University of Jaffna

Professor Alagaiah Thurairajah
Memorial Lecture - 2018

Solving Problems at the Interfaces of Human, Natural, and Engineered Systems

by

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University of oklahoma, USA

on
Friday 09th November 2018
at 3.00 p.m

at
Kailasapathy Auditorium
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Professor Alagaiah Thurairajah Memorial Oration – 2018

Vice Chancellor's Message

Late Professor Alagaiah Thurairajah was a highly recognized and respected professional, not only in Sri Lanka but also in the world as scientist. He contributed immensely to the development of the University of Jaffna, especially in the most difficult period of the country. He dedicated his time by serving the two terms as the Vice Chancellor to the University of Jaffna, which covers whole Northern Province spreading into three districts at that time too. Professor Thurairajah was also initiated the Jaffna Science Association to serve the best to the community and professionals in Northern Region.

I am very pleased to welcome Professor Kanthasamy K Muraleetharan, from University of Oklahoma USA to deliver Professor Thurairajah memorial oration. Professor Muraleetharan is also an eminent researcher in the same field as Professor Thurairajah. Professor Thurairajah was very well recognized not only as scientist but also known as excellent humble person with very strong leadership for achievements. He had the miracle on having excellent public relations through engineered thoughts. Therefore Profesor Muraleetharan has selected to deliver a lecture with the message on understanding the coupled human-natural-engineered system behavior. This is very important, in today's era, for providing happy working environment while effectively and efficiently achieving the targets.

Professor Ratnam Vigneswaran
Vice Chancellor
University of Jaffna
09-11-2018

Prof. Vigneswaran, Vice Chancellor, University of Jaffna, Prof. Atputharajah, Dean, Faculty of Engineering, members of the academic staff, students, and distinguished guests, it is my pleasure and honor to be here to deliver the 2018 Prof. Thurairajah Memorial Lecture. I didn't know Prof. Thurairajah very well, but I was extremely fortunate to have studied under him at the University of Peradeniya.

When I came to know that I would be giving this lecture, as any good Sri Lankan student would do, I asked whether there are any samples of previous talks. I needed some samples in a hurry because I came to know that I would be giving this lecture only about a month ago when I arrived in Kilinochchi to teach a course at the University of Jaffna's Engineering Faculty. Prof. Atputharajah immediately sprang into action and produced two samples. One of them was an inspiring lecture given by Prof. Abayakoon two years ago on Ethics for University Teachers. I need to warn you in advance that my lecture is not going to be anywhere near the high standard set by Prof. Abayakoon, who also knew Prof. Thurairajah much better than I did. When Prof. Atputharajah asked me to give this lecture, my immediate reaction was why me? Especially, when I could immediately name many people who are better qualified than I am and have contributed more to geotechnical engineering and Sri Lanka than I have. In the end, Prof. Atputharajah, through his characteristic persuasion, convinced me that it can't be just coincidence that I am in Kilinochchi in November and happen to be teaching the University of Jaffna students Constitutive Modeling of Geomaterials, an area where Prof. Thurairajah did pioneering work some 55 years ago, and that I was meant to give this lecture Prof. Thurairajah's birthday.

Prof. Thurairajah instilled in me the love of soil mechanics and geotechnical engineering and motivated me to pursue higher studies in this field. He showed us why soil mechanics is an exciting field and served as a role model for us in the pursuit of excellence. While it is easy to specify strength and properties of other civil engineering materials such as concrete and steel, soils are unique. We don't know what is below the ground until we start exploring and once we find it, we have to deal with whatever is down there. These uncertainties are what makes soil mechanics fun. He was also instrumental in helping me find a graduate research assistantship in the US. Just like he did for Prof. Abayakoon, he taught us advanced soil mechanics while we were instructors and assistant lecturers after our final year exams in Peradeniya. It tells me that he has done this for a countless number of students who went oversees to pursue their graduate studies in geotechnical engineering. Just as a single measure of Prof. Thurairajah's global influence on geotechnical engineering, I recently asked one of my students who is a practicing geotechnical engineer in Southern California, how many Sri Lankan geotechnical engineers are there in Southern California? He replied over 60! Note that this is not in the entire US, not in the entire California, just in Southern California! One of my colleagues in the US jokingly used to call us Sri Lankan Geotech Mafia. I would say, if we are a Geotech Mafia, Prof. Thurairajah would be its Godfather.

As many of you know, Prof. Thurairajah would have been 84 years old. Prof. Thurairajah, a humble human being, was many things in his life. He had a great intellect, was a pioneer in soil mechanics research, unselfishly served this country, often at great danger to his own life, but most of all he loved and cared about people he came across, no matter who they were or where they came from. Today I could have talked about how pile foundations behave during earthquakes or liquefaction of unsaturated soils, these are my primary areas of research, but I decided to talk about human beings. Prof. Thurairajah loved people, so I believe it is fitting that my talk today is about people.

First of all, I would like to acknowledge my colleagues at the

University of Oklahoma's (OU's) National Institute of Risk and Resilience (NIRR; risk.ou.edu), whose work I will be borrowing heavily today. Especially, I would like to thank NIRR's Co-Directors Profs. Hank Jenkins-Smith and Carol Silva and its Associate Director, Prof. Joseph Ripberger. All of them are Social Scientists. At the end I have also included number of references related to this talk.

Many of the problems faced by societies today can be considered "wicked problems." These are complex problems that lie at the interfaces of human, engineered, and natural systems. What I mean by the human system here is how individuals, groups, and communities interact, think, and behave during adverse and normal conditions. Engineered systems are the buildings and all the infrastructure, such as transportation, electric power grid, telecommunication system, etc., that help a modern society function well. Natural systems are weather, climate, and systems responsible for earthquakes etc. that stress both human and engineered systems. Over the last several decades we have made tremendous progress in characterizing the natural systems and designing the engineered systems to be resilient to stresses from the natural systems. *Resilience here is defined as the ability of a system to recover from the impact of an adverse event and be able to do so gracefully and in a timely manner*. Considerably less effort has been focused on understanding how the human system interacts with natural and engineered systems. In other words, how do people and communities react and use buildings and infrastructure systems when subjected to stresses from the natural systems and under normal conditions. Understanding the coupled human-natural-engineered system behavior has implications in many domains, including security (both national and economic), protection of property, community resilience, individual choice, and environmental quality.

I will use two examples to provide some insights into how we can go about studying these complex coupled systems and conclude by providing some relevant problems in Sri Lanka where these techniques can be used. The first example is mitigating risk from tornadoes in the US. Tornadoes are destructive rotating winds caused by complicated weather systems of colliding cool and warm air masses. In the US, the tornadoes are rated on the Enhanced Fujita (EF) Scale that varies from EF0 (65-85 mph winds) to EF5 (greater than 200 mph winds). The second example is related to resilience of communities subjected to multiple hazards.

Between 2007 and 2014, the US experienced 10,000 tornadoes that produced more than $24 billion in property damage. Oklahoma, where I live, sees fair share of these tornadoes every spring. Most of this damage was, however, caused by less intense tornadoes. For example, during the May 22, 2011 tornado in Joplin, Missouri, although the final tornado intensity was classified as EF5, 85% of the damage was caused by the tornado before it exceeded the intensity EF2 (111-135 mph winds). It turns out that it is possible to limit the damages from these less intense tornadoes with relatively inexpensive retrofits to homes borrowed from hurricane regions (e.g. Florida), such as roof straps, and incorporating them into building codes. There is, however, a problem. These retrofits will increase the prices of the houses in a region and therefore developers and home buyers are going to resist implementing these measures. Here is an example, where the engineering solution is very clear, but human side of things is not so. To implement this engineering solution to a common natural hazard, one has to study the human system carefully. Things such as home owners willingness to pay for retrofits and public support for building code modifications has to be measured in a systematic manner and factors that influence public attitude about tornado risk mitigation have to be identified. These measures then have to be correlated to actual tornado risk based on weather measurements and warnings to fully understand the interactions of the human, engineered, and natural systems. Social scientists today, in collaboration with engineers and meteorologists, are using a variety of techniques such as annual nation-wide surveys, panel surveys of specific populations, weather and climate data, and weather reports on social media to study these complex systems.

One of these efforts is by my colleagues at NIRR through the Meso-scale Integrated Socio-geographic Network (M-SISNet) project. This project has been measuring changes in individual and household perceptions, opinions, and behaviors over time using a panel survey that is administered four times a year to an address-based random sample of approximately 2,500 Oklahoma residents. This social observatory has also been used to study the above described problem of implementing tornado retrofits to houses. Home owners' willingness to pay (WTP) for retrofits was studied through the survey respondents answers to the following question: *suppose that an engineer inspected your home and told you that you could install a set of components that would protect the structure of your home from the majority of high-wind events that occur in Oklahoma, including most EF0, EF1, and EF2 tornadoes. Would you install this set of components to protect your home from high-wind events?* The responses were analyzed using rigorous statistical techniques. The survey found, among other things, that the probability of WTP decreased dramatically from about 50% to about 25% when the specified cost of retrofit changed from $2,000 to $8,000. Home owners were also more willing to pay for retrofits when incentives such as a reduction in their home owner's insurance premiums or loans to do the retrofits were provided. The WTP increased with the perceived risk and actual climatological risk (measured using weather reports). Essentially, this study provided city managers a road map to incorporate building code changes and communicate these changes in an effective way to overcome resistance from home owners and developers.

One of the important pieces of information needed to study the complex human-engineered-natural system behavior is accurate weather reports. Prediction of weather and issuance of warnings in the US have improved significantly in the last few decades using advanced technologies such as the Doppler radar. The coverage is, however, still sparse. To overcome this difficulty, NIRR researchers are using social media platforms such as Twitter to "crowdsource" weather reporting to great effect.

My next example is about resilience of communities subjected to multiple hazards. The impetus for studying community resilience in the US came through a Presidential Policy Directive 21 (PPD-21) issued by President Obama in 2013. This directive called all the US federal agencies to ensure that "critical infrastructure must be secure and able to withstand and rapidly recover from all hazards" and to "….address the security and resilience of critical infrastructure in an integrated, holistic manner to reflect this infrastructure's interconnectedness and interdependency." Although this directive referred to critical infrastructure security and resilience, all the agencies realized that it is impossible to study the risk to and resilience of infrastructure system in isolation without considering the people who use these systems, i.e., the human system. A number of agencies including the Department of Homeland Security, the National Science Foundation, and the National Institute of Standards and Technology funded research related to this PPD. Given below are some of my thoughts on what is needed to tackle community resilience in a comprehensive manner.

A community (a village, a city, or a province) consists of people and the built environment. The built environment is the buildings and associated infrastructure systems (e.g. transportation, energy, communication, water and wastewater, flood control, and coastal protection systems). Modern buildings and infrastructure systems depend on each other, i.e., they are interdependent. For example, buildings require water supply, which in turn depends on the electric power grid. Developing a community resilience plan begins with defining the *societal needs* and expectations of a community before, during, and after a disaster. Societal needs are the key driving forces in determining the required performance of the built environment. The societal needs include public safety, emergency response and governance, housing, employment, schooling, and business activity. Once the societal needs are defined, then the expected *performance of the built environment* can be deduced. This is, however, an iterative process. The existing conditions of the built environment will have to be factored into determining the societal needs in a realistic fashion. For example, a community with aging/inadequate flood protection system has to expect disruptions during a major rainfall event and develop an emergency response based on this initial condition. In addition to the existing conditions, anticipated *hazards* will be the driving forces in evaluating the performance of the built environment. Of course, *cost* will be a primary driving force in not only defining societal needs, but also in improving and/or maintaining the expected performance of the built environment. Some of the expertise and skills needed for developing a community resilience plan are: social science of disasters, emergency governance, resource allocation, business activity modeling; vulnerability, and interdependency modeling of infrastructure networks; probabilistic hazard characterization and geospatial modeling; and infrastructure financing and loss modeling.

Multiple manmade and natural hazards are the risks faced by communities. Characterizing these hazards will require an interdisciplinary effort by teams of meteorologists, climate scientists, seismologists, hydrologists, etc. Similarly modeling infrastructure systems will require collaboration of experts from many fields of engineering and sciences. One should be able to not only model and predict the behavior of a component in an infrastructure system such as a bridge, but also be able to predict the behavior of an entire infrastructure system such as a transportation network and its interdependency on other systems. This will require engineers and scientists from many disciplines such as civil, electrical, telecommunication engineers, mathematicians, and computer scientists collaborating together. Finally, a robust real time geospatial framework such as GIS (geographic information system) coupled with social observatories like the M-SISnet and social media platforms will be needed to ensure a community rebounds quickly and gracefully after a disaster.

I believe solving complex problems at the interfaces of human, engineered, and natural systems in Sri Lanka will also require comprehensive interdisciplinary efforts. Social scientists to characterize human perceptions and behavior should be an integral part of these interdisciplinary teams. In my opinion, Jaffna water supply issue is one of these wicked problems where engineering solutions may be obvious, but if you don't understand how people are going to perceive and react to these solutions, it will be nearly impossible to successfully implement these solutions. Social scientists should be involved from the beginning to systematically study how farmers in Iranamadu area perceive engineering and water supply solutions, what incentives are more effective, and how best to explain the benefits of these solutions to them and others. Similarly, panel surveys of populations in Jaffna should include people's perception of critical water supply issues such as saltwater intrusion and contamination from agrochemicals and the factors that influence their attitudes toward water conservation. As far as community risk and resilience is concerned, I would think communities subjected to heavy rainfall and associated flooding and landslides would require a multihazard risk characterization and resilience solutions similar to what I described earlier. Obviously, Sri Lanka is not the US, and may require careful consideration of several other dimensions to solve these wicked problems successfully. In conclusion, Prof. Thurairajah loved people and worked tirelessly to improve their lives in this country. So I urge you to include people's perceptions and attitudes from the ground up in solving your wicked problems.

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Prof. Kanthasamy K. Muraleetharan is the Kimmell-Bernard Chair in Engineering and a David Ross Boyd and a Presidential Professor of Civil Engineering and Environmental Science at the University of Oklahoma (OU), Norman, Oklahoma, USA. He is also the Associate Director for Infrastructure and Engineering at OU's National Institute for Risk and Resilience. Prof. Muraleetharan obtained his B.S. (First Class Honors) in Civil Engineering from the University of Peradeniya in 1983 and his M.S. and Ph.D. in Civil Engineering (with Geotechnical Engineering emphasis) from the University of California, Davis, in 1987 and 1990, respectively.

He joined OU in 1994 after working as a consulting engineer in California for 6 years. He is a registered geotechnical engineer in California, the highest level of registration available for a practicing geotechnical engineer in US. In California, he worked on several major projects such as the earthquake engineering design of Port of Los Angeles' Pier 400 and geotechnical and environmental investigations for the Los Angles Metro Rail subway tunnels. At OU he has been a Principal Investigator (PI) or Co-PI on research grants totaling over $10 million and participated in many educational initiatives including the School of Civil Engineering and Environmental Sciences' US National Science Foundation (NSF) funded Sooner City project. He has published over 125 journal and conference papers and delivered invited lectures in many countries. He has also served on several NSF Site Visit Teams reviewing major research facilities and programs in US.

Professor Muraleetharan is a member of the American Society of Civil Engineers (ASCE) Geo-Institute's Soil Properties and Modeling and Unsaturated Soils Committees and Engineering Mechanics Institute's Poromechanics Committee. He was elected as a Fellow of ASCE in 2006. At OU, he has received a Presidential Professorship, Regents' Award for Superior Teaching, College of Engineering Alumni Teaching Award, and the George W. Tauxe Outstanding Civil Engineering Professor Award (an award given by the students). In 2009, he was given the David Ross Boyd Professorship, an award named after the first president of OU and is the highest teaching award given to a faculty member at OU.

Prof. Muraleetharan is interested in large-scale computer simulations of infrastructure (bridges, roads, levees, port facilities, etc.) subjected to extreme events (earthquakes, hurricanes, tornadoes, etc.), validations of these simulations using small-scale (e.g. centrifuge models) and full-scale testing, and resilience of infrastructure systems following extreme events. He is also interested in simulation of static and dynamic behavior of saturated and unsaturated soils using finite element methods, centrifuge and laboratory testing of saturated and unsaturated soils, constitutive modeling, and soil-structure interaction.

Viras Printers Inuvil