CTE Distinguished Speaker Series

DR. RICHARD T. T. FOREMAN LECTURE

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10:30 am CT

Dr. Forman: Thank you very much Katie and distinguished residents. It's a great honor to be here. I want to start with two or three anecdotes or comments at the beginning before I launch in.

The first is, I grew up in your neighbor state of Georgia and though I don't sound that way. This morning I got up in the snow and it was dark, I crunched out in the snow and fed the birds in my backyard and then came down here.

I spent a year in graduate study in the Research Triangle Area before it was called the Research Triangle Area at another distinguished university that has devils in the name. I came to love North Carolina. I explored literally many parts of it.

Then I also wanted to mention that I just saw Professor Arthur Cooper whom I was just delighted to see. I haven't seen him in a number of years. He is a very distinguished ecologist here at NC State.

What I would like to share with you today are some thoughts about road ecology in the following way. We have spread an enormous net over the land, North America - almost 5 million miles of public roads. A quarter of a billion vehicles use that net.

Most of the net was put out before its day, before the rise of modern ecology. It's an engineering marvel. It's an economic success story. It has provided unprecedented human mobility. It has stretched the boundary of social interactions, greatly facilitated the movement of goods across the country. In effect, it's at the core of today's society and economy.

This network, these roads are superimposed on mountains and valleys, rivers, plains, they team with natural flows, that is ground water, surface water flow across that land. Wind carries seeds and spores and soil. Wildlife forage, and then they disburse. Sometimes they migrate and fish do also. In effect, nature's never-ending flows, horizontal flows and movements across the land mold the land mosaic and produce the patterns to provide diversity.

These two giants, the net and the land, are in an uneasy embrace. The road system ties the land together for us. It divides nature into pieces. And therein lies the opportunity for us.

Nature is degrading roads; roads are degrading nature. Both of these factors are costly to society and have maintenance costs. These are increasingly receiving public attention and this translates into the need for political action.

Meanwhile traffic is increasing and the curves, as many of you know, are increasing at a greater rate than almost all the other statistics you can name. So there's a greater call for new knowledge and skills.

Just in time, the science of road ecology perhaps is meshing, is jelling, bulging with useful applications. Its roots are in vegetation, stream ecology, wildlife ecology, chemistry, hydrology and more. Yet the new catalysts are intelligible, the new kid on the block, that helps to bring this together as landscape ecology.

I'd like to start with the first image to show you a little about how and where I fit into all of this or don't fit in, in some ways. This is a book that came out in 1997. There was a National Research Council project I was involved in with a lot of very bright engineers, economists, policymakers and atmospheric scientists.

If you could blot out that highway there for a moment, that's tough to do, but if you could blot that highway out, what you would see out there is what I have been seeing for the last 20 years and what I've been describing and what I've been analyzing. The landscape - a large area heterogeneous, lots of flows, patterns there, changes over time as if you turned a kaleidoscope.

Now, add the highway, which is there, and landscape ecologists really didn't even notice the road system. Even though in most landscapes it's the most prominent feature out there, one of the most prominent features in most landscapes. And yet, we didn't study it. It's the least ecologically known feature. Now that in itself is a challenge, for scientists like me, that's a challenge.

So I spent 20 years or so studying that landscape as an object and understanding - analyzing it just as if it were a human body or a cell, that has an anatomy, a structure in which things flow through it, it works, it has a functioning and it changes over time.

So this illustrates one of the applications of that in a very primitive sort of way and this is - these are illustrations of some of what we call the "spatial solution," or what I call the spatial solution. What it in a sense it says is if you have such large area and you don't know much about it, don't spend all your life or don't wait until you know every animal and every plant and every piece of soil and every clean water.

There are some principles, some spatial principles that make sense everywhere, or at least that becomes the norm model that you have to justify that don't work and these are simple ones here. A few large patches of natural vegetation, those are what those big green blobs are.

A second one is greenery along major streams. Now I call these indispensables, and that's a very strong word in the English language because it means they're indispensable, it means there's no known technical or feasible alternative to providing the ecological benefits that a few large green blobs will provide or that greenery along vegetation.

Art Cooper could name 20 ecological values of vegetation along streams. The bulk of them can't be provided any other way - benefits to society and benefits to nature - except by having vegetation along there. A third one there is connectivity among the large green blobs. A fourth one is bits of nature scattered around the less hospitable matrix. There are probably a few others. These are just basic spatial solutions that should be present in any landscape.

Here is a more, perhaps a stronger one, this says given that they're different land uses, how do you fit them together optimally - ecologically, optimally? How would you fit in this case nature and pastureland and the build environment that what NP&B mean there? So what this suggests this model the aggregate without (unintelligible) model suggests that you aggregate large blocks of nature there - large green areas. Then you have big blocks of pastureland, and you have big blocks of built areas there.

Second thing it does is it says take little pieces of nature, the little Ns there and spread them around over the big Bs and big Ps - over the developed areas of humanity.

The third thing it says is for the small Bs and Ps, the individual houses and suburbs and towns and villages, concentrate them along the major boundaries, between the major types there. So you'll follow most of the small Bs and Ps are along the major boundaries.

There's one other thing it says there. It's the idea to provide for hermits. The farther you get from a big B, the big built area, city or town, the farther you get from it the greater distance between the little Bs. So actually there's a hermit house, let's see if I can find it there, well anyway, way down here in the middle of that pasture, way down at the bottom, it's the most isolated place on there, and so you're saying, the farther you get. So we visualize this as an ecologically optimum way to arrange different land uses.

Let's put some roads in the system and I'd like to see how many people know this book? Raise your hand if you know this book. All right. So, this is the "Green Book."

I didn't know about this book until six years ago. But the Green Book is absolutely fundamental to the design of roads and everything having to do with roads. A new edition there. I'd never seen it and I see many of us in the room have never seen it before. I mean, it is an absolutely critical - every cul-de-sac and every housing development follows that Green Book, almost. Although you're allowed to deviate - as I understand it, you're allowed to deviate from it if you can justify now that you have something better.

I put down there in the lower right, “What’s VMT?” I could ask the same question, but I won’t. Six years ago I had never heard the word “VMT.” And VMT means “vehicle miles traveled” and it’s absolutely central to transportation planning. It’s the most common phrase among transportation planners in my experience. VMT. It’s very important. In fact one of the panelists I think is going to talk about that, probably.

So my point here is that we ecologists and people outside the transportation field are faced with things that mean nothing to us. We have to learn. We have to be open to learn. If we are open to learn, there’s a lot there and maybe we can begin to communicate. So, taking that step is very important.

This, if you look on the horizontal axis here is road density. If you look on the right side, you’ll see Japan over there. Japan, of the various countries I’ve put up there, has the highest road density and you’ll notice that Canada, New Mexico and the United States have the lowest road density over on the left side of this for the countries I’ve put there.

The second thing that you see- if you look at the numbers in parentheses, that’s the actual kilometers, those are the actual kilometers, lengths in those countries. So you’ll see the United States has about six times as many, as long or more miles of road or kilometers of road than Japan and Canada, which are the other countries there.

The third thing on this map or this diagram, is if you look on the vertical axis here, the total road length relative to population, relative to you or me or all of us there, you’ll notice that Canada has the greatest road length, although the United States is close to it, per person. Mexico is at the bottom. Very few roads per person, although I think there are probably some questions of what is a road in Mexico for these data, and so there - and these other countries are sort of in between there.

Now those are the kinds of numbers and statistics that are very common in the transportation field. Those are the kinds of things that we ecologists almost never deal with, sometimes, but not often.

So that's sort of setting then this, you know the road system is tying the land together for us and it's subdividing nature into pieces. Now this is where I'm going. I'd like to spend some time on wildlife. I'd like to spend some time on water and vegetation and I'd like to broaden the perspective in this presentation.

Under wildlife you will notice that we have effects on populations and then I'll talk about public disturbance, noise.

Now, when I first began working six-seven years ago with transportation folks, they were really worried about me. It was on a National Research Council thing. Real worried because they were worried that I was going to focus on road kills.

And that's the public - that's what the public sees and that's what some of the transportation folks were worried about that I would see. And I say I saw it but I said there are many more interesting and important things than that and universally they were really relieved that I wasn't going to push road kill.

So this is an attempt to give some perspective on that. Sometimes they get this point - if you look on the left side there, you have the population, a population going along with some variability and doing fairly well, it's a large population, low extinction probability. Then you put - we put in a road and the obvious thing is that you remove some habitat, that's what habitat loss is - not very interesting conceptually; it is important to the animals, however.

The second item is reduced habitat quality. Now the thing we mostly focus on there is the edge effect next to a road, the microclimate gets in and drives out the edge and there's studies on that various places. What I'm going to show you in a minute is that there are many more things, including traffic disturbance, traffic. So there's a road part of that and there's a traffic part of that.

The third aspect of decreasing a population size is road kill, or I like mortality. I'm going to say almost nothing about that. I'll show you one image on that.

The fourth aspect of decreasing this population is the barrier effect, reducing the connectivity that I started out with that animals and species move across the landscape. There are good ecologists that argue that animals must move, that's controversial but that's a possibility.

Finally, you're left with the small populations with a higher probability of local extinctions; that is disappearing locally. So that's the overall picture here and I just want to emphasize that in decreasing population sizes of animals, there are four processes going on, or one can boil them down to four major processes. All of which are important.

I'm going to show you one image right now on road kills and then I'm going to focus the rest of the time on the second one there, reduced habitat quality in the area of - I think that's what I'm doing.

This nice handwritten thing illustrates that this is a progress - this book is in progress and my thinking is in progress. Look at the horizontal axis at the bottom. Those are a whole series of mitigations that are done by various states that mitigate - minimize environmental damage and in this case it's for deer-vehicle collisions. That's the issue. So the horizontal axis you have ten or a dozen ways that we try to decrease deer-vehicle collisions.

Then on the right side of that graph are the ones that focus on modifying human behavior and on the left side are ones that focus on modifying deer behavior. So you see you can focus on either trying to change the way we work or the way the animals work.

You'll notice then the curve of the dash line on the right shows that in a survey of 43 states done by (Rowman & Bissinette) a few years ago, the states reported that a lot of these mitigations on the right side are done. That's what that peak in the dotted line shows and on the left side is the success rate, perceived success rate, I should say. That is their feeling that they were successful and you will notice that the high successes, perceived successes, are on the left side where they aren't done or very few of them are done.

So there's a big disconnect between what we're doing and what seems to be successful there. The numbers at the bottom of the graph are the numbers of states reporting research programs that they have done research, at least one research project, on each of those mitigations. You'll notice that most of the research has been done on the right side and while they're little has been done on the left side there.

So I put that up as an illustration of the disconnect between what we do and what seems to be successful, but also an opportunity for some bright people in this room to change that.

A little bit of the issue of the barrier effect, the fourth part of that population decrease. This is in Florida. That's a standard 25-foot wide and 8-foot wide box culvert, a chunk of concrete. It's dropped into place.

The costs and the methodology are all worked out. This is on Route 29, north of the Everglades and in that particular one I've seen the Florida panther tracks going through there.

They are still building these. They know exactly how to do them and where to put them and so forth. Some fencing goes with them. Florida is flat so they have to build up the road a little bit. They're done for black bears and Florida panthers. They have worked, up to a point.

That's a superimposed image there of a Florida panther and an alligator going through. This is in the ones along I-75 near the Everglades. This was done several years ago - a couple of dozen - more than two dozen of these were done down there for two objectives.

One was to reconnect water flows into the Everglades that were blocked by this east-west highway, and the second was for this endangered Florida panther, which there are maybe only 50 left in the world, perhaps. It was successful on both counts, according to the people involved.

That is what it did bring, indeed, a lot of these - it did bring a lot more surface water down in the Everglades and indeed they cut the population death rate from about five per year down to about 1-1/2 per year, although I understand last year there were quite a few killed down there by automobiles or by vehicles. So more or less it was successful or a whole series of very expensive projects - a lot of Federal and State money.

However, one of the interesting things is they accomplished something else; the whole fauna went through these things, including the alligators. I mean - and just every animal, and so they didn't anticipate that and so it almost was like a landscape connection, these various things.

Here is another underpass - these are underpasses I'm showing you right now. This is in Banff National Park, the Trans-Canada Highway is going up there - a four-lane highway, 20,000 vehicles a day, I believe, in summer. I calculate that it is roughly 100 feet wide and maybe 15-20 feet high and they have a whole lot of different designs of underpasses up in Banff National Park.

As some of you know, the Canadian Rockies have all kinds of animals, big animals, tough animals, and of the various designs, this is the best. This is the most successful. Grizzly bears go charging through there. Elk go through there. Deer go through there. Black bears go through there. Wolves go through there. Cougars go through there. That design is very successful.

Now notice in the previous one what you could see as you look through it as if you were a deer or some animal or bear or something trying to go through there, you can see the far side, but you can see much. Look at how at the eye level there you can see much more widely. This is a more expensive structure, but it's a very successful structure for a wide range of animals.

The only animal they aren't getting going through there in significant numbers they were expecting is a Moose. Moose don't seem to be using any of them, actually.

Now, let's go up above the highway - this is again Banff National Park - and have you every seen an overpass, a green bridge, vegetation going across it? That's going across that Trans-Canada Highway. There are two of those up there. There are five in the Netherlands. There are two in New Jersey. There's one in southwestern Utah. There are only three in the United States. I've heard there's one in British Columbia - I don't know that. There are lots of them in Germany. In fact, there are a dozen under construction. They're huge ones.

Switzerland there has been - I know two of them, one of them is 200 meters long or wide and one of them is 140 - a big thing. Now, that was - those two things are barrel vaults. It's based on the European model, as I understand it, by law in the European countries it has to be strong in order that a row of NATO tanks can go across it. Now we don't have that problem in this country, fortunately.

So this is based on the European model so it's really massive. There's a meter or more of soil at the narrowest place there - at the top, and they plant trees and what-have-you there. Animals love it. All the big animals go across that.

However, there's an interesting message about this and that probably applies widely. People say, well, you know, some animals aren't going to use it. There was a learning curve.

The first female Grizzly didn't use it until the fourth year, possibly the fifth year; at least the fourth year. Wolves didn't use it in any numbers until the fourth year. So they learned to use it. So a lot of our projects where we build something and then we test them for a year or so are missing the learning curve of the animals. That is an important point.

The second thing I want to say about that is that those structures were prefab. They were carted there on trucks. They were assembled on the side and they were dropped into place and it took about a day and a half to drop them both into place. Traffic wasn't discombobulated for more than a short period there.

So technologically it's very feasible and I mention the massiveness of these things. I would hope that we could come to some good civil engineers and ecologists and they would sit down together and come up with some designs where they aren't so massive and expensive. That's a tractable thing I would think.

Here is one. This is the first one built in the Netherlands. Here we are up on the structure looking across and you will notice it's hourglass-shaped. It's really a pretty curve.

Now, this actually is too narrow. In the middle it's only 15 meters wide. Videotape has shown that animals like the deer and others come up to the middle and they have fright. It's too narrow. The Dutch have done the most research on this. They've just finished one like this except its 30 meters wide in the center and 80 meters wide on the two sides.

Notice that there's a really interesting visual aspect. If you're an animal way over on one side, you can look diagonally across and you can see your target vegetation. Similarly, an animal over there can look diagonally across. So these hourglass things have a lot of animal behavior advantages to them.

The Germans don't necessarily make it a perfect curve, but they make it straight lines and then that way. Notice the pond in the front to help attract the animals. The rain that falls on these things has piping - gravel and piping system that just pipes the water to these ponds and they believe small mammals and large mammals love that.

Now let me shift to the other aspect of wildlife and this has to do with the traffic - traffic disturbance. This is the Dutch work again - a group - a whole series of publications there - bird density, these are songbirds in the woods in the forest.

Songbird density is a function of distance from motorways or highways with 50-60 thousand vehicles per day. Now that's like a busy interstate highway outside of a city, roughly, I mean to give you a scale there. So it's very common to what we have in our country, and what you will notice is that the birds there - the curve on the left for all species indicates that a few hundred meters out from the edge of the highway, bird density is affected by traffic disturbance.

For the most sensitive species, this is in woods mind you, going through forest, the most sensitive species for several hundred meters out. The measured decibel levels, the measured noise levels of those points are sort of 35 to 45, 36 to 43 decibels there, kind of like a quiet reading room in a library, for example there.

So, those kinds of data made you stand back and think, "That's a long distance to be decreasing birds." In fact, bird density decreases by one-third, 30-33%, in that first few hundred meters and bird diversity also decreases by one-third. So both diversity and density are dropping for a long distance out.

So we got interested in that and we said let's try that out a little bit and so here we are in Massachusetts. Some of you who have been west of Massachusetts there's a ring road, Interstate 95 or Route 128, that's over there on your right. Ardery Road, Route 2 going west from Boston like for 25 kilometers and it comes to another ring road, Interstate 495 out there.

So what we did was we mapped the roads and that whole landscape that you can see there roughly within about ten kilometers on each side of that highway, and we mapped them by traffic volume.

Now ecologists don’t know what traffic - don’t think about traffic volume numbers. So if I said 10,000 or 5,000, most of us wouldn’t have the foggiest notion what you mean by that. So I’ll show you in a moment. But I’ve mapped this according to traffic volume. We mapped then all of the openings suitable for grassland birds in that landscape, and there are 84 of them there. The black dots where they’re absent and the Ms and Ds where meadowlarks and bobolinks are present.

The next one, this is for the scientists, I’m sorry, I’ll put this up for 30 seconds here, or less. We did a logistic regression analysis trying to figure out whether traffic volume and distance from road is important relative to the size of the clearing, how far the clearing is from the next clearing and what the adjacent habitat to each clearing was, whether it was a built area or forest.

To summarize here, on the left side there, in that area there, you’ll see the distance here is the traffic volume varies here - distance for road is significant, that’s what those double asterisks mean - highly significant, for certain traffic volumes. Area of the open patch is significant - but that’s - ecologically we all know that. The percent adjacent built area, that is what’s around these clearings was not significant, (unintelligible) birds present, and the distance to the nearest other opening was not significant.

So what we found out basically was that traffic - that the highway and traffic was significant. Here’s the same thing on the right for regularly breeding animals, rather the left is for the presence of the grassland birds and they’re more or less the same there. I’ll show you the difference in a moment.

Now this is getting more interesting. Here we've done on the left side here, you read that axis there, the horizontal axis is traffic - I'm sorry, the horizontal side is distance from a road. In this case it's a local road - a local collector street in my landscape - in our landscape and it has 3,000 to 8,000 vehicles per day on it. That's not too many.

The vertical axis is the size of the clearings and in this case the circles represent regular breeding animals. You'll notice that all the circles are above this horizontal line - that horizontal line is about seven hectares, that's 18 acres. In other words, the birds didn't breed regularly in any woods - any cleaning less than 18 acres.

The triangles represent the presence of birds. The circles represent their regular breeding. So what you'll see is that in fact the triangles get really close up to the highway and there's no real effect of the local collector road on the presence or the breeding of birds. So at that traffic volume, we found no effect.

Now look at the right side of this. This is for a through street with 8,000 to 15,000 vehicles per day. Transportation people can relate exactly to that number. The rest of us maybe can relate to a through street, although not too well, not too rigorously. And again, the circles, now this is regular breeding animals only above 18 acres so we won't talk about that anymore, but notice the difference this time. There's no circles - all the circles are a few hundred meters to the right of the highway.

In other words, none of the animals are breeding regularly within a few hundred meters of the highway with a traffic volume of 8,000 to 15,000 vehicles per day, for a commuter day, that's a 24-hour commuter day.

Triangles, however, are to the left of that, so apparently that traffic volume isn't affecting the presence of the grassland birds. So that through street, the presence of birds isn't affected, but the breeding of birds certainly is affected.

On the left side, we've got a bigger road. This is a two-lane highway in our landscape with 15,000 to 30,000 vehicles per day. Two-lane highway. Notice again the breeding birds, the circles are farther to the right - in this case, several hundred meters. In this case, the triangles also - not many triangles there - but apparently there's an equal effect on the presence of birds.

So for the two-lane highway, it looks like, you know, 700 meters or several hundred meters from a highway, both breeding and presence of in this case, grassland birds are significantly affected and if you look at the right-hand side by the final one, here's a two-to-four-lane highway with 30 to 170 thousand vehicles per day, show some big, busy highways, there are three of them.

Here you'll notice the circles are all to the right a kilometer or more. So that near these busy highways, the big highways, the multi-lane highways, four-lane to eight-lane highways, there's no regular breeding taking place within about 1200 meters - within several hundred meters, the same thing for triangles. There are hardly any triangles to the left of that distance.

Now that's a long distance. But what it says is, if you're interested in songbirds, you're designing for nature reserves, for example, you're spending money for a nature reserve, don't put them near busy highways. And don't put them very close at all or don't put the highways near the nature reserves.

Now let's go a little more quickly to vegetation and water, this is something familiar to all transportation folks. Water flows downhill and that we put ditches in here to catch and that on slopes like this that natural flows in and flow out in a cut bank, you know, the cut bank on the upslope, water oozes out there. It oozes out and it goes down into the ditch and on the upside goes down through a culvert and down toward a stream.

Well now what does that do? Well it does a number of interesting things relative to the stream. One thing it does is it takes ground water, turns it into surface water, and heats it up. So the water going into the stream is warmer. Now cold water fish like trout and salmon don't like that so much.

Another thing it does is that when it comes out of the culvert it may form a channel and erode some material down to the stream and flatten out the stream bottom, it may not, it may. Another thing it may carry nutrients down into the stream and the various consequences there.

So that really innocuous looking or sometimes very attractive looking road cut - think of the ground water flowing and what happens to the ground layer when it hits that. It comes down, goes through the ditch, goes into the culvert and has various effects down there.

This is standard storm water pollutant components. Not the kind of thing you talk about over dinner maybe, but that's what happens. Ohio Administration - those are the kinds of things that come out of the water that run off of streets and highways. So you think about "Where does that go?"

The take home message is twofold. One is these various heavy metals and other things come from both road and roadside sources and vehicular sources. The second thing that's interesting to me at least is, that there are quite a few of them coming from each of these. That is, if you want to look for a magic bullet to solve ground water pollutions from storm water, there isn't one.

There isn't one. It's going to take an action at a whole range, at least from the source control point of view, take an action on a whole range of activities there.

Oh, I wanted to say one other thing about that. The bulk of those pollutants or pollutant constituents, their ecological effects are only measurable for meters to tens of meters out from the highway. In other words, those aren't things, there are some exceptions, but by and large, those chemicals aren't things that are affecting long distances like that traffic noise or traffic disturbance effect.

I just want to say on the traffic noise and traffic disturbance, no one has proved that - proven that it is traffic noise, but the Dutch work, which is the best on this, pretty much eliminates the alternative hypothesizes, so it's most-likely it is.

Okay. Now, look at this. This is interesting. The horizontal axis's hard surface. Isn't that a great axis? Hard surface or impermeable surface, impermeable is a little bit strong for me. In percent >from zero to 100. And on the left side you have natural ecosystems - no hard surfaces, no roads, no buildings for example.

Then you have quarter acre housing or it's about 20% you can see there. You could have in that area you have quarter, I'm sorry, one acre and a half acre and a quarter acre and on up to industry and commercial areas. You can see those, those are average figures of the U.S. Department of Agriculture.

Now look at the water flow coming in. Rain comes in equally over all of those; let's assume 100% precipitation.

Then if you look at those arrows pointing vertically, that's evaporative transpiration. That's the evaporation of water vertically. You'll notice it doesn't change too much along that hard surface grade. It decreases about by a quarter there, from 40% to 30%.

But look at the horizontal arrow going to the right. That's runoff, surface runoff of water. It's five times as much. Then look - so much more surface runoff. Look at the shallow infiltration. That decreases a lot. And then look at the deep infiltration. Those numbers there decrease enormously there.

So then ask yourself, "What's the effect on the streams in the landscape?" That's what the articles, and various articles in the Journal of American Planning Association and elsewhere, conclude that in the zero to 10% hard surface zone the streams are in good shape, relatively speaking, and then in the 10 to 25 they're impacted, to the right they're degraded. So that's putting the hydrology, the water flows in with the housing and so on, but using hard surface as your common communication tool or element.

The native and exotic species going from a road shoulder out to the outer roadside, if you look at this - the curve going steeply upward - that's native species diversity and not surprisingly with a road shoulder going outward increases a lot. Look at the top curve. Those are the non-native species, exotic species. About constant and at a high level for all four of those habitats.

Then look at the bottom where you have rare, non-native, the rare exotics. What that says, there aren't so many, about one-fifth of the total exotics are rare. That's interesting. About a fifth of the total number of exotics are rare, that is, only one or two or individuals. And then look at rare natives, more out, not surprisingly.

But those are the things that in state after state we should be looking for. Those are the rare species in our roadsides. We should be doing something about that. And that few states perhaps are, many states aren't, most states aren't.

Here's something - this is a man who went out to a car wash and for three months he collected the water coming out of the car wash. He filtered out all seeds and he put all the seeds on a soil and grew all the plants that came up. This is what he found out.

He found out that the plants from the city and the surrounding cropland - most of the plants were from the city and the surrounding cropland. He found some plants also from the native community, the wooded communities there, both herbaceous plants and woody plants.

But this is really the one - these are the plants that came from afar. That is they weren't known in that urban region and therefore came from somewhere else. Those are transported by the cars and cleaned of by the wash. There are over 20 species there, not many seedlings, but over 20 species in this three-month period were brought in by the cars at this one car wash from other regions.

Let me add a comment there. There's a lot of talk about transportation and exotic species, a lot of finger pointing. Our federal highway has a wonderful book on native and exotic plants, what you can plant in North Carolina and what you can't, what you should, shouldn't, and so forth and what's there. I should say that there's not a lot of evidence that - of exotic plants actually going from roadsides into nature reserves or from roads - and invading nature reserves, or invading from roadsides to ranchland or pastureland or going from roadsides into cropland. It must happen. I can't find the literature for it. And so, some research needs to be done there.

This is a question of roadsides and esthetic quality. What's the ecology of esthetic quality? Big subject. There is one study in southern New England, a rather extensive study, interviewing a whole lot of people and given a whole lot of photographs and ranking them and so forth. What the people did, they came out with that these were the top three, the best average preference quality, water, agriculture and these are the worst three, farm and successional.

Now, what I've done over here is to add sort of the ecologist typical overall ecological quality that where the best, ecologically best has three stars and the worst has one star. The take-home message is they don't correlate. Visual quality and ecological quality aren't correlating at least in the simple-minded kind of analysis here. So what do you do?

So what you can do then is to find ones that have fairly high levels of both and simply focus on them, and there are some there. Let's go to the next one.

That's an unfair oversimplification of a big complicated subject, but I want to keep going here.

Now, let me spend my last 10 minutes, do I have about 10 minutes Katie, on some broader perspectives.

The first thing I want to do, I want to get the landscaping ecologists and the engineers talking. So the rare effect zone is focused in that direction.

The second is to take the network and how it's linked with the land. So we've been talking mostly about individual roads and animals and what-have-you. Then the third thing, I'll mention the book.

Here we are back in Massachusetts. Same place. This is a - well what we did was we went along that same highway, and it shows you some aspects of the birds - is 25 kilometers from here to here, four-lane highway, roughly 50,000 vehicles per day along here.

We measured a whole lot - we estimated a whole lot of things, like intermittent channel was straightened for the highway, intermittent channel affected by salt, wetland drainage, stream channel and so forth. Roadside exotic invading forest and those are all mapped along there. Then we also have the dash lines indicating - this was actually earlier data so the dash lines would be wider now, but when we had - the data we had when we did this a couple or two or three years ago, that represents the traffic - the perceived estimated traffic noise effect zone.

So when we go to zone there, factors which you are extending outward from the highway more than 100 meters, so a football field, extending outward more than the distance of a football field.

That then lead us to this idea of road effect zone and it works like this. There's a road and on the right side there are a whole series of ecologically related factors. And in this particular image, a little bit old, each one of those is related to one or a number of specific studies, so those are real.

How far out from the road does that effect extend? That's what the arrows to the right are. It's the distance out in those particular studies. You can see some are wide; some are narrow.

We said well there are some processes operating to change the width of those. And one of them was gravity and water flow and so I've got upslope and down slope there. And upslope and down slope, are the water and water carry transported items. You can see them on the right there. The arrows are much further to the right than they are to the left. So there's an asymmetry there.

The middle ones are the items like dust and some air pollutants that are carried by wind. And again, some are more to the right than the left. The bottom one has to do with the suitability of surrounding habitat. When you go out for a hike and you stop by the road, you either go to the right or you go to the left. You usually go according to well it looks more interesting over here, or more birds, or whatever.

So the suitability of the habitat depends - determines a bunch of things that go out that way, wildlife and other things. What we're left with is a zone. What we call a road-effect zone. It's the zone in which ecological effects go out. Its how far are a statistically significant effect can be measured. What the zone is, it's very uneven, it's asymmetrical, highly convoluted boundary and there are actually a few fingers. The Ps represent the points where you cross a corridor like a stream or hedgerow or something like that where these fingers where the effects extend much further.

Landscape ecologists and watershed biologists and conservation biologists and others that take these real broad views and say, "You've got to consider the whole landscape." The highway engineer that does a real careful, meticulous, elegant job in a narrow zone next to the road. How are you going to get those two perspectives together? I mean, for society.

This to me is a quantative way of getting together. The zone that's shaded there is the minimum effect that has to be considered in highway planning, road planning and upgrading projects, and other project maintenance sometimes. So that's a concrete way and some of you talk about that.

We took that and applied it to the whole United States. We asked the question, "How much of the United States area is ecologically affected by and in the case of the United States, four million miles of public roads. There are more roads, but four million miles of public roads? One hundredth of them, that is about 40,000 that are interstate highways, about one-tenth of them belong to the U.S. Forest Service, although the Forest Service readily admits it doesn't know exactly how many roads it has. These people keep putting in roads illegally. What's the total effect of that four million miles of public roads?

Well using the road effects zone for the whole country, we calculated - here's the total road length on the left side, secondary roads, rural and primary roads, standard highways statistics. Then we said what's the total land area effected ecologically for each of those, and when you add them together, you get this figure right here. About 20% of the total, about one-fifth of the total U.S. area is effected ecologically, directly effected ecologically by our road system.

That's the first estimate anybody every made for that. It's rough. Hopefully somebody will do it and do it a lot better. The article I published on that, the various considerations this and a whole lot of things that may decrease and a whole lot of things that will increase it. My interpretation is that number's going to increase, almost inevitably. So I would consider this conservative - one-fifth of the U. S. ecological effect.

Let me say a few things about networks here. Wildlife biologists have spent a lot of time on road density, the denser the roads, the more problems there are for wildlife. There are pretty elegant studies on the effects on wolves, on bears and other animals. You're up in Canada and the United States, and so this is to illustrate another point.

That here on the left side, this is a low road network up there and this is a high road network there. Here's some wildlife - one animal avoids the road, that's this animal right here. One animal crosses the road and sometimes gets hit, there. So, there's an effect then of those two aspects of high and low road density. That would be important for wolves, for example.

Another effect of road density is on fragmentation of the populations. You're taking one big population and turning it into several little ones, each of which is smaller and each of which has a higher probability of bumping into the horizontal axis of extinction; just even if nothing but randomness was operating. Then human access, a higher road density obviously makes more access. There's some hydrology aspects, there's some stream aspects, there's some fire aspects.

The bottom line to this is that road density has been - ecologists have focused on wildlife. I'd just like to extend that idea to a whole range of things that road density affects.

Road density is very easy to measure. You know, it's the number of miles or lengths per square mile, average for example. What's more - and I find that from what little I've done with it - I find that it's useful but moderately insensitive. So it's a first cut.

More sensitive and more important is the form of the network. These four all have the same road network, I'm sorry; all have the same road density. They all have the same road density, but look at the difference in the form. So the exercise then - as some of my students do this, you can do it - is suppose you're going to add 10% of roads to that network. You know, you're in a fringe area and there's development going on or you're the Forest Service and you're going to cut some more and need some more roads.

Where would you put them to be ecologically optimum? And, where would you not put them? And for each of those four situations. Very interesting.

Then say, suppose you're into restoration. You want to improve that road network it was put out there before the day and before, most of it, and before the rise of modern ecology. Suppose you want to improve the United States, that 20% of the United States. Where would you remove 10% of the roads? It's a very interesting exercise.

So, basically, road - the network form is a much more sensitive and promising measure than of the whole landscape than road density, although road density is a first cut.

Here is one of your good neighboring states here. This is a study by Dan Smith who has been doing some GIS modeling and trying to advise the Florida DOT, Department of Transportation, as to where they should put their money. I think he's got DOT funding for this, but the fact remains, a very interesting study. It's probably the first one, not exactly the first, but it's the first of this type in the United States, in recent times. There are some others.

And so what he did was he got nine ecological variables. Now, I don't want to go into those because you can raise questions about them. But they had to do with, you know, bears and rare biodiversity and rare species and zones and what-have-you. So he mapped them, using GIS, every 100 meters for all the highways, actually for the whole state. Then he mapped these things. The frequency of problems, potential problems, did some field work - I don't know how he could have done all that.

But any way, this is kind of a product, in progress product, of that. So what you see, the more dark circles there are the more problems there are. You can see if you were the Manager - suppose you were manager, suppose you were the head of the North Carolina Department of Transportation, wouldn't it be neat to have that to say, "Well we're going to put our dollars here and not over there. And there's good science behind the reason why."

I'm skipping important steps in this process and I've already told you one of them is what were the original nine variables there. But more-or-less they're sort of okay.

There is another study in Banff National Park where somewhat different - but it focused on animal movement. Animal movement is different than population size and there's more sense of it. So you can put a road in here and run a snowmobile up through here and the animals will move, they will change their behaviors. That may or may not be important. I mean it is in certain cases, but animal movement - population size more people would probably buy into and this is closer to population size, but this gets more into a lot of other things important, like water.

Here is an alternative. Here is a really simple one. This was done in the Netherlands by law. The Parliament has decreed that the Ministry of Transport, Public Works and Water Management must do this and they've been given money.

What they do is they have a map of the - its called the National Ecological Network for the whole country - a small country but you can do it for North Carolina. It's a map and the big black blobs there are basically large green vegetation patches. They're roughly, that is what the big green is. The thick dark lines, for example, on the lower right, are the known major wildlife corridors or expected wildlife corridors. So basically you've got a patch and corridor network there.

I'm sorry, the water corridors you can see there, going down through the middle and so on. Basically, it's a patch corridor network that the Parliament has required the Highway Department and others to use in their planning. Then the Ministry of Transport comes along and puts the road network on and that's what the thinner lines are - those are the major motorways and highways in the Netherlands.

What they do is they identify - they call them bottlenecks - I would call them conflict areas, but they identify the bottlenecks where that - the ecological network and the road network run into each other. Where are the problem areas? All the circles are the identified problem areas.

The circles with crosses are the ones where there are big problem areas, where they had to make major mitigations such as that overpass that I showed. Five of those stars represent overpasses and I think the other two represent in-progress or planned in-progress ones.

The Cs represent places where they can't mitigate, just because there's location of industry or something or other, and so they have to compensate. For the Dutch, by law that means to take an equivalent amount of ecological value and provide it somewhere else. It doesn't have to be the same thing.

They could have a block, a wildlife corridor and provide wetland, or they can mess up a wetland and provide a wildlife corridor, preferably nearby. So that's a very simple way of planning different.

The Dutch, that's one of those crosses on the previous image, you're going along on an interstate highway, this happens to be a motorway, the 850 there, and you see a sign up in front of you that says "Wildlife Crossing." Isn't that neat? Everybody sees it.

Now look up on top of there, you'll notice that, its hard to tell from here but I'll tell you, there's a two meter soil berm there, that is two meters high, its soil, its got a shape like this and cross-section and they plant shrubs and small trees on it – that's what you see, some birches and other trees growing up there, shrubs - and there's one on each side. When you go up on it, it's a grassland, its quiet and they tell me you don't have much light there at night on the highway.

It was real quiet and it was big enough for a soccer field up there in that open grassland. I commented, when are we going to play soccer. The man said, "Well, it's big enough for the Dutch to play soccer but not the Americans." I said, "Oh, why is that?" He said, as some of you may know, the Dutch are pretty good at it. So he turned off his mike and he said, "Well, because the Americans play like sheep. You know, the ball goes over there; well I'll go over there after it. The ball goes, well I'll go. So you see you need a bigger field there."

That's expensive there. That's a massive structure there. It works, at least - and that's a different subject, how you measure what works. Interesting subject.

This is in Australia. This is in the agricultural areas of Australia. What it is - it's a two-lane highway - this happens to be western Australia and you find them in Victoria and other places, Queensland - that's a two-lane highway, that's approximately 30 meters wide, a 100 feet wide, a football field - no a 100 feet wide - a football field would go from here to here. So that's a strip of 40 meter wide vegetation - natural vegetation - another one here - that would be one football field length there.

You see this is going for miles and miles. It connects a big green blob there, another big green blob up there, another one here, and that's the way the Australians in their intensity of agriculture areas are protecting by diversity. A very different strategy.

I think Australia is probably the most ecologically and most connected country in the world. But I want to contrast something. The Dutch and the Australians - that's not just central to your existence, but I want to mention that the Dutch and Australia are the only countries I know that by law, at national levels, they have to mesh transportation and wildlife, I'm sorry, and biodiversity. There are different ways of expressing this. That's why - and so they do it and they do it in fundamentally different ways.

The Dutch want to connect across these big highways like that overpass. The Australians want these strips of vegetation along the highways.

This is the book - the final thing I want to mention. This is the book that will be out in seven months or so and these are the folks that are working on the book. I'm just one - spearheading it along with my colleague, Dan Spurling in California. They were - some of you may know these names, some of you won't. They illustrate that this is a synthesis of ecologists and transportation experts.

It's a wonderful experience. I can't express it any other way than that. I learned so much, they learned so much. Some of us started into this project feeling that roads are basic - road systems with traffic - are basically bad. Well they do provide some social and economic benefits. Some of us went into this project saying, "Roads are really good although they have some environmental problems." That's a really different way of coming at it and to be able to work together and affect maybe hopefully affect one-fifth of our nation is kind of neat.

That will just show you the various topic areas, not too dissimilar from what I've just gone through. Some road stuff and traffic planning at the beginning, some wildlife and vegetation aspects, and mitigations in the middle, and some water and chemical effects on the ecosystem.

I skipped over wind and atmospheric effects. I'm happy to talk about wind, air pollutants and greenhouse gasses. There are so many reports on that subject that are really good and it's changing so fast that we are only - we're not really dealing with that in this book. We have a very cursory section there.

Then the exciting stuff is tying the land together with the road network.

Just to emphasize that there's a research opportunity here. There's a big research opportunity. I went and gave a talk some years ago and I used this image to try and think of some theories that might be useful in road ecology and I kept coming back to special models as a way to begin to develop theory.

Some of these models like network theory are well worked out in transportation literature, I mean huge literature of the traveling salesman probably, look at this thing, I've got to deliver to thirteen cities. What's the optimum route? Or, I've got some goods I've got to transport, I need some redundancy or stability in my system incase there's a strike or a breakdown of rail or something. And how do you get circuitry in your routes? It's a big literature and it's a fascinating, a wonderful literature, I enjoy it.

Anyway, so it's a research opportunity here, and the next one is the last one. Then there are some applications, like what I've done here is highlight five or six what I call categories of policy that are going to evolve I think if we're going to have an impact. These should be familiar after what I've been saying. Here we are in the lower left, perforate the road with underpasses and tunnels and culverts, there are all kinds of things, the technology is there. You can commercially buy amphibian tunnels and just put them in place, made commercially. There are dozens of these overpasses in Germany of various sorts and more being built as we speak. To the right, the traffic disturbance, or traffic noise effect, various burms, and raising the road combinations there of.

And then there are design issues, engineering issues, what make noise? Well, the road surface makes noise, after the Dutch studies were done the ministry of transport immediately, the next time they changed the surface, they put down a quieter surface on their motorways. Right away – they could put their research right to work. Road surface makes noise, tire design makes noise, the engine makes noise, and the vehicle aerodynamics makes noise. Those are design issues and the vice president of Ford Motor Company, a very bright woman, she said look, we can address all of those if the incentive is there. We can make vehicles' traffic noise decrease. And there's the traffic issues of concentrating traffic on primary roads. I've moved (VMT) over here probably, and percent trucks, those are big issues in noise.

Finally in remote areas, closing and removing roads that reduce human disturbance. Another big policy area there. So, there are research opportunities, there are policy opportunities, and I thank you very much for your time.

END