Sue Nelson

Hello, I'm Sue Nelson and welcome to the Create the Future podcast brought to you by the Queen Elizabeth Prize for Engineering, celebrating engineering visionaries, and inspiring creative minds.

[Music]

Guru Madhavan is a Senior Director of Programmes at the National Academy of Engineering in the United States, where he focuses on engineering practice, communication, and policy. He grew up in a rural area near Chennai in India. But after taking a degree in systems engineering at the University of Madras, he travelled to New York to do a Master's and PhD in Biomedical Engineering. He has awards for innovation, engineering sciences and education, and is also known for his books, especially *Applied Minds: How Engineers Think*. Vint Cerf, a former winner of the Queen Elizabeth Prize for Engineering no less described it as offering 'a compelling explanation of the engineering perspective'. So, I began with that perspective and ask Guru how engineers think?

Guru Madhavan

There is no uniform approach to how engineers think because the varieties of creations and the consequences attached with engineering are just so different and cosmopolitan. That took me on this entertaining narrative journey, part self-exploration, part professional exploration. I came down to basically three essential attributes that characterize the engineering mindset. The first relates to bringing structure where there's none and this is a fairly uniform habit of the engineering mind. How do you operate in an environment where there are too many variables and considerations? And how do you organize, how do you bring order to the approach, is something that relates to structure, application, and a context. The second element is the invariable scenario for operating under constraints. And even if there are no constraints, engineers, good engineers, know how to apply constraints to fuel their creativity. After all, we are limited by physical laws and human behaviour and policy constraints. So, this is a unique characteristic of engineering design approaches. The third aspect is to make judicious trade-offs. In life, not everyone can have everything, engineering design is also that way. You package them all together, the structure and the constraints and the trade-offs, what I call the 1-2-3 punch of the engineering mindset, basically provides an architecture for how engineers think.

Sue Nelson

And why did you want to write a book about that?

Guru Madhavan

Part of the motivation was to really understand how engineering, which is arguably one of the oldest cultural practices, perhaps even created for survival instinct, the art, the philosophy, know-how, which is far more ancient than the sciences of know-what. Being such a consequential profession, I really was motivated to understand what drives the engineering sensibility and its willingness to contribute to society at large, deal with relentless failures, yet produce accountability in practice. How do you do that? And being such a human activity, that really motivated me to explore the foundational question, how do engineers think? That's what got me going on that journey.

Sue Nelson

Is it something you think that's innate, or is it a way of thinking that can be taught and learnt?

Guru Madhavan

It is readily trainable and I think, if you even look at the origins of civilization, some of the ways of thinking that we now take for granted must have sounded foreign, unnatural. So, these are trained attributes one can diligently put one's mindset in different circumstances and get better at those. If you look at some of the most

successful engineering companies, they take this kind of learning and unlearning quite seriously, that is a precondition for success in engineering.

Sue Nelson
Do you think engineers are misunderstood if people don't have a similar mindset?

Guru Madhavan
I don't want to live in a world where everyone thought like an engineer, even though the work that we do is consequential. But I think element of cognitive diversity is utmost importance and I think engineering sensibilities have a fair amount to offer to the social structures around us and to make better sense of the world in terms of enabling better sciences and also simultaneously to consider not just the technology possibilities, but also fruitfully integrate the behavioural and the policy dimensions which are becoming increasingly more challenging and then the complex systems that we have created for ourselves. By understanding the elements of the engineering mindset, and all the possibilities, and the unwarranted consequences attached to engineering design, we can be better consumers and creators of engineering.

Sue Nelson
Engineers often use the word 'creative' to describe their job. But that's not often the first profession that comes to mind if you use the word 'creative'. Do you think artists and engineers have more in common than they realise?

Guru Madhavan
Engineering was originally known as one of the practical arts. Even the term engineer, the modern context goes back to the 11th century, I believe, much before the word scientist was invented, which was in the 1830s. So there's a level of history here that we need to be cognizant of and also the task order, so to speak, that the society has given engineering and then the contract that exists between what engineers create and how society consumes them, and vice versa. Now, I think we have a much better opportunity to really step back. Having been through the technological developments, we can now ask the question, how do we bring engineering fruitfully into some of our civic processes, and at the same time, also bring some of the civic consciousness into the world of engineering so there's a bilateral benefit, and we can better marry them to get better benefits out of engineering going forward. Because no other profession gets to the scale, in terms of creation and consequences, as engineering.

Sue Nelson
Is this why you've advocated that so called hard sciences such as engineering could benefit from more engagement with the humanities and arts?

Guru Madhavan
Absolutely, that is something that we're getting even more active in terms of articulating at the National Academy of Engineering. In fact, the next five years to strategic themes of our work at the National Academy of Engineering relates to people, systems, and culture. Merely focusing on engineering to serve the people, systems, and culture is not enough. We need to now focus equally importantly, on the people, systems and culture of engineering so that the profession itself can become more inclusive, more appealing to the widest range of thinkers, including, especially artists and humanists who can contribute widely to the professional development.

Sue Nelson

You brought the person, a sort of humanity aspect to the fore in your book and it seems like that's very deliberate. Do you want people to associate engineering with people, with its impact on the world?

Guru Madhavan
One of the cultural tendencies we have created to achieve certain things to the benefit of society, how do you go about understanding the anatomy and physiology of the problem sets that we deal with? There's much to be learned from how different human beings approach them. And in this case, they all happen to be engineers, for example, Alfred Hitchcock had a completely different approach, than the French engineers who built their guns to achieve better efficiencies back in the time of Louis the 14th. So, there are many different circumstances, many different viewing angles, so to speak about engineering, and I like to think that engineers are dual citizens in the world of disasters and blessings. Simultaneously, using the tools of wonder and worst-case scenarios. Anything that engineering produces can and does affect people in the best or the worst possible scenarios. And I think bringing in the higher construct of cultural responsibility is crucial. See, good science is peer reviewed, but accountable engineering is reality refereed and that's why failures are unforgiving in engineering. It becomes paramount to bring in ethics, economics, environmental considerations, into the core design of engineering.

Sue Nelson
You mentioned the effect of culture there, how has growing up in India affected your outlook, particularly, as you're now living and working in Washington?

Guru Madhavan
I was born in an orthodox Hindu family in South India, my grandfather was a local village priest, I tried to help him out as a priest in the morning. So a fairly traditional upbringing. My education was on an assembly line because of the sheer competition. My entry into engineering was basically like arranged marriage. It was only after years of practice and getting into different forms of experiences and advanced studies, I finally fell in love with engineering, appreciating the broader possibilities and the responsibilities that come with it.

Sue Nelson
What do you mean by forced marriage? Because you are the first engineer in your family's history. And that's, you know, from the number of engineers that I've interviewed for this podcast, that's often quite unusual. So many of the engineers have family members that shines a light on other aspects of engineering or the possibilities within the profession.

Guru Madhavan
India has a rich tradition of producing a lot of engineers. So engineering, medicine, and law are fairly common. At one point in my 10th grade, I had to make a decision where I belonged professionally, that's why engineering sounded like a well-trodden path, and seemed like the way to go. And as arranged marriage is common in India, I took the path of engineering to profoundly realise the value that comes with an engineering mindset to better engage with problems of all kinds.

Sue Nelson
So has that background affected how you approach policy and engineering now that you're living in the United States, or was it an easy switch to make?

Guru Madhavan
I'll give you one example to explain how local culture affects you. And I'm not talking about temporary cultural experiences, but some of the foundational ones someone born in India, even some of the religious scriptures

emphasize the notion of caretaking. That happens to be a big function of engineering that seldom gets discussed. Oftentimes, we focus on how engineering is able to produce dazzling innovations which we're all grateful for, but it happens sometimes at the expense of forgetting the kind of dull, diligent and the mundane activities of engineering, specifically talking about maintenance in society, which is a cultural responsibility, relentlessly producing new objects that may or may not be needed is a questionable act. That's why we need to simultaneously also think about some of the activities that are unseen and happen in a daily format. Oh, in fact, over 70% of engineers are in maintenance related duties that keep the world running. It is an underrecognized struggle. It relates to even with the whole notion of inspiration and perspiration. Right? Perspiration, which has so much connection to maintenance, even there's an acronym for the word sweat, sewer, water, electricity and telecommunication. How do you ensure that systems such as those that are essential for our daily living, ultimately civilizational survival, get emphasized? There are aspects of this kind of caring and caretaking, that are available in the Hindu scriptures. So, there are a lot of influences that can be brought in from the world of Humanities and philosophy into the rich practice of engineering that are seldom communicated to the broad audiences. And I'm interested in focusing on the things that are right in front of you, but others don't pay attention to.

Sue Nelson

Now, both your books Applied Minds and Making Better Choices extend beyond the traditional discipline of engineering and you know, you've already discussed how the sort of mindset and incorporating the humanities and arts and creativity. Did your early study of systems engineering create this foundation for you about interdisciplinary thinking?

Guru Madhavan

Yes, I was very fortunate to have a broad engineering education. I was simultaneously taking courses in civil engineering, mechanical engineering, electronics, electrical, computing, and eventually found a fascination in biomedical systems. I was also fortunate to be a junior engineer in a number of industries. One of my favourite experiences was building a controller for a cooker that mixed the ingredients to produce chocolate. So literally a Charlie in the Chocolate Factory moment. But I think the background in systems engineering, in addition to what I retrospectively can appreciate, the value that it brought to me, the elements of structure constraints and trade-offs. But also the ability to what's called 'transcending the levels of abstraction'. Too often, we get too fixated on some of the specifics to the point that we lose sight of the overall system. How do you go about pinching and zooming on different functions of interest? What I'm trying to say is, if you're designing an SUV, you want to not just focus on the technologies that are innate to the SUV that are propulsion, battery, radiator, alternator, you name it, but also really zoom out of that to look at the global carbon circulation. And also, at the same time, go back to an extremely specific tool within the car, say, controllers. At any point in time, how do you go up and down these levels of abstraction, and you're able to aggregate those functions. Now, this is something that was explicitly taught in my training as a systems engineer that seems to have a lot of value beyond just the projects involving coordination and policy and behaviour, but also for acts of daily living. And in that regard, I'm very fortunate to have had the education that still influences my thinking.

Sue Nelson

Now, you wrote an op-ed for The Wall Street Journal in the early part of the pandemic that said that COVID recovery would come down to engineering, do you still think that's true?

Guru Madhavan

Absolutely, yes. Because the recovery as we are looking at, is subliminal. And also as a confidence boosting mechanism there's not a switch that could be just turned off or on to just make the pandemic go away, but also really providing an architecture for future preparedness efforts. With the systems engineering sensibility, we

have an opportunity to rethink the notions of immunity, the notion of preparedness and how we want to conduct ourselves going further. Given the amount of politics personal preferences that creep in to even seemingly simple things that could basically stanch the pandemic. Without engineering, we cannot imagine telework, I cannot imagine broadband, or even this conversation that we're having right now. In a number of ways, the invisible public health systems made possible through engineering innovations and maintenance is something that we need to be proud of, but also use some of those successful elements to help guide our path forward to better prepare for future pandemics.

Sue Nelson
I mean, this sounds like a perfect fit for your description of engineering as a profession, 'with profound consequences'. I'm sure you didn't necessarily have a pandemic in mind when you used that phrase, but what were you thinking about when you said that?

Guru Madhavan
I read a line some years ago by philosopher Paul Virilio, who wrote that when you invent the ship, you also invent the shipwreck. The point that's in that statement is technology can simultaneously produce luxuries and liabilities. How do you constantly live in this polarity? Is the question and I think in a number of ways, technology has compressed time and space and in a way has also contributed to the pandemic that we are living through and also going to facilitate our rescue from it. Ultimately, it goes back to the point that you just raised. How do you better engage with such a consequential profession, not only as an actor in it, but also as a dependent on it?

Sue Nelson
You have a blog called The Barefoot Engineer, first of all, where did that name come from?

Guru Madhavan
It goes back to my childhood. I used to walk in our villages barefoot so it is something that just takes me back to my childhood fascination, my experiences, me being in contact with reality, so to speak, and you can see the engineering connection.

Sue Nelson
And what appeals to you about blogging over say, Twitter, or YouTube, or even TikTok?

Guru Madhavan
I've developed an interest in writing short form pieces in recent years, that allows me the opportunity to compress some complex concepts and also simultaneously write about a problem set or suggest certain ideas or concepts that are not being considered. The short form pieces are a helpful way for me to publicly think about what I'm personally thinking.

Sue Nelson
Where will you go next do you think, are you very comfortable, I was going to say 'thinking about thinking', but also being involved about policy and shaping the next generation, perhaps how people think about engineering in the future?

Guru Madhavan
I'm very fortunate to be in a position where what I write about is something that I can also practice for a living at work. So, there's a seamless connection between my day job and my personal interests in terms of professional contributions. I foresee continuing some of these crossover concepts, bringing them together,

putting them out for public consumption while improvement thinking about those subjects. And also continuing my narrative communication through long-form writing, notably narrative nonfiction books. That's how I foresee practicing engineering or articulating the importance and the consequences of engineering that we all need to be in better engaged with.

Sue Nelson
If there was one piece of advice to engineers about a project that they're working on, something to think about, something to keep in mind, what would it be?

Guru Madhavan
One such incident happened in my own life, a graduate school course, it was an elective that I had to take as a requirement, but the subject that I chose was completely offbeat for me. That ended up changing my worldview. I took a course on cultural evolution and the perspectives that I learned from fellow students and the kinds of readings that I was doing completely changed my perception of engineering and the way I went about it. If you look at the core of how engineering develops in society, there are so many evolutionary concepts that can better explain that engineering and evolution have so much in common to bring in the kind of the systems engineering perspective into this Mother Nature takes on system as a unit of selection very carefully, varies and selects traits and the attributes and then the best practices from that evolve and they get honed in practice, but the only difference between that way of doing in nature and that way of doing an engineering is engineering is deadline driven, goal oriented. So, there in comes the constraints. Of course, natural constraints are completely different than technical constraints. I think there are a lot of synergies in bringing an evolutionary approach to engineering which could better enable us to take on some of the complex, wicked civic issues that we have been under engaged in. The advice to an engineering student or a young professional, even a practicing engineer is to try and get into a subject that you would normally not get into. That will create an experience that you would not have planned for. In my case, it turned out to be profoundly beneficial.

Sue Nelson
Guru Madhavan thank you so much for joining me on the Create the Future podcast. Find out more about the Queen Elizabeth Prize for Engineering by following @qeprize on Twitter and Instagram or visit qeprize.org. Thanks for listening and join me again next time.