Integrating Transportation Planning with Land Use and Conservation Through Decision Support Tools

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NatureServe
A conceptual framework to integrate conservation planning

• Conservation *is* a land use supporting public values like any other land use
• They key to rectifying conflicts among uses is to reveal where uses *must* occur and what is the *envelope of options* where they can occur
• Collaborative land use planning will allow testing of options that identify where the objectives of each use can be met without foreclosing the ability of any one to be met
Rare plant population
Regional habitat connection
Prime ag soils
Regional hwy corridor
Forest of sufficient size for interior bird species
Infrastructure served
Economic devpmt area
Envelope of options
Rare plant population
Planning Phase: The Funnel vs Collaboration?

Needs
- Political will
- Agency commitment
- $$

Transportation
Planning

Conservation
Planning

Land Use
Planning

Integrated
Public/Institutional
Processes

Transportation Planner

Species Data

Scenic views

Ag lands

Land use

Historic sites
Project Phase: Integration via Decision Support

Efficient integration of results of sector planning, data, expert knowledge

Minimum necessary and targeted expert engagement
What is a Decision Support System?

• Helps you do specific activities vs general tools
• Guides you through a process
• Incorporates expert knowledge/models AND user values
• Provides automation and documentation of the process
Issues from a Tools Perspective

• Tools are developed for particular sectors and their processes, data, assumptions
• Spatial place-based tools have data commonalities that may support process integration
• Using a collection of tools and processes may grease the skids for human collaboration across sectors by revealing connections and lowering the bar for mutual understanding
Some Uses of DSS for Integration Conservation & Transportation

- Guiding least-conflict routing of transportation (macro scale at planning phase, site scale at project phase)
- Rapid evaluation of multiple route options
- Integrating multiple objectives (e.g., transportation, development, conservation) for long-term plans or short-term projects
  - Predicting and evaluating long-term cumulative effects
  - Revealing areas needed (irreplaceable) for any particular objectives
  - Revealing options for achieving objectives to mitigate conflicts
Example Process of Cumulative Regional Assessment & Planning

1. Develop regional conservation database
2. Develop conservation “cost” surface to guide road routing
3. Develop land use & transportation needs and databases
4. Create optional corridors, evaluate, & refine into transportation scenario
5. Model secondary “growth” effects & integrate into scenario for cumulative assessment
6. Finalize plan and establish mitigation

NatureServe
About the Tools

- Quantm: transportation route optimization tool applied through a service contract
- CommunityViz: land use planning framework tool applied as desktop software
- NatureServe Vista: conservation framework tool applied as desktop software

None of these tools are required to do this analysis or any can be used in any combination with other tools. NatureServe Vista has no formal relationship or linkage to any of these tools.
What is Quantm?

- Worlds first advanced planning system for corridor and route optimization developed over 15 years by Australian Government and Quantm.
- Addresses complex route planning issues, investigating millions of alignment options.
- A tool that empowers Planning Engineers with the ability to consider “all reasonable alternatives”, upfront and equally.
- Quantm provides training, support and system access – the system is applied by the agency or appointed consultant.
Facilitating integration of *all* planning aspects in a single analysis
Inputs to QUANTM

- Terrain model (DEM and/or DTM)
- Geology and Earthworks costs
- Geometry
- Structure Costs
- Constraints
  - Linear – engineering criteria
  - Zone – *environmental, biological, cultural, resource, mitigation, ROW*, etc.
3-Dimensional analysis throughout
Alternative showing earthworks and constraints

<table>
<thead>
<tr>
<th>Project</th>
<th>Scenario</th>
<th>Alignment: FEC_129_126v3TI_9TI_9</th>
<th>Total Land Clearing</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foothill</td>
<td>FEC_132</td>
<td>559 ha</td>
<td>$147,187,000</td>
<td></td>
</tr>
</tbody>
</table>

1. Aluval13  
2. Aluval123  
3. Aluval124  
4. Aluval120  
5. Coastal Sage Scrub-Gnatcatcher  
6. Riverside Fairy Shrimp  
7. Wetlands - ADEWET, CDFG, CDFGRTIP  
8. Waters of the US  
9. Coast Live Oak woodland  
10. Mexican Elderberry woodland  
11. Southern Coastal Needlegrass grassland  
12. Elymus grassland  
13. Giant Wild-Rye grassland  
14. Beardless Wild-Rye grassland  
15. Deergrass grassland  
16. Undeveloped/Agricultural/Open Space  
17. Residential  
18. Recreational (Golf Course, Parks)  
19. Commercial/Industrial/Mixed Use  
20. Public Facilities and Institutions  
21. Undeveloped Residential  
22. Landfill  
23. MIL/SP - State Beach  
24. MIL  
25. MIL/PF (Residential)  
26. Calochortus catalinae  
27. Dudleya multicaulis  
28. Brodiaea filifolia  
29. Calochortus wendell intermedius  
30. Hordeum intercedens  
31. Microseris douglasii ssp. platycladus  
32. Atriplex coetleri  
33. Haplopappus palmeri  
34. Juniperus californica  
35. Jurisdictional Wetlands  
36. SAGEBRUSH-BUCKWHEAT-SHRUB  
37. ANNUAL GRASSLAND  
38. SOUTHERN CACTUS SCRUB  

Click on Extra Costs for Environmental impacts

[Quantum]
About CommunityViz®

• GIS-based tool for geographic decisions
• Real-world 3D models
• Interactive scenario analysis
• Intuitive, powerful, and flexible
• Made available to the public at very low cost by the Orton Family Foundation

Uses ArcGIS technology
Formula-driven indicator charts update dynamically
Dashboard for changing assumptions and settings
Ready-made or custom analyses
Interactive 3D models
Multiple scenarios can be studied side by side

• GIS-based tool for geographic decisions
• Real-world 3D models
• Interactive scenario analysis
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CommunityViz Growth Modeling

Hypothetical “build-out” capacity for each scenario:

Road Proposal 11 shown here. Note that “Avoidance” areas are constrained from building.

**Scenario A:**
Large-lot residential development

**Scenario B:**
Commercial and mixed-use zones
CommunityViz Growth Modeling

Results are available for all 4 scenarios. Potential changes to policies and assumptions can still be tested and explored.
CommunityViz Growth Modeling

CommunityViz also estimates a wide variety of economic, environmental, and social impacts for each of the 4 scenarios:

Just a sample of the many impacts available, all variable by year and other assumptions, are shown here.
A framework tool for cumulative assessment and conservation planning
About Vista

- Custom GIS application based as an extension of ESRI’s ArcMap 9 with spatial analyst
- Licensed software with full integrated help manual, live technical support, available training
- Supports both conservation experts & planners/managers
- Incorporates expert knowledge/models AND user values
- Commercial grade design and engineering
- Provides automation, documentation, & repeatability of the process
Basic Vista Extension Components

User
- Planners
- Managers
- GIS analysts
- Ecologists
- NGOs

Custom Interface
Desktop and web

Analytical models

Framework
Data handling, metadata, project tracking, etc.

Output Visualization and Reporting

Data
- Spatial Extent
- Spatial Attributes
- Non-spatial data
- Expert Knowledge
- Social Values

Technology Platform
ESRI ArcMap 9.0, MS Access, Windows .NET

Input to User Decision Process

DSS Components
Vista Status & Support

Software Versions
- Released Version 1.0 on March 1, 2005
- Version 1.3 released Mar 1 2006, 2.0 under development with possible release Mar 1 2007

Development Sponsors: ~$3.4M versions 1-2.0

Development Partners
- Environmental Systems Research Institute (ESRI)
- University of California –Santa Barbara
- US Geological Survey
  Florida and Wyoming Heritage Programs

Endowment ~$1.6M permanent maintenance and support
- Doris Duke Charitable Foundation
- The Nature Conservancy
- Centex
Applications So Far

- 20+ permanent licenses
- 100+ trial downloads
- 10+ direct NatureServe projects spanning:
  - Industry, government, NGOs
  - 30 k acres—12M acres
  - Forestry, Conservation, Land Use Planning, Public Land Management
- Pikes Peak COG has adopted Vista
Some Jargon

- **Conservation Elements**: the features you wish to conserve representing biodiversity & other conservation values
- **Element viability/integrity requirements**: representing the site or population needs for proper condition and minimum size
- **Element conservation goals**: representing the requirements for metapopulation persistence or ecosystem functioning in the planning region
- **Compatibility**: representing analysis of current or alternative futures to meet element requirements while maximizing options to meet other land use objectives
- **Scenario**: any mapped features representing land use or management practices, infrastructure, natural or human-caused disturbance, invasive species, pests, disease, etc.
Core Conservation Concepts

Conservation planning and implementation need to happen at multiple scales to account for such things as

- wide ranging species
- natural disturbance regimes
- patchily distributed species, and
- ecosystem processes and succession.
But Scales Must Be Linked!

How to get from here… to here

And from site decisions to roll-up of progress toward regional goals
Core Conservation Concepts

Conservation planning must be dynamic to account for:

- Changing threats and opportunities
- Improved knowledge about biodiversity and response to threats
- Changing policies and economics
- New discoveries, surveys, mapping, etc
Conservation Planning: Vision vs Process?

Dynamic Ranking of Conservation Value

Courtesy UCSB
Vista Supported Process

- **Institutional Process**: Identify values to be conserved
- **Expert Knowledge**: ID/develop data, incorporate knowledge
- **Database Construction**: GIS, Data Entry, Documentation
- **Analyses**: ID Gaps, ID conflicts & priority areas
- **Implementation**: Develop compatible land use scenario
- **Monitor Goals**: Reprioritize according to goal achievement
Three Analytical Approaches

Define High Value Areas

Select important values (elements & characteristics)

Overlay maps of elements

Identify general places to conserve or avoid development

Reduce Conflict

Import baseline and evaluate scenarios

Identify conflicts and opportunities

Reduce conflict/generate mitigation plans

Create Solutions

Select elements, set conservation goals and design rules

Integrate data on threats and cost

Generate optimal solutions for meeting goals

Conservation Strategies

Increasing data requirements, complexity, integration
How Vista Works

Data & Expert Knowledge Inputs

- Element Distribution & Confidence Data
- Current Land use, infrastructure, pollution, etc
- Alternative Land Use/Activity Scenario
- Element Conservation Goals
- Element Response To Land Use/Activity

Intermediate Processes & Products

- Join and rasterize
- Landscape Integrity Index
- Element Conservation Layer
- Aggregation and Weighting

Outputs

- Aggregated Conservation Value
- Conflict Intensity Indices
- Evaluation Report
- Site Land Use/Mgmt Specification

Scenario Evaluation

- Scenario Optimization
- Scenario Modification
Core Conservation Concepts

Selecting the elements for conservation attention should reflect:

- Laws: what must be protected
- Values: what does the community, stakeholders, decision makers want to protect
- Scientific concepts such as coarse and fine filter assessment, ecosystem function, etc.
## Conservation Elements

Representing Composition, Structure, and Function of Regional Landscapes

<table>
<thead>
<tr>
<th>Fine Filter Elements</th>
<th>Coarse Filter Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Focus of land trust</strong></td>
<td><strong>Focus of land trust</strong></td>
</tr>
<tr>
<td><strong>acquisition and easements</strong></td>
<td><strong>collaboration w/government &amp; industry</strong></td>
</tr>
</tbody>
</table>

### Species
- Imperiled, Declining, Vulnerable, Endemic
- Management Indicator Species

### Ecological Communities
- Rare plant communities
- Rare aquatic communities
- Unique environments

### Ecosystems
- Groups of communities interconnected on land and waterscapes;
- Natural pattern and process at local scales useful for management and monitoring

### Already identified priority areas

### Non-Biological Elements
- Scenic views
- Archaeological & cultural sites
- Valuable agriculture soils
- Natural hazard zones
Spatial distribution maps of each element come from:
  • Heritage data
  • land cover maps
  • modeled distributions
  • museum collections
  • local information sources

Each element occurrence has:
  • A viability/integrity score
  • A confidence score

Modeled distributions
Modeling Condition

Landscape Integrity Indices

– Combines land use, roads, infrastructure, pollution, etc.
– Model weights effects, adds distance effect
– Can be element-specific
Defining Goal Achievement

Version 1:
• Adequate number of element occurrences or area in project region (metapopulation viability, ecosystem processes)
• Adequate size of occurrences (population potential, ecological functioning)
• Occurring in areas of compatible land use supported by reliable policies

Version 2:
• Same as version 1 plus:
• Adequate “condition” of occurrences (habitat quality)

Can set minimum and preferred goals to express levels of risk of loss
Core Conservation Concepts

Elements have individual conservation requirements and responses to development, management, disturbance, disease, etc. The process of evaluating current condition, threats from anticipated future uses and disturbances, and options for achieving conservation should be sensitive to these individual element needs and sensitivities.
Scenario Integration

• Scenarios describe land-use policy of the planning area.
• Vista automates input from raw data sources
• Facilitates maintaining current baseline map and experimentation with alternatives
Scenario Evaluation

What components can be in a scenario?

- Current, proposed, predicted land use
- Current and planning land management
- Current and predicted spread of invasive species, disease, pests
- Predicted disturbance (wildfire, windthrow)
- Mitigation/restoration practices
- Policies, regulations, and funding mechanisms
Scenario Evaluation

Elements

GIS Intersect & Table Lookup

Conservation Goals

Evaluation Report

Goal Performance by Element

Element Response To Land Use/Activity

Land-use Type

Policy Type

Scenario Outputs
Creating Solutions

• Mitigate conflicts using Site Explorer until all goals are achieved using information about element distribution and compatibilities
• Generate an optimal solution with MARXAN then bring back in to Vista for more precise evaluation and assignment of land use and implementation mechanism
Modeling Condition

Landscape Integrity Indices

- Combines land use, roads, infrastructure, pollution, etc.
- Model weights effects, adds distance effect
- Can be element-specific

Greater Yellowstone Area
Vista in a DSS Toolkit
Transportation Example

Other Sector Tools
- Transportation Planning
  - Quantm
- Land Use Planning
  - CommunityViz

Tools for Conservation Experts
- Conservation Optimization Tools:
  - MARXAN, SPOT
- Ecological Process Tools:
  - Connectivity, restoration modeling
- Biodiversity Tools
  - Element Distribution Modeling Tools:

Current Tool Suite
Planned Tool Additions
Future Planned Tool Interoperability
Tool Interoperability Model

Diagram indicates interactions among Vista, Quantm, and CommunityViz. Bold lined boxes and arrows indicate primary path of information to be demonstrated.
Demonstration
Live Vista w/existing inputs from Quantm & CommunityViz
Closing the Loop

- Vista-generated mitigation scenario should be re-evaluated in CommunityViz for impacts on socioeconomic objectives
- Continued fine-tuning iterations between Vista and CommunityViz could help reach an acceptable solution to maximizing achievement of multiple objectives
Conclusions & Recommendations

• Goals are more appropriately set and are more flexibly met over large regions

• Optimization of conservation solutions saves time and facilitates focus on implementation but must be done iteratively with transportation and land use tools

• Getting started:
  • Can start basic and build detail over time
  • Include the institutions that have the data and expertise needed
## FL Demo Level of Effort

<table>
<thead>
<tr>
<th>Activity</th>
<th>Source</th>
<th>Approx. Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input conservation data into NatureServe Vista</td>
<td>Florida Natural Areas Inventory</td>
<td>2 weeks</td>
</tr>
<tr>
<td>Identify high conservation value areas</td>
<td>NatureServe Vista</td>
<td>&lt;2 hours</td>
</tr>
<tr>
<td>Generate proposed highway routes</td>
<td>Quantm</td>
<td>1 week</td>
</tr>
<tr>
<td>Generate secondary growth effects</td>
<td>Community Viz</td>
<td>1.5 weeks</td>
</tr>
<tr>
<td>Identify areas of conflict between proposed transportation routes and conservation values</td>
<td>NatureServe Vista</td>
<td>1 day</td>
</tr>
<tr>
<td>Create optimal plan via alternative land use decisions and mitigation efforts</td>
<td>NatureServe Vista</td>
<td>4 hours</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>~4 weeks</td>
</tr>
</tbody>
</table>
Planned Features for Vista 2.0

- Multiple uses per land unit (for compatibility/conflict mapping)
- User-defined element response to land use
- Assisted import from heritage Biotics system
- Tools for modeling landscape condition
- Calculating sub-region goals

- Aquatic analysis support?
- N-SPECT integration under evaluation
Getting Started

• Start analysis early enough to make a difference
• Appropriate definition of the regional context
• Public process for establishing values
• Investigation of existing studies, plans, priorities for conservation
• Discipline experts required
  – Ecological scientists
  – Conservation planners
  – GIS specialists
EBM Tools Program

Program Objectives
• Identify available tools that may be useful for performing ecosystem-based management.
• Characterize the tools in a knowledge base
• Prioritize the tools for further description and investigation for investment
• Develop and coordinate a network of tool providers and practitioners
• Conduct outreach and training
Acknowledgments, resources, & Questions

- FHWA
- Quantm
- Placeways/Orton Family Foundation (CommunityViz)

Resources

- Funding to support pilot implementation of Vista on CWCS implementation
- Other poss cost-share programs

From “The Onion”

DOT: Dangerous Intersection Causing Some Pretty Cool Accidents

October 13, 2006 | Issue 42-42

SACRAMENTO, CA—The California Department Of Transportation (Caltrans) released a study Monday that focused on a problematic intersection in Livermore, CA estimated to be nine times more likely to have extremely cool, awesome, or just plain unbelievable accidents than anywhere else in the state.

"Law enforcement and EMT crews have long been aware of the location's reputation for hosting dozens of the most wicked, twisted, and sick smashups around," said Officer Bill Metz of the Livermore Police Department, which assisted Caltrans in compiling data for the study. "The traffic patterns, poor signage, pavement quality, and sharp changes in gradient combine to make this the single sweetest place to watch a traffic accident."
Screenshots in lieu of Demo
Example: Red Cockaded Woodpecker

- A Federal Endangered Species with required protection
- Distribution based on potential habitat
- Ground surveys required to verify
- Development restrictions and/or HCP may be required

Blue occurrences meet adequate size requirements, red areas are below minimum size but still may provide habitat.
Depicting Conservation Values

Vista conservation value summary. Overlays and combines attributes of conservation elements to provide relative value scores.
Integrating Transportation Planning

Categorized Vista output used as input to Quantm road routing optimization software (black lines indicate 50 optional alignments and purple indicates best performing option)
Integrating Land Use Planning

Current land use map indicating mostly green space

Growth model map indicating substantial new urbanization

CommunityViz growth model on right

Legend:
- Unknown specific natural use
- Natural area recreation and open space
- Unknown specific working/occupied use
- Low intensity working landscape
- Low-density development
- Minor road
- Unknown specific high intensity use
- High intensity working landscape/recreation parks
- General urbanization: homes, commercial, industrial, etc.
Evaluating Transportation Impacts

Road corridor imported and evaluated in Vista. Compatibility conflict map for current land use with new proposed road. Pink-red colors represent and index of number of conservation elements in conflict with the land use/infrastructure preventing goal achievement.
Evaluating Transportation Impacts

All tools provide reports. Example Vista report on quantitative goal achievement for conservation objectives

<table>
<thead>
<tr>
<th>Name</th>
<th>Distribution Area (acres)</th>
<th>Occcs</th>
<th>Percent of area</th>
<th>Protected and Goal Met (acres)</th>
<th>Occcs</th>
<th>Percent of goal</th>
<th>Compatible Goal Met (acres)</th>
<th>Occcs</th>
<th>Percent of goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wetlands</td>
<td>4,134.7</td>
<td>426</td>
<td>40 percent of area</td>
<td>1,910.6</td>
<td>145</td>
<td>115.52%</td>
<td>2,672.1</td>
<td>257</td>
<td>161.57%</td>
</tr>
<tr>
<td>Watersheds Priorities 4-6</td>
<td>7,098.1</td>
<td>167</td>
<td>40 percent of area</td>
<td>3,121.2</td>
<td>58</td>
<td>109.93%</td>
<td>3,397.2</td>
<td>66</td>
<td>119.85%</td>
</tr>
<tr>
<td>Watersheds Priority 3</td>
<td>4,832.5</td>
<td>84</td>
<td>60 percent of area</td>
<td>1,893.9</td>
<td>24</td>
<td>65.32%</td>
<td>2,046.5</td>
<td>33</td>
<td>70.58%</td>
</tr>
<tr>
<td>Watersheds Priority 2</td>
<td>224</td>
<td>40</td>
<td>70 percent of area</td>
<td>30.3</td>
<td>7</td>
<td>19.32%</td>
<td>125.4</td>
<td>16</td>
<td>79.97%</td>
</tr>
<tr>
<td>Woodstork</td>
<td>4,393.1</td>
<td>297</td>
<td>50 percent of area</td>
<td>1,257.9</td>
<td>94</td>
<td>57.27%</td>
<td>2,173.8</td>
<td>186</td>
<td>98.96%</td>
</tr>
<tr>
<td>Sandhill</td>
<td>1,023.9</td>
<td>27</td>
<td>60 percent of area</td>
<td>277.6</td>
<td>6</td>
<td>45.19%</td>
<td>639.7</td>
<td>20</td>
<td>104.13%</td>
</tr>
<tr>
<td>Gopher frog</td>
<td>16.1</td>
<td>1</td>
<td>80 percent of area</td>
<td>16.1</td>
<td>1</td>
<td>125%</td>
<td>16.1</td>
<td>1</td>
<td>125%</td>
</tr>
<tr>
<td>Red-cockaded woodpecker</td>
<td>7,573.4</td>
<td>7</td>
<td>60 percent of area</td>
<td>927.3</td>
<td>2</td>
<td>20.41%</td>
<td>3,190.4</td>
<td>3</td>
<td>70.21%</td>
</tr>
<tr>
<td>Celestial lily</td>
<td>2,803.4</td>
<td>6</td>
<td>80 percent of area</td>
<td>571.3</td>
<td>6</td>
<td>25.47%</td>
<td>1,965.5</td>
<td>6</td>
<td>87.64%</td>
</tr>
<tr>
<td>Scrub</td>
<td>973.3</td>
<td>603</td>
<td>50 percent of area</td>
<td>9.6</td>
<td>6</td>
<td>1.97%</td>
<td>118.5</td>
<td>112</td>
<td>24.35%</td>
</tr>
<tr>
<td>Bald eagle</td>
<td>1,915.7</td>
<td>7</td>
<td>40 percent of area</td>
<td>1,324</td>
<td>3</td>
<td>172.78%</td>
<td>1,324</td>
<td>3</td>
<td>172.78%</td>
</tr>
<tr>
<td>Florida sandhill crane</td>
<td>9,452.7</td>
<td>123</td>
<td>70 percent of area</td>
<td>2,050.7</td>
<td>58</td>
<td>30.99%</td>
<td>2,709.9</td>
<td>70</td>
<td>40.95%</td>
</tr>
</tbody>
</table>
Imported & evaluated CommunityViz urban growth model and Quantm road into Vista to evaluate cumulative impacts. Pink-red colors represent and index of number of conservation elements in conflict with the land use/infrastructure.
Developing Mitigation Scenarios

CommunityViz growth model on right & Vista mitigation scenario

Vista mitigation scenario

Growth model map indicating substantial new urbanization
Evaluating Cumulative Impacts

Compatibility conflict map for mitigated scenario. Remaining conflict (red) indicates a management conflict between a shrubland and forest to support an endangered species. Such remaining conflicts must be resolved over larger spatial extents.