

ANALYSIS OF REMOTELY SENSED DATA FOR PLANNING TRANSPORTATION NETWORKS

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ABSTRACT

Analysis of remotely-sensed and hyperspectral data has significant potential application in the areas of planning of, and better decision support for, transportation networks. With increased demand for better transportation facilities and rapid urbanization, there has been large-scale modification of land cover systems. This rapid and often haphazard growth couples with increasing pressure by expanding population needs, resulting in deterioration of infrastructure facilities, loss of productive agricultural lands and green open spaces, loss of surface water bodies and depletion of ground water aquifers zones. Rapid growth and land development also contributes to air pollution, contamination of water, human health hazards and micro-climatic changes. For these reasons, a holistic assessment for change detection in land use and land cover of growing cities has become particularly important in understanding change and its impact on natural resources and human residents of the surrounding areas. With this knowledge, suggesting measures to alleviate the problems can be facilitated.

An environmental assessment will be conducted to study the impacts of relocating segments of the CSX railroad out of significant population growth areas along the environmentally sensitive Mississippi Gulf Coast. The environmental assessment project will be jointly managed by the Mississippi DOT and FHWA and is intended to make broad use of remote sensing and geospatial technologies. The project has been awarded to a consulting team and will be supported by the technical and research resources of the National Consortium on Remote Sensing in Transportation (www.ncrst.org).

Using the CSX railroad relocation as a test case, an analysis framework is proposed for using remote sensing and geospatial information to support environment assessment and planning tasks for a transportation network. Using remote sensing and spatial technologies to plan for and assess the impacts of a transportation network requires a phased approach in which different remote sensing and geospatial information types are acquired and used at different phases for different purposes. From general tasks such as developing base map materials, screening alternatives, assessing alternatives, and analyzing constraints to very specific, detailed tasks such as wetland mapping and optimizing the proposed alignment both horizontally and vertically to minimize impacts and costs, remote sensing and geospatial information can be used to assist in environmental assessment, planning, and preliminary design.

INTRODUCTION

Remotely sensed images provide a global information resource. Compared to traditional methods of data collection in transportation systems, remote sensing provides a greater quantity of data and can be collected more frequently. Remote sensing data are becoming increasingly available to transportation organizations and to decision makers who must plan current projects and for future growth and development of the region. Gaining maximum

benefit from these data resources will require research involving new data analysis approaches and the development of tools for the manipulation of these data sets.

Background

At present, the coastal counties of Jackson, Hancock, and Harrison in Mississippi (fig.1), are being assessed for relocating segments of the existing CSX railroad out of populated areas. Over the past 30 years, considerable changes in land use, population, wildlife habitation, demographics, and socio-economic conditions have occurred. In this time frame Interstate 10 (I-10) was completed, and the coastal communities have evolved from small fishing communities (with a total population of around 240,000 in 1970) to a complex mixture of residential, commercial, industrial, and resort areas. The result was a dramatic increase in urbanization and a population growth of around 50 percent (http://www.ncrste.msstate.edu/publications/ncrste_tn003.pdf).

Due to increased development in the area of interest, problems arise with regard to safety, the environment, and railroad-community conflicts. Major problems caused by the existing CSX railroad include train noise, horn-sounding, vibration in residential areas, risk of hazardous materials releases, highway grade-crossing delays, increased accident risks, and storm water flooding due to rail right-of-way location. The railroad right-of-way and multiple grade crossings in densely populated tourist areas slow traffic movements, increase highway congestion, and slow emergency evacuations during hurricanes and floods; hence there are preliminary plans to relocate the existing CSX railroad out of populated areas along the Mississippi Gulf Coast (O'Hara and others, 2002).

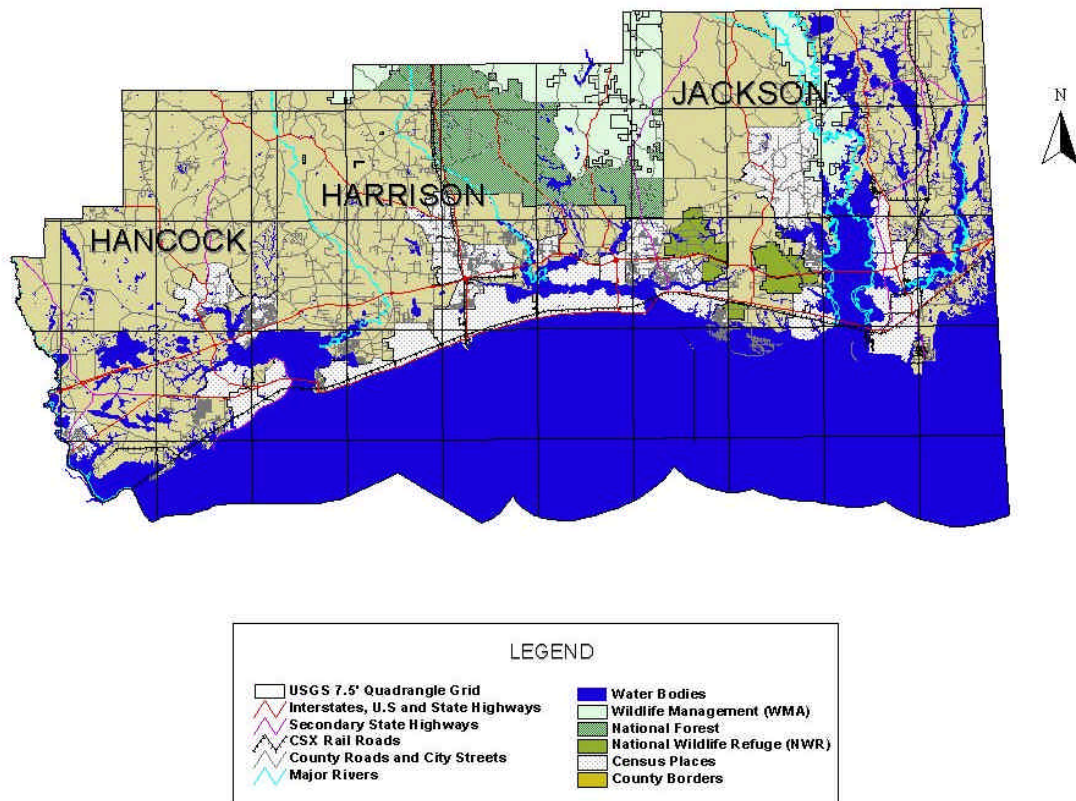


Figure 1. Mississippi coastal counties, cities, transportation features, and selected environmental features.

PURPOSE AND SCOPE

A framework is presented for a phased approach to the acquisition and use of remote sensing and spatial information to support an environmental impact study for a multimodal transportation project. Traditional methods of planning and conducting environmental assessment of the impacts of planned transportation projects involve time consuming and expensive ground surveys, which can take years to complete in order to arrive at an acceptable alignment. By examining the same problem with the help of GIS and remote sensed data it is hoped that specific assessment tasks can be identified wherein the use of spatial data, tools, and technologies reduce costs, decrease time, and provide better solutions. The proposed CSX railroad relocation and environmental assessment study to be conducted for areas along the Mississippi Gulf Coast will be used as a test case study to fully develop the framework concepts.

ENV-160 Rev. 10/2001		MISSISSIPPI DEPARTMENT OF TRANSPORTATION ENVIRONMENTAL DIVISION ENVIRONMENTAL CLASS OF ACTION DETERMINATION		
DISTRICT NO: _____ F.A. NO: _____ PROJECT NO: _____ HIGHWAY NO: _____ SECTION NO: _____ COUNTY: _____		7. APPROVED BY:		
1. PROJECT TERMINI:		DISTRICT ENGINEER _____ DATE _____		
(A.) EXISTING CONDITIONS:		ROADWAY DESIGN DIV. ENGINEER _____ DATE _____		
(B.) PROPOSED IMPROVEMENTS:		ENVIRONMENTAL DIV. ENGINEER _____ DATE _____		
(C.) NEW ROW REQUIRED: <input type="checkbox"/> YES <input type="checkbox"/> NO		8. FHWA CONCURRENCE:		
2. ENVIRONMENTAL CONSEQUENCES EVALUATION (CHECK ONE)		SIGN.	MIN.	NONE
A. LAND USE IMPACTS				
B. FARMLAND IMPACTS				
C. SOCIAL IMPACTS				
D. RELOCATION IMPACTS				
E. ECONOMIC IMPACTS				
F. JOINT DEVELOPMENT				
G. CONSIDERATIONS RELATING TO PEDESTRAINS & BICYCLISTS				
H. AIR QUALITY IMPACTS				
I. NOISE IMPACTS				
J. WATER QUALITY IMPACTS				
K. PERMITS				
L. WETLAND IMPACTS				
M. WATER BODY MODIFICATION & WILDLIFE IMPACTS				
N. FLOODPLAIN IMPACTS				
O. WILD & SCENIC RIVERS				
P. COASTAL BARRIERS				
Q. COASTAL ZONE IMPACTS				
R. THREATENED OR ENDANGERED SPECIES				
S. HISTORIC & ARCHAEOLOGICAL PRESERVATION / 4(f) LANDS				
T. HAZARDOUS WASTE SITES				
U. VISUAL IMPACTS				
V. ENERGY				
W. CONSTRUCTION IMPACTS				
X. ENVIRONMENTAL JUSTICE IMPACTS				
3. PUBLIC INVOLVEMENT RECOMMENDATIONS:				
4. ACTIONS REQUIRED:				
CATEGORICAL EXCLUSION <input type="checkbox"/>		106 CONSULTATION <input type="checkbox"/>		ENDANGERED SPECIES ASSESSMENT <input type="checkbox"/>
EA/FONSI <input type="checkbox"/>		EIS <input type="checkbox"/>		NOISE STUDY <input type="checkbox"/>
		SHPO LETTER <input type="checkbox"/>		4(f) STATEMENT <input type="checkbox"/>
CLASS DETERMINATION:				
5. WETLANDS FINDING (CE ONLY):				
6. OTHER REMARKS:				

Figure 2. Mississippi DOT form showing environmental assessment tasks required for transportation projects.

Ideally, for environmental assessment studies, project planners, environmental analysts, engineers, and decision makers desire high quality photography, topography, and other base map information to be available from the first day of the project. Although much of the data are available in an appropriate 1:24,000 scale for conducting preliminary planning and assessment work, determining the availability of high quality base map materials for all geographic areas to be considered for the project is the first requirement of such a framework system. Typically, 1:24,000 scale standard data sets are available nationwide in GIS format for such data as quadrangle (topography) maps from Digital Raster Graphics (DRGs), elevation data from USGS Digital Elevation Models (DEMs), and ortho-imagery from Digital Orthophoto Quarter Quads (DOQQs). Other 1:24,000 scale data that are needed to conduct preliminary analyses may not be available in digital format, but typically are available as paper maps for which stable base materials can likely be acquired. For initial tasks related to developing base map materials, screening alternatives, assessing alternatives, and analyzing constraints, spatial data readily available in GIS format must be inventoried, a list of needed data must be compiled, and the needed data that are not available in digital GIS formats must be digitized from stable base materials, attributed with the necessary information, checked for accuracy, and documented through the compilation of metadata.

The initial phase of the framework approach is intended to reduce the geographic areas considered for the project by spatially identifying several (two to three) potential corridors approximately one mile in width (of other sizes depending on the requirements of the project) that pass initial screening tests of environmental factors, alternatives assessment, and constraints analysis. The second phase of the framework approach is intended to select the most feasible or the preferred corridor and consider alignments in that corridor that minimize impacts and costs while maximizing benefits of the planned transportation service. To conduct the second phase of the framework approach, additional high accuracy image and elevation data must be collected to facilitate refined screening and analysis of the areas in consideration.

Scoping of Likely Corridors and General Task Phases

In approaching the first phase of the framework approach, several general routing options are hypothesized as being the most likely for broad consideration in developing corridor alternatives:

- Selection of a general route that relocates the CSX railroad corridor to areas away from populated coastal areas and near to the existing I-10 corridor across the Mississippi Gulf Coast.
- Selection of a route that relocates the CSX railroad corridor to areas away from populated coastal areas and north of Lake Pontchartrain, traversing the northern portions of the three coastal counties; Hancock, Harrison, and Jackson.
- Selection of a general route that relocates the CSX railroad corridor areas away from populated coastal areas and following a more northerly route potentially traversing parts of Pearl River, Stone and/or George counties.

It is likely that the selection of any of these general routes relocating the CSX away from population areas would help resolve many or all of the rail-community conflicts and improve freight rail service and operations in the region. However, significant parts of the Gulf Coast are within National Forest, state parks, wildlife management and refuge areas, conservation areas, and wildlife sanctuaries. These sensitive environmental conditions coupled with a high rate of population growth and land development provide a challenge in developing the region in a manner that is both sustainable and preserves the natural environment. This makes screening environmentally sensitive and population growth areas a task that is particularly challenging for the study.

In the proposed phased approach, initial analyses entail screening of environmental factors, alternatives assessment, and constraints analysis. These initial activities will benefit from using high resolution multispectral satellite data for detecting sensitive environmental areas and other geospatial data layers to screen for features such as national forest, state parks, wildlife management areas, national wetlands inventory areas, flood zones, conservation and refuge areas, and other mapped areas with environmentally sensitive characteristics in order to narrow the choices down to two or three prospective corridors for consideration. In the second phase, additional data with high accuracy such as high spatial and spectral resolution hyperspectral image data and high resolution LIDAR data will be acquired and processed so that it may be analyzed to help determine the preferred corridor, to identify the most suitable paths/segments, and to optimize alignments within the preferred corridor to minimize environmental impacts and construction costs.

PHASED APPROACH TO USING REMOTE SENSING AND GEOSPATIAL TECHNOLOGIES FOR TRANSPORTATION PLANNING

Phased Approach Characteristics

The proposed framework for a phased approach to the acquisition and use of remote sensing and spatial information to support an environmental impact study is based on getting the right data to the people who need it at the right time. Having necessary data at the right scale, resolution, and accuracy when it is needed is necessary to minimize delays, to reduce costs, and to facilitate important decision-making processes in transportation planning and related environmental assessment studies. However, the cost of remote sensing data acquisition and processing, the time required conducting complex feature detection and extraction, the significant storage needed for high resolution data, and many other factors add significant cost and time consuming activities to project efforts. The framework for a phased approach must consider that [for remote sensing and geospatial technologies as well as for traditional methods] costs increase for acquisition, processing, analysis, storage, use, documentation, distribution, and archival as data are acquired at higher spatial and spectral resolution and at higher accuracy. Simply stated, it is not realistic, practical, cost-effective, or desirable to have, from the project onset, all of the data that might be needed for a project for all geographic areas the project might be located. Therefore, a characteristic of the proposed framework for a phased approach is that the acquisition of high resolution, high accuracy data should be carefully planned and collection should be restricted to those areas determined to comply with initial screening requirements. Furthermore, the acquisition of these data should be carefully scheduled (seasonally) to maximize the benefits provided by the data acquired. The seasonally changing landscape characteristics should be considered with respect to the limitations of remote sensing technology and the complexities of extracting useful information from data that have spatial as well as temporal characteristics.

The Mississippi Gulf Coast is a collection of sensitive environments in a state of rapid change. The coastal landscape comprises a complex mixture of environments including estuaries, marshes, and pine savannahs, meander belts traversing wooded river bottomlands, sandy beaches, terraced uplands, and deltaic river outlets. In such a landscape, using remote sensing and spatial technologies to plan transportation features and to assist in assessing environmental impacts requires careful consideration of the seasonal changes in complex land cover, influence of salt water marshes and tidal fluctuations on wetness of the landscape, and of characteristic land cover and ecosystem features that the planning and assessment task must consider. Whether acquiring spectral data for assessing land cover or acquiring elevation data to assess the topography, careful consideration to temporal changes and planning data acquisition accordingly should be a primary component of the framework so as to assure that desired information products can be successfully generated from remote sensing data.

The proposed framework for a phased approach to the acquisition and use of remote sensing and spatial information to support an environmental impact study; therefore, has the following characteristics:

- The framework for a phased approach is intended to provide the right data, (at the right scale, resolution, and accuracy) to the right people, at the right time.
- The initial phase is intended to use spatial analysis to reduce the geographic areas considered for the project.
- During the initial phase, spatial data readily available at appropriate scale must be inventoried, a list of needed data must be compiled, and the needed data that are not available in digital GIS formats must be digitized from stable base materials, attributed, checked, and documented.
- The second phase of the framework approach is intended to conduct additional and/or refined analysis to select the most feasible corridor.
- To conduct the second phase of the framework approach, additional high accuracy image and elevation data must be collected to facilitate refined screening and analysis of the areas in consideration.
- The acquisition of highly accurate remote sensing and spatial data should be carefully planned and the geographic extent of data collections should be restricted to those areas determined to comply with initial screening requirements.
- The acquisition of highly accurate remote sensing and spatial data should be carefully scheduled (seasonally) to maximize the benefits provided by the data acquired.
- Processing and analyzing remote sensing and spatial data and extracting needed information should be conducted carefully, with each step validated and documented.

PHASE ONE REQUIREMENTS

For the CSX railroad relocation study, the first phase will require the compilation of standard data at an appropriate scale for screening, assessing alternative, and analyzing constraints to arrive at a preliminary collection of potential corridors.

Table 1. List of data layers required for phase one.

Required Digital Geo-Spatial Data	Source of GIS Data
Multi spectral and Hyperspectral Imagery	USGS, NASA, Spot Imaging with other image distribution companies, products available AVHRR, ASTER, Spot 4 imagery, Ikonos, and IRS-1C, and Quickbird data
Synthetic Aperture Radar (SAR) Imagery	InterMap Global Terrain (GT2) Data and NASA data sources
Orthophotography	USGS, Local government and private orthophotography distribution companies
Land Use Land Cover	USGS, NRCS, MARIS, planning districts, and local units of government
Topography	USGS, MARIS, the COE, and local units of government
Transportation	USGS DLG files, MDOT, local units of government
Hydrology	USGS, MARIS and MDEQ
Floodplain data	Federal Emergency Management Agency (FEMA)
Property Ownership	Tax assessors of the counties within the study area/may require partial or complete digital compilation
Political Boundaries and Demographics	USGS DLG files and U.S. Census Bureau TIGER/Lines files
Soils	NRCS, USDA, MARIS and MDEQ (Requires Digital Compilation)
Wetlands	National Wetland Inventory Maps (NWI), and NRCS
Archeological and Historic Resources	Requires Digital Compilation
Farmlands and Forests	US Forest Services, USDA, and NRCS
Scenic Streams	Requires Digital Compilation
Threatened and Endangered Species	Requires Digital Compilation
Unique and Environmentally Sensitive Areas	Requires Digital Compilation
Coastal Zone Impact	Requires Digital Compilation

The preliminary tasks in the first phase include developing a list of required data, inventorying available data that are on the list, and determining which data sets must be digitally compiled from non-digital sources. The compilation of data from non-digital sources can be time consuming and tedious, but is necessary for the screening of mapped features. Accurately compiling and documenting the needed data must be completed prior to screening, alternatives assessment, and analysis of constraints.

Phase One Analyses

The first task in phase one is the creation of a base map using digital ortho-imagery, topographic data, and other data layers as needed or desired. A geodatabase should be compiled of all data layers needed for phase one. All database components should be transformed to the same coordinate system to assure that accurate overlay analyses may be performed. When all data sets have been compiled and transformed, screening analysis, alternative assessment, and analysis of constraints can be conducted. Depending on the area of the study, the requirements of natural resource agencies, the sensitivity of environmental systems in the area, and the flexibility permitted for developing the project design, an assessment matrix can be developed for the screening, alternatives assessment, and constraints analysis tasks.

Table 2. An example assessment matrix for environmental screening, alternative assessment, and constraints analysis.

Spatial Layer	Feature Items	Priority	Criteria Limits
Land Use	Wildlife refuge	Critical	Project should not pass through wildlife refuge
Topography	Slope	Important	Acceptable only if slope is less than 10%
Soil	Soil type	Desired	Not expansive clay type, preferred class B
Population data	Population density	Important	Density less than XX people/square mile
Wetlands	Wetlands	Important	Wetland/buffer zone impact < 50 Acres
Hydrology	Streams	Desired	Limited modification of stream beds and riparian habitats
Transportation	Aviation features	Desired	Cannot pass through aviation facilities
Archeological and historic resources	Cultural resources	Critical	Cannot pass through
Flood plain	Floodway	Important	Project should not be build in flood plains
Threatened and endangered species	Endangered species	Critical	Should not fall within < N mile radius (depends on species)

The spatial data layers included in the assessment matrix are ranked based on feature items, assessed priority, and established criteria limits. Overlay analyses are conducted to determine those areas that best fit the matrix criteria. In some cases, trade-offs are included in analysis scenarios that involve modification of feature items and criteria limits. Trade-offs can be designed to account for complex issues that are not adequately captured by the digital geospatial data. Finally, a group of spatial layers, feature items, priorities, and criteria limits are selected and a matrix or matrices are adopted and used to evaluate the area to quantitatively determine the best locations for placing the transportation corridor. The quantitative results are reviewed and refined to result in the selection of several corridors that are possible, best meet the criteria of the assessment matrix or matrices, and fall within those areas hypothesized for general routing requirements for the proposed corridor.

Arriving at a list of several corridors to be considered for the selection of a preferred corridor is often a process that involves quantitative analyses, qualitative input by decision makers and citizen groups, and making trade-offs arrived at through discussions and consensus building with stakeholders.

Phase One Results and Recommendations

Phase one is complete when the screening activities, alternatives assessment, and constraints analyses have produced results that have been refined, quantitatively ranked, and qualitatively accepted (including possible modifications). The resulting two to three corridors (of approximately one mile width and 100-mile length in general

east-west direction) to be considered for the CSX railroad relocation would be recommended by the assessment team for further refinement and analysis using data of higher accuracy and higher spatial and spectral resolution.

PHASE TWO REQUIREMENTS

The geographic extent of the corridors recommended in phase one should be used to plan the acquisition of additional data of higher accuracy and resolution for the second phase of the study. These data would typically be acquired in a scale and resolution appropriate for design and preliminary engineering studies and would likely include the following data types:

- 1" = 200' scale digital ortho-imagery for producing engineering quality maps.
- One-meter resolution hyperspectral image data for accurate classification of vegetation types.
- LIDAR data for producing two-foot accuracy DEMs and two-foot contour maps.

The high resolution digital ortho-imagery will be used to refine the base map of the area for the production of high quality corridor maps. The corridor map products are used to refine the outline of the corridors and to visually inspect the area for the occurrence of features or environmental conditions that require attention. The accuracy of the ortho-imagery should be verified and documented. A set of highly accurate geo-control points should be established for each of the corridors so that horizontal and vertical accuracies of data and information products may be determined.

The hyperspectral image (HSI) data will be used to generate a high resolution land cover data product. There are two different approaches to the analysis of hyperspectral imagery, the spectral unmixing approach and the statistical classification approach. Spectral unmixing is based on models, which predict the spectral signature of a pixel given a certain mix of components. The statistical approach involves using pattern recognition theory to classify each image pixel into a set of predefined classes (Landgrebe 1999). Regardless of how the HSI data are processed and classified, the accuracy of the image data and the classification data product should be assessed and documented.

LIDAR data will be processed to provide a bare earth DEM which will be used for topographic and hydrologic analysis. The LIDAR-based DEM will typically be supplemented with break line information to improve the usefulness of the data for evaluating the hydrology of the area as well as for topography analysis and generation of contours for the area.

Phase Two Analyses

The selection of the most suitable corridor will involve refined geospatial overlay and screening analysis of environmental factors and impacts including the following:

- Social/Economic Impacts (land use and neighborhoods, noise, visual effects, energy, farmlands, parks and recreational facilities),
- Ecological Impacts (wetlands, water quality, wild and scenic rivers, floodplain & drainage, air quality, hazardous materials/waste, wildlife, threatened and endangered species),
- Historical and Cultural Impacts (archaeology and paleontology), and
- Other unanticipated issues identified during the process.

The assessment matrix developed for phase one will likely be refined and modified for use in phase two of the study. The combination of data collected in phases one and two will be used to support final decisions about the most suitable corridor and to identify and suggest alignment optimizations for the selected corridor. The phased assessment will provide many sources or data which can be used to perform any number of analyses. In many cases, concerns of natural resource agencies about specific environmental conditions will require that specific assessments be rigorously conducted and documented. The application of the acquired remote sensing and spatial data in decision support analysis may include (but is not limited to) the following example areas:

- Wetlands Analysis, Assessment, and Mapping – Geospatial data and analysis technologies are used to assess vegetation cover, hydrologic conditions, and soil conditions arriving at estimations for areas likely to meet wetlands criteria as well as areas that are ideal for wetlands mitigation. When combined with potential alignment optimization applications, wetlands assessment applications can be used to design transportation corridors that minimize impacts on wetlands areas and identify ideal mitigation strategies to assure environmental sustainability (O’Hara, 2002).
- Habitat Analysis, Assessment, and Mapping – Geospatial data and analysis technologies are used to quantitatively assess habitat areas, connectivity, and fragmentation. When combined with potential alignment optimization applications, habitat assessment applications can be used to minimize impacts of transportation on environmentally sensitive areas.
- Alignment Optimization – Geospatial data and analysis technologies are integrated in an application that considers construction information and geospatial data to determine best option alignments which meet constraints, consider environmentally sensitive areas, and consider construction criteria.

Phase 2 Results and Recommendations

Using data collected during both phases, a refined assessment matrix and spatial overlay analysis model would be developed and provided for the selection of the most feasible alternative among the proposed corridors. The use of remote sensing data, tools, and technologies would be supplemented by on-the-ground surveying and field assessment work where needed to conduct corroborating field assessments and to validate the accuracy of spatial analysis results.

Phase two of the assessment is complete when

- All data sets have been acquired, processed and documented;
- Spatial data products have been developed, validated, and assessed for accuracy;
- Assessment matrices and overlay analyses models have been developed and agreed upon;
- Model refinement and analyses result in the identification of the most suitable alternative corridor; and
- Remote sensing and geospatial data products are further used to identify and optimize alignments in the selected corridor that minimize impacts and costs while providing maximum benefits of the planned service.

SUMMARY AND CONCLUSIONS

A framework for a phased approach to the acquisition and use of remote sensing and spatial information to support an environmental impact study is proposed and detailed. The approach involves two phases, the first of which reduces the geographic scope to a manageable few corridors for which screening criteria, assessment of alternatives, and analysis of constraints are met and for which the collection of high accuracy data can be carefully planned, scheduled, and accomplished. Given the acquisition of high accuracy data, refined screening may be conducted and data may be used in decision support analyses to select the best corridor and to identify and optimize ideal alignments within the most suitable corridor.

The proposed framework for a phased approach to the acquisition and use of remote sensing and spatial information in transportation projects has been prepared in **coordination with plans by the NCRST to support the CSX railroad relocation environmental assessment study**. This study will be a landmark in scope as the first to broadly use remote sensing data and geospatial technologies for conducting key environmental assessment tasks for a multimodal transportation project that covers a broad geographic area. The effort will result in an improved understanding of how remote sensing data and geospatial technologies may be used in environmental assessment studies to conduct specific assessment tasks that result in better answers (or answers equivalent to those provided by standard methods) at reduced costs in less time than using traditional methods. The current work will provide a wealth of information about how geospatial and remote sensing data can help streamline environmental assessment processes and help to improve the transportation services that are delivered to the general public.

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