

ROAD ECOLOGY: A LOOK BEHIND THE BOOK AND THE FIELD

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Abstract: The field of road ecology, slowly emerging over two decades, offers great promise to transportation, nature and society, and a recent book, *Road Ecology: Science and Solutions*, should help catalyze the field. The objective of this article is to provide additional insight into the book by highlighting its process of development, and pinpoint some underlying bases for expecting the field to accelerate. The book evolved from: recurrent environmental problems; early international work; and TRB and ICOET initiatives. Fourteen co-authors from academia and government, including two spearheaders, four transportation experts, one hydrologist, nine ecologists, and a supporting cast of forty from the transportation and environmental communities created the book. Several broad challenges required solutions: present the best possible science; reveal an array of useful applications; avoid drowning in detail; and mesh authors to complete the book in two years. Also key specific decisions molded the book: title, publisher, sponsors, and royalties; focus on USA, Canada, and mainstream road network; peer-reviewed literature, and no specific solutions recommended; several topics with minimal, and with ample, coverage; and the nature of the final chapter. Since publication, salutary evidence indicates that the book is reaching: the transportation and environmental communities; educated public and conservation organizations; and decision-makers. Several trends in addition to the book seem to be catalyzing the field of road ecology. Rapid growth in research and the development of useful applications is evident, and important promising opportunities now lie on the palette of the diverse specialists. The conceptual objective of the field for society appears to be safe and efficient mobility meshed with natural processes and biodiversity. Thus the area along and adjoining the entire road network should significantly improve ecologically, while also strengthening the network of ecological flows and large green areas across the land.

Background

Our road system emerged from a road network developed over centuries, motorized vehicles added in the past century, and sealed asphalt/concrete road surfaces added over decades. The transportation community plans, builds, studies and manages this massive road system for the benefit of society.

Not surprisingly, public concern with the environmental effects of such a system which began early and over the past two decades, seems to be accelerating (Lay 1992, Canters 1997, National Research Council 1997, Center for Transportation and the Environment 2002, Transportation Research Board 2002). Thus, environmental protection has grown to be one of several central foci of the transportation community. Yet this environmental protection has been largely based on scattered, indirect and limited ecological knowledge or theory relative to roads/vehicles, and with little direct role of the mainstream ecological community.

Into this near-vacuum has appeared a promising new area of knowledge. Road ecology explores and addresses the relationship between the natural environment and the road system. The maturing of landscape ecology (Forman 1995, Turner et al. 2001) and its linking of key ecological specialties at the scale of a road system (Saunders and Hobbs 1991, Canters 1997, Bennett 1999), was a background or catalyst for the field. Moreover a group of ecologists and transportation experts recently coalesced to pull the threads of knowledge and theory together in a book, *Road Ecology: Science and Solutions* (Forman et al. 2003). Building on earlier foundations, this book is helping to develop and underpin an emergent field of road ecology with its own body of principles and applications.

Thus the objectives of this brief article are to:

1. Provide underlying insight into the book by elucidating its process of development; and
2. Highlight some ways the field of road ecology is being catalyzed that benefits the road (or transportation) system, nature, and society.

The Book, *Road Ecology*

Four dimensions here highlight the intellectual development of the book: (1) genesis, (2) authors and supporting cast, (3) broad challenges requiring solutions, and (4) specific decisions made.

Genesis

Recurrent environmental problems relative to the road system effectively represent the spark for the book (table 1) (Lay 1992, National Research Council 1997, Forman et al. 2003). Mud and dust, erosion and sedimentation, roadkills, degraded biological diversity, air pollutants, and greenhouse gases result from roads and vehicles. Without these and their apparent worsening, no book would have appeared. Rather than being just an ecological analysis of such things, the added "solution" nature of the book results from the presence of existing working solutions, especially international. For example, wildlife overpasses in The Netherlands and elsewhere, underpasses as in Florida, amphibian tunnels in Europe, diverse erosion-control methods, and roadside habitat- and wildflower-enhancement techniques are widely distributed (Langton 1989, Aanen et al. 1991, Bekker et al. 1995, Evink et al. 1996, Harper-Lore 1999), but in many cases less widely known.

Table 1.
Genesis of the Book

Recurrent environmental problems Early international work TRB committee on transportation and environment First ICOET, and subsequent meetings

In thinking about the origins of the book, I first think of research and discussions on the subject of roads and ecology in the late 1980s and early 1990s with Dennis Saunders, Richard Hobbs and Andrew Bennett in Australia (Saunders and Hobbs 1991, Bennett 1991, 1999) and Hein van Bohemen, Hans Bekker and Paul Opdam in The Netherlands (Bekker et al. 1995, Canters 1997). [Although I had lived in France in the 1970s and had met Heinz Ellenberg in Germany in 1985, the early important work in both countries (Ellenberg et al. 1981, Forman et al. 2003) did not reach my consciousness until much later.]

In 1994 I joined an impressive National Research Council TRB (Transportation Research Board) committee on transportation and the environment (table 1), where I met Daniel Sperling, Kevin Heanue and Thomas B. Deen. Although the committee was focused on atmospheric pollutants and gases (National Research Council 1997), by early 1995 my role had already evolved into highlighting, with worldwide examples, many other important components of the future road ecology for the committee. I mentioned to Tom Deen (former long-term TRB executive director) that the effects of roads seemed greater than those of vehicles. He wisely said that I had much to learn and took me under wing, but also listened as my summer 1995 TRB-supported research on the ecological effects of surface transportation provided much grist for committee discussion.

Another major step occurred in 1996 when I met Gary L. Evink, Paul Garrett, Bill Ruediger, and several others interested in wildlife management and roads; they had been brainstorming and organizing a conference on wildlife and roadkill (Evink et al. 1996). At this first ICOWET (International Conference on Wildlife Ecology and Transportation) conference, I was honored to give a lead-off presentation, and then published my first road-ecology article focusing on concepts and existing international mitigation-solutions (Forman and Hersperger 1996). I was hooked. That led to presenting a paper on the North American road-ecology situation at a 1997 Dutch conference on infrastructure and habitat fragmentation (Canters 1997, Forman et al. 1997). Then Julia A. Jones and I organized a road-ecology symposium at the 1998 Ecological Society of America (ESA) meeting, and I kept learning and meeting interesting contributors while giving papers at the 1998, 1999 and 2001 ICOET conferences (Evink et al. 1998, 1999, Center for Transportation and the Environment 2002, Forman et al. 2003).

Meanwhile the TRB committee produced a 1997 National Academy Press book, *Toward a Sustainable Future: Addressing the Long-Term Effects of Motor Vehicle Transportation on Climate and Ecology*, which, alas, had only half a chapter on non-atmospheric environmental effects (National Research Council 1997). Yet (I was later told), this was the first major mainstream-transportation publication in the USA highlighting the diverse effects of surface transportation on wildlife movement, biodiversity, erosion, sedimentation, and aquatic ecosystems.

Feeling that enough road-ecology literature existed and that the subject was ripe to coalesce, I promptly proposed a TRB committee for the task. This recommendation was favorably reviewed by key TRB standing committees and by Executive Director Robert Skinner. Time would be required to raise funds and for a committee to deliberate. Yet, seemingly everyone would benefit by a more rapid process, and, with considerable road-ecology literature accumulated, I briefly considered writing a book myself. Quickly it became clear that a better book could be produced if specialists in diverse key areas collaborated on the project. Also, transportation experts needed to be included so that the book would have a real impact, and not be easily dismissed as musings of an environmental academic from the Northeast.

Authorship and Supporting Cast

Dan Sperling, an automotive engineer expert in alternative fuels (Sperling 1995) and director of America's premier academic research institute in transportation, immediately saw the potential of the idea. He agreed to co-spearhead the project, and brought extremely different experiences and perspectives, plus numerous talents that complement mine (table 2). Moreover we both bubbled with intellectual curiosity and sensed incipient synergy. So, with TRB's informal blessing, we moved ahead to invite a team of authors to produce a book on a rapid two-year schedule.

Table 2.
 Authors and Supporting Cast

Daniel Sperling and Richard Forman, spearheaders
 Fourteen co-authors
 • Four transportation specialists, 1 hydrologist, 9 ecologists
 • All mid- to high-level; half academia, half government
 Forty in supporting cast, especially transportation community

Fourteen authors were intrigued with the significance of the proposed project and agreed to collaborate, not on an edited volume, but as full co-authors on the whole book. All were mid- to high-level in their respective fields, who knew how to write and produce in a timely manner and understood the challenges of producing such a book. Four were transportation specialists (Kevin Heanue, Carol D. Cutshall, Thomas Turrentine and Dan Sperling), one a hydrologist (Thomas C. Winter), and nine ecologists (John A. Bissonette, Anthony P. Clevenger, Virginia H. Dale, Lenore Fahrig, Robert France, Charles R. Goldman, Julia Jones, Frederick J. Swanson and me). Half were from academia [Utah State University, Carleton University, Oregon State University, Harvard University (2), and University of California-Davis (3)] and half from government [USDA Forest Service (USFS), Federal Highway Administration (FHWA), Parks Canada, Wisconsin DOT (Department of Transportation), Oak Ridge National Laboratory, and U.S. Geological Survey (USGS) (2)]. The significance of the topic, plus continuous visible progress, kept this wide array of personalities from fragmenting.

Dan Sperling's main role was to facilitate the book development process and help engage the transportation community at every step. My primary role was to shepherd the process of writing, reviewing, revising and weaving text, plus incorporating illustrations. The authors were the intellectual superstars.

A supporting cast of forty enormously strengthened the book, especially in making it useful for the transportation community (table 2). These framers-of-issues and solvers-of-problems listed in the book's acknowledgments (Forman et al. 2003) included colleagues from TRB, DOT, ICOET, ESA, IALE (International Association for Landscape Ecology) and elsewhere. Two early meetings of authors began with presentations and discussion by transportation experts (Fred G. Bank, David G. Burwell, Michael Cameron, Mark A. Delucchi, Judith M. Espinosa, Gary L. Evink, Martin Lee-Gosselin and Leslie M. Reid). Thereafter, small groups of authors periodically met. Outside ecologists and transportation specialists were continually consulted on organizational, informational and analytic issues, and they also reviewed chapter drafts. At the end, highlights of the book were presented at two national/international meetings.

Broad Challenges Requiring Solutions

Several major challenges persisted though the book development process. One goal was to accumulate and present the best possible science (table 3). This meant searching a scattered literature and relying on peer-reviewed journal articles. Government reports [e.g., from FHWA and EPA (U.S. Environmental Protection Agency)] and other gray literature were cautiously used where information was scarce for an important subject. Individual scientific information and points were presented, but also interrelated or synthesized. From this, attempts were made to pinpoint or highlight emergent patterns and principles. To limit book length and book price, and thereby increase potential readership, a selection from the array of possible topics and mere encapsulation of some topics had to be done. Thus, for instance, chemicals in road surfaces, chemical spills, statistics on roads and vehicles, roadside management techniques, insect roadkills, forestry roads, network theory, and aquatic ecosystems received relatively brief treatment. Conversely, quirks in a time-pressured process resulted in some topics receiving rather lengthy consideration.

Table 3.
 Broad Challenges Requiring Solutions

Accumulate and present best possible science
 Reveal array of useful examples, applications and solutions
 Keep eye on "ballgame," avoid drowning in detail
 Mesh diverse authors to produce book in two years
 Writing, reviewing, revising, and weaving

Another goal was to reveal an eye-catching array of useful examples, applications and solutions. Focusing on existing rather than proposed solutions perhaps made the book more useful, and emphasized that many actions can be implemented now rather than waiting for more research and development. In some cases, monitoring and research results will be the basis for developing new or improved applications. Also, gaps in knowledge are pinpointed and suggestions for new solutions are scattered through the text. An abiding challenge in the face of an onrushing cascade of information, ideas and solutions was to avoid drowning in

detail, and “keep our eye on the ballgame.” This task mainly fell to the spearheaders. Although each topic was so interesting or so important, the ballgame was to compellingly present the science and solutions of road ecology.

Meshing the talents of 14 diverse specialists to create a book in a timely manner was an expected challenge (table 3). Three authors (John Bissonette, Anthony Clevenger and Lenore Fahrig) went charging ahead and had rather sophisticated drafts of two wildlife chapters reviewed and ready before some other chapters were barely launched. A few authors were unexpectedly slow, but only a few. One (former) author dropped out near the outset, which I regretted but respected. Another (former) author had to drop out later, and still another (Robert France) joined the group mid-stream. Two other authors tried to drop out, but they had done so much and were so valuable that we could not let them go. As expected, all authors went through periods when they simply could not work on this book. The spearheaders, Dan Sperling and I, were also writers, and sometimes I had to bug Dan for writing. Much more often though, I would put aside the pieces that I was designated to write in order to catalyze others into action, so some of my pieces were among the laggards.

The short two-year goal to complete the manuscript, which we accomplished in 27 months, was about right. It kept the pressure on. It made us succinctly extract and focus on the essentials. At the end everyone was really ready for the sharp drop in letters, e-mail messages, and manuscript drafts, which had consumed us for so long. Although the manuscript then went from our desks to the publisher’s desk, my work did not decrease for another six months, which was an intensive period of working with the publisher trying to produce a nearly error-free landmark book.

In general, authors volunteered to write half-final-length first drafts of sections within a chapter, which were at least somewhat related to their expertise. Typically these skeletal drafts were then reviewed by two other authors and a spearheader, and the original author then revised text to a second draft. At that stage normally the text of the section was melded into and considered a part of the collective book manuscript. When a chapter as a whole reached approximately second-draft stage, it was usually sent to two outside reviewers. Reviews came back to the various first-draft authors represented in a chapter, who once again made revisions. Concurrently, drafts (six in total) of the whole book manuscript went at 2two to three month intervals to all authors for comments and revisions. Significant interweaving of text took place in this process. In this way, the entire manuscript progressively became a product of the whole team of 14 authors.

Specific Decisions Made

Many important decisions had to be made that effectively molded the final published product. Most were made collectively by the authors, either in a meeting or usually in response to written questions. Most decisions were easily and quickly made. In contrast, for example, selecting the book title took six months of collectively making lists, narrowing them, adding to them, narrowing them again, and voting. When a decision had to be made promptly, Dan Sperling and I made it jointly. With ample mutual respect, agreement was almost always easy. The following key decisions were made:

- A. The book title chosen was the overwhelming choice from the final list of five options. Parenthetically, metaphors and evocative titles garnered little support in this group.
- B. Although John Wiley & Sons was the top choice as publisher based on a fairly extensive investigation, our large diverse potential audience and our insistence on an affordable paperback edition from the outset led us to Island Press. The editors were enthusiastic and helpful, and our final product was very close in specifications to those in the book proposal, with one exception: the text was about a hundred pages longer than originally envisioned.
- C. The FHWA and The Nature Conservancy (TNC) were among a handful of potential sponsors we collectively favored, and both accepted. At times we seemed close to attracting the USFS, EPA, American Association of State Highway and Transportation Officials (AASHTO), and the Transport Association of Canada (TAC) as sponsors, but none worked out. Late in the process we were delighted to attract the largest state DOT, California Department of Transportation (Caltrans), as a sponsor. We think FHWA, Caltrans, and TNC make a wonderful set of sponsors for this book.
- D. With fourteen equal authors, annual book royalties would make no one rich, so we agreed to donate royalties to TNC. Surprisingly the logistics were quite difficult.
- E. Because transportation data from different nations varied in assumptions, methods and availability, and because the authors were all North American, we chose to focus on North America, highlighting the USA along with Canada. Two authors are Canadian (Lenore Fahrig, Robert France) and a third works in Canada (Anthony Clevenger). Nevertheless, we abundantly cited world literature and examples in road ecology.
- F. We agreed at the outset to focus on the mainstream transportation system of America (and the world), rather than on remote roads or USFS roads (the last is ca. 10% of the total USA public-road system; Forman et al. 2003) which have been of interest at least to some ecologists. About 80 percent of the

U.S. network has <400 vehicles/day, whereas 20 percent is used by most traffic on major highways and around cities, and also is of most interest to the transportation community.

- G. The authors decided at the outset to focus on peer-reviewed published literature, and minimize dependence on government reports and other gray literature. In a few important areas the scarcity of published literature required our use of reports and other papers, which seemed to represent the best science available. Such areas, of course, represent promising research frontiers.
- H. The authors were enthusiastic about including case studies, applications and solutions, but with one caveat, which was especially important to some authors working for government. No specific solution or application was to be recommended by the book. The general solution of applying road ecology for the benefit of society is of course implicitly recommended.
- I. A few authors wanted to include rail transportation in the book because of some similarities in ecological responses to roads and vehicles (Forman 1995, Canters 1997), and because railroads are an alternative transportation mode to roads. (No one recommended including aircraft or ship transport). However, most authors felt that we had our hands full with roads and vehicles (which turned out to be true), so rail issues were not included.
- J. The ecology of visual quality along the road network is barely introduced in the book despite its potential importance. This resulted from an indirect process rather than a specific decision. The half-final-length first draft for this was rather lengthy, and generated little enthusiasm and some disagreement. Over time, as seemingly more important issues continuously arose, the subject remained on the "back burner." When activated, the text was typically shortened to minimize disagreement rather than expanded to provide a fuller picture. It remains a subject in need of rigorous treatment by ecologists among others.
- K. Since global climate change and atmospheric pollutants and greenhouse gases are large active research areas and the subject of several recent books and reports, we chose to only briefly introduce these road-ecology subjects. Readers were encouraged to go from our introduction or overview to the mushrooming global-atmosphere literature.
- L. Roadkills receive ample emphasis in the book. This fits with the perception of the public, as well as some in the transportation community, of what road ecology is perhaps mainly about. Roadkill of, for example, kitty cats, deer and moose, generate considerable public concern. Yet overall, current evidence suggests to me that roadkill is of minor ecological importance compared with the barrier/fragmentation effect or the traffic disturbance/noise effect on wildlife (Transportation Research Board 2002, Forman et al. 2002, 2003). However, three of the authors (John Bissonette, Anthony Clevenger and Lenore Fahrig) have published research on roadkill. So, in view of these diverse considerations, maybe the coverage of roadkill in the book is about right.
- M. The effects of road-salt are presented in a rather long section. This resulted from several authors having some interest in the subject and each independently writing a piece on it. When the pieces were put together, the resulting quite-long section with diverse insights and examples was difficult to appreciably shorten.
- N. Finally, the nature of the final chapter remained up in the air for a long time. Few authors wanted to write first drafts of pieces from a final-chapter outline until the earlier chapters had coalesced or matured, which only occurred near the end. Thus a final chapter as a summary or synthesis of the book could not happen unless the spearheaders quickly wrote it at the end, which would have satisfied no one. For the same reason, a set of tidy conclusions based on the results of the book chapters could not be done. The route chosen, an intriguing final chapter that opens the reader up to further ideas and solutions, thus happened by default. Still, the authors seemed to like this question-posing, brainstorming, emergent-idea, proposed-new-solution, and future-oriented focus as the culmination of the book.

The Field of Road Ecology

Let us now turn briefly to the future and how the 2003 book, *Road Ecology*, may be helpful to the emerging field of road ecology. The Netherlands, France, Germany, Switzerland, Australia and some other nations have effectively had small or temporary government programs under various names in this area since the 1970s or 80s (Ellenberg et al. 1981, Saunders and Hobbs 1991, Aanen et al. 1991, Bekker et al. 1995, Evink et al. 1996, Canters 1997, Forman et al. 2003). In the USA, as noted above, in the mid-1990s the TRB, focusing on atmospheric pollutants and gases, and ICOET, emphasizing wildlife and roadkills, in effect began linking the transportation and ecological communities (Evink et al. 1996, National Research Council 1997). The greatest obstacle seemed to be the scattered and little-known literature and existing mitigations, and the absence of a book that pulled these together into a logical compelling framework. Indeed, what are the core areas, and what other areas tend to fall in or fall out, of road ecology? The book, *Road Ecology*, was produced to help fill that gaping lacuna.

Some key developments in reaching target audiences are now pinpointed because of their potential importance for the field and for transportation. Then a diverse set of threads, "catalyzing a future," are identified which show promise for energizing the field of road ecology, as well as noticeably improving both surface transportation and nature on the land around us.

Reaching Target Audiences

In the eight months since publication of *Road Ecology*, several extremely promising events have occurred that bode well for rapid growth of the field. First, a luncheon briefing for Congress was organized by Island Press with the support of Defenders of Wildlife, Smart Growth America, and other organizations (table 4). Dan Sperling and I presented road ecology to a packed receptive audience in the Rayburn Building on Capitol Hill (Washington, D.C.), which included representatives of 63 Congressmen and Senators, all key federal agencies, numerous interested organizations, and the media. The event was in the context of the upcoming Congressional reauthorization of the giant U.S. transportation act.

Table 4
Reaching Target Audiences

Decision-makers:
presentation on Capitol Hill
Educated public and conservation organizations:
magazine and newspaper articles
Transportation and ecological communities:
book sales and communications

Second, about 20 mostly major magazines and newspapers have published articles on aspects of road ecology and mentioned the book. Many of the magazines are of public-interest and conservation organizations. Thus a significant portion of the U.S. educated public potentially interested in this subject may have seen one or more recent articles on it. Such articles are still coming, as reporters and writers interview a continually expanding set of specialists in this area. Scholarly reviews of the book are just beginning; four, all positive, have arrived so far.

Third, the book is selling well for this genre of exposition. Bulk orders from the USFS, U.S. Fish and Wildlife Service, and others have been received. Countless letters, messages and discussions confirm that both the transportation and the environmental communities are getting the book. More telling, the first printing of 2,000 copies sold out in five months. A nice side dimension of such rapid sales is that in the second printing the authors were able to expunge essentially every known error (all details) early in the life of the book.

Taken together these three trends are promising (table 4). *Road Ecology* is reaching to policy- and other decision-makers, to the educated public including conservation groups, and to both the transportation and ecological communities. These multi-pronged trends that seem likely to continue should stimulate and support the field of road ecology ahead.

Catalyzing a Future

While the process of creating the *Road Ecology* book and the brief trends since publication provide insight into the potential nature of the field ahead, many other threads are linking to create the field. I have already highlighted at least three important dimensions, the long-term mainly European work in this area, the activities of TRB, and the conferences and printed reports of ICOET.

Conceptual threads that may develop into distinct theories, such as the road-network-effect and population-reduction-sequence, also underlie the field of road ecology (Forman et al. 2003). Furthermore, problem-solving applications and solutions for environmental problems stand behind and are likely to catalyze the field. Also consider that an array of important tractable opportunities and challenges now conspicuously lies on the plate of every road-ecology-related expert. Each reader can add to the following illustrative list of important opportunities, in effect creating agendas for action:

Transportation engineers (diverse)

- Design less-expensive and effective wildlife overpasses
- Create quieter road surfaces, and design quieter vehicles and tires
- Design ecological (and aesthetic) berms to reduce traffic noise propagation
- Reduce the concentrated array of chemicals along roads
- Disconnect roads from streams, ponds and lakes

Transportation planners

- Mesh engineering and ecology using the road-effect zone for highway planning
- Develop and use regional models for wildlife movement, biodiversity and hydrology(as done for air quality)
- Identify and protect large green patches in developing exurban areas

Transportation economists

Begin cost-benefit analyses of numerous road-ecology alternative solutions
Use regional/local network analysis in ecological priority setting for fund allocation

Hydrologists

Disconnect roads from streams, ponds and lakes
Restore natural wetlands above and below roads
Reestablish natural groundwater and stream flows near roads

Ecologists (diverse)

Develop road-ecology theory and principles
Evaluate the barrier-fragmentation effect on demography/genetics of small populations
Clarify road-vehicle effects on aquatic habitats and species
Evaluate landscape interactions among large green patches, wildlife corridors, and roads
Evaluate vegetation options from planted wildflowers to variegated microhabitats
Examine the ecological effects of traffic noise
Determine the optimal frequency and distribution of different wildlife passages

I see three broad legs or components of road ecology (three parts in the book): (1) vegetation and wildlife; (2) water, chemicals and atmosphere; and (3) road systems. Other specialists might recognize a somewhat different balance. Still, we would all probably agree that now we need to build theory and principles, as well as stimulate and publish research. We should now greatly expand the use of known applications and solutions, while also developing others. And we need to build public and policymaker support. Combining widespread pilot projects, with monitoring, with research, and with public education could quickly convert the politically impossible into the politically probable.

Finally, consider what might be the overall objective of applying road ecology to transportation and the land for society (Forman et al. 2003). At a conceptual level:

Safe and efficient mobility should be successfully meshed with natural processes and biological diversity.

To achieve this, specific visible and verifiable goals are essential. Thus:

The area along and adjoining the entire road network should significantly improve ecologically, while also strengthening the network of ecological flow and large green areas across the land.

Dedication: I dedicate this article to the organizers and participants of the early ICOET conferences, from whom I learned so much.

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