientific and Technical Research Organization.
(2016) N.N.Ambraseys Distinguished Lecture Award, European Association for Earthquake Engineering
(2013) Bolt Medal, awarded by the Seismological Society of America, EERI, and COSMOS
(2010) Rotary Foundation Science Award
(2004) NATO Summit Science Award
(1999) United Nations SASAKAWA Disaster Prevention Award.
(1996) Ford Foundation, European Award for Conservation of Cultural Heritage

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