Transportation Decision-making –

Principles of Project Evaluation and Programming

Impacts on Wetlands and Other Ecosystems

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Chapter Outline

1. BASIC CONCEPTS
2. WETLANDS
3. MECHANISMS OF IMPACTS
4. IMPACTS AT VARIOUS TDP PHASES
5. PERFORMANCE GOALS FOR IMPACT ASSESSMENTS
6. PROCEDURE FOR ECOLOGICAL IMPACT ASSESSMENT
7. KEY LEGISLATION AND MITIGATION
8. METHODS AND SOFTWARE PACKAGES
Introduction

Ecology:

a science dealing with physical & functional relationships between biotic elements (flora and fauna) and their abiotic environment (habitat).
Transportation projects and policies can adversely affect the quantity and quality of wetlands, woodlands, and other ecological systems.
ECO - CONCEPTS

- **Community** - collection of plants/animals coexisting in specific domain; defined based on predominant plant/animal species.

- **Habitat** - physical location where organism resides for shelter and food; terrestrial, aquatic (freshwater/coastal), or arboreal.

- **Biotope** - area of relatively uniform physical conditions providing habitat(s) for a specific group of plants and animals.

- **Ecosystem** - biotic community and its abiotic environment.

- Ecosystem classification: Based on:
  - dominant organism
  - dominant biotope
Ecosystem classification based on biotope:

- **Terrestrial (continental) ecosystems:** characterized based on dominant vegetation/habitat type.
  - **Examples:** forests, agricultural, savannas, woodlands, scrubs, grasslands, mires, marshes, rock exposures, wastelands, etc.

- **Freshwater ecosystems:** involve inland waters; include natural or man-made still water or flowing water.
  - **Examples:** *lentic* ecosystems (ponds and lakes) or *lotic* ecosystems (creeks, streams and rivers), ditches, canals, springs and geysers.
ECO – CONCEPTS (3)

- Ecosystem classification based on biotope:

- **Coastal (or oceanic) ecosystems**, characterized by meeting point between land and sea/ocean.

- **Examples**: coastal zones consist of three sub-zones - *littoral* (intertidal or shore); *supra-littoral* (maritime); *sub-littoral* (marine).

- **Wetlands**: unique ecological systems representing transition zone from terrestrial to aquatic habitats, linking land and water.

- **Examples**: marshes, swamps, bogs, and fens.
ECO – CONCEPTS (4)

- **food chain** - hierarchy of feeding patterns of various organisms in an ecosystem.

- An organism is a predator of other organisms that are positioned after it in the chain; and is also a prey of organisms that are positioned before it.
Food webs - cyclic food chains

- Vegetation is consumed by herbivorous animals
- Herbivores serve as prey for larger predators (carnivores)
- Carnivores and herbivores, through excretion or death and decomposition, provide nutrients for scavengers and ultimately to vegetation.

Cyclic nature of food chains - indicative of energy flows from one organism to another: vegetation transforms solar energy into chemical energy (through photosynthesis) which is then transferred to herbivores and then to carnivores.
Example of a Food Web

Marsh Vegetation (includes many species of sedges, grasses, bullrushes, algae, etc.)

Energy Transfer

Herbivores → Carnivores

Vegetation
ECO – CONCEPTS (7)

- **Ecological productivity** - rate at which an ecosystem utilizes abiotic elements (soil nutrients, water, sunlight, carbon dioxide, etc.) for producing living matter.

- **Ecological succession** - change in the biotic or abiotic characteristics of a community over a period of time.

- **Ecological stability or resilience** - a measure of the ability of an ecosystem to recover from deleterious disruptions.
Wetlands (1)

- Are special ecosystems that receive additional consideration in environmental impact planning and legislation due to their important ecological, social and economical functions and benefits.

- Characterized by regional and local attributes such as climate, soils, topography, hydrology, water chemistry, vegetation, and other factors, including human disturbance.

- Types and locations can be obtained from the Natural Resources Conservation Service office, local public works or planning department, and the U.S. Fish and Wildlife Service’s National Wetland Inventory
Wetlands (2)

Functions:

- polluted water remediation (thereby improving water quality),
- hazard management (flood control, drought relief, and shoreline stabilization), and
- ecological protection and preservation (habitats/sanctuaries for many rare, threatened or endangered species of plants and animals).
Wetlands (3)

**Marine** (in the vicinity of an ocean) - Bays, Sounds, Coastlines

**Estuarine** (coastal wetland where fresh and saltwater meet) - Tidal salt marsh, Tidal freshwater marshes, Mangrove swamps.

**Lacustrine** (shallow water) - Low-lying areas surrounding lakes, ponds, and reservoirs.

**Riverine** (flowing water) - Drainage basins along freshwater rivers, streams, and creeks, Forested swamps, Shrub swamps

**Palustrine** (standing or very slowly flowing water) - Non-tidal marshes, Bogs
Impact Mechanism (1)

- Conversion of Land to Bases and Spaces for Transportation Facilities
- Earthworks: Land Excavation, Dredging, and Filling
- Collision between Vehicles and Wildlife
- Spillage and Leakage of Hazardous Material from Transportation Vehicles
- Disposal of Transportation Vehicles and Parts
- Intended or Unintended Transportation of Species

- Habitat Fragmentation
- Reduction of Specie Populations
- Introduction of Non-native Species

Disruption of the Food Chain
Imbalance of the Ecosystem
Impact Mechanism (2)

Which species are affected?
- Large animals
- Birds of prey
- Small game
- Water-based animals
- Common field crops
- Native vegetation
- Aquatic plants
- Federally listed species

A discussion of the various direct and indirect impact mechanisms, by specie type, is provided in Table 12-2.
IMPACTS AT VARIOUS TDP PHASES

- **Locational Planning & Preliminary Field Surveys**
  - System planning and design phase - no direct ecological impacts.
  - Location decisions – Can affect impact mechanisms that are direct (e.g. excavation, dredging, filling) or indirect (habitat fragmentation or species depletion).
  - Site investigation / project feasibility analysis - intrusive geotechnical, geophysical, and geodetic field investigations.
IMPACTS AT VARIOUS TDP PHASES

- Transportation System Design can …
  - Reduce land retention of surface runoff or disruptions in the species migratory patterns.
  - Interrupt tidal flows in coastal wetlands.
  - Disrupt water flow patterns.
  - Affect surface- and groundwater (via cut and fill activities).
  - Flooding (inadequate culvert design).
  - Impair survivability of wetland flora (and fauna that depend on wetland flora) via changes in water level.
Construction

(a) Toxification and Eutrophication

- Leakage/spillage of fluids from construction equipment; emission of engine exhausts; disposal of construction spoil.
  - These pollutants, trophic magnification, exert lethal impacts on higher-order consumers in food web in terrestrial or aquatic environments.

- Use of material of organic nature to fill areas located in watersheds can lead to leaching and subsequent increase in downstream concentrations of nutrient for aquatic flora, thereby enhancing eutrophication of downstream impoundments.
IMPACTS AT VARIOUS TDP PHASES

- **Construction**

  (b) Changes to the Physical Base

  - Right-of-way clearing and construction in/near surface water courses, adversely affects animal species.

  - Felling trees in facility right-of-way allows more sunlight to penetrate previously-covered areas; thus
    - Modifies ground micro-climate
    - Alters diversity of flora and fauna species
    - Facilitates growth/demise of certain specie populations, and
    - Ultimately impacts the balance of predator and prey populations.
IMPACTS AT VARIOUS TDP PHASES

Construction

(c) Movement of Soil Masses (Earthworks)

- When soil masses are excavated, moved from one place to another, filled, and compacted, ecosystems are affected by the resulting food web changes and trophic dynamics.

- Movement of soil masses results in changing levels of local water table and therefore influence plant associations that depend on water content of soils.
  - This, in turn, affects the animals that depend on such plants for habitat, or food supply.

- Aquatic environments where earthworks are carried out experience increased water turbidity.

- Soil compaction activities lead to reduced permeability of surficial soils, decreased recharge of groundwater sources, increased surface run-off, and increased erosion.
IMPACTS AT VARIOUS TDP PHASES

- **Transportation Operations**
  - Affect noise level, quality of air and water
  - Causes a reduction in ecological quality
  - Direct impacts include plane and auto collisions with birds and deer.

- **Transportation Facilities Maintenance**
  - *(a) Vegetation Control*
    - Machine mowing – results in soil compaction in the median and right-of-way areas, thus reduce rate of surface water percolation and increase likelihood of localized erosion.
    - Noisy and physically-intrusive mowing - disrupt animal/bird nesting
    - Use of herbicides, paints, and preservatives obliterate certain target plant species and impair animal reproduction.
(b) Pollution through Maintenance Stockpiling and Maintenance Operations

Stockpiling of maintenance materials and supplies cause

- leaching of chemicals through local soils, with ensuing effects on neighboring vegetation and soil organisms,
- wind dispersal of toxic materials and irritants, with potential effects on other terrestrial biota, and
- alteration of physical, chemical, and biological attributes of existing habitat at the stockpile area.

Spillage and leakage of petrochemicals and other volatile compounds used for facility maintenance can affect plants, animals and their habitats.

These could lead to the depletion of species, particularly those of protected, threatened, or endangered status.
Performance Goals for Ecological Impact Assessment

- Diversity of the Ecosystem
- State of Habitat Fragmentation
- Survival of Significant Species
  - Rare Species or Habitats
  - Keystone Species
  - Indicator Species
- Diversity ofSpecies
  - Simpson’s Index
- Ecosystem Stability
- Ecosystem Quality or Productivity
Diversity of the Physical Base of the Ecosystem

- **Abiotic diversity** - the variation in composition and structure of the ecosystem physical base.

- **Regional (or landscape) diversity** - refers to variety of biological communities (distribution, sizes, shapes, etc.) and the relationships between each other as well as their physical base.

- Transportation projects can destroy physical bases, reduce landscape diversity, and impair species survivability.

- Determination of ecosystem diversity at a regional level:
  - A qualitative process
  - Based on field sampling of similar areas of different ecosystems
  - Assessing diversity of each area based on Nr. of different species.
PERFORMANCE GOALS FOR IMPACT ASSESSMENTS

State of Habitat Fragmentation

- Refers to divided state of ecosystem’s physical base by natural barriers or by man-made activities or structures created by highway and railway construction.
  - Example: dense network of roads in a region yields a highly fragmented habitat, while a sparse road network in a similar region yields a lightly fragmented habitat (See Figure)
- Through fragmentation, habitat is rendered into land pieces too small to sustain certain animal species, particularly larger animals.
- New interfaces between ecosystem and man-made developments increases exposure of ecosystem to human activity and weather vagaries (sunlight penetration and wind erosion), restricted movements of animals, and introduction of new (and often, predatory) species.
PERFORMANCE GOALS FOR IMPACT ASSESSMENTS

Significant Species and Habitats

- Specific species or habitats for EIA: selected on basis of rarity, contribution to ecosystem, or inherent ability to provide indication of threats or opportunities in the ecosystem.
  - **Rare** species and habitats contribute to genetic diversity and ecosystem stability.
  - **Keystone** species are those whose removal would likely lead to significant disruptions in the structure and relationships in an ecosystem.
  - **Indicator** species have certain unique characteristics that enable identification of any prevailing unfavorable or favorable environmental elements such as air pollution and nutrient levels, respectively.
Diversity of species

- Ecosystem species diversity can be measured in terms of Simpson’s Index (D):

\[
D = \frac{N(N - 1)}{n_1(n_1 - 1) + n_2(n_2 - 1) + \ldots + n_s(n_s - 1)}
\]

- Where
  
  \( D \) = Simpson’s Diversity Index for the ecosystem,
  
  \( s \) = number of different species in the ecosystem,
  
  \( n_i \) = number of individual organisms in species i,
  
  \( N \) = total number of organisms in all species in the ecosystem
Example 12.1

Consider 3 independent communities with the same number of organisms, N. Numbers of species A, B, C, D and E are estimated. Compute Simpson’s diversity index for each community and comment on results.
Table E12.1

<table>
<thead>
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<th></th>
<th>Community</th>
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<tbody>
<tr>
<td></td>
<td>1</td>
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<tr>
<td>Specie A Population, $n_A$</td>
<td>250</td>
</tr>
<tr>
<td>Specie B Population, $n_B$</td>
<td>250</td>
</tr>
<tr>
<td>Specie C Population, $n_C$</td>
<td>250</td>
</tr>
<tr>
<td>Specie D Population, $n_D$</td>
<td>250</td>
</tr>
<tr>
<td>Specie E Population, $n_E$</td>
<td>0</td>
</tr>
</tbody>
</table>

| Total population of individual organisms, $N$ | 1000 | 1000 | 1000 |
|Simpson’s Diversity Index, $D$ | 4.01 | 5.02 | 1.50 |
\[ D = \frac{N(N - 1)}{n_1(n_1 - 1) + n_2(n_2 - 1) + \ldots + n_s(n_s - 1)} \]

\[ D_1 = \frac{1000(1000 - 1)}{4 \times 250 \times 249} = 4.01 \]

\[ D_2 = \frac{1000(1000 - 1)}{5 \times 200 \times 199} = 5.02 \]

\[ D_3 = \frac{1000(1000 - 1)}{810(809) + 70(69) + 30(29) + 50(49) + 40(39)} = 1.50 \]
Ecosystem Stability

- Defined as its ability to resist disturbance and stress or return to equilibrium after it has been subjected to stress.

- Increased diversity is not necessarily associated with increased stability.

- Transportation actions could also degrade the ability of an ecosystem to recover from subsequent natural or man-made disruptions.
Ecosystem Quality or Productivity

- The productivity of a terrestrial ecosystem can be represented by soil fertility, because a more fertile substrate is more capable of supporting a larger number of plants and therefore, animals.

- Examining soil fertility maps together with maps of soil types and their erodibility.

- For aquatic ecosystems, population density (the number of individuals per unit area or volume), is an indicator of productivity.

- Ecosystem quality indicates the total living matter produced in an area and also gives an indirect indication of the existing pollution levels.
Framework for Assessing the Impacts Ecological Impacts of Transportation Actions

1. Identify the Species of Interest
2. Define the Study Area and Temporal Scope
3. Collect data and Carry out an Inventory of the Ecosystem of the Study Area
4. Describe the Proposed Changes in the Selected Transportation System Action
5. Identify the TDP Phases of the Transportation Action that are likely to affect the Ecology
6. Select the Appropriate Ecological Performance Measures
7. Data Analysis to Predict Ecological Inventory after the Transportation Intervention
8. Estimate the Ecological Impacts (Change in Ecological Performance Measures)
9. Evaluate the Predicted Ecological Impacts (Compare with Established Thresholds)
METHODOLOGY FOR ECOLOGICAL IMPACT ASSESSMENT

Step 1: Identify the Species of Interest
The analyst should identify plants and animal species that are likely to be affected by the transportation action.

Step 2: Define the Study Area and Temporal Scope of Impacts

Step 3: Collect Ecological Data and Carry out an Inventory of the Ecosystem of the Study Area

- **General Data Sources**: Existing publications on ecological conditions at or near the areas of interest. Note: nr. animals and plants in a habitat can change significantly across seasons.

- **Data Types**: Geological and soil survey maps
  - Vegetal cover type on the basis of surficial geology and soils,
  - Can yield estimates of specie populations.
  - Such data can be supplemented by aggregate data from
    - Aerial photographic prints and satellite images.
    - Data at local biological data centers at governmental agencies.
Step 4: Describe the Proposed Changes in the Selected Transportation System Action
- Step influences the mechanism and scope of the ecological impact
- All expected structures, including main, auxiliary, and other structures related to the transportation project should be considered.

Step 5: Identify the TDP Phases of the Transportation Action that are likely to affect the Ecology
- Note that besides construction, other TDP phases can also result in significant ecological impacts. For example, increased speed limits on a highway passing through a woodland area can increase the number of vehicle-animal collisions.

Step 6: Select the Appropriate Ecological Performance Measures
- Table 12-5 presents performance measures that could be used for common types of species.
Estimating the Change in Species Population
An Example

Example 12.2

Deer population in a woodland = 2500
Total birth = 720
Average survival rates
    Existing population = 0.8
    Newborn = 0.68

Due to proposed railroad project
    Recruitment will be reduced by 10%
    Reduction in survival rates
        Existing population by 40%
        Newborn 15%

Estimate the change in deer population due to the railroad project
Solution:

Without the project

Expected deer population in summer =

\[(2500 \times 0.8) + (720 \times 0.68) = 2490\]

With the project.

Deer survival rate = 60% of 0.8 = 0.48
Birth = 90% of 720 = 648
Survival rate of newborn = 85% of 0.68 = 0.578

Expected population in summer.

\[N = (2500 \times 0.48) + (648 \times 0.578) = 1574\]

The railroad project will cause a reduction in the deer population by

\[(2490 – 1574) = 916\] or 37%
### Table 12.3: Data Collection Techniques By Species Type

<table>
<thead>
<tr>
<th>Species</th>
<th>Data Collection Techniques</th>
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| Large Animals                | Small area: Direct inspection and count in the whole area  
Large area: Direct inspection and count in arbitrary plots and project counts over the total area of appropriate habitation  
Open topography: Estimates based on aerial photographic prints by experienced photointerpreters  
Other techniques: Consult local wildlife biologists from federal/state wildlife agencies                                                                                                                                                    |
| Birds of Prey                | Common species: A usable population statistics and information can be retrieved from local wildlife biologists from federal/state wildlife agencies  
Less common species: Estimates and locations of nesting, breeding, and feeding areas can be obtained from biologists affiliated with the Audubon Society, Natural Heritage Program, or other related wildlife protection agencies  
The change in sizes of nesting and feeding areas can be estimated using GIS or planimeter based on before and after superimposition of aerial photographs, mosaics, or topographic maps.                                                                                           |
| Small Game                   | Similar to that discussed for Birds of Prey. Consultation with the U.S. Fish and Wildlife Service is mandatory if the species are threatened or endangered                                                                                                                                                                                                 |
| Water-based Animals          | Fish and Shellfish: Measure water quality parameters such as dissolved oxygen content, pH level and coliform bacteria count  
Waterfowl: Measure change in length of shoreline of suitable habitat and number of individual water bodies using GIS or a mechanical tool (map measurer) based on before and after superimposition of aerial photographs, project plans, or maps. Using this information, a wildlife biologist/specialist can provide an estimate of changes in the quantity of pairs of nesting waterfowl that can be supported by the habitat. |
| Field Crops                  | The number of acreage of field crop land to be acquired can be estimated directly using GIS or a planimeter. These numbers can be also established from local offices of the Farm Services Agency (FSA) of the U.S. Department of Agriculture.  
The size (area) of field crop to be affected by ROW herbicidal spraying can be estimated as a function of type of application system, wind direction, and velocity.                                                                                             |
| Listed Species               | The procedure for counting or estimating the number of listed species is similar to that discussed for large animals, predatory birds, and natural vegetation with assistance from wildlife biologists, zoologists, botanists, and plant physiologists.                                                                                                                        |
| Native Vegetation            | Change in acreage of native vegetation can be can be estimated directly using GIS or a planimeter based on before and after superimposition of aerial photographs or maps of vegetative cover by a skilled photointerpreter.                                                                                                         |
| Aquatic Plants               | The change in acreage of aquatic plants habitat area and the change in total available aquatic habitat can be estimated and derived, respectively, using GIS or a planimeter based on before and after superimposition of large-scale aerial photographs by a skilled photointerpreter. Infrared photography and remote sensing are particularly helpful in such procedures. |
Figure E12.3.1

The graph illustrates the relationship between the Habitat Suitability Index and the Level of Given Characteristic (x). Different experts are represented by distinct symbols: Expert 1 (△), Expert 2 (×), Expert 3 (◊), Expert 4 (○), and Expert 5 (+). The combined (Points) and combined (Model) curves are shown as solid lines.
Impact of a Project in terms of Habitat Units (HU)

1. Immediate Impact

\[ \Delta HU = HU_B - HU_A \]
\[ = (Area_B \times HSI_B) - (Area_A \times HSI_A) \]

B = Before project
A = After project

2. Long term impact

\[ \Delta HU - Years = \int_{t_1}^{t_2} HU_B(t)dt - \int_{t_1}^{t_2} HU_A(t)dt \]
A project will decrease the area of a wetland from 3 acres to 2.31 acres. Availability of clean water will decrease from 90% to 65%.

Determine the reduction in habitat suitability index assuming water availability is the predominant ecological characteristic. Calculate the overall short term impact on habitat units.
Solution 12.4

\[ HSI = 1 - e^{-0.00028X^2} \]

Where \( X = \) Percentage Level of a Characteristic

**Before the Project**

Area \( B = 3 \) Acres  
\( X_B = 90\% \)

\[ HSI_B = 1 - e^{-0.00028*90^2} = 0.95 \]  
\[ HU_B = 3 \times 0.95 = 2.85 \]

**After the Project**

Area \( A = 2.31 \) Acres  
\( X_A = 65\% \)

\[ HSI_A = 1 - e^{-0.00028*65^2} = 0.74 \]  
\[ HU_A = 2.31 \times 0.74 = 1.710 \]

\[ \Delta HU = \frac{(2.85 - 1.71)}{2.85} = 40\% \]  
**Reduction**

Therefore, Immediate Ecological Damage = \(43\)
Example 12.5

Given historical and projected data on HIS and wetland area

Determine the long term ecological damage expected due to a proposed railroad project.
Table E12.5

Data on Habitat Suitability Index and Wetland Area

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<tr>
<td>HSI</td>
<td>0.85</td>
<td>0.84</td>
<td>0.82</td>
<td>0.81</td>
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<td>0.79</td>
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<tr>
<td>Area (acres)</td>
<td>15</td>
<td>15</td>
<td>14.9</td>
<td>14.9</td>
<td>14.8</td>
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<td>14.8</td>
<td>11.2</td>
<td>11.2</td>
<td>11.2</td>
<td>11.2</td>
<td>11.1</td>
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Figure E12.5
Change in Ecological Quality Trend due to Transportation Action

![Graph showing the change in ecological quality trend due to transportation action. The graph includes two equations:

- \( HU = -0.1866t + 12.704 \) with \( R^2 = 0.97 \)
- \( HU = -0.0334t^2 + 0.5341t + 4.159 \) with \( R^2 = 0.99 \)

The graph plots habitat units (HU) against years (t), with 0 representing Year 1999.]
Solution:

Long Term Ecological Damage

\[ \Delta HU - Years = \int_{7}^{13} (-0.1866t + 12.704)dt - \int_{7}^{13} (-0.334t^2 + 0.534t + 4.159)dt \]

\[ \Delta HU - Years = \left[ \frac{-0.1866t^2}{2} + 12.704t \right]_{7}^{13} - \left[ \frac{-0.334t^3}{3} + \frac{0.534t^2}{2} + 4.159t \right]_{7}^{13} \]

\[ \Delta HU - Years = 65.028 - 36.359 = 28.669 \ HU - Years \]
KEY LEGISLATION

The Endangered Species Act of 1973

- Passed 1973 to protect and recover endangered and threatened species of fish, wildlife, and plants.
- “Endangered species” - “species which is in danger of extinction throughout all or a significant portion of its range”
- “Threatened species” - “species which are likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range”
- List of ES and TS periodically updated in Federal Register and website of U.S. Fish & Wildlife Service.
- Requires consultation with agency responsible for endangered species.
- Requires federal agency or its contractor to prepare biological assessment report to identify affected listed species.

Laws Related to Wetlands and other Habitats

- Rivers & Harbors Appropriation Act, Migratory Bird Treaty Act, Migratory Bird Conservation Act, Fish and Wildlife Coordination Act
- Table 12-6: History of Federal Legislation on Ecology and Wetlands
Mitigation at Various Phases of the Transportation Development Process

(a) System Planning Phase:

Subject to resource and other constraints, attempts should be made to select transportation modes, alignments and facility plans whose construction and operations would directly or indirectly cause the least adverse ecological effects. Ecological preservation and sustainability should be advocated, encouraged, and pursued.

(b) Locational Planning Phase

- In locating an alignment within a corridor, planners should give due consideration to the existing locations of wetlands, woodlands, bushlands, grasslands, and forests, as well as the population and diversity of plants and animals supported by such habitats.
- Habitats to be avoided during corridor and alignment location are those containing regionally unique abiotic and/or biotic components.
Mitigation at Various Phases of the Transportation Development Process

(c) Design Phase

- Facility elements can be designed in a manner that helps palliate the ecological impacts. The design of structures can include features that provide erosion control (such as slope surface protection at embankments, rip-rap lining of bridge/culvert inlets, etc.).

- Furthermore, habitat re-engineering techniques can be employed and typically include habitat restoration or preservation such as land banking, habitat purchasing, tree and native grass planting, and stream undertaking.
Mitigation at Various Phases of the Transportation Development Process

d) **Construction Phase**
- Construction supervision to ensure compliance with requirements geared towards ecosystem preservation.

e) **Maintenance Phase**
- Impact mitigation at this phase influenced by ecological considerations at TDP design phase.
- Hydraulic, erosion control and ecological structures to be inspected/maintained regularly.
- Vegetated areas within/near the transportation facility should be maintained to minimize harm to flora/fauna and habitat.
- Ecological monitoring – carry out as part of normal agency routine maintenance (inspect receiving wetlands, stream beds, etc. for signs of diminished ecological quality.)
METHODS AND SOFTWARE PACKAGES FOR ECOLOGICAL IMPACT ASSESSMENT

- **Wetland Functional Analysis (WET II)**
  - Developed for FHWA by US Army Corps of Engineers
  - Addresses functional features of wetland ecosystems such as wildlife habitat and quantity/quality attributes of the wetlands.
  - Predict wetland performance before/after transportation intervention.

- **Hydrogeomorphic Classification Method (HGM)**
  - Reference-based wetland functional assessment technique
  - Compares attributes of a wetlands proximal to transportation project with those of a reference system
    - Thus estimates the relative impacts in terms of wetland performance.

- **Habitat Evaluation Procedures (HEP) Software**
  - Given area of available habitat and Habitat Suitability Index (HSI) for various types of species, assesses
    - Impacts of alternative transportation projects or policies
    - Effectiveness mitigation efforts.

- **Others:** Table 12-7: Methods and Software used in Ecological Impact Assessment
Conclusions (1)

- Ecosystems classification basis: biotope type, dominant specie or physical feature

- Special status of **wetlands** - vital ecological functions of remediation, hazard management, and ecological preservation.

- Transportation projects/policies disrupt physical & functional relationships between biotic elements and abiotic environments.

- Transportation disturbances to ecosystems may be direct or indirect, through mechanisms such as
  - Physical base degradation
  - Direct depletion of biotic elements => food chain disruptions and energy cycle impairment
  - Adverse ecological succession, loss of productivity, or ecological destabilization.
Conclusions (2)

- Ecological impacts may be categorized by the stage of the transportation development process at which they occur.

- Framework presented for ecological impact assessment
  - Definition of the analysis area and temporal scope, and affected species,
  - Description of the transportation intervention and relevant TDP phases
  - Data collection, data analysis to determine the ecological impact levels (population dynamics, gap analysis, habitat-based evaluation)
  - Evaluation of the impact levels vis-à-vis established standards.

- Mitigation
  - Avoidance and minimization
  - Rectification
  - Preservation, and
  - Compensation

- Computer software packages for EIA or for evaluating the efficacy of mitigation activities: WET-II, HGM, HEC, HIS, etc.