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F. Sustainability and Compliance

BUILDING A CASE FOR A NEW TRANSPORTATION SYSTEM

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Abstract: The author examines our current transportation system from a whole systems perspective. The examination includes an evaluation of the current system's performance under four criteria. In four appendices, the questions of whether the current system is clean, affordable, safe and efficient are explored. An alternate system is described in the body of the paper, with comparisons for each of the measurement criteria found in the appendices. A discussion of the necessary steps for a transition from one system to another follows. Issues explored include infrastructure logistics, economic impacts, and changes in community dynamics. Regulatory, finance, and policy tools available to facilitate the transition with minimum disruption are discussed as well.

Taking a Whole Systems Approach

Every region of the world has a transportation system created in response to the politics, economics, culture and physical characteristics of that region. All have common components: infrastructure, technology, institutions and values. Many remote Alaska villages have no road access and rely instead on riverboats, bush planes, ATVs and snowmobiles. The city of Venice, Italy moves its three hundred thousand plus residents and thousands of tourists by canal boats and pedestrian lanes, virtually car-free.

In the continental US, our system can best be described as auto-centric, with public transit, air traffic, trains, and ferries supplementing the use of private motor vehicles. The evolution and impacts of this system have been thoroughly examined by critics, supporters, and reformers. Almost without exception, transportation analysts approach our complex system from a specialized interest perspective. As a result, there is a great deal of information available about the environmental impacts of transportation (see Appendix A for a summary), its economic implications (see Appendix B), its health and safety measures (see Appendix C), and its relative efficiency (see Appendix D). What appears to be missing is an approach that examines the system as a whole. A whole systems approach is critical because it allows two questions that don't arise in any other context. First, how do we want a transportation system to function within our society? Second, what would such a system look like? These questions prompt us to set criteria and then design to achieve them.

A Personal Perspective

Examining how transportation fits into the weave of one life in our society reveals the ways in which this system interacts with every other aspect of public and private life. A hundred profiles of Americans and their relationships to transportation would reveal a thousand permutations on the same themes: health, safety, expense, enjoyment and/or separation from the larger community and the natural environment, and the simple ability to get places on time. Perhaps the overriding theme, however, would be the desire for something better.

Sitting at my desk by a window on the eighth floor, I hear the roar of freeway below. Continuously. I am disturbed, not just physically by the constant infiltration of noise but also by the impacts I observe. Mount Rainier often is obscured by a haze that extends, brown and fuzzy, for miles. On ozone alert days, I call an asthmatic friend to remind her to stay indoors in the afternoon. Several times a week I hear an ambulance, patrol car, or fire truck trying to make its way down Sixth Avenue, repeatedly using its siren, horns, and speakers to induce the stop-and-go drivers to nudge over just far enough to let the emergency driver squeeze through. I think of the life at risk, the damage unnecessarily increased by the slowed response of the aid car.

And every so often I notice Life Flight lifting off or setting down at Harborview Medical Center, not one obstacle in its way.

On the street corners, pedestrians wait to cross at the light or dash across the intersection when they see a gap in the flow of cars. During peak commute times, about five hours each day, I see them wind between vehicles blocking the intersections in their press to make it through just one more light. Sometimes they yell at the driver, or smack the car. On one occasion, I witnessed the driver strike back, a new expression of road rage. And over the last few years, I have learned never to step off the curb on a green light without checking to make sure no driver is running the red signal or taking the corner abruptly. I see a near miss close to every day now. 12 years ago, the Seattle custom of waiting for the walk sign seemed odd to me.

Living less than three miles from the office, I am fortunate to almost never have to drive in to work. When Agency guests arrive, they are often stunned to learn we cannot validate their parking under the building. Nine to twenty-two dollars is a lot to ask of someone who also has to deal with traffic in order to access our services. If they only need to run in for a moment, they may find a metered spot within a few blocks, for $2/hour in quarters. Or if they can get into one of the surface lots within a few blocks, they may get to park for a mere five to seven dollars. Out of town visitors staying nearby fare better, as long as they forego a rental car. When I drive on work time, I allow 20 extra minutes for the 8-block loop needed to access the freeway if I am headed south of town. My easiest work travel takes place on the train to Portland, working during the train ride from one downtown core to the other. Factoring in gas and parking, sometimes it is actually cheaper as well as faster.

To get home, I usually take the bus. My fare is covered by FlexPass, a non-taxed benefit of my job. The stop is only three blocks down the hill, a five to ten minute walk depending on traffic lights. The ride itself is fifteen to twenty-five minutes, depending on traffic and the number of stops needed by riders. Sometimes the bus is right on time, leaving my stop at regular twenty-to-thirty minute intervals. Other times it is twenty to thirty minutes late because of traffic problems downtown; and when it arrives there are no seats left. On a snowy day, it is better to walk than to wait. Once on the bus, I usually catch up with a neighbor, read, or just close my eyes and unwind. If I have a bag or package, it rides on my lap. At night, the bus schedules drops to once an hour and stops completely after midnight.

When it isn't too cold, dark or wet, I often walk instead. A brisk 40 minutes, it can be quicker than the bus; and I enjoy the chance to breathe, move, and think about my day. Walking up Sixth and turning onto the I-5 overpass, I look down at the crawling highway, take a deep breath of exhaust-filled air, and give thanks that I'm not stuck down there everyday. Off the main street, traffic is slower and I can see the changes of the seasons in the yards I pass. In my neighborhood, almost every street connects to another; and traffic circles or speed bumps are common ways of slowing down cars to keep children and others safer. The unplanned slow-down is parking congestion. My neighborhood is older, a mix of single family houses, duplexes, and apartments. There are some garages; but many people park on the street. On some of the smaller streets, one car must pull over to let another pass. We have not started using one-way signs, resident parking decals, or no-parking-this-side signs to maintain the flow - yet.

My own car sits on the street, waiting to be used a few times each week. Since it sits out most of the time, I chose an old, slightly battered model. Every time I see the small oil spots on the street, I feel guilty; but the engine tear down is more expensive than this car warrants. When a car prowler hits the area, it is almost always left untouched. The plastic-and-tape windows on other cars reminds me that I'm lucky to be able to afford comprehensive insurance, be able to take time off work for repairs, and to not need my car to keep my job. For the commonest errands - grocery, drugstore, library, videos - a short walk to nearby stores is a pleasure. For bigger shopping or a trip any place not right off an easy bus route, I take the car. If there is an event in or near downtown after work, I'll usually take the bus home, pick up the car, and use it instead of staying downtown and riding home after the event. After breaking my arm last summer, I learned to stay downtown and catch a taxi if I missed the bus timing. It feels like a luxury, because it is both expensive ($7-10) and fast (5 to 10 minutes). At the same time, the lack of stress from not rushing home, getting into the car, and finding parking makes it a very attractive option.

For years, I have been dreaming of better options for transportation. Driving down the highway at night, radio on and mind free, it is easy to imagine the asphalt gone and the roadway covered in grass. If I try, I can feel the car lift a few feet and glide along the mown pathway. This flight of fancy brought me to an earnest question: why are we still rolling in boxes on top of paved roads? Is this the best transportation system we can design, construct and maintain? What good elements keep us building on our current platform? What would a better system look, sound, and feel like? What would it take to change the infrastructure? What would a better system achieve, in terms of human and ecosystem health, safety, efficiency, equity, and quality of life?

Thinking Bigger, Expecting More

The immense amount of effort being directed towards improving our current transportation system demonstrates that there is money, technology, professional expertise, social support, and political will to pursue and achieve improvements on the status quo. In fact, the demand is so great that there seems to be funding, research and marketing directed to a multiplicity of very targeted changes to address narrowly defined problems. Air quality concerns drive research and production of cleaner fuels, hybrid engines, lighter cars, and better community design. Safety concerns motivate better braking systems, internal sensing devices, on-board GPS use, hands-free cell phones, stronger body alloys, and at the same time, a proliferation of larger, heavier personal vehicles. Water quality concerns drive road placement and land-use decisions, as well as the use of less toxic brake components and auto maintenance practices. Citizen groups organize to prevent road placement or widening in some areas, obtain it in others, and slow down or speed up traffic in selected areas. Political leaders at every level vow to "do something" about stopping sprawl, re-vitalizing urban cores, and reducing commute times. Banks finance both experimental location-efficient mortgages to encourage short commutes and thousands of well-established car loan programs annually, to keep commuting by car within the reach of most workers.

The sheer magnitude of the effort suggests progress. Indeed, when any one innovation or trend is evaluated against its stated objective, it can usually be deemed successful. But when we examine our indicators of healthy, vibrant communities, we see a continuing decline across many measures, from air quality to biodiversity to time spent with family and friends. This negative trend suggests that improvements in selected aspects of the system cannot deliver a satisfactory system. For example, changes to cleaner fuels will not reduce the number of collisions or the acres of productive soil paved over. For each area improved, a multitude of negative impacts remain untouched, like heads on a hydra.

In order to transform transportation from a system where ecological destruction, economic strain, lost life, and lost quality of life are tolerated as necessary by-products of the system's function (moving people and things between places), we must conceptualize a system with minimal, acceptable costs. In other words, we must envision a system that is as clean, safe, affordable, and efficient as possible. If we start with high expectations, we may be surprised to find that the technological capacity, economic means, and political will to design and implement such a system already exists. In fact, by thoughtfully re-directing the vast resources invested today in band-aiding the current system, we may go naturally beyond creating a system with minimal harmful effects to one with actual restorative potential.

Envisioning the Future

Life in the City

Looking out over the downtown core from the 44th story office window, one sees rooftops interlaced with green space. At street level, pedestrians and cyclists move within the green space on separate trails, occasionally crossing a narrow street left in place for service vehicles or crossing a bridge over a stream brought back to the surface. Every few blocks, people enter the second-story stations of the transit system, enter a waiting car or call one to their location with their transit pass. They enter the cars in ones, twos or threes and zip quietly along the guideway directly to their destinations. Birds, frogs, and children can be heard through the open windows of shops and offices. Travelers leaving town take transit to the train station and ride the high-speed rail to the next city. As night falls, the city hums with locals and suburbanites shopping, going to the theater, eating on café terraces, and playing in the many pocket parks. From the rooftop garden of an apartment building, a child watches the stars come out.

Cityscape

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If this picture of urban life sounds utopian and hard to transpose over the reality of today's urban landscape, it is probably not the science-fantasy aspect of fast, quiet, responsive transit that strikes the odd note. Rather, the radical aspect is the changed relationship of the city's human inhabitants and its ecosystem: green space and living systems are interwoven with commerce, culture and recreation. The key to the transformation comes from using a new approach to transportation to re-frame the use of land in a densely built, heavily used area.

Changing the Urban Landscape

Currently, several types of transportation use the same surfaces. Private motor vehicles, taxis and buses carry passengers; while cars, trucks and bikes make deliveries. Vehicles must stop for each other, for pedestrians, and for parking. Pedestrians have separate rights-of-way but must yield at every intersection to vehicles. With so much happening at once in the same space, congestion and collisions are inevitable. Fortunately, urban densities lend themselves well to separation of functions through layering, as we commonly see with highway overpasses and transit tunnels.

A critical technology for landscape transformation is Personal Rapid Transit (PRT). PRT systems used small, automated vehicles captive to a reserved guideway to move small groups of passengers or a standardized load of cargo. Vehicles arrive at stations located one-quarter to one-half mile apart (either free-standing or housed within a building) on demand and travel directly to the destination requested, by-passing intermediate stations. Guideways can be placed on-grade, below-grade, or above ground. Optimal placement, 16 feet above ground, allows safe passage underneath for people, animals, and road vehicles. A number of different PRT systems have been designed (see Appendix E), with each sharing the same defining characteristics: automated vehicles captive to reserved guideways, small groups of passengers in each car, service on demand available 24 hours/day, and direct service without stops between points facilitated by off-line stations. Because a PRT network offers an acceptable service substitute to private autos, it can allow their displacement and the subsequent redevelopment of they land they consume.

Once the network of guideways has been laid out along existing rights-of-way, our attention shifts to the surface level. Here a variety of uses require a smooth surface to operate safely. These include bicycles, scooters, roller skates, and most wheelchairs. Pedestrians need reasonably level surfaces for safety, but not completely smooth ones. Pathways reserved for wheelchair users and walkers, with porous pavement to allow drainage, could be placed adjacent to paved paths to assist with their runoff. Or, they could be separated to allow walkers the highest sense of safety from bicyclers and others moving at higher speeds. Finally, some access to buildings by larger vehicles may always be needed, particularly for emergency and utility service purposes. Recent residential developments demonstrate that a narrow single-lane road with a modest shoulder is adequate even for heavy, fast-moving vehicles such as fire trucks and ambulances. If the safety issues raised by the high-speed turns and short braking distances of emergency vehicles can be addressed satisfactorily, porous pavement even for these uses will be possible.

As a side benefit of the new layout, the visual impact of some vertical elements of the cityscape can also be reduced. Where telecommunications and power lines are not already underground, these can be concealed within PRT guideways. Light posts, now commonly constructed forty or more feet tall to cast a broad pool of light onto streets, can be reduced in height or replaced by attaching softer, more diffuse bands of high-efficiency lighting (e.g., LED) to the underside of PRT guideways (which need no lighting on the top).

The space needed for pedestrian paths, wheel-trails, and narrow, limited-use roads and guideway post space will be significantly less than the amount consumed currently by roads, parking, bike lanes, driveways, and sidewalks. Once the task of designating the rights-of-way for each of those uses is completed, the opportunity for real creativity begins. Due to the existing street grid and alley-ways' often redundant provision of access to buildings, and the greatly reduced need for surface vehicle access to buildings served by PRT, some portions of the city street network will be completely dispensable, freeing those sections for re-development. In other segments, wide streets and their on-street parking lanes will be reduced in width, freeing the remaining strip for other uses.

The uses for the varied public and private "found spaces" within a city will depend both on what the site is appropriate for and on the most pressing needs in that locale. In buildings with underground parking, several stories will become available for uses not dependent on daylight (storage, and some manufacturing, stores and offices). In open spaces of adequate dimension for new buildings, (such as parking garages and surface parking lots) schools, housing, offices, stores, and public buildings may be constructed.

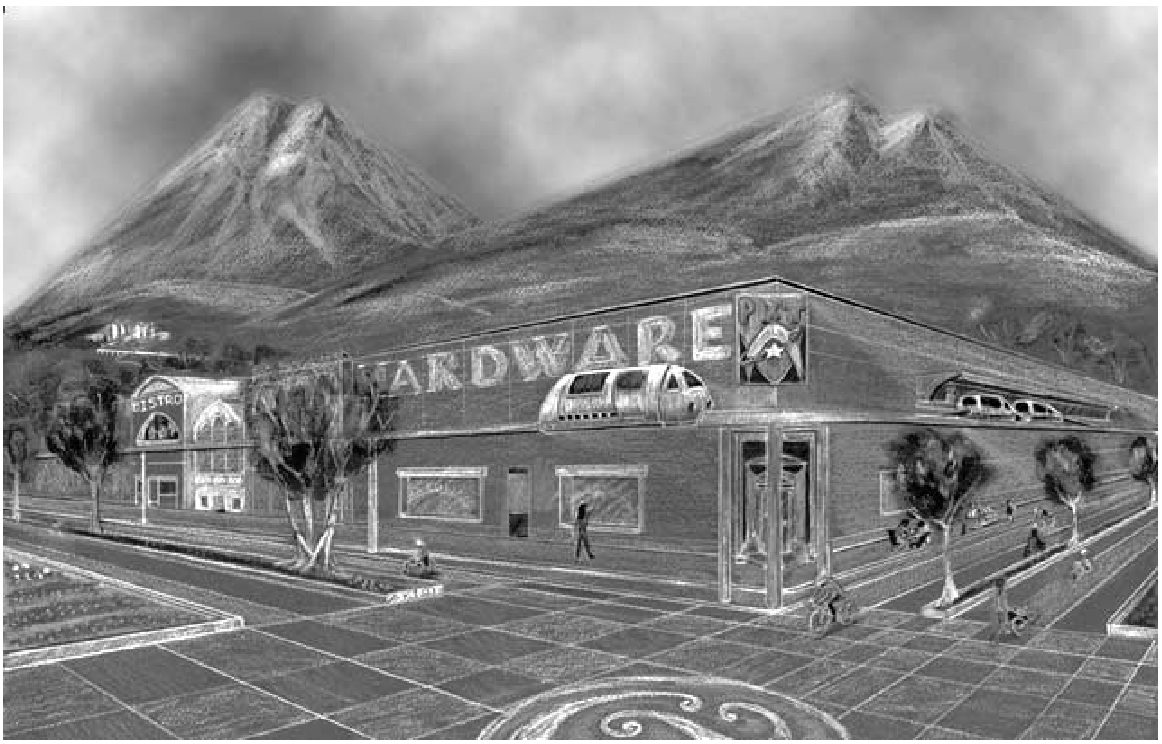
However, the degree to which urban areas already exceed the proportion of impervious surface allowable to avoid devastating impacts to natural ecosystems (see Appendix A), warrants cautious land use planning. A given municipality may find that its goals for protecting and restoring habitat, avoiding combined sewer-storm drain overflows, and reducing heat island effects are achievable only if the maximum amount of asphalt and concrete is removed and replaced by green infrastructure. Green infrastructure enhancements may include turning parking lots into pocket parks or community gardens, connecting existing patches of green belts together to form viable wildlife corridors, planting vegetation for bio-remediation of runoff in the long, narrow strips adjacent to paved paths and narrow surface roads, and daylighting streams (ie, uncovering those previously diverted to underground culverts and paved over). The particular combinations used will vary from one city to the next, but the common outcome should be an improvement in access to city amenities, health and safety of humans, health of local ecosystems, and 'livability' factors (quiet, shade, walkability, water features, etc).

Life in the Suburbs

Most residents of mini-ranchettes still own a private vehicle, used for commuting to the park and rides for PRT commutes into the city or to the nearest village center for shopping, services, school or work. In the older subdivisions, most people take the PRT to the village center or the city, using a neighborhood station car for trips to the locations not accessible by PRT. Village centers, created by one of two routes, house the majority of suburbanites.

One type are those where the old main-street layout, with shops, services, housing, schools and parks, allowed for PRT to be adopted in a manner similar to the urban areas. Biking and walking are common, vehicle use within town is limited, and a few miles of guideway with a dozen stations serve a few thousand people. Housing off the mixed-use, main street area tends to be clustered near the PRT stops, and several parking lots on the fringes of town hold visitors' cars, a few villagers' private vehicles, and a few station cars. At its far ends, the village PRT network connects to the next village's network or to the nearest city. Between them lie fields, forest, and a narrow country highway available for limited use by motor vehicles.

Village Center



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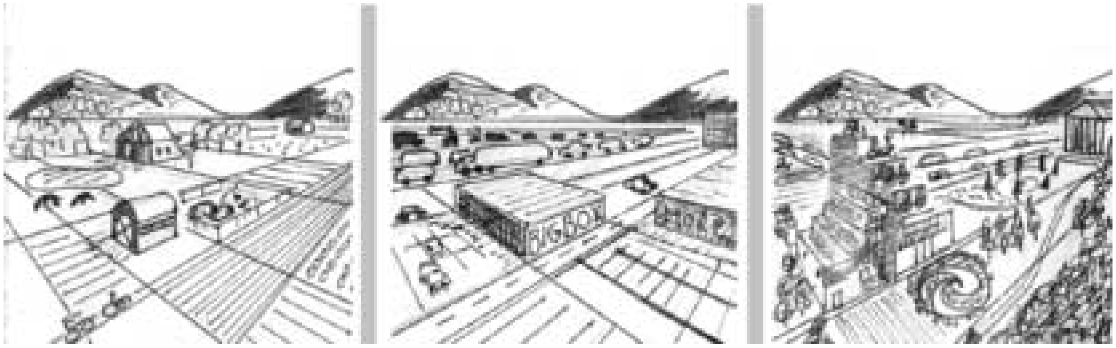
The second type of village center grew deliberately out of greyfield redevelopment, with PRT use in mind during the design. As one old-timer describes it, "My family owned hundreds of acres in this valley until the Depression, about a hundred years ago. They raised vegetables, hay, and some livestock. There was a creek through the valley floor, some ponds with good fishing, and woods with game. During my father's day, the highway came through and developers parceled the valley out. They put in a mall, some of those big-box stores, a couple hotels, and some office parks. The rest was just roads between all that. By the time my kids were born, even the little farms eking it out between the developed areas were gone. But then about 20 years ago, after they got the PRT running in the city, there was a big push to re-develop the valley all over again. First they took the malls and other big boxes and added floors, mixing in housing all over. Then they brought the PRT in to link up the buildings and took out hundreds of acres of parking, leaving just these skinny roads, walkways and bike trails. They uncovered the creek and recreated some of the ponds; and they planted thousands of trees. I was already near retirement then; but I'll tell you, I got out and did my part, and my grandkids helped, too. They put a school in one of those old big-boxes, and used all the old parking spaces for playfields. They even set some land back up for farming, with some clusters of houses on the far edges of the fields. About 10 years ago, I moved into one of the new units on top of the old mall. From my terrace, I can see the new woods, the pond, and one of the fields. I don't think my father would quite recognize this land; but I think he'd be pleased."

Valley Trypitch



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Comparing System Impacts and Benefits

Unfortunately, it is not possible to place the current transportation system, an auto-centric model with heavily paved urban areas surrounded by paved and sprawling suburbs, in a direct comparison to the described alternative. The latter does not yet exist to provide comparison data. However, some aspects of the latter model do exist and can be used to help determine whether the net gains of a transformation from one model to the other are significant enough to warrant the effort required to design and implement the transition.

To arrive at a measure of the net benefit, three issues must be pursued: the new system's requirements, the impacts displaced by the new system, and the overall level of impact after the transition is complete. The CASE criteria can again be utilized to examine the various types of relevant impacts. (See appendices A through D for new system expectations.) To keep the before and after comparisons distinct, it is helpful to examine transitions issues separately.

Managing the Transition

Transforming a system entails changing each of its elements (infrastructure, technology, institutions, and values) in a coordinated process. Often, the physical process is the least complicated part. A more complex, vital step is creating the consensus and partnerships necessary to enable the players to fit into a unified game plan. With political leadership and broad-based collaboration, nearly every financial, legal and logistical challenge can be resolved.

Participation: Players and Process

To effectively re-design a community, all the diverse interests within that community must be considered. All will share an interest in creating a cleaner, more affordable, safer and more efficient area in which to live and work. However, each person or group will place more importance on one or two of those factors than the others. Where one party advocates for protecting one interest at the expense of others, a sense of competition will lead to division and even polarization. Because local political leaders must make the final decisions and will be held accountable by all the parties involved for the outcomes, they bear the burden for creating and facilitating a public process that minimizes division and leads to solutions with the best long-term implications.

A process that engages all stakeholders in a constructive manner must begin with a clear statement of intent for the major outcomes, an identification of those involved and their roles, and an explanation of how all of the parties' input will be used in the decision making process. Non-governmental leaders in the community should be informed and consulted early on, because they control resources necessary for implementation and they influence the thinking of their constituencies and peer groups. Listening sessions, design charettes, and public information sessions all offer means for managing the different stages of the process. At every stage along the way, both social marketing and the press should be employed to crystalize key issues and inspire support.

Four categories of participants will play differing but equally important roles. First, governmental organizations with expertise in relevant areas need to communicate with one another early on, for coordinated input. Examples include metropolitan planning organizations (MPO's), community development corporations (CDC's), and state or regional inter-governmental councils. These groups offer key insights into the potential for either using or changing existing regulations and ordinances to promote the desired changes. Second, urban planners, landscape architects, naturalists, transportation engineers, and others with technical expertise can offer their professional opinions on the issues relevant to their fields. Third, interest groups from the chamber of commerce to low income housing advocates will reveal the aspirations and concerns that determine their support or opposition to particular aspects of proposed changes. Finally, neighborhoods can represent the needs and concerns specific to their geographic and demographic characteristics. As the different parties make their voices heard, maximum transparency of the process is needed to dispel fears that certain groups have more access to and influence with decision-makers.

Infrastructure Logistics

The actual physical placement of new infrastructure and redevelopment of the old should follow simple, common-sense steps to minimize disruption in the areas being changed. Before any implementation occurs, however, local zoning rules must be reviewed and revised to allow the new uses anticipated. Many localities, for instance, prohibit mixed-use neighborhoods and features that enable increased density.

Because PRT infrastructure is one of the lightest transportation infrastructures, installing it into spaces with existing uses need not be unduly disruptive. Whether guideways are suspended from building sides or support posts, the preparation support can be completed with only a brief street closure, one city block at a time. When a course of supports is ready, a night crew can close the affected streets to traffic for a few hours and place the 60 foot sections of guideway in place, minimally affecting operations in the installation area. Renovations to buildings that will host PRT stations on their second-story levels and the construction of stand-alone stations can also be completed ahead, affecting only the immediate area during that time.

Once PRT is installed and operating in the urban core, creating car-free areas is the next step. Blocking vehicle access to areas whose use will be converted can occur nearly simultaneously to creating any new pedestrian or bike trails. Actually converting blocked roads from asphalt to its next use can happen on the time frame allowed by available resources, both human and financial. Next, the PRT service web can be extended to outlying neighborhoods, with guideway installation leading reductions in car access to developed zones as expansion continues.

As motor vehicle use is pushed outwards towards outlying neighborhoods and suburbs, the traditional modalities should be ready to adapt. To avoid park and ride overflows, transit providers may want to move the busses displaced from the urban core to the neighborhoods now acting as feeders. Providing station cars at the urban-fringe car lots will serve both urbanites now living without car ownership and residents outside the core who are relying more heavily on transit than when bringing their vehicles into the core was allowed.

Regulatory and Finance Tools

A number of federal statutes offer some authorization and resources for the goals of a local effort to improve transportation and land use. These include the Farm preservation Act, the Fair Housing Act, the Americans with Disabilities Act, the Transportation Equity Act for the 21st Century (TEA-21), and a variety of environmental statutes (NEPA, air quality, water quality, environmental justice, brownfields, endangered species). Of these, TEA-21 is probably the most significant, as the largest public works spending bill ever. Its stated goal of developing a transportation system that meets the CASE criteria, combined with billions of dollars in funding, makes it a powerful tool. Communities pursuing PRT in conjunction with land use changes could pursue funding under several of its programs, including Surface Transportation, Congestion Mitigation and Air Quality Improvement, the Federal Transit Act, and Research for Intelligent Transportation Systems.

For transition support separate from federal authority and funding, localities can pursue a number of options. These include public-private partnerships, bonds, tax shifts, and applying public funds saved from avoided automobile infrastructure costs to PRT construction and subsequent redevelopment efforts. To the extent that local governments can work with business and landowners to compensate them for revenue base shifts and land use impacts, both opposition and disruption will be averted.

Conclusion

The tremendous negative impacts of making do with our current transportation system compel citizens, scientists and political leaders to pursue improvements. The system and its impacts are so thoroughly interwoven into the fabric of life, however, that changing any one aspect simply shifts impacts. To achieve our larger social goals, we must first approach transportation as a whole system, seeing how the various parts interact. Then we must conceive solutions that take these interactions into account and create positive change in the relationships between the elements. Although their implementation may pose many challenges, the potential benefits oblige us to try.

Biographical Sketch: Mary Bell Austin works in EPA's Seattle office and serves as the smart growth coordinator for Region 10 (Alaska, Idaho, Oregon, Washington and 267 federally-recognized Tribes). In addition to being a point of contact and information clearinghouse for Regional staff in a variety of programs which address or are affected by the environmental impacts of construction and development, she provides some technical assistance and training to Agency partners interested in applying smart growth and/or green building principles at a project level. Mary Bell holds a B.A. from Duke University, a J.D. from the University of Washington School of Law, and is currently pursuing LEED (Leadership in Energy and Environmental Design) certification.

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CASE STUDY IN IMPLEMENTING AN EFFECTIVE ENVIRONMENTAL COMPLIANCE MONITORING PROGRAM FOR HIGHWAY CONSTRUCTION PROJECTS

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Abstract

With the realization that construction of a highway can result in additional un-permitted impacts to natural resources and that environmental commitments made by the Department are not always implemented, the Army Corps of Engineers requires the Pennsylvania Department of Transportation to contract an independent environmental compliance monitor for large projects. The responsibilities of the environmental compliance monitor are to ensure that impacts to natural resources are minimized, additional un-permitted impacts do not occur, and documented environmental commitments are implemented. For past transportation projects, environmental compliance monitoring was strictly based on erosion and sedimentation control monitoring. The compliance monitor was often viewed as an antagonist to the project and input was ignored if it conflicted with the project schedule or resulted in additional construction cost. Expansion of the monitors responsibilities to include environmental compliance monitoring presented the task of meshing monitoring responsibilities and implementing a monitoring program that is viewed by highway contractors and construction managers as an integral component of the overall project. The Pennsylvania Department of Transportation, I-99, Route 220 Improvements Project provides a case study in implementing an effective environmental compliance monitoring program. Principal components of the monitoring program include environmental final design review, environmental sensitivity training for contractors, established hierarchy of communication, complaint inquiry/resolution procedures, on going agency coordination, and Departmental support. The Route 220 environmental compliance-monitoring program resulted in the resolution of conflicts between environmental compliance monitoring and construction through developing a team concept. At the core of the team concept approach was the premise that all parties respect the responsibilities and roles of each member and that the focal point of the project was environmentally based. This environmental monitoring approach to highway construction has not only resulted in minimizing additional impacts to permitted resources but has eliminated impacts to un-permitted natural resources. In addition the monitoring procedure has kept the project in compliance with permit conditions and environmental commitments.

Biographical Sketch: Marvin Klinger is a Senior Environmental Manager and has more than 14 years of transportation planning experience. The focus of his career has been the completion of documentation to achieve environmental clearance for highway improvement projects. His responsibilities include data collection, impact analysis, and documentation for the wide range of natural resource issues related to transportation projects. As a result, he is on the forefront of today's most pressing environmentally related transportation issues such as the development of innovative mitigation strategies, the implementation of environmental streamlining, and the evaluation of environmental constraints on a regional level. Mr. Klinger is employed at Skelly and Loy, Inc. an award-winning multidisciplinary consulting firm with six east coast offices and more than 210 employees. Skelly and Loy was recently recognized as one of the top 200 National Environmental Firms and one of the top 500 National Design Firms by the McGraw Hill Engineering News-Record.

ENSURING ENVIRONMENTAL COMPLIANCE THOUGH THE MITIGATION MONITORING PROGRAM

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Abstract

Environmental objectives must be considered continually throughout all phases of project development (planning, project definition, final design, construction and post-construction). In preparation of anticipated expansion of Dallas Area Rapid Transit's (DART) Light Rail System (LRT), HOV System, Commuter Rail System, and associated support facilities, DART has recently drafted Environmental Impact Assessment and Mitigation Guidelines for Transit Projects. The primary purpose of this document is to provide a consistent approach in the consideration of environmental impacts, mitigation, and the implementation of mitigation monitoring programs for those actions requiring mitigation. This paper will focus on the development of the mitigation monitoring program as a tool to ensure that environmental commitments made during planning and project development and identified in the environmental documents are implemented during construction, maintenance and operations.

Whenever a proposed project will result in potentially significant adverse environmental impacts, measures must be taken which will minimize or avoid that impact. These mitigation measures may require additional project elements, revised locations, additional activities, modified operations, or other commitments. Where such measures are identified and committed by DART during project planning, a program for monitoring or reporting on the project's compliance with those measures will be established.

The purpose of the Mitigation Monitoring Program is fourfold:

- To specify recommended mitigation measures identified during the project development process and ensure that the appropriate mitigation measures are incorporated into the final design process;
- To monitor the implementation of the mitigation measures as the project proceeds through the final design process, construction, and its operation;
- To resolve issues identified during the environmental process that are contingent upon the outcome of the design as it progresses through the more detailed stages of development; and
- To report on progress towards implementation of mitigation measures to responsible parties.

The Mitigation Monitoring Program is designed to guide transportation planners, project managers, project engineers, and environmental specialists, as well as neighborhood and community leaders and others in the implementation of mitigation measures identified in the appropriate environmental document. The Mitigation Monitoring Program provides DART with a tool to finalize and monitor the implementation of mitigation measures in order to minimize impacts on the surrounding community and ensure NEPA compliance. This $250,000 effort resulted in an 18-month study of DART's policies and procedures and compared the monitoring programs of other transit agencies around North America.

Biographical Sketch: Jerry Smiley, AICP, is an Environmental Division Manager with Wendy Lopez & Associates, Inc, and is also a certified planner with more than 12 years of experience providing consulting and technical services associated with environmental, comprehensive, and transportation planning. He has served as a project manager for environmental impact statements, assessments, and baseline reports, as well as major investment studies for numerous state and federal clients, including the Texas Department of Transportation, DFW International Airport, US Army Corps of Engineers and Trinity River Authority. He is currently the Program Manager for Dallas Area Rapid Transit's General Planning Consultant – a multi-year, multimillion-dollar contract to provide transit and environmental planning services. Mr. Smiley graduated with a Masters in Environmental Science and a Masters in Public Administration from Indiana University in 1989. He is completing his tenure as Environmental Network Chair for the state chapter of the American Planning Association.

INDUSTRIAL ECOLOGY: THE ROLE OF ENVIRONMENTAL LIFE-CYCLE ANALYSIS IN TRANSPORTATION SYSTEMS

Mansour Rahimi, PhD, Associate Professor, Industrial and Systems Engineering, University of Southern California, Los Angeles, CA 90089-0193 Email: mrahimi@usc.edu, Phone: 213-740-4016, Fax: 213-740-1120

Abstract

The environmental consequences of transportation are significant; and, vehicular sources account for one-quarter to more than one-half of all nationwide emissions of pollutants including carbon monoxide, nitrogen oxides, and organic substances and carcinogens such as benzene, 1,3-butadiene, formaldehyde, toluene, xylene, and others. However, it is spurious to conclude that vehicular (primarily tailpipe) emissions are the only, or only significant, environmental consequence of transportation. And, to identify and assess these other consequences, the use of life-cycle analysis (LCA) methods is recommended. For example, when transportation is examined on this basis, significant environmental consequences are identified in other life-cycle stages including vehicle production and the extraction, production, and distribution of fuel. And, because of these life-cycle consequences, it is clear that “simple” solutions such as cleaner fuels and electric vehicles are inadequate to mitigate the environmental impacts of vehicular travel.

There has been only limited research to-date that has modeled and optimized the operation of a transportation network or system where environmental impacts were considered among the optimization objectives. And, previous research has been limited primarily to consideration of criteria pollutants (tailpipe emissions) and/or to optimization of a single variable. More importantly, from the perspectives of decision theory and environmental sustainability, it is not the *impacts* (e.g., pollutant emissions) that should be optimized; but, rather, it is the *consequences* of the impacts (e.g., human health and ecological damage) that are important and should serve as the basis for optimization. And, available life-cycle impact assessment (LCIA) methodologies provide a means for identifying and assessing such consequences.

This paper will develop and demonstrate a methodology for optimizing the operation (vehicle assignment, routing, and scheduling) of a public transit (demand-responsive, paratransit) system based on the joint optimization of cost, service, and environmental (consequence) objectives. In order to do this, a life-cycle inventory (LCI) model of the transit operation will be developed, wherein environmental (and cost and service) impacts are specified as functions of vehicle routing and scheduling parameters.

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MODELING THE EFFECTS OF ROAD NETWORK PATTERNS ON POPULATION PERSISTENCE: RELATIVE IMPORTANCE OF TRAFFIC MORTALITY AND 'FENCE EFFECT'

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Abstract: Roads affect animals in three adverse ways. They act as barriers to movement ('fence effect'), enhance mortality due to collisions with traffic, and decrease habitat size. We study the relative importance of the first two effects using a spatially explicit individual-based model of population dynamics. We discuss our results with respect to the suitability of fences along roads as a measure to reduce road mortality. The results reveal a much stronger effect of road mortality than of the 'fence effect'; the influence of traffic mortality is always much more significant when the proportions of individuals avoiding the road and those that are killed on the road (in relation to the number of individuals encountering roads) in the two situations compared are the same. The results indicate that putting up fences along roads might be a useful interim mitigation measure until more suitable measures will be applied. However, fences must be used with caution because they could increase extinction risk for species that have large area requirements and small population sizes. In the second part of this paper, we outline a comparison of different configurations of road networks. We ask if different spatial arrangements of the same amount of roads (e.g., 'bundling' of roads) have consequences for the strength of both the 'fence effect' and road mortality. The model results indicate longer times to extinction in case of a 'bundling' of roads but the proportion of populations going extinct within 500 time steps does not change significantly.

Introduction

Should we put up fences along roads?

Nature conservationists, traffic planners, and landscape planners are increasingly concerned about the effects of roads on animal populations (e.g., Canters 1997, Glitzner et al. 1999, Trombulak and Frissell 2000, Lodé 2000). The discussion of the pros and cons of available mitigation measures includes the question of whether fences are a suitable measure to reduce traffic mortality due to collisions with vehicles.

Much data have been collected about absolute numbers of road kill (Trombulak and Frissell 2000, Knutson 1987). However, very few data are available on the proportion of animals killed related to total mortality. Such data exist for very few species; among these are otters in Eastern Germany (Stubbe et al. 1993) and hedgehogs in the Netherlands (Huijser and Bergers 2000).

The question arises as to whether fences along roads would be a helpful measure to prevent the animals from venturing onto the road even if we don't know how many individuals of a population are killed on roads in relation to total mortality in that population. On the other hand, fences would make road crossings impossible and lead to a complete separation of the habitats on either side of the road. For some species, this effect might be even more adverse than the enhanced mortality due to vehicle collisions. The question as to which of these two effects is more severe has been asked by Carr et al. (*in press*). Currently, the use of fences is the subject of great controversy in traffic planning institutions and nature conservationists. Therefore, we wanted to compare the relative importance of both effects, isolation (the 'fence effect' of a road) and traffic mortality, in a simulation model.

The net effect of fences is not obvious because there are a number of different mechanisms involved (e.g., demographic stochasticity, dispersal of juveniles to find unoccupied habitat, searching for mates, re-colonization of empty habitats, traffic collisions, interaction with other species, interaction with other impacts on the population such as intensified land use). It is difficult to separate these mechanisms in an empirical field study. A simulation model is a useful tool to separate and compare different mechanisms that are responsible for the effects of roads on population density and to investigate their relative importance.

The purpose of this paper is to present the results of our computer simulations and to outline the framework of which these simulations are a part. We address the following questions:

- Under what conditions is a fence expected to be harmful to population persistence?
- When does the 'fence effect' (due to road avoidance) have a recognizable effect on population density and persistence?
- What is the relative importance of the 'fence effect' and road mortality?

The larger project aims not only to examine the effects of a single road but also to compare different road network patterns with respect to their effects on population density and landscape connectivity. In addition, the project will develop a method to describe landscape connectivity as a function of network indices and species characteristics and to rank different road network patterns according to their predicted effects on landscape connectivity and population density and persistence.

Expectations about a road's 'fence effect' and traffic mortality

Research questions

Roads influence animal populations in three different ways (e.g., Jaeger et al., *in prep.*): (1) *habitat loss* (due to pavement and embankment and to emissions from the road such as noise and salt), (2) *collisions* of individuals with vehicles on the road, and (3) *avoidance* of venturing onto the road ('*fence effect*'). As the notion of the "barrier effect" means reduction of movements across the road and includes both road avoidance behavior and traffic collisions, we prefer the notion 'fence effect' as used by Krebs et al. (1969) and Krebs (1996). 'Fence effect' denotes the effect that animals encountering a road don't try to cross it and, therefore, are separated from the habitats on the other side of the road. We describe traffic mortality and 'fence effect' by the two variables ρ for the degree of road avoidance and κ for the proportion of animals killed on the road (Fig. 1).

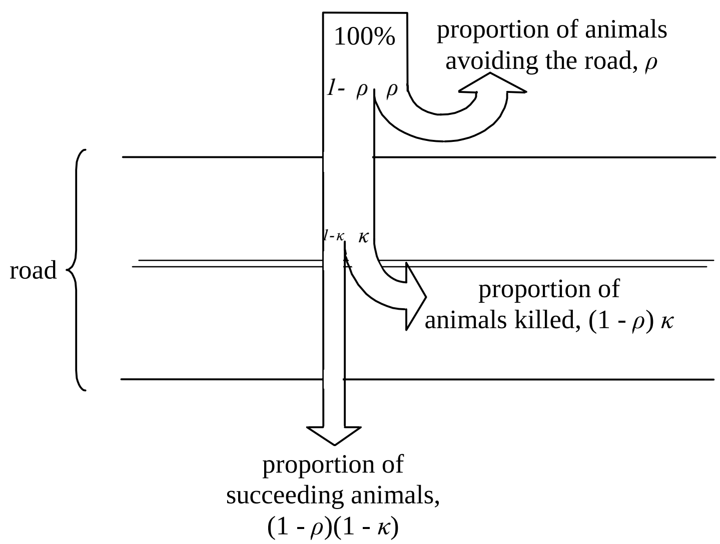


Fig. 1. The degree of road avoidance, ρ, and the proportion of animals killed on the road, κ, are specified independently of each other between 0 and 1.

Both range between 0 and 1. Barrier strength, β, denotes the sum of both effects and ranges from 0 to 1 as well. Note that 'fence effect' denotes the effect of a road (with ρ between 0 and 1) and should not be confused with 'effect of a fence' (with ρ = 1). Putting up fences reduces the proportion of animals killed but substantially enhances ρ, i.e., it enhances the 'fence effect' to is maximum. We investigate the following research questions:

- At which values of road avoidance would we expect to observe an effect of road avoidance ('fence effect') alone on population density and persistence?

- At which values of traffic mortality would we expect to see an effect of traffic mortality alone on population density and persistence?
- Which one is more important?
- Under what conditions would we expect a mitigation of traffic mortality by putting up a fence?
- When would we expect an aggravation due to the fence?

What would we expect?

Theoretical considerations show that, in principle, both cases are possible (mitigation or intensification due to a fence), depending on the magnitude of traffic mortality. Putting up a fence means that ρ is set to 1 (unless there are underpasses or overpasses or leaks in the fence) and κ is set to 0. Without the fence, κ may have any value between 0 and 1. We denote the value of ρ in the situation before putting up the fence as ρ_0. When κ increases (e.g., due to increasing traffic density on the road) and if ρ is assumed to be constant, we expect to obtain a curve like the one in Figure 2. (If road avoidance increases as well, the curve may look different.)

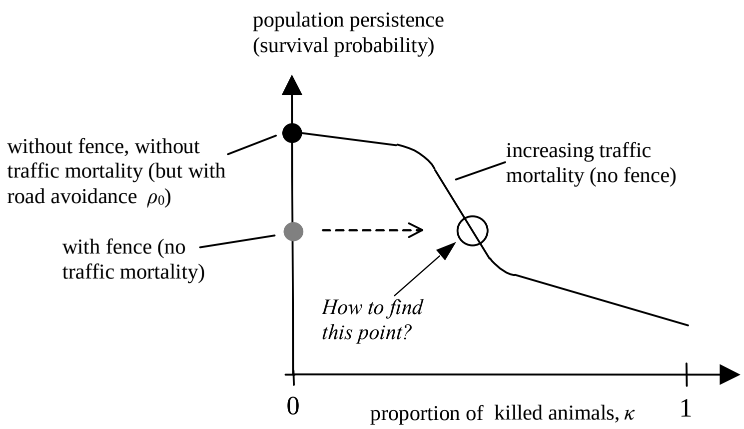


Fig. 2. Expectation for the effect of increasing road mortality, κ, as compared with the effect of a fence. At some value of κ, the curve for population persistence (as a function of traffic mortality) assumes the value of population persistence for putting up a fence. The situation where all animals crossing the road are killed is always worse than the effect of a fence (the animals return but are not killed).

At what values of κ does a fence act as a mitigation, i.e., when is population persistence higher for the situation with a fence than for the situation without the fence? We expect the fence to always reduce population persistence (as opposed to no fence and no traffic mortality) because of three closely related mechanisms:

- Separation of a population into smaller sub-populations: smaller populations have higher demographic stochasticity and, therefore, a higher extinction risk. In general, this can not be compensated for by a *larger number* of (small) populations because of the following two mechanisms.
- Lack of re-colonizations of empty habitats where the former population has gone extinct: this results in the loss of habitat because habitat that cannot be accessed is not inhabitable.
- Lack of density-dependent dispersal (for population regulation): missing the option of leaving the present habitat when the population has grown to carrying capacity. This means that the population in this particular habitat cannot grow any further because of a lack of balancing between (temporarily) growing and declining populations.

There are more mechanisms that explain why the isolation of habitats can be harmful for the persistence of animal populations (see the discussion), but we focus on these three mechanisms in the model used in this study.

A given probability of traffic mortality is always worse than the same probability of not crossing the road because when an animal is killed is also does not cross the road (i.e., two effects). Therefore, the curve for population persistence as a function of traffic mortality eventually has to go below the value for the fence (Fig.

2). Fig. 3 (a) and (b) show the situations that are possible. Either the fence reduces population persistence to a value > 0, or the fence reduces the population persistence to 0 (and the curve goes down to the *x*-axis).

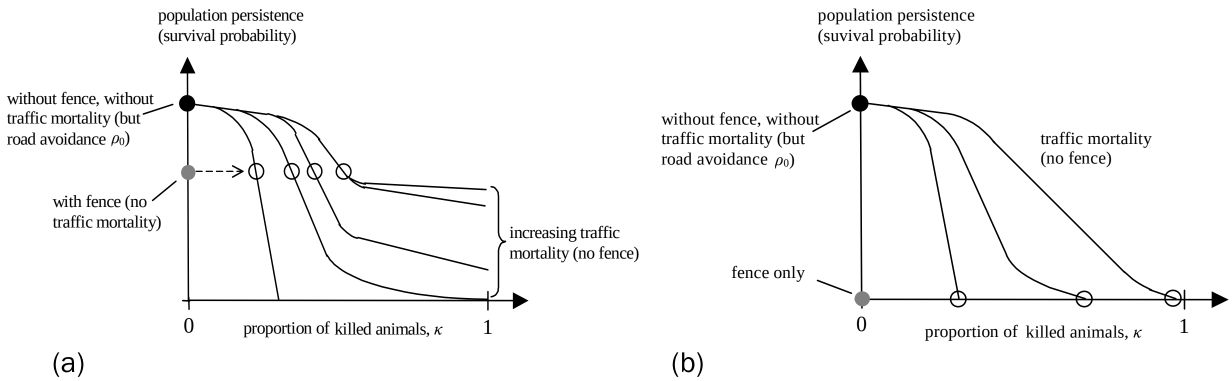


Fig. 3. Scenarios that can occur: (a) Possible scenarios if the fence alone does not lead to a 100% extinction risk. (b) Possible scenarios if putting up the fence (ρ = 1) leads to a 100% probability of extinction of the population: the points of intersection on the *x*-axis. In this case, the curve will go down to the *x*-axis.

It follows that there is always a critical value of the proportion of animals killed on the road, κ_c, so that for all $\kappa > \kappa_c$, the animals would be better off with a fence. However, there is also a section with lower values of κ where the influence of the fence on the population is more adverse than the traffic mortality. This leads us to the question: At what magnitude of road mortality is a fence expected to be advantageous?

Methods

We used a spatially explicit individual-based stochastic model of population dynamics. The model was developed earlier to investigate the effects of habitat fragmentation on population persistence (Fahrig 1997, 1998). We extended the model to include roads and different kinds of animal behavior at the roads during the movement phase (cmp. Schippers et al. 1996). Fig. 4 and 5 show the structure of the model. For subroutines 2, 3, and 4, see Fahrig (1998).

Accordingly, our model has three more parameters than the original GRID model:

- proportion of animals encountering the road that avoid it, ρ;
- proportion of animals trying to cross the road that are killed on it, κ;
- median dispersal distance.

The 'barrier effect' with barrier strength β includes 'fence effect' and road mortality. The barrier strength, β, describes the reduction of successful movements across the road ($\beta = \rho + \kappa - \rho \cdot \kappa$).

During the movement phase the animals move in a straight line with a dispersal distance between 0 and maximum dispersal distance and with an angle between 0 and 360º chosen randomly. On its way to the new habitat cell, an animal may encounter a road and a decision is necessary if it wants to cross the road or not. This is done randomly with probability (1-ρ). Three different types of behavior at the road are available when the individual encounters a road and does *not* want to cross it:

- it stops at the road and waits for the next round of movement;
- it moves along the road for the remaining portion of the dispersal distance;
- it goes to the road and tries to move a second step away from the road with the remaining part of the dispersal distance.

On the road, the animals are killed with probability κ.

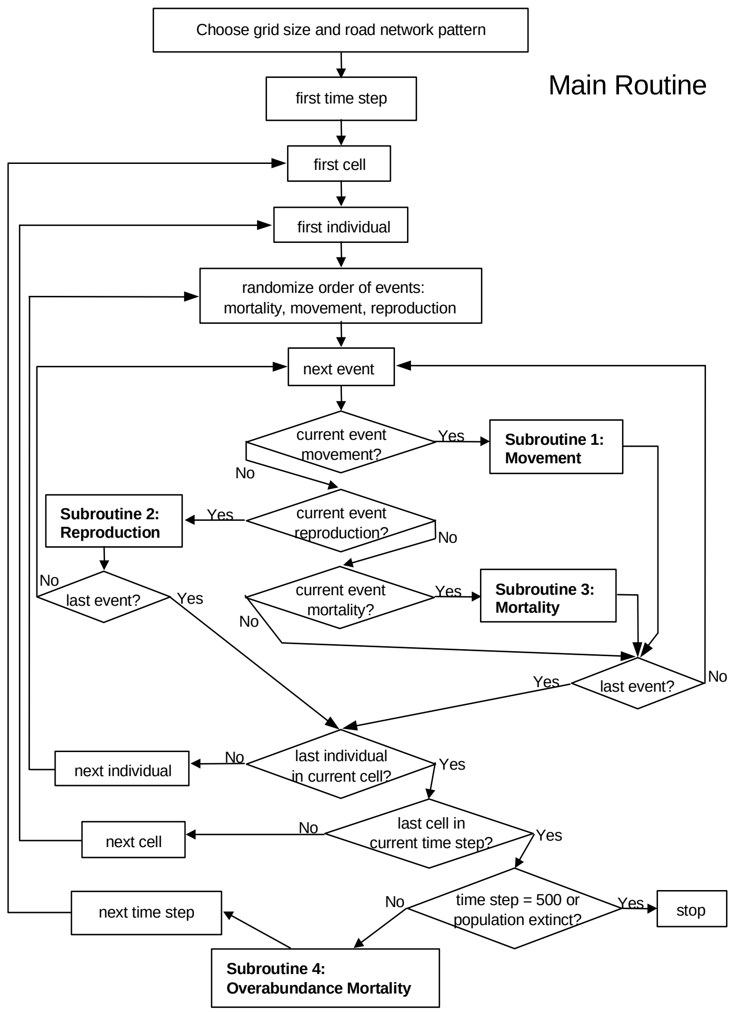


Fig. 4. Flow diagram of the main routine in the simulation model.

If the dispersal path would require an animal to cross more than one road the animal decides if it wants to cross the road or not for each road separately. If it once decides to avoid a road it will avoid all the other roads it encounters during this round of movement as well (not shown in Fig. 5).

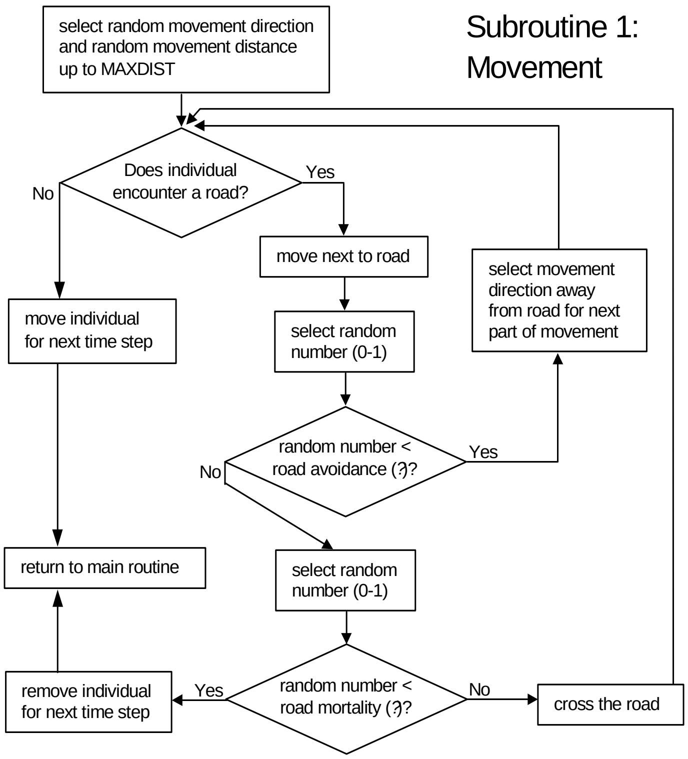


Fig. 5. Flow diagram of the model subroutine for individual movement.

Parameters used in the simulation are given in Tab. 1. All cells were breeding habitat. In the 25x25 grids we applied the results of Bowman et al. (*in press*) for the dispersal distances. Throughout the simulations we used reflecting boundaries and movement type (3) at the road, i.e., moving away from the road (at any angle chosen randomly) for the remaining part of the dispersal distance. We chose parameter combinations where we would observe an extinction risk slightly higher than 0 when there is no road present because we are especially interested in the effects of additional roads on species that already have some extinction risk, e.g., endangered species. We then conducted 1760 model simulation runs with 20 runs for each parameter combination. We varied both proportion of animals avoiding the road, ρ, and traffic mortality, κ, independently between 0 and 1 in steps of 0.1. Road configurations are shown in Fig. 6 and 7.

Table 1
Parameter values held constant through all simulation experiments

Parameter	Value	
Model / landscape size	4 x 4 grid (16 cells)	25 x 25 grid (625 cells)
Starting number of individuals	40	300
Time steps in simulation	500	500
Reproduction probability (RPROB)	0.5/individual/timestep in breeding habitat cell	0.5/individual/timestep in breeding habitat cell
Mortality probability in breeding habitat	0.35/individual/timestep	0.4/individual/timestep
Movement probability in breeding habitat	1.0/individual/timestep	1.0/individual/timestep
Offspring per reproduction	1	1
Maximum cell occupancy	5 individuals	25 individuals
Maximum movement distance	1 cell	8 cells
Type of movement distance distribution	uniform distribution	exponential distribution (with median movement distance of 1.4 cells)

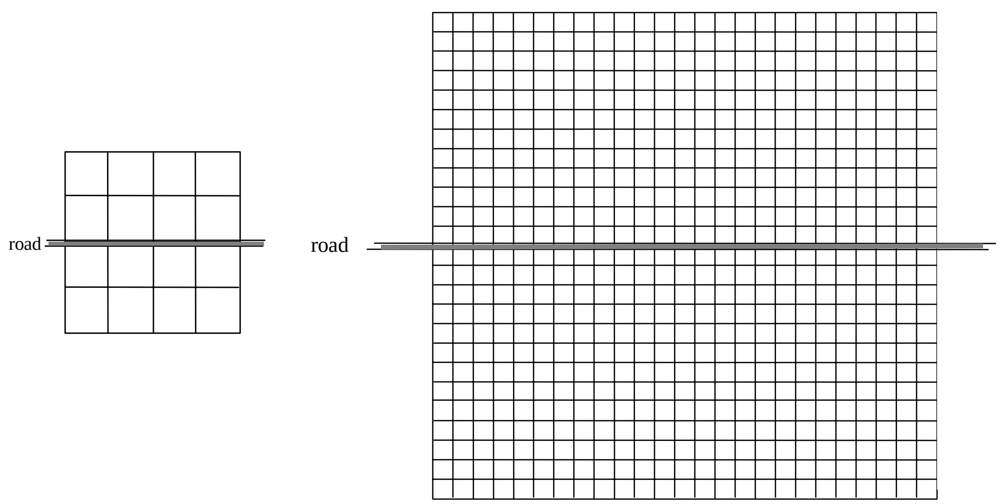


Fig. 6. Positions of the roads in the first series of model runs. (a) 4x4 grid model; (b) 25x25 grid model.

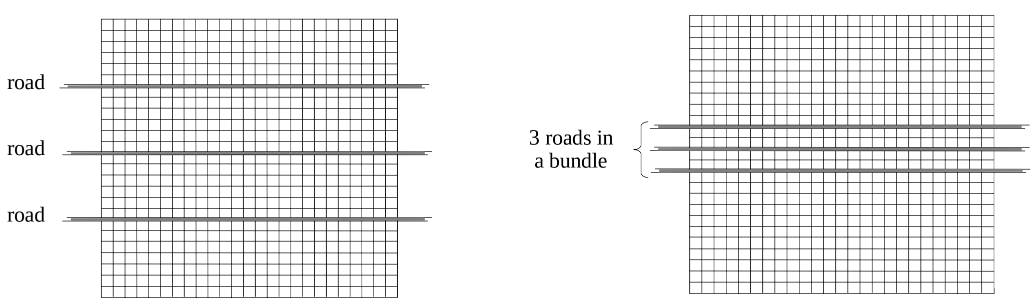


Fig. 7. Positions of the road in the second series of model runs (25x25 grid model). (a) even distribution; (b) bundling of roads.

Results

We recorded both the number of individuals in each habitat patch and in total, and the time to extinction in each habitat patch and in total. We also recorded the number of re-colonizations in each patch as well as the calculated extinction probability.

Small grid (size of 4x4), one road

Figure 8 shows an example of the number of individuals in the two habitat patches in a run of the 4x4 grid model (Fig. 6a). Traffic mortality has a much stronger effect on survival probability than road avoidance (Fig. 9). If κ equals 1, a fence would be better because even though the two habitats would be isolated no animals would be killed any more. However, a fence still would lead to extinction with a probability of 100%. The average extinction time in case of a fence is 230 time steps as opposed to 40 time steps in the situation with $\kappa = 1$. If $\kappa < 0.3$ a fence would be worse, if $\kappa = 0.3$ a fence would be an improvement because the time to extinction would be longer. In this situation, a fence could be a useful measure for a couple of years until a more effective mitigation measure will have been realized.

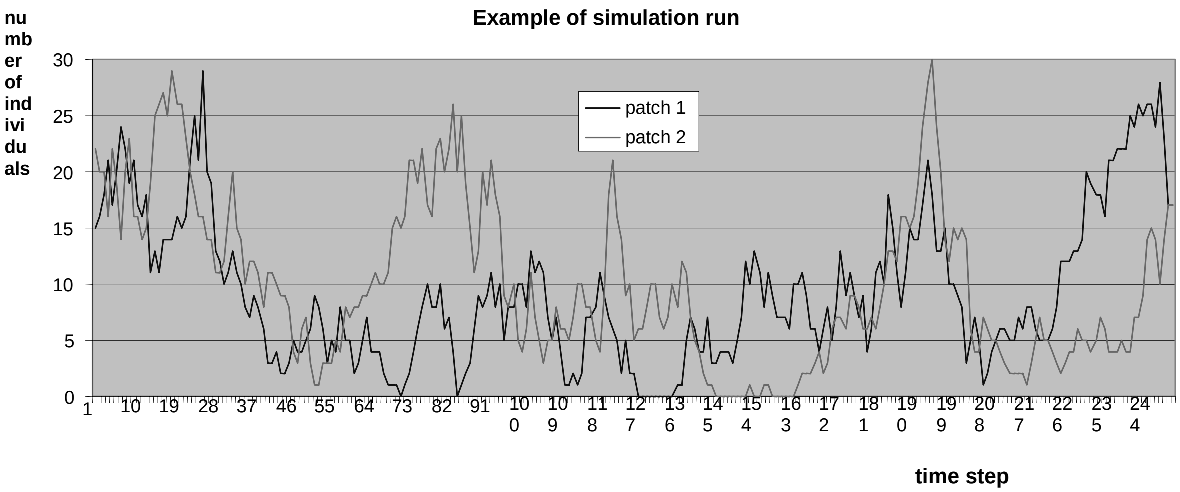
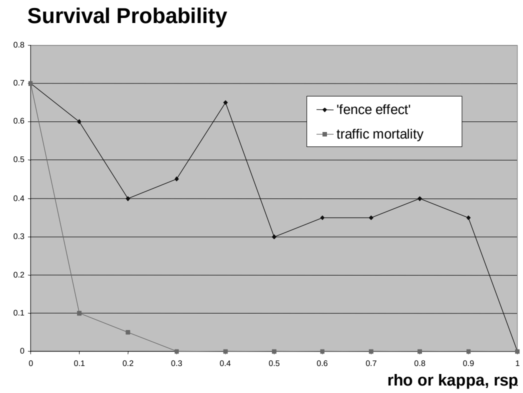
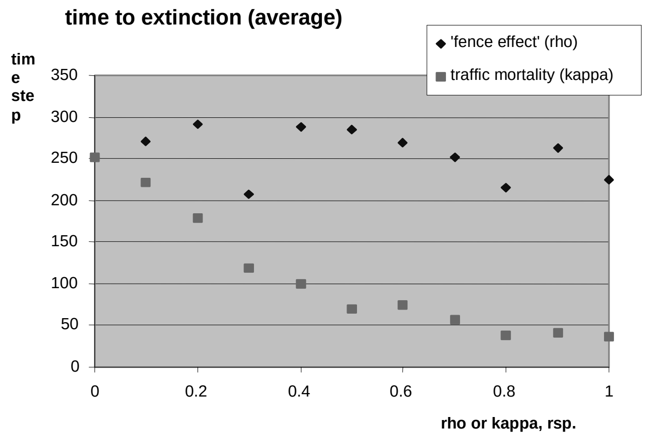


Fig. 8. Example of a simulation run for the 4x4 grid (270 time steps shown) with road avoidance of $\rho = 0.8$ ($\kappa = 0$): 3 re-colonizations in patch 1 and 3 re-colonizations in patch 2 are observed. (Number of individuals after 500 time steps = 30).



(a)

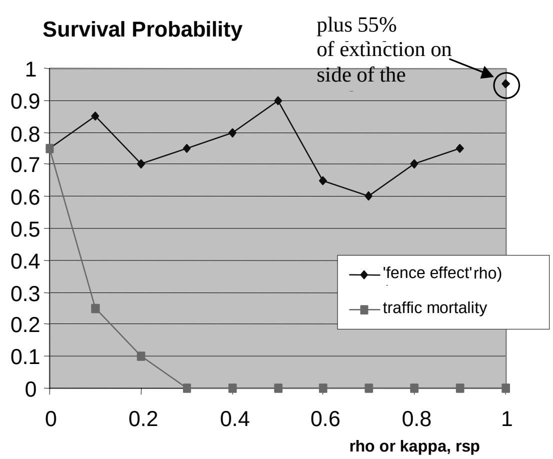


(b)

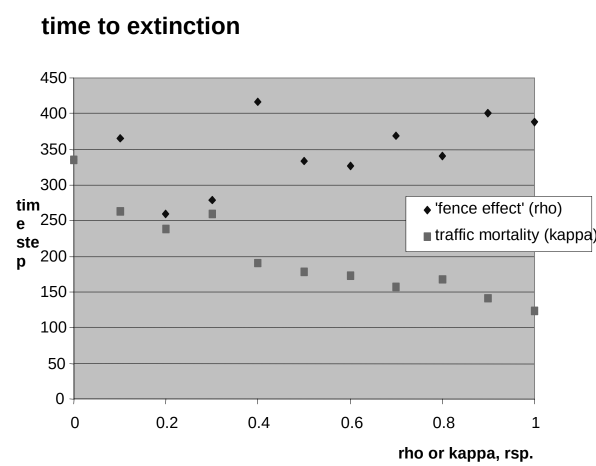
Fig. 9. Results for the relation between road mortality, κ, or road avoidance, ρ, respectively, and (a) survival probability, (b) average extinction times based on the runs that went extinct within the 500 time step limit of the simulations. (4x4 grid with one road; 20 runs for each parameter combination).

Larger grid (size of 25x25), one road

The results are shown in Fig. 10. The effect of traffic mortality on survival probability is very strong whereas the effect of the 'fence effect' is not significant. A fence would lead to higher survival probability than would traffic mortality for almost any value of $\kappa > 0$. However, in 55% of all runs with total road avoidance, the population on one side of the road went extinct. Such an event is equivalent to 50% habitat loss because the habitats are isolated and cannot be re-colonized.



(a)



(b)

Fig. 10. Results for the relation between road mortality, κ, or road avoidance, ρ, respectively, and (a) survival probability, (b) average extinction times based on the runs that went extinct within the 500 time step limit of the simulations. (25x25 grid with one road, Fig. 6b; 20 runs for each parameter combination).

Bundling of roads

Next, we conducted a series of simulations with the two patterns shown in Fig. 7 with three roads to compare them with each other and with the results from the previous situation with just one road (Fig. 6). The results are shown in Fig. 11 and 12. They exhibit a stronger effect of traffic mortality than in the situation with one road whereas the 'fence effect' is not significant in either case. As before, a fence would lead to higher survival probability for almost any value of $\kappa > 0$. However, for total road avoidance in case of a uniform distribution of the road, one patch went extinct (or, equivalently, 25% habitat loss) in 15% of all runs, two patches went extinct (50% habitat loss) in 25% of all runs, and three patches went extinct (75% habitat loss) in 45% of all runs. When the roads were bundled in the center, the equivalent habitat loss in case of total road avoidance was 8% in 10% of all runs, 16% in 10% of all runs, and 50% in 35% of all runs (extinction occurred in 40% of all runs). As for traffic mortality, the average time to extinction was higher for the clumped arrangement of the three roads (e.g., twice as high for $0.5 < \kappa < 1.0$) as opposed to the dispersed distribution.

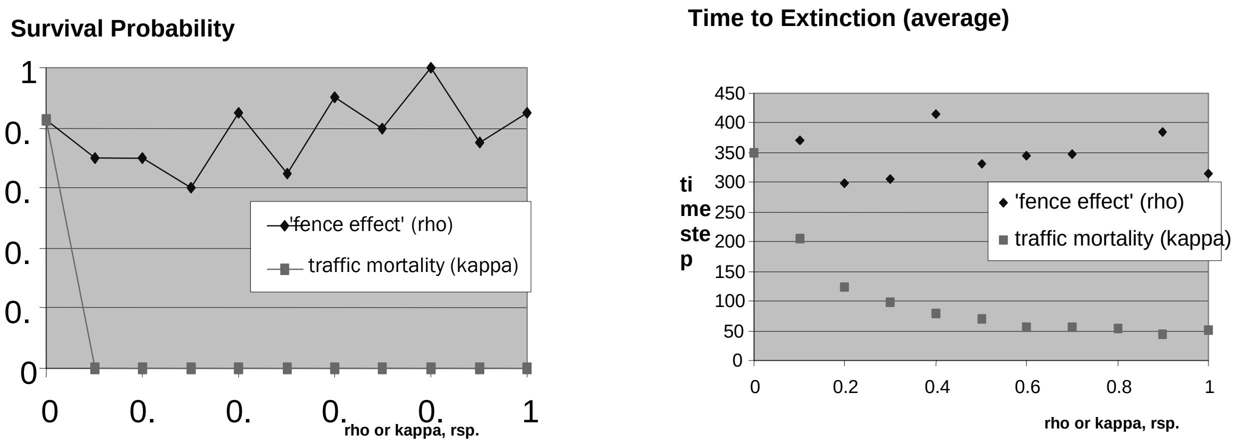


Fig. 11. Results for the relation between road mortality or road avoidance, resp. and (a) survival probability, (b) average extinction times based on the runs that went extinct within the 500 time step limit of the simulations. (25x25 grid with three roads distributed evenly, Fig. 7a).

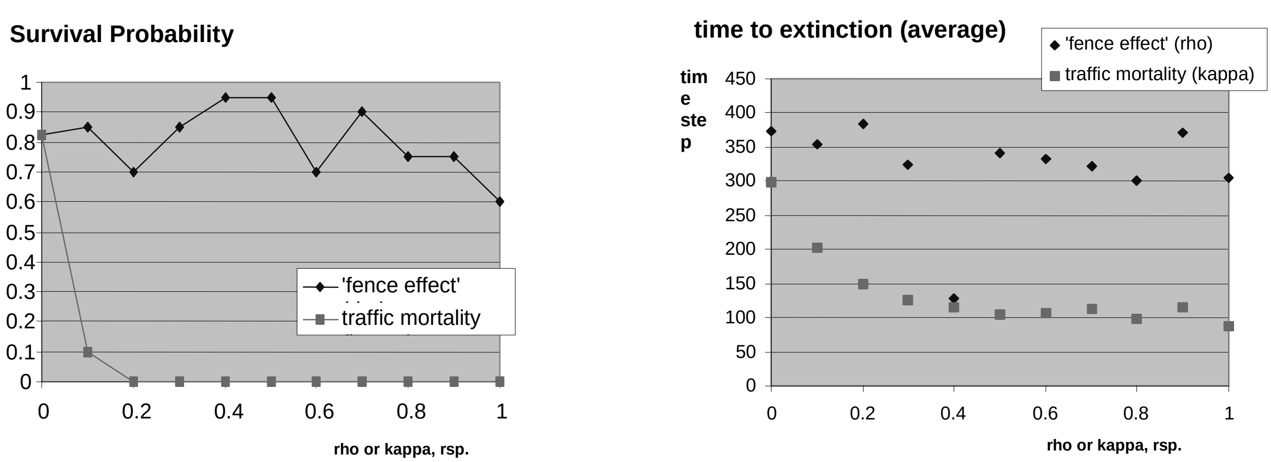


Fig. 12. Results for the relation between road mortality or road avoidance, resp. and (a) survival probability, (b) average extinction times based on the runs that went extinct within the 500 time step limit of the simulations. (25x25 grid with three roads bundled in the center, Fig. 7b).

Discussion

The results underline that the influence of road mortality can be much stronger than the 'fence effect'. Our results also indicate that small populations can be reduced by the 'fence effect' of a road and can go extinct as a consequence of a real fence. We don't know what the values of ρ and κ really are. In case of small populations, the results for the 4x4 grid indicate that a fence would not be a reliable measure if the strength of traffic mortality, κ, is not known. However, the simulation results of the 25x25 grid suggest that, for large, stable populations (that can be seriously affected by traffic mortality), a fence would not be harmful. Therefore, the use of fences seems appropriate if there are no large animals with a small population size around. In dealing with small, endangered populations, we need to know more about the extent of road mortality to be able to decide if a fence would be more harmful or not.

Mechanisms that may enhance the 'fence effect' or decrease the effect of traffic mortality

The 'fence effect' in our model includes enhanced extinction risk in smaller populations due to demographic stochasticity and reduction of re-colonization numbers, as well as reduced regulation of population density due to a reduction of density-dependent dispersal. However, as the individuals in the model act independently of each other, mechanisms such as the process of finding mates or unbalanced sex ratios in small populations are not included. In addition, the individuals in the model don't necessarily stay in the patch that they just have re-colonized. Individuals move in a randomly chosen direction and, therefore, may leave that patch over the next couple of time steps. The individuals don't perceive themselves to be immigrants into an empty habitat in which it would be important (for a higher population persistence) to stay. Therefore, we would expect re-colonization in nature to be more effective than in our model.
Mechanisms that may enhance the 'fence effect' of a road include the need for landscape complementation (e.g., breeding habitat, foraging habitat, and winter habitat), inbreeding effects in smaller populations, and the Allee effect, i.e., reduced per capita growth rate at low population density, e.g., Hanski (1999: 31f), including difficulties in finding mates, unbalanced sex ratios in smaller populations. These mechanisms should be tested independently in future model simulations. If several of them apply at the same time, the 'fence effect' might be much more important.

However, a strong argument supporting our results is related to the concept of effective population size (e.g., Lande and Barrowclough 1987). This means that most of the mechanisms mentioned above correspond to an effective population size that is lower than would be indicated by the number of individuals. Therefore, our result with regard to the question of when we would observe a 'fence effect' will change quantitatively but not qualitatively. These changes also could influence the relative importance of the 'fence effect' and road mortality.

Further issues that may have an influence on the results concern mechanisms that might buffer the effect of road mortality and the choice of model characteristics. In some populations, birth rate may be density dependent. An increase of birth rate (as a reaction to reduced population density) may partly compensate for road mortality. However, this only can occur when birth rate is not at its maximum possible value. (Otherwise we would expect an Allee effect.) Endangered species may be already at a low population density, so their birth rate would probably not increase but dwindle when the population size further decreases.

In our simulations, breeding habitat was everywhere. Therefore, wherever the individuals move to (whether or not they cross the road), they always find breeding habitat. This is different from Fahrig (1997, 1998), where breeding habitat was fragmented. In her study, fragmentation of breeding habitat curtailed population growth by a reduction in both reproductive and survival rates because more individuals move into non-breeding habitat where survival rate is lower and the animals cannot reproduce. The increasing avoidance of crossing the road (i.e., increasing ρ) makes the dynamics of the two adjacent patches more and more independent of one another until they are isolated. In our model, this is the only cause of the 'fence effect'. For example, if one patch is a sink (e.g., because it has a lower birth rate than death rate), it can be sustained by incoming individuals from an adjacent source patch. When the avoidance of the road becomes stronger, the sink no longer has enough immigrants and the population will go extinct. (This is not demonstrated in this paper but could be shown in a configuration with a large and a small patch.) A second effect of this mechanism is a lack of re-colonization of empty habitats. If two patches are connected, their populations can survive even if each of them becomes extinct from time to time, because the connections provides for re-colonizations. If they are separated, their populations will not be re-vitalized once they go extinct.

The model results indicate quite a long time lag of the road effects. Therefore, effects after building a road may not be visible instantly but after tens of years as discussed by Findlay and Bourdages (2000). According to our results, the time lag for the 'fence effect' would be greater than the time delay of road mortality. It would be interesting to add a road at some point in time during a simulation run and investigate the time delay in the model in more detail.

Recommendations

Not all animals have the same value of traffic mortality (κ). Thus, for some species a fence would be advantageous, while for others it is not. It may be good to accept a fence as an interim measure that has a negative impact but does not destroy a population if it saves populations that are on the edge of extinction. In accordance to our results, we propose the following hierarchy of measures:

1. Remove road,
2. Close road (completely or at certain times),
3. Use fences in combination with overpasses/underpasses,
4. Use fences (as an interim measure),
5. Do nothing.

In many cases, fences can be better than nothing but, ultimately, crossings are required. The result that the population on one side of the road went extinct with a high probability when road avoidance was total (ρ = 1) underlines the ultimate need for overpasses and/or underpasses to allow for re-colonization.

A major problem of fences is that they are there all the time (night and day, all year round) and affect all species larger than the mesh size of the fence that move on the ground. Traffic density, however, may vary considerably over time, and the animals might be able to cross successfully at certain times (low traffic periods) if there is no fence.

Because of the issues discussed above, recommending to put up fences along roads everywhere would be precipitate. However, our results indicate that, under certain conditions, a fence could be a very useful provisional measure to slow down the decrease of population density until more effective measures are implemented (if the roads cannot be closed or removed). There are conditions under which putting up fences is worsening the situation for some species. This means that putting up a fence is not generally useful and should not be misunderstood as a means to cushion pangs of conscience. However, under certain conditions that have to be explored in more detail in future studies (modelling and field studies), fences can be helpful for mitigation, e.g., in combination with other measures.

Outlook: network indices and landscape connectivity

In the next steps of our project, we will compare different configurations of road networks to derive landscape connectivity indices based on the effective mesh size, *m* (Jaeger 2000). The relative importance of 'fence effect' and road mortality may vary with different spatial arrangements of the roads. We describe road patterns, including the amount of traffic and the spatial distribution of the roads, using network indices. We estimate the effects of the road networks on landscape connectivity (Tischendorf znd Fahrig 2000, Tischendorf 2001). The results are the basis for describing landscape connectivity as a function of network indices and species characteristics (such as dispersal distance, dispersal rate, reproduction rate, and mortality). This allows us to design ecologically scaled landscape indices (ESLI), as discussed by Vos et al. (2001), to rank different road network patterns. We will discuss the following research questions:

- Which indices are used in transportation science to describe road network patterns?
- Are these indices of any use for predicting the effects of different patterns of roads on landscape connectivity, species persistence, or population density?
- What other indices have a higher predictive value?
- Is it feasible and advantageous to design ecologically scaled landscape indices (ESLI) to predict landscape connectivity, species persistence, and population density? Which indices (network indices or ESLI) are better understood by traffic planners and more likely to be used?
- Can we derive some general rules for an ecologically sustainable design of road patterns?

Acknowledgements: We are grateful to Jason C. Nicolaides for programming assistance. We thank Jeff Bowman for inspiring discussions, Bernd Gruber, Katharina Tluk von Toschanowitz, and the members of the Landscape Ecology Laboratory at Carleton University, Ottawa, for stimulating discussions about road effects as well as Julie Brennan, Jeff Holland, Rebecca Tittler, and Melissa Vance for helpful comments on an earlier version of the manuscript. This work was supported through a postdoctoral scholarship from the German Academy of Natural Scientists Leopoldina to JJ (grant number BMBF-LPD 9901/8-27) and an NSERC operating grant and a PREA award to LF.

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List of Illustrations

Fig. 1: The degree of road avoidance, ρ, and the proportion of animals killed on the road, κ, are specified independently of each other between 0 and 1.

Fig. 2: Expectation for the effect of increasing road mortality, κ, as compared with the effect of a fence. At some value of κ, the curve for population persistence (as a function of traffic mortality) assumes the value of population persistence for putting up a fence. The situation where all animals crossing the road are killed is always worse than the effect of a fence (the animals return but are not killed).

Fig. 3: Scenarios that can occur: (a) Possible scenarios if the fence alone does not lead to a 100% extinction risk. (b) Possible scenarios if putting up the fence (ρ = 1) leads to a 100% probability of extinction of the population: the points of intersection on the *x*-axis. In this case, the curve will go down to the *x*-axis.

Fig. 4: Flow diagram of the main routine in the simulation model.

Fig. 5: Flow diagram of the model subroutine for individual movement.

Fig. 6: Positions of the roads in the first series of model runs. (a) 4x4 grid model; (b) 25x25 grid model.

Fig. 7: Positions of the road in the second series of model runs (25x25 grid model). (a) even distribution; (b) bundling of roads.

Fig. 8: Example of a simulation run for the 4x4 grid (270 time steps shown) with road avoidance of ρ = 0.8 (κ = 0): 3 re-colonizations in patch 1 and 3 re-colonizations in patch 2 are observed. (Number of individuals after 500 time steps = 30).

Fig. 9: Results for the relation between road mortality, κ, or road avoidance, ρ, respectively, and survival probability, (b) average extinction times based on the runs that went extinct within the 500 time step limit of the simulations. (4x4 grid with one road; 20 runs for each parameter combination).

Fig. 10: Results for the relation between road mortality, κ, or road avoidance, ρ, respectively, and survival probability, (b) average extinction times based on the runs that went extinct within the 500 time step limit of the simulations. (25x25 grid with one road, Fig. 6b; 20 runs for each parameter combination).

Fig. 11: Results for the relation between road mortality or road avoidance, resp. and (a) survival probability, (b) average extinction times based on the runs that went extinct within the 500 time step limit of the simulations. (25x25 grid with three roads distributed evenly, Fig. 7a).

Fig 12: Results for the relation between road mortality or road avoidance, resp. and (a) survival probability, (b) average extinction times based on the runs that went extinct within the 500 time step limit of the simulations. (25x25 grid with three roads bundled in the center, Fig. 7b).

Table 1: Parameter values held constant through all simulation experiments

TRENDS AND SOLUTIONS TO UNSUSTAINABLE LAND USE IN THE MID-ATLANTIC REGION OF THE UNITED STATES

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Abstract

Current land use and transportation trends, coupled with increasing consumption of vital resource lands and habitat, are undermining 30 years of environmental progress and threatening the quality of the air, water, land and living resources in the Mid-Atlantic Region. This Trends and Solutions Series is a comprehensive, data-driven, visual presentation that describes the trends and forces behind sprawl development, unsustainable transportation trends, consumption of vital resource lands, and destruction of habitat in the Mid-Atlantic Region. The Series also includes trends in quality of life, economic data, and showcases solutions to current land use problems, including transit-oriented development.

For the past three years, the EPA Region 3's Center for Sustainability has been developing and presenting the Series, which has been viewed by over 1000 people, including government officials, universities, local government officials, and non-profit organizations. The goals of the Series are to 1) concretely link air, water, land pollution, and loss of habitat with current land use and transportation practices; 2) promote better transportation and land use decision-making by local governments and citizens by visually demonstrating land use strategies that protect the land, air, and water, promote healthy communities, and advance a sustainable economy.

Data and trends has been synthesized into a complex and telling story of how land use and transportation choices, including the dramatic increased in impervious surfaces such as roads, highways and parking lots, are now being linked with a decrease in water quality and aquatic life. Data includes sources from EPA, DOT, USFWS, U.S. Forest Service, National Resources Inventory Data, American Farmland Trust, and the Chesapeake Bay Program. Most of the indicators have been reviewed for validity by a team of EPA scientists and managers.

UTILIZATION OF A DESIGNATED ENVIRONMENTAL MONITOR FOR THE DESIGN, CONSTRUCTION, AND REGULATORY COMPLIANCE OF TRANSPORTATION PROJECTS

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Abstract

In April 1999, the Maryland State Highway Administration (SHA) initiated construction of the U.S. Route 113 project in Worcester County, Maryland. This multi-phased interstate roadway project will upgrade and dualize approximately 24 miles of existing two-lane highway to improve vehicular safety and traffic flow. As a special condition of the U.S. Clean Water Act, Section 404 permit, the SHA was required by U.S. Army Corp of Engineers-Baltimore District (COE) to utilize an independent Environmental Monitor to ensure compliance with all environmental permits and commitments, and to ultimately reduce the amount of total wetland and stream impact. Although the basis for the COE requirement can be found in Section 1505-2(c) and 1505-3 of book 40 of the Code of Federal Regulations (CFR), a designated Environmental Monitor has rarely been used or required.

The US 113 project included the first large-scale Design/Build effort that the SHA has undertaken. The planned phasing sequence is for Phase I and Phase III to be completed in a Design/Build manner, with Phase II and Phase IV in a traditional fully designed and advertised-for-bid manner. The COE permitted the entire project based on approximate thirty-percent complete designs and authorized an impact of 27 acres of nontidal wetlands and 1,975 linear feet of stream channel. The COE permitted this large impact with the understanding that the Environmental Monitor would be on-site on a daily basis to ensure that impacts would be avoided and minimized during construction using best management practices and other impact minimization methods. In addition to monitoring environmental permit compliance, the Environmental Monitor also ensures implementation of commitments made in documents completed during the National Environmental Policy Act (NEPA) process such as Environmental Assessments (EA), Environmental Impact Statement (EIS), Record of Decision (ROD) and the Memorandum of Agreement (MOA) for cultural resources.

The role of the Environmental Monitor is in addition to the services normally requested for Environmental Construction Inspection (ECI) in a number of ways. The Environmental Monitor must be the on-site environmental manager and problem solver. The Environmental Monitor is charged with three broad responsibilities:

1. To review design and construction activities with emphasis on avoidance and minimization and to ensure environmental commitments and requirements are incorporated into the construction of the project.
2. To function as an unbiased independent source of environmental expertise, including making recommendations of measures and actions to reduce impact and to rectify non-compliance issues.
3. To function as a liaison between the public, the participating department of transportation (DOT), and the regulatory agencies, specifically in relation to environmental commitments and coordination with the COE for problems/issues that may arise regarding construction associated with jurisdictional Waters of the United States.

Ideally, the complete environmental monitoring effort begins with involvement in the initial design phase and extends throughout the life of the construction project. To fulfill the assigned responsibilities, the Environmental Monitor performs daily inspections of the entire project site, maintains a physical presence during the full length of construction activities within environmentally sensitive areas, obtains periodic water quality data from streams and stormwater management facilities, and reviews all submittals for the ongoing project designs.

The Environmental Monitor is to be highly involved with project construction and public involvement/information aspects, including:

- Impact Avoidance and Minimization Documentation
- SWM ponds and planting

- Water quality
- Stream relocations/crossings
- Wetland protection/restoration/mitigation
- Existing vegetation protection
- Off-site fill/borrow areas (environmental issues)
- Construction staging areas (environmental clearances)
- Cultural and historical (Section 106/Section 4(f)) issues and commitments
- Other commitments made through the federal and state environmental review process including those made during the NEPA process.
- Information management including the development of a project website that provides information to the public on such topics as project description, need and purpose, construction schedules, and detours.

To date, Phase I (the first Design/Build portion) of the project has been completed and is open to the public for use. Phase II has undergone traditional design and advertisement and is currently in the eighth month of construction. Upon completion of Phase I and the as-built surveys, a final report was prepared that provided specific information on the avoidance and minimization measures that were undertaken during the Design/Build process, the total of wetland and stream impact for the respective phase of construction, and the amount of wetland and/or stream impact that was avoided through the efforts of the Environmental Monitor team. As a result of the environmental monitoring effort, there was a reduction of 2.34 acres of wetland impact from the original 8.97 acres of impact permitted by the COE. Additionally, there was more than an acre of forest impact reduction. There were relatively minor incidents in which the project became non-compliant with erosion and sediment control issues and the COE permit. Through the efforts of the Environmental Monitor, the non-compliance was discovered quickly and rectified within a timely manner, thereby avoiding potentially costly delays, COE fines, and project shut-downs. Environmental Monitor efforts are currently ongoing for Phase II and minimization efforts are consistently documented both from the design process and the current construction activities.

Based on the results of the first phase of construction, the use of an Environmental Monitor team for large environmentally complex projects, such as the U.S. 113 project, is a successful merging of the achievement of public infrastructure goals and adherence to current environmental regulations and policies. The SHA is continuing to use an Environmental Monitor for other transportation projects largely because of the success of US 113-Phase I. The SHA has identified important tangible benefits that have been brought to the transportation construction process as a result of using an Environmental Monitor. These benefits include the avoidance of costly delays and potential shutdowns from non-compliant actions; potential reduction of environmental impacts that lead to a reduction in mitigation costs and overall project costs; detection of unforeseen environmental problems/issues; the opportunity for SHA to receive immediate professional environmental advice and recommendations regarding a specific issue; the ability for the public to receive accurate information on design and construction issues and a timely response to their concerns; and a cost-effective method of proactive environmental protection. The total cost for the US 113 project is approximately $115 million. The services of the Environmental Monitor will cost approximately $980,000, approximately 0.85% of the project cost.

The utilization of an Environmental Monitor is a progressive mutually beneficial cooperative effort between DOTs and state and federal regulatory agencies. This type of cooperative effort can continue to set the stage for more expeditious initiation and completion of complex public-need/transportation projects throughout the country in a cost-effective manner, ensuring that appropriate environmental protection standards and safeguards are emplaced.