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Environmental Impact Assessment of Transportation Projects: An Analysis Using an Integrated GIS, Remote Sensing, and Spatial Modeling Approach

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ENVIRONMENTAL IMPACT ASSESSMENT OF TRANSPORTATION PROJECTS: AN ANALYSIS USING AN INTEGRATED GIS, REMOTE SENSING, AND SPATIAL MODELING APPROACH

By

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Transportation projects will have impact on the environment. The general environmental pollution and damage caused by roads is closely associated with the level of economic activity. Although Environmental Impact Assessments (EIAs) are dependent on geo-spatial information in order to make an assessment, there are no rules per se how to conduct an environmental assessment. Also, the particular objective of each assessment is dictated case-by-case, based on what information and analyses are required. The conventional way of Environmental Impact Assessment (EIA) study is a time consuming process because it has large number of dependent and independent variables which have to be taken into account, which also have different consequences.

With the emergence of satellite remote sensing technology and Geographic Information Systems (GIS), this research presents a new framework for the analysis phase of the Environmental Impact Assessment (EIA) for transportation projects based on the integration between remote sensing technology, geographic information systems, and spatial modeling. By integrating the merits of the map overlay method and the matrix method, the framework analyzes comprehensively the environmental vulnerability around the road and its impact on the environment. This framework is expected to:1) improve the quality of the decision making process, 2) be applied both to urban and inter-urban projects, regardless of transport mode, and 3) present the data and make the appropriate analysis to support the decision of the decision-makers and allow them to present these data to the public hearings in a simple manner.

Case studies, transportation projects in the State of Florida, were analyzed to illustrate the use of the decision support framework and demonstrate its capabilities.

This cohesive and integrated system will facilitate rational decisions through cost-effective coordination of environmental information and data management that can be tailored to specific projects. The framework would facilitate collecting, organizing, analyzing, archiving, and coordinating the information and data necessary to support technical and policy transportation decisions.

CHAPTER 1 INTRODUCTION

The first chapter begins with a general background emphasizing the environmental effect of transportation projects and the importance of the environmental impact assessment. Current problems are stated and reviewed. The research objectives are discussed and the research methodology is explained. Finally the scope and organization of the dissertation is described.

1.1. Introduction

Developments in the transportation industry have had a considerable impact on the natural environment. Transportation is the main source of greenhouse gas emissions in the United States, and mobile sources are among the largest contributors to local air pollutants in urban areas throughout the world. Roads and parking create impervious surfaces that increase water runoff and produce urban heat island effects. (DeCicco and Mark, 1998; Greene, D.L., 1996)

Transportation facilities also can cause habitat fragmentation, generate noise and vibration, and impact wetlands and other natural ecosystems—as well as affect historic resources, community cohesion, and other social and community characteristics. Because of the wide range of potential impacts to the natural and human environment, the U.S. National Environmental Protection Act (NEPA), the Clean Air Act (CAA) and amendments, and other legislation require environmental analysis of impacts in order to implement transportation projects (Carson, 1992).

Given this situation, implementation of transportation projects is confronted with a range of challenges in controlling the undesired effects on the environment. Environmental Impact Analysis (EIA) has been developed as a tool to address environmental issues in decision making. Over the past few decades EIA systems have been adopted world wide, and the EIA process has evolved to meet concerns about applying the decision making process to strategic environmental assessment (Kreske, 1996).

Environmental Impact Assessment (EIA) is defined by Glasson et al. (1999) as a systematic process that examines, in advance, the environmental consequences of a proposed development action). In EIA, the environment is viewed as a system comprising human beings, fauna and flora, soil, water, air, the climate, and the landscape; and EIA is also concerned with the interactions among these components. EIA provides a unique opportunity to predict ways in which the environment may be improved as part of the development process. EIA also predicts the conflicts and constraints between a proposed project or program and its environment. It indicates whether mitigation measures need to be incorporated to minimize problems. It also enables monitoring programs to be established to assess future impacts and provide data on which managers take informed decisions to avoid environmental damage (Hensher and Button, 2003.)

1.2. Statement of the Problem

Any transportation project may have some impact on the environment. The general environmental pollution and damage caused by roads is closely associated with the level of economic activity. An increase in National Gross Product (NGP) is likely to lead to an increase in the environmental cost of transport. In actuality, environmental problems are likely to be ignored unless they are addressed in connection with specific projects. If there is to be any significant environmental impact, it is recommended that specialist advice from environmentalists and conservationists should be sought (United Nations, 1990). Some headway has to be made to consider at the very least the most severe environmental impacts arising from a proposed scheme in qualitative terms, if not quantitatively, by adapting suitable conservation strategies. Although EIA is dependant on geo-spatial information in order to make an assessment, there are no rules per se as how to conduct an environmental assessment. Currently, the particular objective of each assessment is dictated case-by-case based on what information and analysis are required (Booz et al, 2003). The Federal Highway Administration (FHWA), which is responsible for all aspects of the environment pertaining to the nation's transportation systems, issued its own "Guidance for Preparing and Processing Environmental and Section 4(F) Documents" (FHWA, 1987). The document identifies the expected content of environmental documents. There are no requirements defining how the evaluation must be conducted or what data sets and analyses must be utilized for the assessment. This goal of the dissertation is to streamline the process.

Also, the conventional way of doing Environmental Impact Assessment (EIA) study is a time-consuming process because it has a large number of dependent and independent variables which have to be taken into account (e.g. land use, land price, population density, socio-economic level, road accessibility, railway accessibility, air quality, ground water quality, noise level, biological content, historical value, archeological and visual importance), which also have different consequences. Traditionally, environmental data was collected to test hypotheses and simulate environmental systems using in situ (field) methodology (Booz et al, 2003). The emergence of satellite remote sensing technology in the late 1970s revolutionized environmental data collection. Also, the appearance of geographic information systems (GIS) in the mid 1960s reflects the progress in computer technology (Campbell, 1996). GIS have evolved dramatically as a tool of automated mapping and data management in the early days into a capable spatial data processing technology. However, it remains true that data used in GIS are predominantly taken from existing maps. The ability to utilize spatial data from images in the more established technology of remote sensing and to link them with cartographic data of GIS will result in a great advantage that will demonatrate the mutual benefits of the two technologies (Campbell, 1996). A comprehensive discussion about the potential use of remote sensing technologies in transportation took place at a conference on remote sensing for transportation (TRB, 2000). The discussions suggested many opportunities as well as challenges for remote sensing applications in transportation.

A general agreement in the discussion is that full potential of both GIS and remote sensing can be achieved only after the technologies are integrated. Although the needs for the integration have been realized, there are many compelling reasons to recognize and obtain the benefits of coupling. These have to do with the current limitations of the technologies themselves (Parks, 1993). Remote sensing and GIS are the latest technologies and tools which will produce much more accurate results and perform various analyses even in complex situations.

The focus of this research is to develop a framework for the analysis phase of the Environmental Impact Assessment (EIA) for transportation projects at the network level. This cohesive and integrated system will facilitate rational decisions through cost-effective coordination of environmental information and data management that can be tailored to specific projects. The framework would facilitate collecting, organizing, analyzing, archiving, and coordinating the information and data necessary to support technical and policy transportation decisions.

1.3. Dissertation Objectives

This research integrates geomorphologic information with data from other environmental resources to illustrate the opportunities and constraints for land-use planning. It is based on the belief that adequate EIA can only be obtained through precise and reliable assessments of impacts on the different environmental components (physical, biological, aesthetic, and socio-economic) and through the use of well tested, reliable integration tools. The objectives of this research can be summarized as following:

1. Develop streamlined procedures for the assessment of the impact of transportation projects on the surrounding environment;
2. Update GIS legacy database at transportation agencies with the useful, well formatted, accurate and timely data extracted from remotely sensed images, using image processing and data fusion techniques.
3. Develop a decision support Framework that greatly enhances the ability of transportation agencies to make informed decisions.
4. Utilize case studies from transportation projects, in the State of Florida, to illustrate the decision support framework.

1.4. Research Methodology

The research methodology can be divided into three main phases: problem identification phase, framework formulation phase, and completed framework phase. Each phase includes several steps to achieve the objectives of that particular phase. Figure 1.1 illustrates the different phases and steps for the research methodology.

1.4.1. Problem Identification

This phase includes reviewing current practices of Environmental Impact Assessment in general and for transportation projects in particular to pinpoint the deficiencies in these practices. The objective of this step is to establish the need for a more efficient, quantitative, and reliable procedure for environmental impact assessment for transportation projects. Another step is reviewing the concepts and principles of Geographic Information Systems (GIS) and how they are applied effectively as a tool of automated mapping and data management. Moreover, another step is to review the concepts and principles of Satellite Remote Sensing and Digital Image Processing techniques. The objective of the two previous steps is to find optimum integration between the two technologies to utilize spatial data from images in the more established technology of Remote Sensing and to link them with cartographic data of GIS.

The objectives of the problem identification phase are to define the scope of the research and to establish the background necessary to accomplish the research objectives.

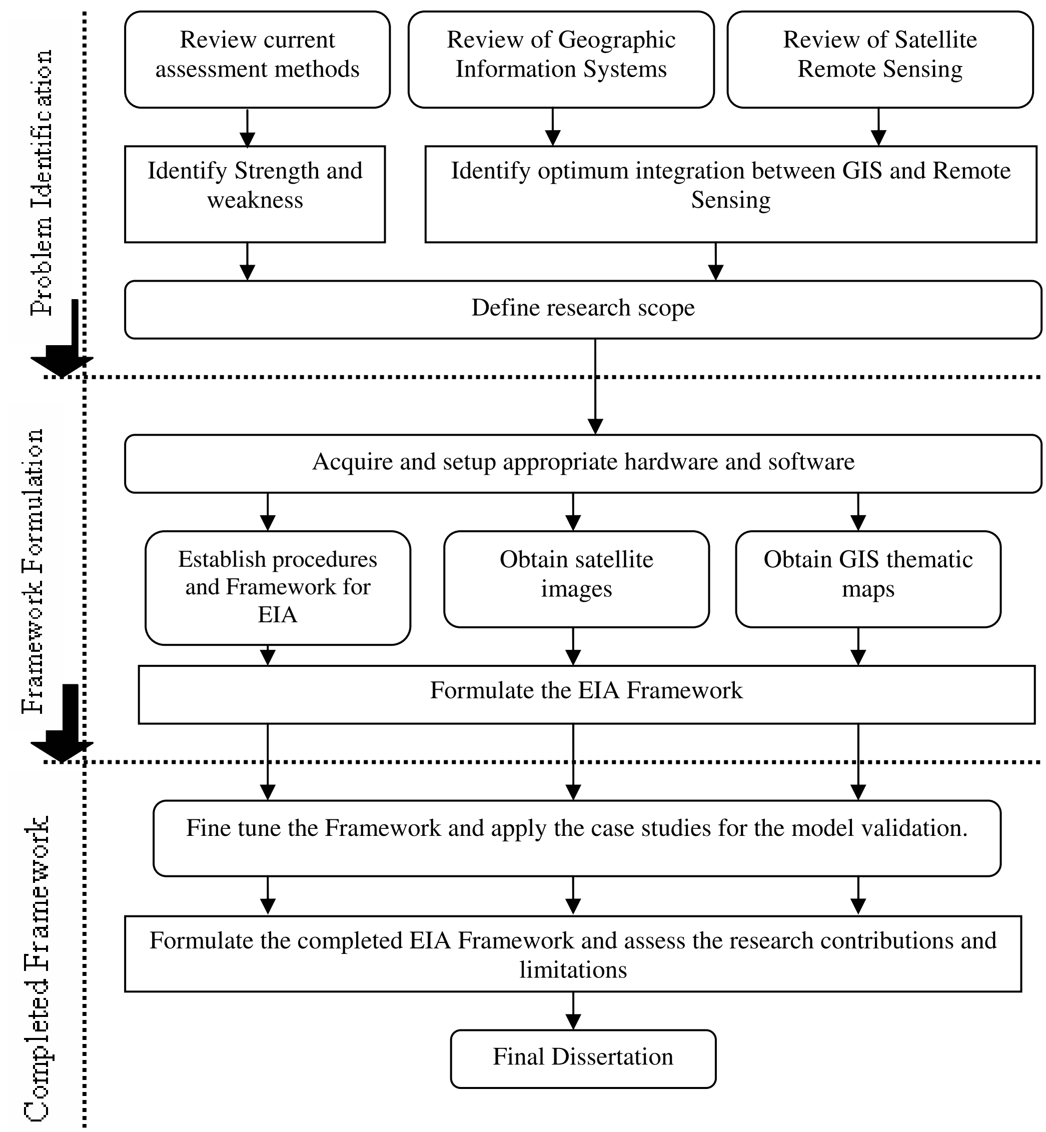


Figure 1.1: Research Methodologies

1.4.2. Formulation Phase

The first step is to acquire and setup the computer hardware and software required for the different phases of the research. Another step is to establish the procedures for how to conduct an environmental assessment by identifying the proposed evaluation to be conducted, what data sets and analyses to be utilized for the assessment. This step is achieved by reviewing literature, interviewing experts, and reviewing the state-of-the practice and participating in the internet forums.

The next step is acquiring the *thematic maps* which can be used in EIA studies including both base maps and derived maps, of different scales. As for the *base* maps, it is possible to reconsider and recode various geographic, geotechnical and hydrogeological maps, available in literature. As for the *derived* maps, it will be possible to refer to existing examples of stability and hazard maps made by local agencies.

The next step is to acquire the characteristics requirements of the satellite images (spatial resolution, temporal resolution... etc.). After obtaining the images, computer software is used to identify patterns in images according to pre-established rules of assessment and these images are integrated with the existing thematic maps through a spatial data fusion model.

1.4.3. Framework Completion Phase

The final stage of the research is utilizing case studies from transportation projects, in the State of Florida, to illustrate and apply the framework and develop the training files for the framework data extraction. The objective of this step is to make the framework consistent in extracting the information required.

The next step would be to synthesize all the previous steps to finalize and refine the framework. More examples, if needed, would be tested to validate the reliability of the framework and any necessary adjustments will be made. Finally the write-up of the completed dissertation will be provided.

1.5. Dissertation Structure

This dissertation is organized into six chapters. Chapter one introduces the research background, states the research problem, specifies the research objectives and significance, and introduces the research methodology. Chapter two lays necessary background about environmental impact assessment and its applications for transportation projects and includes a review of prior research efforts. Chapter three presents the basic theory of the Geographic information system (GIS), remote sensing, and the integration between them. Chapter four reviews the concepts of digital image classification and outlines the theories, algorithms, and techniques used for image processing. Chapter five focuses on the methodology used to implement this research. Chapter six presents the application of the analysis on case studies from transportation projects, in the State of Florida, to verify the consistency of the developed framework. Discussions and conclusions of the study are presented in chapter seven.

CHAPTER 2 ENVIRONMENTAL IMPACT ASSESSMENT

The objective of this chapter is to review the literature on environmental Impact assessment (EIA). This chapter is broken down into five major sections. The first section represents a definition of the environmental Impact assessment. The second section gives a review of the EIA history. The third section gives a summary of the EIA Process for transportation projects. The fourth section represents the different methods commonly used for conducting EIA. The last section is a review of the literature on the integration between the Environmental Impact Assessment and the emerging technologies such as GIS and Remote Sensing.

2.1. Definition of EIA

Environmental Impact Assessment (EIA) is a systematic process that examines, in advance, the environmental consequences of a proposed development action (Glasson et *al.*. 1999). The emphasis, in contrast with many other environmental protection actions, is on prevention and mitigation in anticipation of a development action. According to Canter (1977), an environmental assessment seeks to evaluate the consequences of a proposed action on each of the descriptors in the environmental inventory. The environmental inventory serves as the basis for evaluating both potential adverse and beneficial impacts on the environment arising from a proposed development action. By definition, an Environmental Inventory represents a complete description of the place where a particular proposed action is being considered.

2.2. EIA History

Throughout history, societies have exploited the environment to meet their needs for food, shelter and security. However, it was not until the latter half of the twentieth century that societies began to realize the irreparable degradation being caused to the physical environment (Levy, 2000; Rau and Wooten, 1980). By the end of the 1960s, mounting concern in the US about human impact on the environment resulted in the passage of the National Environmental Policy Act (NEPA) of 1969 (Canter, 1977; Rau and Wooten, 1980; Levy 2000). The purposes of this act are to declare a national policy which promotes efforts which prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of human beings and to establish the Council on Environmental Quality (CEQ). The Act contained legislative procedures and created the Environmental Protection Agency (EPA).

Significantly, Section 102 (2) c of NEPA requires Federal agencies to "include in every recommendation or report on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment, a detailed statement by the responsible official on: The environmental impact of the proposed action; Any adverse environmental effects which cannot be avoided should the proposal be implemented; Alternatives to the proposed action (Canter, 1977).

This detailed statement or report became known as an “Environmental Impact Assessment” or EIA contains the findings of the Environmental Mitigation (EM) as well as recommendations for the mitigation of environmental impacts, and alternatives to the proposed developmental action. The process of carrying out a formal EM and producing an EIA has become embedded in the NEPA process (Glasson *et al.,* 1999).

An EIA discloses the laws and regulations that are applicable to a proposed action and states whether and to what degree a proposed action would comply with these laws. Compliance with regulations does not take place via the

EIA. The only law an EIA complies with is NEPA or a comparable state law (a SEPA). Environmental regulations are written broadly because they apply to a wide range of agencies. Thus, they provide agencies wide latitude in their EA methodologies and processes. Since 1970, guidelines and regulations have provided the basic requirements for preparation of an EIA, but a great deal of flexibility, as well as ambiguity, is also in the regulations. The courts have provided interpretations of the regulations, clarifying some parts while leaving other parts ambiguous. In some cases the courts have made conflicting decisions. Thus, over the course of the last 25 years, individuals who have managed and prepared EIAs have developed their own style and method of EA preparation that work best for them (Kreske, 1996).

2.3. The Environmental Impact Assessment Process

2.3.1. Process Participants

Proponents— A project proponent is the agency or private entity, such as a developer or landowner, which requires funding approval, or a permit from another agency (Kreske, 1996). If a permit is necessary for a proposed project, the "*proponent*" applies for a permit and is therefore referred to as the "*applicant*." The primary role of the proponent is to provide information regarding the design, construction, and operation of a proposed action or project. For a new highway project, the proponent would likely be the FHWA.

Lead Agency—The lead agency is responsible for preparation of the EA and for making a decision on the proposed action. Regardless of whether an EA is a federal or state document, and regardless of who prepares the document, it is the lead agency that is responsible for its content and conclusions. If someone other than the lead agency prepares an EIA, such as a consulting firm, the lead agency must provide independent review of the document and ensure that it meets the agency's standards. A lead agency may be a federal, state, or local agency with authority to approve, permit, or fund a private proposal and with authority to act as a lead agency in the preparation of EIAs (Kreske, 1996).

EIA team—EIAs are prepared by an interdisciplinary team of individuals, such as scientists, engineers, and planners, which may be employees of the lead agency, private consultants, university professors, and agency staff. The required number and type of professionals depends on the range of issues addressed by an EIA. An EIA team consists of professionals with the credentials and experience to analyze the elements of the environment that are within the scope of an EIA. The team members' responsibilities are to provide objective analyses commensurate with the level of significance of a potential environmental impact and within the accepted professional standards. The lead agency and the project proponent also should be members of the team to provide the required guidance.

Public Reviewers—The role of reviewers is to understand the proposed project, provided suggestions for alternative ways to meet the purpose and needs of the project, and critically review a Draft EIA. Lead agencies may choose to have the public more involved in the process than is specifically required by regulations, such as identifying potential alternatives or mitigation measures for significant environmental issues. Public review of an EA is done by private citizens, agencies having jurisdiction by law or expertise, and those who have specifically requested notification. The public review process is not intended to make decisions based on a vote, but is an opportunity for the public to provide input and express concerns regarding the ongoing process so that decision-makers can make better informed decisions.

2.3.2. Overall Process

The principle steps involved in executing an EIA are shown in Figure 3.1. The process begins when a private individual, an agency, or an organization, proposes an action or a project. At this stage, the proposed action or project usually is conceptual or preliminary in design. The lead agency (federal or state) determines whether the proposal is excluded from the requirements to prepare environmental documents. Actions that normally do not result in significant impacts are afforded "Categorical Exclusions" (federal) or "Categorical Exemptions" (some states) and, therefore, do not require further environmental review. Agencies have lists of actions that are excluded or exempt from environmental documentation if the action clearly would not result in significant impacts (Glasson et al., 1999). If the proposed project is excluded from further environmental review, the project continues to the planning stage. If, however, a proposal is not excluded from environmental review, the lead agency must determine if the proposed activity will result in significant environmental impact.

The requirement to prepare an EIA hinges on whether a proposed project would result in significant impacts to the environment. This decision is called the "threshold determination". Although "significance" is highly subjective, the Council on Environmental Quality (CEQ) provides some guidance on whether actions would be significant through consideration of “context” and “intensity” (Canter, 1977). If the lead agency cannot determine whether the proposal would result in significant environmental impact, an Environmental Impact Assessment (EIA) is prepared to aid in determining whether any impacts from the proposed action would be significant. The EIA may be prepared by the lead agency, a proponent, or a consultant. If an EIA is prepared by a proponent or consultant, the lead agency reviews the document for adequacy. If the EIA concludes that the proposed project would not result in significant environmental impacts, the lead agency issues a "Finding Of No Significant Impact", FONSI (federal), or the equivalent at state level, which is publicly reviewed.

If, however, it is determined either before or after the EA that the proposal may result in significant impact, the lead agency publishes in the Federal Register (for federal EIAs) a "Notice Of Intent" (NOI) to prepare an EIA and the public scoping process for an EIA is begun. States have similar notification processes. Scoping is the process of collecting and compiling public comments that determine what actions, alternatives, environmental effects, and mitigation measures will be addressed in an EIA.

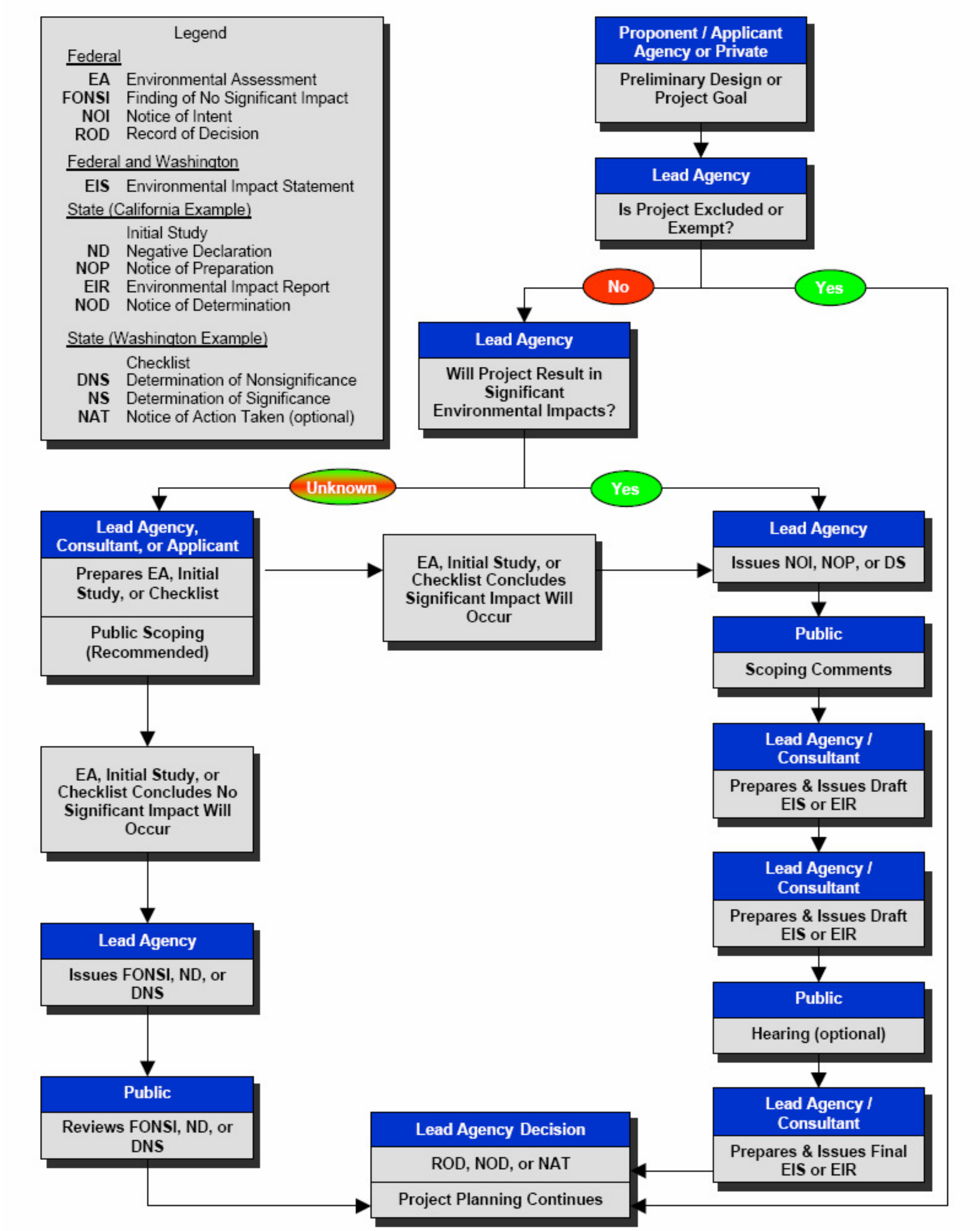


Figure 3.1: Diagram showing the steps and players in a "typical" environmental review process (Adapted from Kreske, 1996)

The amount of scoping necessarily varies by agency, the type of environmental review, and the complexity of the proposed action. Although public scoping is encouraged, many federal and state agencies do not require it for environmental determinations that precede an EIA. Hacklay et al. (1998) argues that the effectiveness and quality of the entire EIA process depends on the quality of the scoping stage. Unless an accurate scoping is performed, possible omissions and errors could damage the entire EIA process. According to Hacklay et al. (1998) scoping must fulfill two seemingly contradictory requirements; good scooping must be comprehensive and complete, and it must be performed within a short time with limited resources. The next major steps involve preparing a Draft EIA and distribution of the Draft EIA for public review. A consideration of alternatives can also allow people not directly involved in the decision-making process to evaluate various aspects of a proposed project and understand how certain decisions were arrived at (Glasson et al., 1998). If a project is deemed to have unacceptable impacts, then an Environmental Impact Statement can result in a "no-build" outcome. A critical step in the EIA process is the presentation of the Environmental Impact Statement (EIS) results. If carried out incorrectly, this step could also potentially compromise all the work done on the EIA and result in its negation. After public review of the Draft EIA, a Final EIA, which responds to comments on the draft document, is then prepared and publicly distributed. The main differences between the basic federal and state processes are in the names of some of the documents and time frames for actions that take place in the process. Depending on the agency jurisdiction for the project location, type of project, and type of approval being sought, the agencies involved in the process and details of procedures will vary.

2.3.3. Streamlining the EIA Process

Because the environmental assessment processes is complex and usually involves many players with different agendas, there is a pervasive perception that the environmental process results in extensive delays and additional costs in completing transportation projects. Part of the problem stems from the fact that the roles and responsibilities of federal, state, and local agencies are often in conflict (Kreske, 1996). Whereas federal and state agencies are responsible for land and natural resource management, local agencies are focused on systematic development and services of private land. Developers and agencies with construction responsibilities struggle with overlapping, duplicate, and conflicting regulations. While CEQ regulations encourage agencies to combine their planning and EA processes, few agencies have the knowledge or latitude to change their procedures to attempt different approaches. Some agencies, however, are identifying ways to reduce duplicative regulations and they streamlined the process by combining some planning and environmental processes.

The US DOT, in response to Section 1309 of TEA-21, implemented a coordinated review process for construction projects that require environmental assessment. The goal of this review process is to establish performance measures and benchmarks to evaluate transportation and environmental decision making for the purpose of reducing project delays. Environmental streamlining is the term used for a new way of doing business that brings together the timely delivery of transportation projects with the protection and enhancement of the environment. Because major transportation projects are affected by dozens of Federal, State, and local environmental requirements administered by a multitude of agencies, improved interagency cooperation is critical to the success of environmental streamlining.

2.4. Environmental Impact Assessment Methods

EIA methods are usually taken to include the means of gathering and analyzing data, the sequence of steps in preparing a report, and the procedure (who does what and when). The essential ingredients of the EIA process, such as scooping, Initial Environmental Examination (IEE), and detailed EIA, are universally agreed upon, but EIA techniques vary widely.

Considering the complexity of the interacting systems that constitute the environment, and the infinite variety of possible impacting actions, most practical impact assessment studies use several methods or combinations of methods, a classification of methods and approaches will help in a summary presentation and discussion of the various techniques.

Ad hoc methods

Ad hoc methods provide little, if any, formal guidance for an impact assessment. While varying considerably with the team of experts, they usually identify a broad area of impact rather than define specific parameters which should be investigated or attempt a quantitative assessment. A major advantage is in their ease of use and the possibility to tailor them to the specific circumstances of a given assessment problem without the constraints of a rigid formalism. As a consequence, they depend very much on the background, expertise and experience of the people undertaking them. While fast, and possible to conduct with minimal effort, they do not include any assurance of completeness or comprehensiveness; they may lack consistency in the analysis due to lack of guidance and a specific formalism; and they require the identification as well as the assembly of an appropriate group of experts for each new assessment.

Checklists and matrices

Checklists consist of a list of environmental parameters to be investigated for potential impacts. They therefore ensure complete coverage of environmental aspects to be investigated. Checklists may or may not include guidelines about how impact-relevant parameters are to be measured, interpreted, and compared. A typical checklist might contain entries such as:

1. **Earth:** mineral resources; construction material; soils; land form; force fields and background radiation; unique physical features;

2. **Water:** surface (rivers, lakes and reservoirs, estuaries); coastal seas and ocean, underground; quality; temperature; recharge; snow, ice, and permafrost; Atmosphere: quality (gases, particles); climate (micro, macro); temperature;

3. **Flora:** trees; shrubs; grass; crops; micro-flora; aquatic plants; endangered species; barriers; corridors;

4. **Fauna:** birds; land animals including reptiles; fish and shellfish; benthic organisms; insects; micro-fauna; endangered species; barriers; corridors;
5. **Land use:** wilderness and open space; wetlands; forestry; grazing; agriculture; residential; commercial; industrial; mining and quarrying;
6. **Recreation:** hunting; fishing; boating; swimming; camping and hiking; picnicking; resorts.

Obviously, checklists do carry a geographical, as well as cultural, bias or, if universal in intent, carry a large number of mutually exclusive categories. They are usually also implicitly oriented towards certain categories of projects, related to the history of their development. Further, their elements may be interrelated such that the linear presentation in the listing has to be interpreted as a hierarchical or even multi-dimensional system in many cases.

Various sub-categories of approaches can be identified, based on checklists:

- Simple checklists, consisting of a simple list of environmental parameters.
- Descriptive checklists, including guidelines on the measurement of parameters (e.g., Schaenman, 1976).
- Scaling checklists, including information basic to the (subjective) scaling of parameter values. Important concepts include the duration of an impact, and whether it is reversible or irreversible.
- Questionnaire checklists, containing a series of linked questions, which guide the user through the process. The possible answers are provided as multiple-choice, making the process easy to use even for less experienced persons.
- Environmental Evaluation System (EES): Checklist based, including scaling and weighting (Dee et al., 1972; Lohani and Kan, 1983).
- Multi-attribute Utility Theory: it is basically a decision support (weighting) method that can also be used in conjunction with other approaches to derive the impacts (Keeney and Raiffa, 1976; Keeney and Robilliard, 1977; Kirkwood, 1982).

Impact matrices combine a checklist of environmental conditions likely to be affected with a list of project activities, the two lists arranged in the form of a matrix. The possible cause-effect relationships between activities and environmental features are then identified and evaluated cell by cell. Matrices can be very detailed and large; the classical Leopold matrix contains 100 by 88 cells, and is thus cumbersome to handle (Leopold et al., 1971). As a consequence, numerous extensions and modifications have been developed for almost every practical application (e.g., Clark et al., 1981; Lohani and Thanh, 1979; Welch and Lewis, 1976; Fischer and Davies, 1973). In a more strategic approach, project planning matrices are used to structure and guide the assessment procedures in the goal-oriented ZOPP (*Ziel-Orientierte Projekt Planung*) method (GTZ, 1987).

Overlays

Overlay methods use a set of physical or electronic maps, of environmental characteristics and possible project impact upon them, that are overlaid to produce a composite and spatial characterization of project consequences (McHarg, 1968a, b; Dooley and Newkirk, 1976).

Networks and diagrams

Networks are designed to explicitly consider higher order, i.e., secondary and even tertiary consequences in addition to the primary cause-effect relations addressed by the methods above. They consist of linked impacts including chained multiple effects and feedbacks (Sorensen, 1971; Gilliland and Risser, 1977).

Cost-benefit analysis

Cost-benefit analysis (CBA), in a narrow sense, is an attempt to monetize all effects for direct comparison in monetary terms. While providing a clear answer and basis for the comparison of alternatives, the monetization of many environmental problems is sometimes extremely difficult and thus can affect the usefulness of the method considerably. Numerous approaches to help monetize environmental criteria have been developed. Some of the more frequently used include the *cost of repair*, i.e., the estimated cost to restore an environmental system to its original state, or the *willingness to pay*, based on direct or indirect (e.g., travel cost) approaches to assess the value. An excellent and critical treatment of cost-benefit analysis, and evaluation in environmental planning in general, can be found in McAllister, 1980. A discussion of the principles of environmental extensions to traditional cost-benefit analysis is given in Hufschmidt, James, Meister et al., 1983.

Attempts to overcome some of the weaknesses of CBA have led to numerous extensions and modifications, such as the *Planning Balance Sheet* (PBS) or the Goals Achievement Matrix (GAM). The Planning Balance Sheet (Lichfield et al., 1975) stresses the importance of recording all impacts, whether monetizable or not, and analyzing the distribution of impacts among different community groups. Thus it adds the analysis as to whom cost and benefits accrue to the basic concept of CBA. The Goals Achievement Matrix (Hill, 1967; Hill, 1968; Hill and Werczberger, 1978) defines and organizes impacts according to a set of explicit goals that the (public) action is attempting to meet and identifies consequences to different interest groups. It is also designed to accommodate non-monetizable impacts, and uses a set of non-monetary value weights for computing a summary evaluation; it is thus similar to CBA.

Modeling

Systems analysis and modeling are among the few techniques that allow consideration of multi-dimensional problems that involve multiple (usually conflicting) objectives, multiple criteria, multiple purposes and users, as well as interest groups. Modeling basically attempts to replicate a real-world situation. Also it allows experimentation with the replica in order to gain insight into the expected behavior of the real system. Models, implemented on computers, are extremely powerful tools of analysis, though they are often demanding and complex.

The two main problems, namely, lack of expertise and lack of data, are good reasons to look into the use of computers, in particular into new technologies such as expert systems, interactive modeling, and dynamic computer graphics. The basic idea behind an expert system is to incorporate expertise, i.e., data, knowledge and heuristics relevant to a given problem area into a software system. Environmental Impact Assessment usually deals with rather complex problems that touch upon many disciplines, and rarely will an individual or a small group of individuals have all the necessary expertise at their disposal. The expert systems component of an EIA system can help to fill this gap and at the same time take over the role of a tutor.

The same line of argument holds for the missing data. A forecast of likely consequences and impacts has to be based on some kind of model. Whether that is a mental model, a set of ``rules of thumb'' or heuristics an expert might use, or a formal mathematical model, the necessary information must be somehow inserted in the (mental or mathematical) procedure. If no specific data are available, one looks for similar problems for which information or experience exists and extrapolates and draws upon analogies. This role is usually filled by the expert's knowledge, or by handbooks and similar sources of information (Canter and Hill, 1979).

2.5. Emerging Technologies for EIA

2.5.1. Integrating of GIS and EIA

Even-though EIA and GIS have been used to address environmental problems, few projects have linked the two fields (Harris et al., 1991 & 1997: Hakaly et al., 1998; Schaller, 1990; Zura and Lipar, 1995; Agrawal and Dikshit, 2002). According to Canter (1977) the assessment of environmental impacts arising from proposed development actions requires systematic, reproducible, and interdisciplinary approaches. Canter (1977) points out that the major steps in the environmental assessment, and the steps that require the greatest degree of scientific application of technology, are impact identification, prediction, and assessment. Lein (1998) has also identified certain steps in the EM process where GIS could perform a valuable role. These include impact identification, impact prediction and communication of finding to the decision makers and the public.

Haklay et al. (1998) argue that a GIS-based EIA would improve the effectiveness of the scoping stage for both the developer and EIA experts. GIS visualization plays a vital role during the phases of impact inventory and analysis, mitigation and monitoring. However, GIS goes beyond mere visualization because of its powerful analytical functionality and ability to perform spatial analysis and modeling (Lein. 1998).

In transportation literature, there hasn't much research work in the EIA and GIS integration. This is due to the specific requirements of transportation applications and of the rather late adoption of this information technology in transportation (Thill, 2000).

Nyerges et al (1997) presented a prototype of integration between Geographic Information System (GIS) and Group Support System (GSS) technologies for transportation improvement site selection. This model highlights the possibilities in an inter-organizational coalition decision context. Li et al (1999) adopted the map overlay method and the matrix method for the comprehensive assessment of road environmental impact on the environment and the optimal selection of road alignments.

Armstrong and Khan (2004) developed a methodology that can assist the decision-making process for reducing vehicle emissions in urban areas using GIS.

Malczewski, (2004) presented relevant methods and techniques for GIS-based land-use suitability mapping and modeling, and identified the trends, challenges and prospects of GIS-based land-use suitability analysis. The focus of the research focused on the techno-positivist perspective and the socio-political, public participation perspectives.

2.5.2. Integrating of RS and EIA

Remote sensing is used widely to generate new information and to study environmental change over time (Stromquist, 2000). As example, Cibula and Nyquist, (1987) integrated topographic data and watershed boundaries data with the Landsat MSS data to refine land cover classification of a mountainous forested region in Olympic National Park, Washington. Barale and Folving (1996) presented remote sensing as adequate tool to study the environmental pressure imposed for coastal interactions in the Mediterranean region. Cartalis at al (2000) presented the potential of satellite imagery to support the requirements of environmental impact assessments (EIA).

In Transportation, discussions about the potential use of remote sensing technologies took place at a conference on remote sensing for transportation (TRB 2000). The discussions suggested many opportunities as well as challenges for remote sensing applications in transportation. Oman and Friedl (2000) listed several areas which remote sensing applications could be useful; helping to streamline the NEPA process, watershed assessments; wetlands; water quality, and storm water issues; land use changes; environmental justice; and several others. O'Hara's (2001) analysis focused on identifying and mapping wetland features that occur in agricultural areas. He used high-resolution hyper-spectral image data and high resolution LIDAR data to identify areas in Randolph County, North Carolina with high likelihood of being wetlands. Vegetation classifications, neighborhood analysis, digital elevation, hydrologic information, data on hydric soils, and data fusion methods were used to produce indicators of the likelihood of wetland areas. Laymon et al. (2001) provide an excellent review of the NEPA EA process. They also suggest that remote sensing can be valuable source of information for the process.

King and O'Hara (2002) reviewed several projects at The National Consortium on Remote Sensing in Transportation- Environmental Assessment (NCRST-E) and their potential use in the environmental assessment. They discussed land cover classification from Landsat data as a source of information to advise the public of the proposed action. They noted that Landsat data at 30 m resolution is suitable for general land cover classification, but that high resolution multi-spectral data are better suited for more detailed mapping. O'Hara et al. (2002) made use of remote sensing technologies in an environmental assessment of the impacts of relocating segments of the CSX railroad out of significant population growth areas along the environmentally sensitive Mississippi Gulf Coast. They described the use of the use of U.S. Geological Survey Multi-Resolution Land Characteristics 1992 data set and the Mississippi Automated Resource Information System (MARIS) to generate land cover data and maps. Land cover classification maps, following a modified Andreson et al. (1976) classification scheme, were developed using LandSat 5 scenes.

Kamal and Midorikawa (2004) presented the preparation of a detailed GIS based geo-morphological map using remote sensing data and supplementary geo-information, accompanied with landfill sites of Dhaka city area, Bangladesh, for the multipurpose functionality use.

CHAPTER 3 GIS, REMOTE SENSING, AND THEIR INTEGRATED APPROACH

This chapter outlines the theory and characteristics of remote sensing and GIS. More specifically, the chapter focuses on the characteristics of remote sensing and GIS and describes in detail their integration: the needs for the integration, the levels of integration, and the current impediments to the integration.

3.1. Introduction

Over the past two decades, there has been a large increase in using remotely sensed data for various types of environmental analysis. The commercial success of GIS in the early 1980s makes it possible for computer systems to handle spatial data. Indeed, the 1990s have witnessed scientists' efforts from different fields to push the integration among remote sensing and GIS into a frontier of scientific inquiry.

The objective of this chapter is to review the literature on the integrated approach of GIS and remote sensing. This chapter is broken down into three major sections. The first section gives an overview of the Geographic Information Systems. The second section gives an overview of Remote Sensing. The last section is a review on the integration of remote sensing and GIS.

3.2. Geographic Information Systems (GIS)

3.2.1. Definitions of Geographic Information Systems

Geographic Information Systems are computer-based information systems that enable capture, modeling, manipulation, retrieval, analysis and presentation of geographically referenced data (Worboys, 1997). The uniqueness of GIS comes from its ability to carry out these operations on both spatial and descriptive data simultaneously or separately. Spatial data are two- or three-dimensional coordinates of points (nodes), lines (arcs), or areas (polygons) representing one aspect of a geographic reality (coverage). Descriptive data, on the other hand, refers to the features or attributes of these points, lines, or areas (Huxhold, 1991).

GIS automatically generates an additional set of information which explicitly defines the spatial relationships between geographic features. These are known as topological relationships. Examples are link connectivity, area contiguity (features of the adjacent areas), and area definition (connected lines enclosing an area). Creating topological relationships allows faster data processing, and also allows for performing analysis functions such as route finding, area aggregation and overlaying geographic features. (Huxhold, 1991; ESRI).

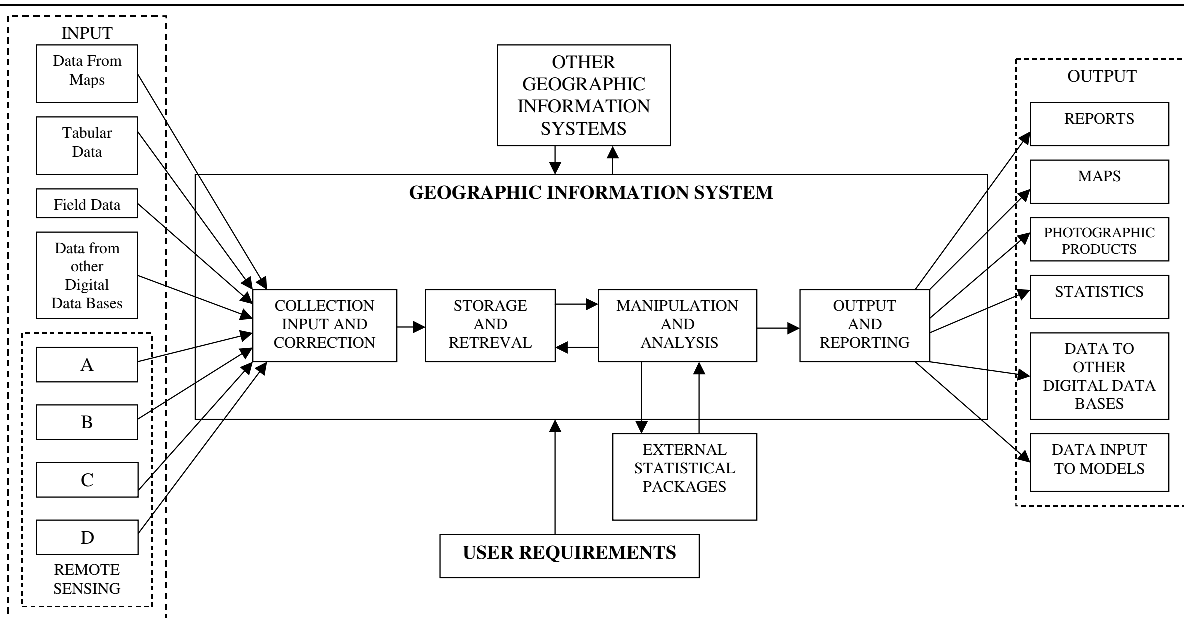


Figure 3.1: Main concepts of a GIS (adopted from Linden, 1990)

Accordingly, complete GIS can be said to have the following major elements (Marble and Arnundson 1988; Linden, 1990) (Figure 3.1):

1. Data input module: for collecting and/or processing spatial data derived from sources, such as existing maps, remotely sensed data and direct digital input.
2. Spatial data base module: in which location and shape data are stored and retrieved in the form of coverage (maps).
3. Attribute data base module: in which descriptive data associated with the spatial features are stored and retrieved.
4. Analysis module: in the form of a group of commands and functions which performs a number of tasks, such as changing form of the data through user-defined aggregation rules, or producing estimates of parameters for transfer to external analytical type models.
5. Output module: to display the retrieved all or selected portions of the spatial database in the term of standard reports or in a variety of cartographic formats and communicate with other systems.

Besides the above-mentioned modules, for GIS to be a real useful tool as a Decision Support System (DSS), user defined procedures in the form of specialized simulation and optimization models have to be represented in the system (Clarke, 1990). This can be accomplished using a general-purpose programming language supplied within the GIS environment, or even outside it, to represent these procedures. An example is an external statistical package such as that shown in figure 3.1.

3.2.2. GIS Data Characteristics

3.2.2.1. Spatial Data

Spatial data is that pertaining to the location aspect of geographical features together with their spatial dimensions. There are two basic data models for geographic data storage; vector and raster data models (Figure 3.2).

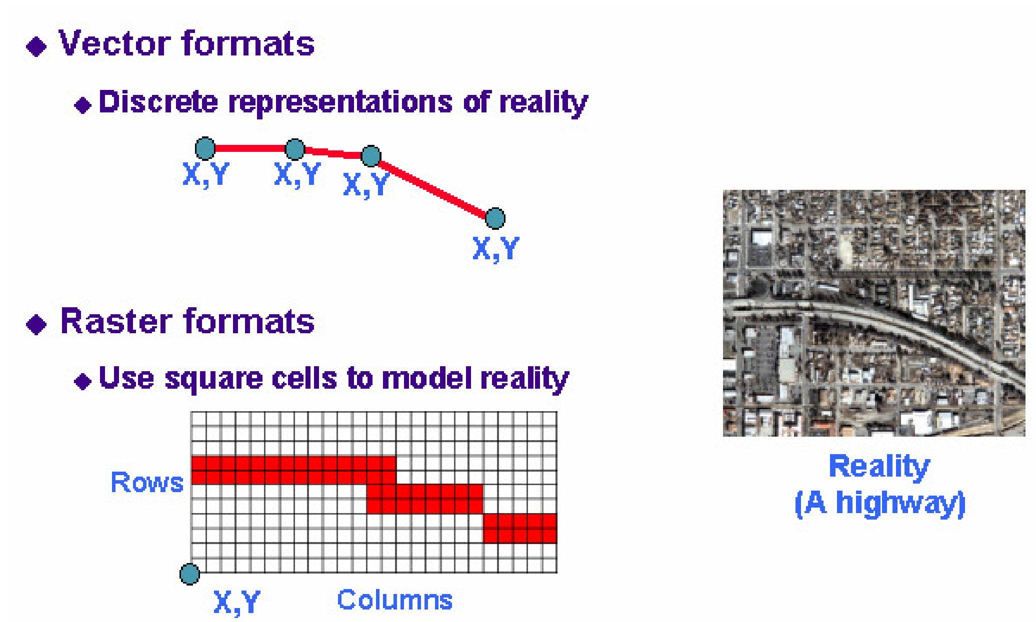


Figure 3.2: Vector and Raster Data Formats

The vector data model represents geographic features similarly to the way maps do. They are approximated by point, line or areas. Points define discrete locations of geographical features which are too small to be depicted as lines or areas, such as road intersections, telephone poles, or buildings. Points can also represent locations that have no area, such as mountain peaks. Lines represent the shape of geographic objects too narrow to depict as areas, such as roads and streams, or linear features that have length but no area, such as elevation contours.

Areas are closed figures that represent the shape and location of homogeneous, real world features, such as states, counties, parcels, soil types, or land use zones. These three features can be presented in GIS in different forms. Within GIS, points can be presented with an (x, y) coordinate system, lines can be presented as a series of points with directions, and a polygon can be presented as a closed line with an area.

The raster data model, instead of representing features by their explicit x, y coordinates, assigns values to cells that cover their locations. Raster format is well suited to spatial analysis and is also appropriate for the storage of data that is collected in grid format. The amount of detail you can show for a particular feature depends on the size of the cells in the grid. This makes raster data inappropriate for applications where discrete boundaries must be known, such as parcel management. Raster data differs from vector data in many aspects. These differences are illustrated in table 3.1.

Table 3.1: Differences between Raster and Vector Models

No.	Raster Data	Vector Data
1	Low spatial accuracy	High spatial accuracy
2	Requires greater storage space on computer	Requires less disc storage space
3	Easy to be analyzed as it is easy for the computer to manipulate some complex number analysis	Difficult to be managed as it is stored in a large list of coordinates.
4	Slow computation (analysis) and display	Quick computation (analysis) and display.
5	Not easy to be understood by the general public	Easy to be understood by the general public
6	Requires low technology and inexpensive systems.	Requires high technology and expensive systems.
7	Used in the applications which concern in the continuous changes such as: environmental characteristics and change detection of the shore line.	Used in the applications which concern in the stable conditions such as urban planning, site selection, and crisis management.

3.2.2.2. Attribute Data

Attributes are the description, measurement and classification of geographic features. Attributes are presumed to be identical to the whole geographic feature. A geographic feature could have many attributes. Generally speaking, attribute data has descriptive, quantitative and qualitative aspects. Descriptive data does not have a quantitative or qualitative nature. Elements of the data cannot be compared with each other in quality and quantity. Examples of descriptive character are: soil types, crop types, vegetation types, etc.

Attribute data can be distinguished by measurements and numbers are quantitative data. Examples are: measurement of spatial features such as length, area, volume and angles, which can be extracted from geographical coordinates of the objects shown on the map. Attribute data can be qualitative data, such as the following: water, air, and soil quality.

Themes, one set of attributes, can be used to identify all spatial features of the world that are related to a particular feature or theme, hence the term "thematic attributes". Each of these features can be further divided into sub-themes, For example, water bodies may include: oceans, lakes, seas, springs, and lagoons.

3.3. Remote Sensing System

3.3.1. Definitions of Remote Sensing

Many definitions of RS can be found in different textbooks (e.g. Campbell, 1996; Lillesand and Kiefer, 1987; Richason, 1979). By examining the elements they share, it is easy to identify a central concept - the gathering of information at a distance from the subject to be studied. Therefore, "Remote sensing is the science of deriving information about the earth's land and water areas from images at a distance. It usually relies upon measurement of electromagnetic energy reflected or emitted from the features of interest." (Campbell, 1996.)

3.3.2. Remote Sensing Characteristics

Energy source, target (object) and sensor are main elements of a RS system. The energy source is electromagnetic radiation provided by the sun or other sources. The target is the object on the terrain of specific interest in a remote sensing investigation. A sensor is a device that receives electromagnetic radiation and converts it into a signal that can be recorded and displayed as either numerical data (digital) or as an image (pictorial).

A pictorial format is required for manual interpretation of images; digital imagery is necessary for numerical and statistical analyses. These two formats can be inter-converted if needed. Image data are presented as a raster array of individual pixels. Each pixel is characterized by a digital number (DN) value, one for each multi-spectral channel. The higher the response received by a channel detector, the higher the DN value.

3.3.3. Image Preprocessing

Image preprocessing is achieved through a variety of mathematical operations on the DN values to improve feature detect-ability and interpretability. Radiometric correction, geometric correction, and atmospheric correction are main components in the image preprocessing. Radiometric correction is concerned with removing errors associated with sensor detectors. Errors associated with sensor detectors, such as line dropout, banding or striping and line start errors. These errors can be handled by filtering methods.

Geometric correction is the process of transforming imagery to remove undesirable or misleading geometric distortions. There are many methods for geometric corrections such as deterministic modeling, statistical modeling and re-sampling. The commonly used one is the re-sampling method which uses Ground Control Points (GCPs) as reference points for image registration.

Atmospheric effects represent alternations of DNs caused by scattering and absorption of solar energy in the atmosphere. The result is increased or decreased brightness of DNs. Atmospheric corrections can be complicated depending on how completely scattering and absorption effects must be removed. Dark pixel subtraction and linear regression are commonly used techniques but with less accuracy. Atmospheric modeling is another way to correct the atmospheric effects, but more information (digital spectral libraries) is needed to classify the data.

3.4. Integration of Remote Sensing and GIS

Having realized a great deal of benefits and a wide application, the remote sensing and GIS communities will continue to put their enthusiasm on the integration between remote sensing and GIS. With the advancement of computer technology and increasing demands of market for the integration, an integrated GIS will become a reality sooner or later. This is particularly true when considering the availability of sub-meter resolution satellite data. The Management of such information necessitates current GIS technology to be adapted, modified, and extended (Ehlers et al., 1989a). These new data sources also require processing functionality not currently standard in many systems (Poulter, 1995).

3.4.1. Prospective on the Integration

Initially, the two technologies (GIS and RS) developed independently. Remote sensing has been viewed as a science, which provides end products in the form of maps, statistics graphs, tabular summaries, and reports (Derenyi, 1991). Most GIS activities on the other hand focused on the creation of new base maps by digital map compilation in stereo-models and on building thematic databases by digitizing existing maps. It is the time now to correct, update and maintain these products, and to expand them by adding new kinds of information which were previously not collected. Digital images which are produced by the various airborne and space-borne sensors are important data sources for these purposes. At the same time, the vast amount of information held in GISs can be utilized in the process of information extraction from remotely sensed images. Therefore, the two technologies provide complementary capabilities. Remote sensing should not be considered an end in itself, displaying classified images on a monitor and performing visual analysis is of limited value. Images or information extracted from images must be integrated in GIS with other information to support integrated data analysis operations. This has already been realized and a number of developments have been carried out in recent years to integrate image data with cartographic data within a GIs. According to a survey conducted by Parker (1989), nearly half of all GISs support both raster and vector data structures. GIS capable of processing both raster and vector data are being commonly referred to as "Integrated Geographic Information System" (IGIS) (Dobson, 1993; Davis and Simonett, 1991).

3.4.2. The Needs for the Integration

The Integration of remote sensing and GIS is mutually beneficial for the following two reasons. First, there has been a tremendous increase in demand for the combined use of remotely sensed data with cartographic data generated in GIS, including environmental and socioeconomic data. Products derived from remote sensing are attractive to GIS database development because they can provide cost-effective, large-coverage data in a raster format, ready to enter into a GIS and convertible to a vector or quad-tree data format for subsequent analysis and modeling applications (Lunetta et al., 1991). Moreover, remote sensing systems usually collect data on multiple dates, which make it possible for monitoring environmental change over time. Remote sensing can also provide information about certain biophysical measurements, such as object temperature, biomass, and height, which are valuable in modeling the environment (Jensen, 1983).

GIS as a supporting tool for environmental modeling needs to integrate remotely sensed data with other types of spatially referenced data. This is particularly true when considering that GIS data are usually made from "out-of-date" existing maps. Remotely sensed data may be used to correct, update, and maintain GIS databases (Nellis et al., 1990; Ehlers et al., 1991).

Second, GIS is predominantly a data handling technology, while remote sensing is a data collection technology. Many tasks, which are quite difficult to do in an image processing system, are relatively easy in a GIS, and vice versa The need for the combined use of remotely sensed data with cartographic data, and the GIS functionality for managing and analyzing such data in environmental studies leads to the integration.

3.4.3. Levels of Integration

From an evolutionary perspective, Ehlers et al. (1989a) proposed a three-stage process of integration between GIS and remote sensing, defined as "separate but equal," "seamless integration," and "total integration."

Level I (separate but equal): Separate databases. Two software modules, GIS and image processing, are linked only by data exchange. The integration at this level should have the ability to move the results of low level image processing (e.g., thematic maps, extracted lines, and so on) to the GIS, and the results of GIS overlays and analysis to image processing software.

Level II (seamless integration): Two software modules with a common user interface and simultaneous display. Such a system will allow for a "tandem raster-vector processing" (Ehlers et al., 1989a), such as incorporating vector data directly into image processing, entity-like control over remote sensing image components (e.g., themes).

Moreover, the system will have abilities to accommodate hierarchical entities (e.g., "house" at one level, "block" at another, and "city" at another), and (spatially, radio-metrically, spectrally, and temporally) inhomogeneous data in a coherent manner.

Level III (total integration): A single software unit with combined processing. It is a long-term goal. In the fully integrated system, a single model will underlie all information in the GIS, which has the flexibility of handling both object- and field-based space representations. Remote sensing will become an integral part of the functionality of the GIS. The integrated GIS will be able to handle temporal and three-dimensional information, and thus play a more important role in the Earth system science. In response to slow progress in remote sensing/GIS integration, Mesev (1997) designed a hierarchical three-level integration schema. Each successive Level in the hierarchy deals with more detailed conceptual and operational factors and issues of remote sensing and GIs linkages.

At the top level of the hierarchy (Level I) are the issues of data unity, measurement conformity, potential integrity, statistical relationships, classification compatibility, and overall integration design. Each of these is more fully examined at Level II, tackling more complex linkages among the five components. Data unity, for example, is divided into factors such as information exchange, data availability, data accessibility, and data creation. Level II factors are further refined to produce even more detailed levels at Level III. For example, data availability is subdivided into awareness, publicity, search, data type, age, quality, and access (Table 3.2). Whereas others have already documented the schemata such as Davies et al. (1991), Mesev attempts to itemize the common linkages and reexamine the relationships, and thus provides a logical and structured framework for direct data coupling.

3.4.4. Applications of the Integration

This section will review the major areas of application of the integration by dividing into two sub-sections: GIS as a tool of image processing, and remotely sensed data as a source to GIS.

Table 3.2: Levels of Remote Sensing-GIS integration (Mesev, 1997, Table 1)

Level II	Level III
Data unity (factors that bring RS and GIS data together)	
Information interchange	Definition of integration, type of information needed, information harmony (spatial units and attributes)
Data availability	Awareness, publicity, search, data type, age, quality, (access or create)
Data accessibility	Cost, agreements, exchanges, sharing, proprietary, resistance, confidentiality, liability
Data creation	Digitizing, scanning, survey information encoding, sampling, data transformation. GPS
Measurement conformity (factors that link data between RS and GIS) "	
Data representation	Data structures (vector, raster, quad-tree, etc.), data type, level of measurement, field-based vs. object-based modeling, interpolation
Database design	Type (relational, hybrid), schema, data dictionary, implementation (query, testing)
Data transfer	Formal, standards, precision, accuracy
Positional integrity (factors that spatially co-ordinate data between RS and CIS)	
Generalization and scale	spatial resolution, scale, data reduction and aggregation, fractals
Geometric transformation	Rectification, registration, re-sampling, co-ordinate system, projection, error evaluation
Statistical relationships (factors that measure links between RS and GIS)	
Vertical	Boolean overlays, dasymmetric mapping, aerial interpolation, linear and non-linear equations,
Lateral	Time series, change detection spatial searches, proximity analysis, textural properties
Classification compatibility (factor; that harmonize information between RS and GIS)	
Semantics	classification schema, levels, descriptions, class merging, standardization
Classification	Stage (pre, during, post), level (pixel, sub-pixel), type (per-pixel, textural, contextual, neural nets, fuzzy sets), change detection, accuracy assessment
Integration design	
Objectives	Plan of integration, cost/benefit assessment. feasibility, alternatives to integration
Integration specification	User requirements (intended *use,* level of training, education), system requirements (hardware, Software. computing efficiency)
Decision-making	Testing, visualization, ability to replicate integration, decision-support, implementation or advocate alternatives, bi-directional updating and feedback into individual RS and CIS projects

3.4.4.1. GIS as a Tool for Remotely Sensed Image Processing

GIS data can be used to enhance the functions of image processing at various stages: selection of area of interest for processing, preprocessing, and image classification. At the stage of geometric and radiometric correction, GIS data such as vector point, area data, and DEMs are increasingly used for image rectification (Hinton, 1996). High-resolution topographic data play an important part in radar image interpretation (Kwok et al., 1987). The impacts of varying topography on the radiometric characteristics of digital imagery can be corrected with the aid of DEMs (Hinton, 1996). Perhaps, the most frequently used vector data sets are ground control points in image rectification, selected from an existing map with a defined coordinate system. Hinton (1996) suggested that with the advance in pattern recognition and line following techniques, lines on images could be registered to roads, rivers, and railways in vector datasets for image registration.

At the stage of image classification, the integration of GIS and remote sensing will facilitate the selection of training areas. Ehlers et al. (1991) emphasized the need for a raster/vector intersection query in order to optimize the operation. This query is capable of providing image statistics within vector polygons without completing any data format conversion or raster masking. The emergence of such an intersection query, therefore, would allow for a better selection of training areas for image classification by examining whether the areas display the spectral response characteristics of a class. Likewise, it is possible to look at changes in image statistics within defined polygons directly without classifying the image and examine the raster result (Hinton, 1996). Moreover, the integration between GIS and remote sensing will allow vector data to be rasterized as "image planes" and incorporated into traditional classification and segmentation procedures (Ehlers et al., 1989a). A closer integration will make it possible to incorporate all GIS data layers in their native format into an image classification. Then, a two-way data flow between the raster image and the vector dataset comes true. This situation occurs only in "polygon classification" (Hinton, 1996), in which image statistics are generated based on polygons, and then returned directly to the GIS database as attributes of the polygons.

The full integration of raster and vector data processing could also be used to restrict the area of image to be processed. This indeed permits masking operations without raster masks, making image processing much more efficient.

3.4.4.2. Remotely Sensed Data as an Information Source to GIS

The automated extraction of cartographic information has been a major application of remote sensing imagery as data input to GIS. Lines and other geographic feature extraction have been achieved from satellite images by using pattern recognition, edge extraction, and segmentation algorithms (Ehlers et al., 1989a; Hinton, 1996). A further development in the integration will produce smoother lines and boundaries, i.e., not stepped appearance, hiding their raster origin. Therefore, satellite images show a great potential in producing and revising base maps (Welch and Ehlers, 1988). The production of base maps by means of remote sensing imagery will make it asier for tracking error propagation in GIS layers because of reliable map metadata. In addition, the extracted cartographic information can be used to improve image classification. Image segmentation polygons derived from optical imagery, for instance, could be very useful for stratifying radar data, which are traditionally difficult to digitally segment owing to their noise (Hinton, 1996).

Another area of the application of remotely sensed data as input to GIS is change detection and map updating. Ehlers et al. (1989b) used SPOT data in a GIS environment for regional analysis and local planning at a scale of 1:24,000, and achieved an accuracy of 93 percent for growth detection. Brown and Fletcher (1994) demonstrated that satellite images could be used to interactively update a land use database by comparing the database with the image statistics within areas defined in a vector database. In the future, a full integration between the two elements will allow for querying the raster pixels within vector areas (both vector topological query and raster/vector intersection querying), and performing analyses without format conversions and overlays. Image statistics within vector polygons are then used to examine change and update maps.

Cartographic representation is the third area of application of remote sensing imagery as an input to GIS. Terrain visualization using satellite images in association with DEMs has been explored as a promising tool in environmental studies (Gugan, 1988). Progress in cartographic animation in recent years changes terrain visualization from static to dynamic state. DEM generation from satellite imagery using image correlation has also been demonstrated for deriving further topographic information for GIS application. A DEM developed from LandSat TM images of a rugged terrain in north Georgia yielded a root-mean-square-error in Z of ±42 meters (Ehlers and Welch. 1987). With more favorable base-to-height ratio and a higher resolution of 10 meters, SPOT data produce better DEMs with RMSE between ±6 to ±18 meters (Ehlers et al., 1989b).

3.4.5. Current Impediments to the Integration and Their Possible Solutions

Current impediments to the integration of remote sensing and GIS are not only related to technical development but also to conceptual issues, our understanding of the phenomena under investigation and their representation in a spatial database. While the technology of computers in general and remote sensing and GIS in particular have continued to improve over the past two decades, many basic research needs in the integration remain untouched. This section begins with a review of conceptual impediments to IGIS (The term for a fully integrated system of remote sensing and GIS), followed by a more detailed discussion of technical impediments for the integration and their possible solutions, and concludes with a general perspective on the limitations of current computer technology.

3.4.5.1. Conceptual Impediments

Davies et al. (1991) identified two sets of major impediments to the integration that are conceptual in nature. One relates to defining appropriate strategies for data acquisition and spatial modeling; another relates to tracking and understanding the impact of data processing steps on output products. Examples of the major impediments are (Davies et al., 1991):

Use of multiple data layers varying in structure, level of preprocessing, and spatial consistency; Multiple (and often poorly known) measurement scales, ranging from "points" to grids to irregular polygons; Unknown measurement errors for most variables;

Unknown spatial dependencies in the data and their propagation through spatial models; Limited ability to verify or validate IGIS model outputs; and limited capability for model sensitivity analysis.

In order to overcome these obstacles, according to Davies et al. (1991), research on scale dependence in surface features and the relationships of absolute and relative scales within a remote sensing context is required. Besides, tools are needed to develop measures of spatial properties of input data, such as spatial autocorrelation, two-dimensional spectral analysis, and block variance analysis.

3.4.5.2. Technical Impediments

A fundamental impediment to the integration is the vector/raster dichotomy. Remote sensing has predominantly used a raster approach to data acquisition and analysis. GIS, on the other hand, are predominantly vector-oriented, although there are also raster-based systems. It has been argued that resolving the problem of dichotomy is a long-term goal (Ehlers et al., 1991).

One possible solution to the dichotomy is to establish a mix of data structures (Ehlers et al., 1991). This involves the use of a high-level declarative language, which supports queries and operations regardless of storage formats;

and a database management system (DBMS), which is capable of handling various types of data representations. Such a DBMS will spare the user repetitive data conversions and transference. Recent advances in GIS technology have removed all technical obstacles to procedures that allow for an easy movement between various physical implementations of spatial data. The main issue is now providing users with efficient and accessible means to do so, which operate with known effects on the data's accuracy and precision (Ehlers et al., 1991).

Research on human vision and perception has given rise to a model of spatial information extraction and object recognition from an image as a three-stage process (Marr, 1982). At the first level, gray values (raster data) are processed (low-level), from which structures (features) can be extracted and manipulated as symbolic descriptors (mid-level). At the highest level, knowledge-based information often coupled with spatio-temporal models gives a predictive description (image understanding) of the "imaged" object (Pentland, 1985). This may lead to a hierarchical image analysis system, in which mid-level and high-level information are stored as vectors and/or objects, while low-level information is stored as raster data (gray values).

More generally, a feature-based GIS model has been proposed to solve the problem of vector-raster dichotomy, as well as 3-D or higher dimensional representation and dynamic modeling (Usery, 1996). This model includes spatial, thematic, and temporal dimensions, and structure attributes and relationships for each dimension. Because features constructed in the model provide direct access to spatial, thematic, and temporal attributes and relationships, multiple representations and multiple geometries such as raster and vector are supported.

A second technical impediment to the remote sensing-GIS integration has to do with the issue of data uniformity (Ehlers et al., 1989c). GIS rely on fairly uniform and predetermined data. Data collection in GIS tends to be separated from data processing, which makes tracking errors a hard task. On the other hand, in remote sensing, data are collected first and the user then has to decide how to use them. Data collection is uneven, and data coverage is far from being uniform. The integration of remotely sensed data requires that the GIS be based on deeper, more complete models of the territory. A GIS data structure as described above may be the solution for the integration (Ehlers et al., 1989c).

CHAPTER 4 DIGITAL IMAGE PROCESSING

Remote sensing technology makes it possible to generate land use/cover maps at regional or global scales. Furthermore the availability of satellite images at high resolution in digital format, its repetitive coverage and multi-spectral capabilities help scientists to monitor land use change over time. This chapter reviews the concepts of Remote sensing image classification. First, an outline of the theories and algorithms for image processing is given furthermore, the classification techniques is give.

4.1. Introduction

Digital image classification is the process of assigning pixels to classes. The central idea behind digital image processing is quite simple. The digital image is fed into a computer one pixel at a time. The computer is programmed to insert these data into an equation, or series of equations, and then store the results of the computation for each pixel. These results form a new digital image that may be displayed or recorded in pictorial format or may itself be further manipulated by additional programs (Lillesand and Kiefer, 1994). The forms of digital image manipulation may be categorized into one, or more, of the following four broad types of computer operations: image rectification and Restoration, image enhancement, image classification, GIS integration. The following sections will review these types of computer-assisted operations.

4.2. Image Rectification and Restoration

The intent of image rectification and restoration is to correct image data for distortions or degradations that stem from the image acquisition process. The nature of such procedures varies considerably with such factors as the digital image acquisition type, platform and total field of view. Discussion about various rectifications techniques can be found in Yang (1997). This procedure can be divided as geometric correction, radiometric correction, and noise removal.

4.2.1. Geometric Correction

Raw digital images usually contain geometric distortions so significant that they cannot be used as maps. The intent of geometric correction is to compensate for the distortions so that the corrected image will have the geometric integrity of the geometric correction process is normally implemented as a two-step procedure. First, those distortions that are systematic, or predictable, are considered. Second, those distortions that are essentially random, or unpredictable, are considered.

Systematic distortions are well understood and easily corrected by applying formulas derived by modeling the sources of the distortions mathematically. Random distortions and residual unknown systematic distortions are corrected by analyzing well-distributed ground control points (GCPs) occurring in an image. In the correction process numerous GCPs are located both in terms of their two image coordinates (column, row numbers) on the distorted image and in terms of their ground coordinates.

These values are then submitted to a least-squares regression analysis to determine coefficients for two coordinate transformation equations that can be used to inter-relate the geometrically correct (map) coordinates and the distorted image coordinates as shown in figure 4.1. Once the coefficients for these equations are determined, the distorted image coordinates for any map position can be precisely estimated.

This can be presented mathematically as:

$$x = f_1(X, Y)$$

$$y = f_2(X, Y)$$

Where (x, y) = distorted image coordinates (column, row)

(X, Y) = correct (map) coordinates

f_1, f_2 = polynomial transformation functions

Several models are available in order to correct the distortion of satellite data. This polynomial with GCPs is an approach that is widely used and results in satisfactory analysis in many applications (Schowengerdt, 1997). Richards and Jia (1999) stated that the nearest neighbor re-sampling is the preferred technique if the new image is to be classified. This method is preferred because it uses only the original pixel brightness.

Nearest neighbor re-sampling simply chooses the actual pixel that has its center nearest the point located in the rectified image. More sophisticated methods of re-sampling evaluate the values of several pixels surrounding a given pixel in the input image to establish a "synthetic" DN to be assigned to its corresponding pixel in the output image. The bilinear interpolation technique takes a distance-weighted average of the DNs of the four nearest pixels (labeled a and b in the distorted image matrix in Figure 4.1). An improved restoration of the image is provided by the cubic convolution method of re-sampling. In this approach, the transferred "synthetic" pixel values are determined by evaluating the block of 16 pixels in the input matrix that surrounds each output pixel (labeled a, b, and c in Figure 4.1).

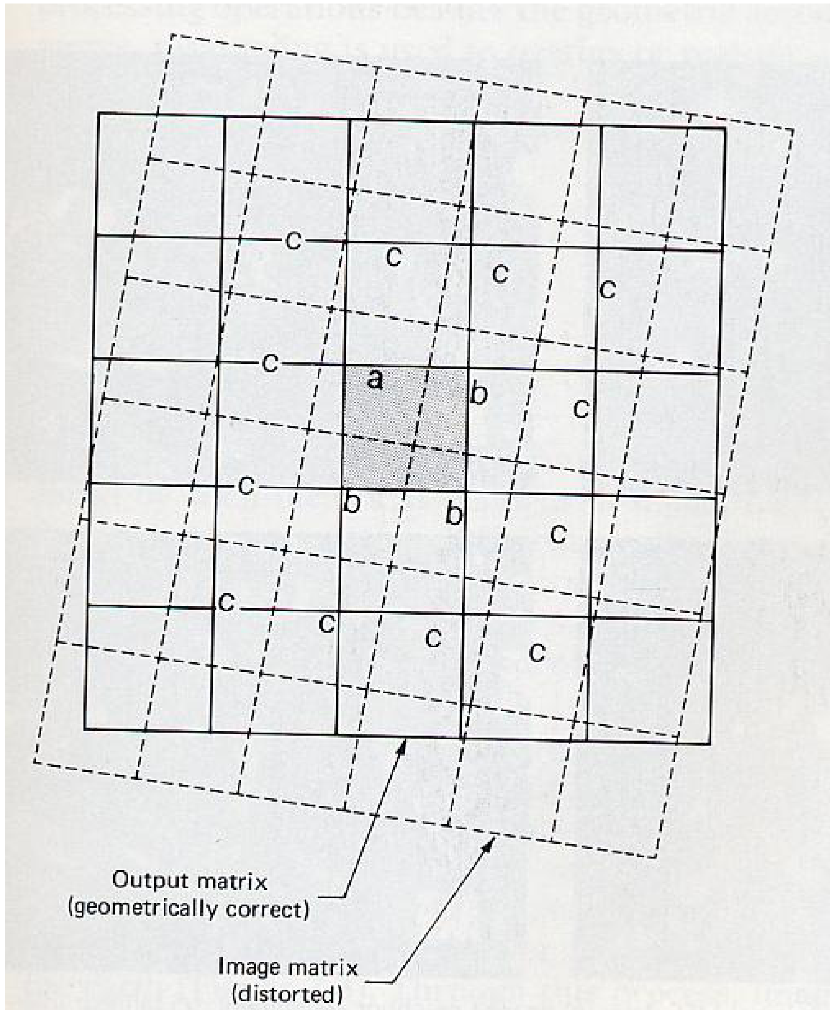


Figure 4.1: Matrix of Geometrically correct output pixels superimposed on Matrix of original, distorted input pixels (Lillesand and Keifer, 1994)

There is a trade off between using nearest neighbor or cubic convolution re-sampling techniques and preserving original data or spatial location. However, Etherridge and Nelson (1979) reported that there was no significant difference in land use classification using the maximum likelihood technique after applying nearest neighbor, bilinear or cubic convolution interpolation. The study by Dikshit and Roy (1996) also showed that using bilinear or cubic convolution re-sampling did not decrease the accuracy of classification. They did recommend using class-training statistics collected from the re-sampled image in classification procedures.

4.2.2. Radiometric Correction

Waits (1991) and Ahern et al. (1987) stated that there are two major radiometric effects on satellite data; a sun evaluation correction and an earth sun- distance of correction. The sun evaluation correction accounts for the seasonal position of the sun relative to the earth. Through this process, image data acquired under different-solar illumination angles are normalized by calculating pixel brightness values assuming the sun was at the zenith on each date of sensing. The correction is usually applied by dividing each pixel value in a scene by the sine of the solar elevation angle for the particular time and location of imaging. Alternatively, the correction is applied in terms of the sun's angle from the zenith, which is simply 90° minus the solar elevation angle.

The earth-sun distance correction is applied to normalize for the seasonal changes in the distance between the earth and the sun. The earth-sun distance is usually expressed in astronomical units. The irradiance from the sun decreases as the square of the earth-sun. Ignoring atmospheric effects, the combined influence of solar zenith angle and earth-sun distance on the irradiance incident on the earth's surface can be expressed as:

$$E = \frac{E_0 \cos\theta_0}{d^2}$$

Where

E = normalized solar irradiance

E_0 = solar irradiance at mean earth-sun distance

θ_0 = sun's angle from the zenith

d = earth-sun distance, in astronomical units

The influence of solar illumination variation is compounded by atmospheric effects. The atmosphere affects the radiance measured at any point in the scene in two contradictory ways. First, it attenuates (reduces) the energy illuminating a ground object. Second, it acts as a reflector itself, adding a scattered, extraneous "path radiance" to the signal detected by a sensor. Thus, the composite signal observed at any given pixel location can be expressed by

$$L_{tot} = \frac{\rho E T}{\pi} + L_P$$

Where

L_{tot} = total spectral radiance measured by sensor

ρ = reflectance of target

E = irradiance on the target

T = transmission of atmosphere

L_P = path radiance

Only the first term in the above equation contains valid information about ground reflectance. The second term represents the scattered path radiance, which introduces "haze" in the imagery and reduces image contrast. *Haze compensation* procedures are designed to minimize the influence of path radiance effects. One means of haze compensation in multi-spectral data is to observe the radiance recorded over target areas of essentially zero reflectance. For example, the reflectance of deep clear water is essentially zero in the near-infrared region of the spectrum. Therefore, any signal observed over such an area represents the path radiance, and this value can be subtracted from all pixels in that band. The second one is transformation of the at-satellite radiance to radiance at the Earth's surface or surface reflectance by accounting for both solar and atmospheric effects. This transformation can range from a simple dark-object subtraction technique or single image normalization using histogram adjustment (Chavez, 1988; and Jensen, 1996) to the sophisticated techniques that use various atmospheric transmission models. These models mostly require ground and/or atmospheric in-situ measurements during the satellite over-flight. Also certain topographic slope and aspect effects are required in radiometric calibration, especially in rugged mountainous terrain (Chavez, 1988; Chavez, 1989; Chavez, 1996; Waits, 1991; and Schowengerdt, 1997).

There are still unanswered questions and uncertainty concerning the need for radiometric correction. Waits (1991) documented that "it does not appear necessary to perform radiometric corrections on raw radiance data to improve classification accuracy. Sandmeier (1995) reported that radiometric correction partially improved land use classification in rugged terrain. The forest stand classification was substantially enhanced, but other land use classes showed little impact from the radiometric correction. However, there is no clear definition of what constitutes adequate radiometric correction. Each user will have a different definition of what calibration level is required for his or her application (Schott, 1997).

4.2.3. Noise Removal

Image noise is any unwanted disturbance in image data that is due to limitations in the sensing, signal digitization, or data recording process. The potential sources of noise range from periodic drift or malfunction of a detector, to electronic interference between sensor components. Noise can either degrade or totally mask the true radiometric information content of a digital image. The objective is to restore an image to as close an approximation of the original scene as possible.

As with geometric restoration procedures, the nature of noise correction required in any given situation depends upon whether the noise is systematic (periodic), random, or some combination of the two. For example, multi-spectral scanners that sweep multiple scan lines simultaneously often produce data containing systematic striping or banding. This stems from variations in the response of the individual detectors used within each band. Such problems were particularly prevalent in the collection of early Landsat MSS data while the six detectors used for each band were carefully calibrated and matched prior to launch, the radiometric response of one or more tended to drift over time, resulting in relatively higher or lower values along every sixth line in the image data. In this case valid data are present in the detective lines but they must be normalized with respect to their neighboring observations. Several procedures have been developed to deal with this type of problem (Lillesand and Thomas, 1994).

Random noise problems in digital data are handled quite differently. This type of noise is characterized by non-systematic variations in gray levels from pixel to pixel called bit errors.

Bit errors are handled by recognizing that noise values normally change much more abruptly than true image values. Thus, noise can be identified by comparing each pixel in an image with its neighbors. If the difference between a given pixel value and its surrounding values exceeds an analyst-specified threshold, the pixel is assumed to contain noise. The noisy pixel value can then be replaced by the average of its neighboring values. Moving neighborhoods or windows of 3 x 3 or 5 x 5 pixels are typically used in such procedures. Figure 4.2.illustrates the concept of a moving window comprising a 3 x 3-pixel neighborhood and Figure 4.3 illustrates just one of many noise suppression algorithms using such a neighborhood.

4.3. Image Classification

Image classification is the process of assigning pixels (multi-spectral data from satellite image) to the desired land use classes (Campbell, 1996). Normally, multi-spectral data are used to perform the classification and, indeed, the spectral pattern present within the data for each pixel is used as the numerical basis for categorization. That is, different feature types manifest different combinations of DNs based on their inherent spectral reflectance and emission properties. In this light, a spectral "pattern" is not at all geometric in character.

Several classification routines exist for the classification of multi-spectral imagery including maximum likelihood, minimum distance, and spectral angle mapping classifiers. The classification routines fall into three main categories; distance Based, probability based, and angular based decision rules.

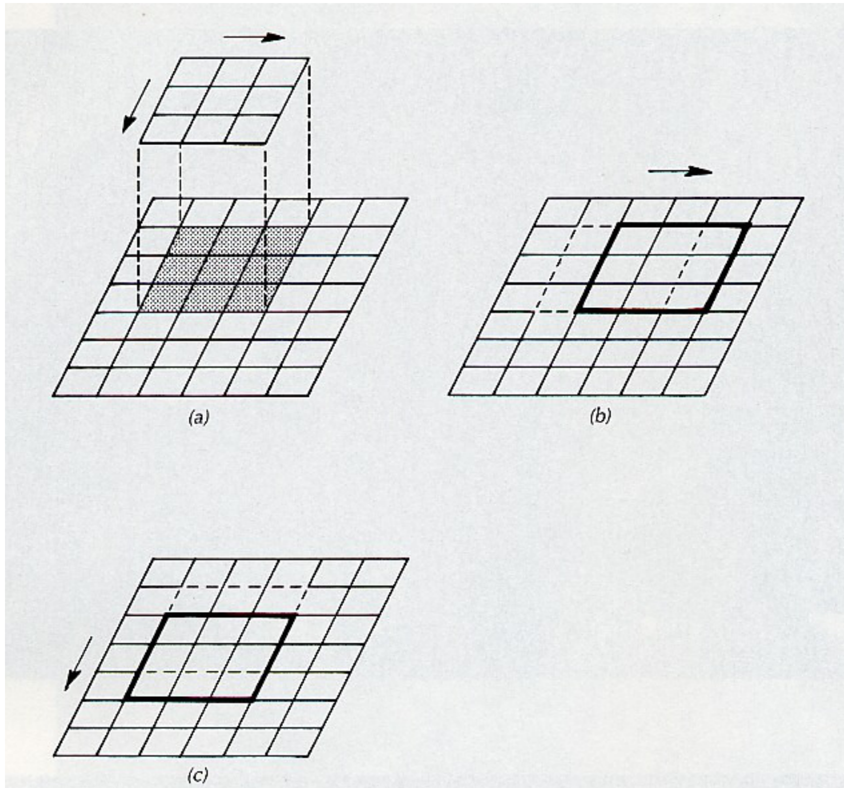


Figure 4.2: The moving window concept: (a) projection of 3x3 window in the image being processed; (b) movement of window along a line from pixel to pixel; (c) movement of window from line to line (Adopted from Schowengerdt, 1983)

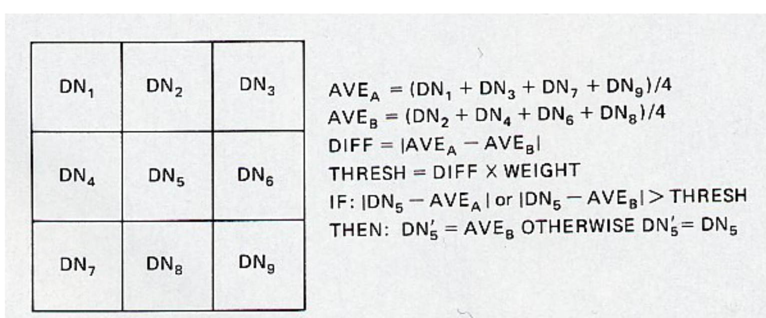


Figure 4.3: Typical noise correction algorithm employing a 3x3 pixel neighborhood. (Lillesand and Thomas, 1994).

New classification routines or, more commonly, modifications to existing classification routines are frequently reported in the literature, an indication that there is no one ideal classification routine to suit all needs and requirements (Kaminsky et al., 1997, Murai and Omatu, 1997, Cortijo and Perez de la Blanca, 1998, Cihlar et al., 1998, Erol and Akdeniz, 1998, Kartikeyan et al., 1998).

Each classification routine consists of a series of trade offs regarding processing time, model complexity, and classification accuracy. The decision regarding the most suitable classification technique is made on a case by case basis with factors such as spectral seperability, number of classes to be identified, processing time and model complexity each playing a role in the decision process.

Following sections will emphasize spectrally oriented classification procedures for land cover mapping. First, supervised classification where the image analyst "supervises" the pixel categorization process by specifying, to the computer algorithm, numerical descriptors of the various land cover types present in a scene. Second, unsupervised classification where the image data are first classified by aggregating them into the natural spectral groupings, or clusters, present in the scene. Then the image analyst determines the land cover identity of these spectral groups by comparing the classified image data to ground reference data.

4.3.1. Supervised Classification

Supervised classification is the process of using samples of known identity (training data) to classify the unknown identity. Knowledge of data and the desired classes is required prior to the classification process and must be obtained from ground truths, aerial photos or maps.

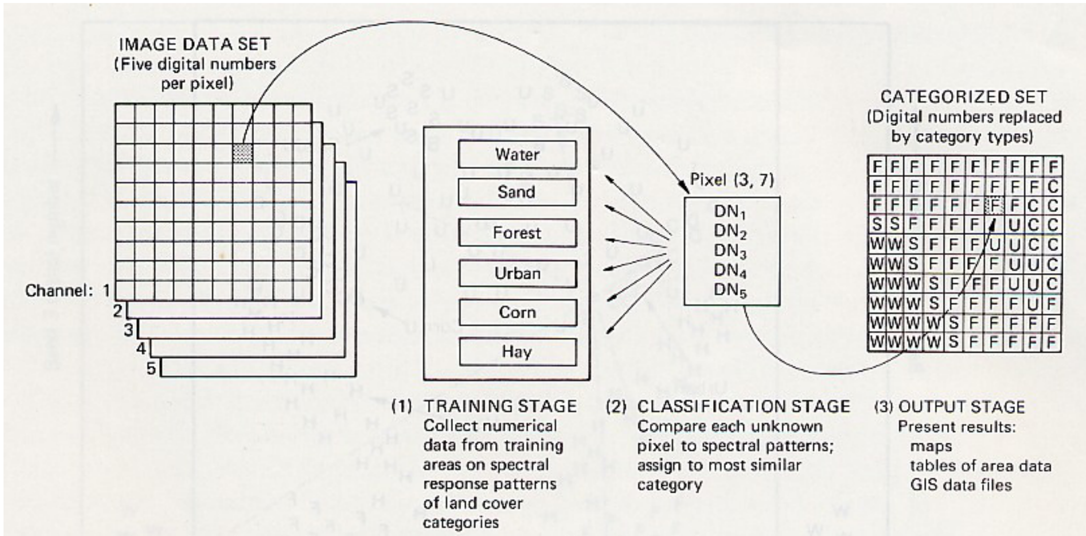


Figure 4.4: Basic steps in supervised classification (Lillesand and Thomas, 1994).

Figure 4.4 summarizes the three basic steps involved in a typical supervised classification procedure. In the training stage (1), the analyst identifies representative training areas and develops a numerical description of the spectral attributes of each land cover type of interest in the scene. Next, in the classification stage (2), each pixel in the image data set is categorized into the land cover class it most closely resembles. If the pixel is insufficiently similar to any training data set, it is usually labeled "unknown." The category label assigned to each pixel in this process is then recorded in the corresponding cell of an interpreted data set. Thus, the multidimensional image matrix is used to develop a corresponding matrix of interpreted land cover category types. After the entire data set has been categorized, the results are presented in the output stage (3). Being digital in character, the results may be used in a number of different ways.

There are several classification algorithms applied in supervised classification which include parallelepiped, minimum distance, mahalanobis distance, maximum likelihood and non-parametric (ERDAS, 1997). The most common and well-known supervised classification uses the maximum likelihood technique which employs a decision rule based on the probability (Bayesian probability theory) that pixels belong to a particular class (Campbell,1996). Some of the most common classification strategies will be in the following sections.

4.3.1.1. Minimum-Distance- to-Means Classifier

Figure 4.5 illustrates one of the simpler classification strategies that may be used. It is mainly based on simple Euclidean distance. The mean value for each class is calculated and the unclassified pixel is evaluated against these mean values. The unclassified pixel is compared to the mean value of each class and assigned class membership based on the closest mean class value, or minimum distance.

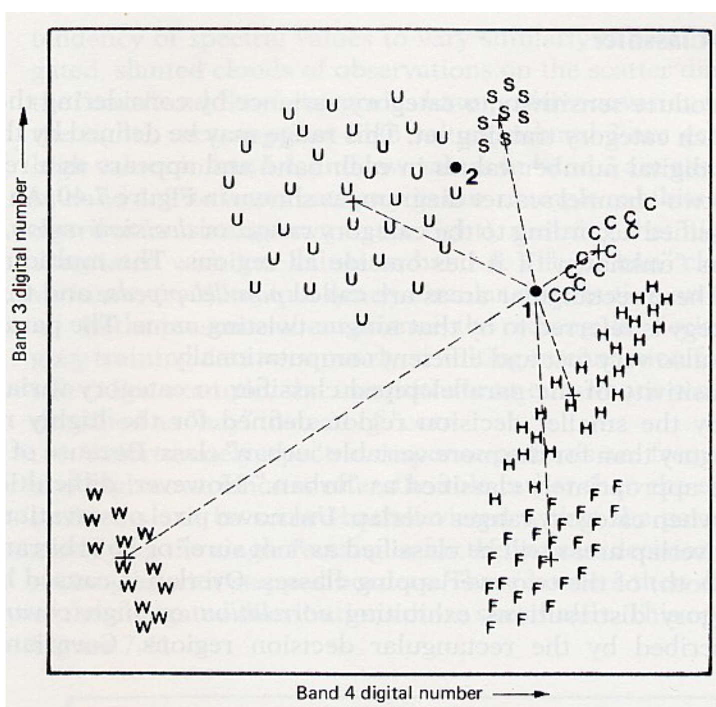


Figure 4.5: Minimum distance to means classification strategy.

4.3.1.2. Mahalanobis Classifier

The Mahalanobis classification Strategy bridges the gap between simple Euclidean distance classification and probability based maximum likelihood classification routines. The Mahalanobis classification decision rule uses minimum distance as the main method of classification but also incorporates a directional weighting component derived from the covariance matrix based on a class average (Richards and Jia, 1999).

4.3.1.3. Gaussian Maximum Likelihood Classifier

The maximum likelihood classification routine is generally regarded as a standard to which other classification routines are compared. The maximum likelihood classification routine is based on statistical probabilities. An unknown pixel is compared to training sites statistically and assigned to class membership based on probability theory. The maximum likelihood decision rule incorporates statistical measures and probabilities utilizing the covariance matrix to assign unclassified pixels to class membership. Figure 4.6 shows the ellipsoidal “equi-probability contours” that are used as a decision regions. In order to sufficiently train the classifier a significantly large number of training pixels must be utilized to accurately estimate the covariance matrix. The classification accuracy for maximum likelihood classification routines depends heavily on the accurate estimation of the covariance matrix (Sohn and Rebello, 2002).

4.4. Unsupervised Classification

Unsupervised classification, sometimes referred to as clustering, uses the identification of natural groups, or clusters present in the multi-spectral image without prior knowledge of data. This classification technique does not use training data as the basis of classification. The pixels with similar spectral characteristics are grouped into unique clusters according to some statistically determined criteria (Jensen, 1996).

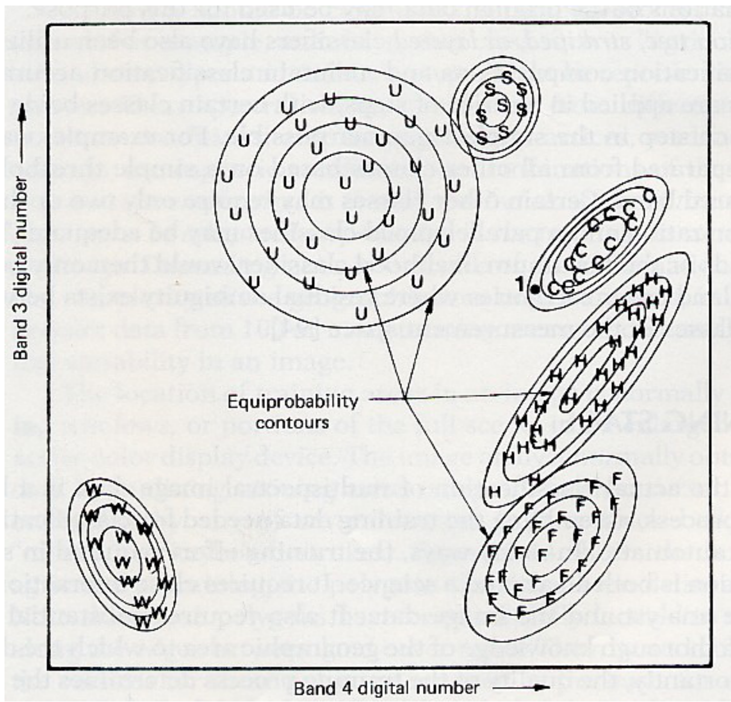


Figure 4.6: Equiprobability contours defined by a maximum likelihood classifier.

There are numerous clustering algorithms that can be used to determine the natural spectral groupings present in a data set. One of clustering methods used in unsupervised analysis is ISODATA which stands for Iterative Self-Organizing Data Analysis Technique. ERDAS (1997) explained the ISODATA clustering method as “it uses spectral distance as in the sequential method, but iteratively classifies the pixels, redefines the criteria for each class, and classifies again, so that the spectral distance patterns in the data gradually emerge."

The basic idea of the algorithm is to accept from the analyst the number of clusters to be located in the data. The algorithm then arbitrarily "seeds," or locates, that number of cluster centers in the multidimensional measurement space. Each pixel in the image is then assigned to the cluster whose arbitrary mean vector is closest. After all pixels have been classified in this manner, revised mean vectors for each of the clusters are computed. The revised means are then used as the basis to reclassify the image data. The procedure continues until there is no significant change in the location of class mean vectors between successive iterations of the algorithm. Once this point is reached, the analyst determines the land cover identity of each spectral class.

4.5. Hybrid Classification

In order to minimize the drawbacks and maximize the advantages of supervised and unsupervised classifications, most analysts select a hybrid approach. A hybrid classification is any combination of supervised and unsupervised classifications (Campbell, 1996). One example of using hybrid approach is to perform unsupervised classification on the data and then evaluate these cluster data with reference data (field survey, aerial photographs or maps). Some cluster data might be subdivided or combined before the analysts label these cluster data. Then these cluster data can be used in a final supervised classification (Schowengerdt, 1997).

The soft classification algorithms, also known as fuzzy logic uses heterogeneous and imprecise nature of the real world approach to assign, which a pixel belongs to each of the class. The traditional classifiers label each pixel as a single discrete class such as forest or water. Fuzzy classifiers permit partial memberships by assign a pixel a membership grade. This takes into account that the pixel may not be the property assigned to a single discrete class. The membership grades typical vary from 0 to 1 (non-membership to full membership). For example, fuzzy classifiers assign a membership grade of 0.3 for water and 0.7 for forest. Analysts can adjust the degree of fuzziness in their classification (Campbell, 1996; and Jensen, 1996).

4.6. Image Classification in an Integrated GIS/RS Environment

In an integrated GIS/RS environment, ancillary data can be used to modify and supervise image analysis operations. GISs are rich in attribute data and topological information. Attribute information stored in a database can be queried by means of a Database Management System (DBMS) which most Digital Image Analysis Systems (DIASs) do not provide. Ancillary information held in a GIS serves as knowledge base. Similar to traditional approaches, the ancillary data stored in a GIS can be used before, during, or after image classification, or in some combination of these. The type of ancillary information used and how and at what stage of the classification it is employed is determined by the analyst depending on the integrated data analysis capabilities of the system and on the specific application.

(a) **Before classification**. The ancillary information stored in GIS can stratify the imagery prior to a classification. The stratification can be performed more efficiently and easily with multiple attributes stored in the database.

Image segmentation is another potential use of ancillary information before image classification. Image segmentation can be performed for several purposes. One purpose is to define the areas of interest within the images using digital map data and perform the classification operation within this area only. By segmenting the image into homogeneous fields and performing the classification on these segments, the classification accuracy can be increased (Belaid et al., 1992; Wooding, 1984).

The other use of ancillary information would be in the selection of training samples. Maps provide information on specific object boundaries and on objects which cannot be determined from imagery alone. Therefore, the object boundaries displayed in superimposition with the imagery and, the attributes associated with the objects would be a perfect guide in collecting the training samples. This would be particularly important for inexperienced users. Several studies have employed ancillary information prior to image classification such as Wooding (1984), Janssen et al. (1990), Belaid et al. (1992), and Ban and Howarth (1996).

(b) **During classification.** During image classification, ancillary data held in a GIS serve as a knowledge base to supplement the image statistics. The apriori probabilities can be defined more efficiently from ancillary data stored in a GIS. If, for example, a priori probabilities based on the areas of known land cover classes are to be defined, the areas of land cover classes can be obtained from the database and the apriori probabilities can be computed using them. Ancillary information has been utilized by several researchers during image classification (Janssen and Middelkoop , 1992; Bedard et al. , 1992, and Kam, 1995).

(c) **After classification.** As in the traditional approach, ancillary information held in a GIS can also be used in post-classification sorting. The other potential benefit of GIS/RS integration after classification can be observed in the accuracy assessment of classification. The percentages of classified pixels computed within each vector polygon can be stored in the database as new attributes (Brown and Manore, 1989).

4.7. Classification Accuracy Assessment

Classification accuracy assessment is accomplished through comparison of the resulting classification maps with reference data. The confusion matrix has been identified as a best practice standard for assessing overall accuracy as well as identifying errors of omission and commission (Foody, 2002).

The confusion matrix, or error matrix, is a representation of classification accuracy with the rows representing the findings of the classification and the columns containing the reference data. The error matrix, if all goes well, is read down the diagonal: the column and row totals for each class should match identically, if not, a classification error exists. This method allows for the identification of both errors of inclusion (commission errors) and errors of exclusion (omission errors). Figure 4.7 shows a sample of the error matrix resulting from classifying training set pixels.

Ground Truth (Known Types)

Classification Results

	A	B	C	D	E	
A	100	0	0	0	0	100
B	0	76	0	3	0	79
C	0	20	90	2	0	112
D	0	4	0	95	0	99
E	0	0	10	0	100	110
	100	100	100	100	100	

Figure 4.7: confusion matrix Sample

There is one commonly used measure of the overall accuracy of a classification. This is called the Kappa coefficient ($\hat{k}$). It also can be defined in terms of the confusion matrix.

$$\hat{k} = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+} \cdot x_{+i})}{N^2 - \sum_{i=1}^{r}(x_{i+} \cdot x_{+i})}$$

Where r is the number of number of rows in the matrix, x_{ij} is the number of observations in row i, and column j and x_{i+} and x_{+i} are the marginal totals for row i and column i, respectively and N is the total number of observations. The Kappa coefficient, unlike the overall accuracy, includes errors of omission and commission. Computation of the Kappa coefficient may be used to determine whether the results in the error matrix are significantly better than a random result ($\hat{k}$ = 0) or to compare if two similar matrices are significantly different (Foody, 2002).

4.7.1. Number of Training Pixels Required

Sufficient training samples must be provided to allow reasonable estimates of the elements of the mean vector and the covariance matrix to be determined. For an N-dimensional multi-spectral space at least N+1 samples are required to avoid the covariance matrix from being Singular. While it can be generally stated that the more training pixels the better, it is important to have as many training pixels as possible because as the dimensionality of the pixel vector increases (e.g. more bands) there is a greater chance that some individual dimensions are poorly represented. Swain and Davis (1978) recommend a practical minimum that 10N samples per spectral class be obtained with 100N being desirable if possible.

4.7.2. Number of Test Pixels Required

Determining the actual number of pixels on the ground that need to be sampled to assess the accuracy of individual categories in classification maps is difficult to theoretically determine (Campbell, 1987). Most approaches aimed at determining the number of test pixel required are based on the binominal distribution or a normal approximation to the binomial distribution. The probability of x pixels, being correct in a random sample of n pixels drawn from a class with an accuracy of θ, is given by the binominal probability.

$P(x;n,\theta) = nC_x \theta^x (1-\theta)^{n-x}$ where x =0,1,…,n

θ is the map accuracy for a class.

Van Genderen et al. (1978) determined the minimum sample size by considering that if the number of samples is too small there will be a finite chance all the pixels could be labeled correctly which would result in an unreliable estimate of map accuracy. Such a situation occurs where x=n giving the probability that all pixels are correct.

$P(n;n,\theta) = \theta^n$

They have noted that p(n;n,0) is unacceptably high if it is greater than 0.05 or more than 5% of the time there is the chance of selecting a perfect sample from the population with an accuracy of θ.

Rosenfield et al. (1982) have studied the number of test pixels required. They recommend that the number of test pixels in each class to be large enough to ensure that the sample proportion (the number of correct classifications in that class/ number of test pixels in that class) is within 10% of the population proportion (p) or the classification accuracy for the class under consideration) at a 95% confidence level. This number can be determined using the following formula (Fitzpatrick-Lins, 1981).

$$N = \frac{Z^2 pq}{E^2}$$

Where N is the number of samples, p is the population proportion of the class, q is 100- p , E is the allowable error, and Z equals 1.96 for the 95% two-sided confidence level. Thus, in the worst case, where p = q = 0.50 and using E =10%; the sample size required in each class is approximately 100.

CHAPTER 5 THE HYBRID FRAMEWORK

This chapter describes the steps required to develop the hybrid decision support framework. The scope and the end users of the framework are presented. The systems used in the framework development are described. The architecture of the proposed framework is given in details.

5.1. Introduction

The basic concept of the proposed framework is to develop a hierarchal decision-tree structure according to the user objectives to include impacts to the natural and the anthropogenic environment from transport projects. This underlying mathematic structure of the model allows for maximum flexibility in the selection of criteria that the Decision Makers (DMs) want to include in the evaluation. DMs might be individuals such as transportion planners and designers, or public entities such as the Department of Transportation (DOT). Moreover, image processing techniques of the satellite images will be used to acquire the historical environmental data and reconstruction of the missing data. Also, a standard analysis approach based on the integration between GIS and the remote sensed data is formalized. Finally, the appropriate analysis to support the decision of the decision-makers will be made to allow them to present these data to the public hearings in a simple manner.

The methodological framework could be applied both to urban and inter-urban projects, regardless of transport mode, as well as to the development of terminals. On physical scale, it is appropriate for project referring to a section, a corridor, or a network. In addition, the project can be extended over several regions in different areas or countries. Alternatives can be considered both at the scheme (conception) level and at project level. Moreover, the methodology handles environmental impacts at any level of detail in the natural and social environment.

5.2. Systems Used

Two GIS software programs- ARC/INFO developed by the Environmental Systems Research Institute in Redlands, California, and ERDAS developed by Earth Resources Data Analysis Systems, Inc. of Atlanta, Georgia- were used extensively in the development of the spatial decision support framework. The ARC/INFO software was used in the manipulation, analysis, and modeling of spatial and non-spatial data. ERDAS was used primarily in the classification and processing of land use and land cover data. Morehouse (1992) and Maguire (1992) present comprehensive overviews and profiles of ARC/INFO and ERDAS software, respectively.

Summarily, the ARC/INFO software uses a hybrid vector data model to manage both locational and thematic data. Locational data are represented in ARC using a topological data model, while thematic data in INFO are represented by a relational data model. The data model consists of a geo-relational model that combines a specialized geographic view of the data with a conventional relational database model structure. Within ARC, a set of unique spatial operators facilitate data analysis. These operators include coverage operators for point, line, and polygon overlays; spatial interpolation using conventional techniques and geo-statistics; map projection and coordinate transformation; and Boolean operations and logical combinations of attribute data (Morehouse, 1992).

The ERDAS software is an image processing and geographic data analysis program that supports some basic GIS functions such as data capture, data manipulation and analysis, and data display (Maguire, 1992). The software program is based on the raster data structure that tessellates geographic space into regular square cells or pixels.

Generally, ERDAS is organized into several modules that support basic functions such as input/output processing, multivariate image processing and analysis, raster-based modeling, 2.5-D and 3-D topographic modeling, and other specialized modules for software development and analysis of attribute databases (Maguire, 1992).

5.3. The Hybrid Decision Support Framework

Figure 5.1 illustrates the general architecture of the proposed framework. The system can be presented by five main processes. The first process is the problem structuring, which is constructing a decision tree from the environmental factors of the problem. The second process is the data analysis, which contains the collection, analysis, logical organization and representation of the relevant data on the territory under examination. This process is required to perform the following operations: treatment of historical data; reconstruction of missing data; territorial aggregation and desegregations of the data accordance with the hierarchies; and selection of zones following criteria indicated by the user. The third process is the Criteria weighting, which is defining how the criteria and geographical regions are weighted against each other in the evaluation phase. For the measurements of criteria-related weights, the proposed framework employs the pair-wise comparison, which is the most efficient weighting method, well-established, with a good record of practicality, operational efficiency and reliability, as well as acceptance by the DM; in terms of being short, easy to understand (Saaty, 1980). The fourth process is the impact estimation phase, which utilize the GIS based map overlay and buffer functions to integrate the merits of the map overlay method and the matrix method. The fifth process is development of the distribution maps for the road impact, which represent the road impact range on the environment. The last phase is the decision analysis phase, which is performing the overlay analysis to select the best alternative. Following sections will discuss these processes in detail.

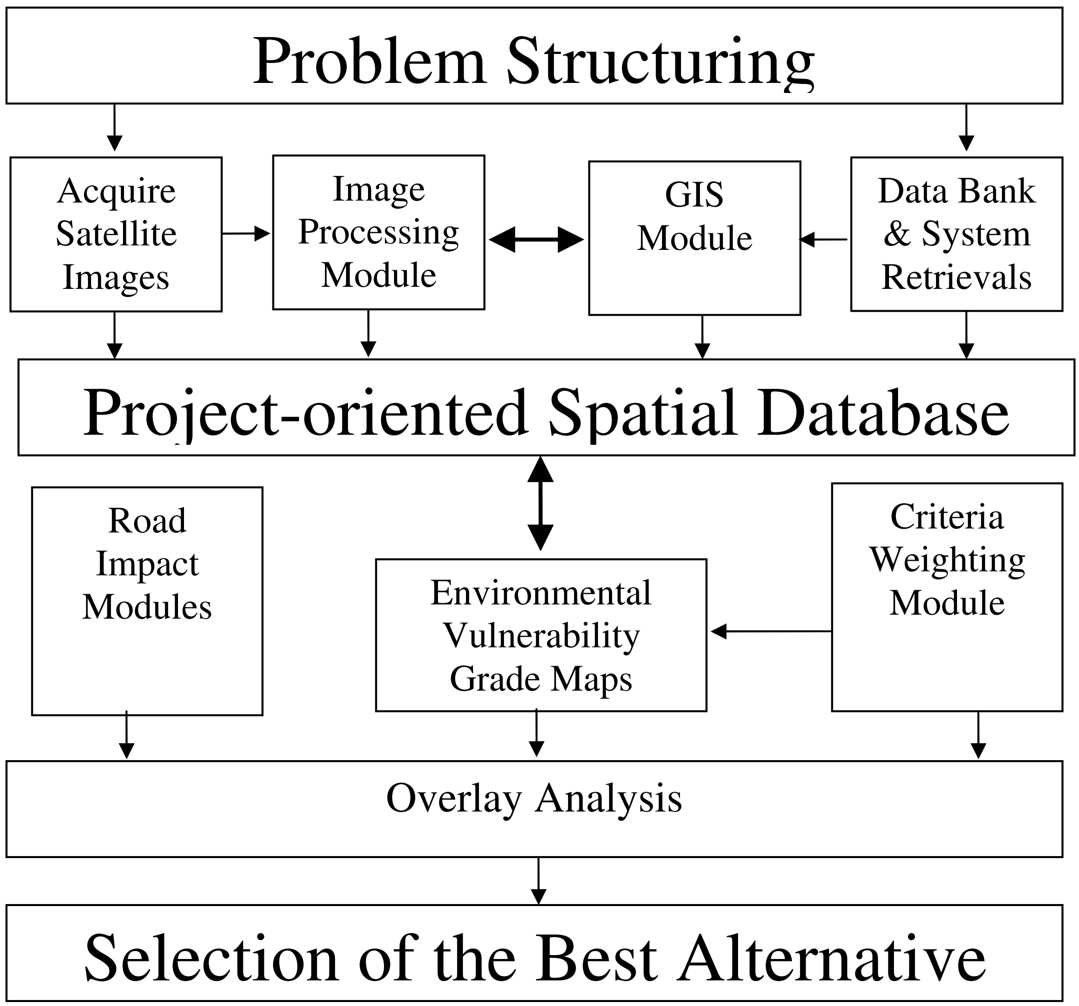


Figure 5.1: General Architecture of the proposed Framework

5.4. Problem Structuring

In this phase the environmental assessment problem will be defined a decision-tree, comprising the environmental and monetary issues consisting of (a) the objectives, (b) the evaluation criteria and (c) how the criteria are combined to meet the objectives.

The ‘objectives’ usually require specifying the goal and the options of the evaluation. Such options can be alternative policies, plans, or projects that extend over a certain geographical region. The main goal of the evaluation is to rank the options. This variation of options over space allows the user to follow a network approach: projects can be broken down to nodes and links and evaluated according to the geographical regions they are located in.

Depending on the objectives, a different set of ‘Criteria’ may be used. Since the criteria are the elements forming a decision, and each criterion requires one or more indicators for its description. The evaluation and ranking of alternative transport options requires the construction of a hierarchy of several sub-criteria which when combined together produce the score of a given option, according to the super-criterion they are related to in the hierarchy. In this manner, any number of criteria groupings, which in turn are grouped into other super-criteria can be formed.

In the proposed Framework, the user, according to her/his objectives can define the form of the hierarchy. An initial set of environmental factors that can be used as framework variants in the hierarchy includes impacts to the natural and the anthropogenic environment from the construction and operation of transport projects of all modes. The formulation of these environmental factors into a decision-tree is shown in figure 5.2.

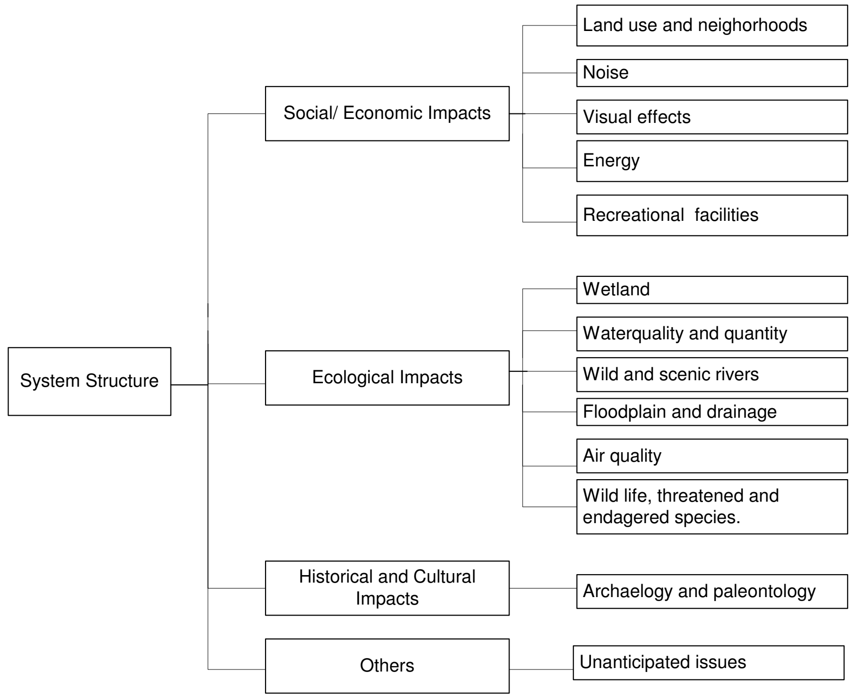


Figure 5.2: Formulation of Environmental Factors into a Decision-Tree

The underlying mathematic structure of the model allows for maximum flexibility in the selection of criteria that the DM wants to include in the evaluation. In constructing such a decision-tree, the following are important:

- Criteria should be able to cope with different modes, countries and type of investments (private/public or both). If necessary, non-technical criteria, such as political and/or ethical should be used.
- The level of aggregation of impacts, at which the approach is typically required to work, should also be taken into account, with the possible introduction of sub-criteria, such as 'public acceptance'. Such sub-criteria should assume a non-zero weight only when further disaggregating is necessary.

5.5. Data Analysis

As shown in Figure 5.1, Data Analysis process can be presented by four sub-processes. The sub-processes , Data Bank & System Retrievals, GIS Module , Acquiring Satellite Images, and Image Processing Module, are presented in details in the following sections.

5.5.1. Data Bank & System Retrievals

The environment is highly variable in time and space. For this reason, and because available environmental data are often widely scattered, incomplete, and incompatible, the selection of data sets is a difficult but not impossible task. Data collection can be very expensive given the large amounts of data required for the Environmental Impact Assessment (EIA) process. The state-of-the-practice applications use the data banks and retrieval systems to speed up the impact assessment process by optimizing the use of existing data and by helping to eliminate wasteful redundancy.

The Florida Geographic Data Library (FGDL) , which is warehoused and maintained at the University of Florida's Geo-Facilities Planning and Information Research Center (GeoPlan), was selected as a mechanism for distributing aerial photographs and spatial (GIS) data throughout the state of Florida. The main reason for choosing it is that this system has been designed carefully and well managed, as well as the fast track of the updating procedure.

5.5.2. GIS Module

Considering the limitations of Data Bank & System Retrievals, such as the hidden traps within such a system due to the changes of equipment, sitting, etc. and data gaps and incompatibilities amongst systems, the proposed framework utilizes the GIS platform to fuse all the required data sets available at the outset of an impact assessment. All GIS collected layers have to be re-projected to the same geographic reference to establish an implicit spatial-correspondence relationship between themselves, which facilitates subsequent data processing and analysis. The Florida Coordinate Systems in which map distortion has been minimized by dividing the state into three zones must, by state law used for surveying and the completion of engineering maps (SOF, 2001). For that reason, the Florida-based (FGDL) Albers Equal Area projection was selected as a base projection.

5.5.3. Acquiring Satellite Images

If there is any missing part of the data, which is the case in most, if not all, of the projects, the satellite remote sensing images will be used to collect the supplementary data. Dozens of remote sensing satellites are be circling the Earth, each acquiring a very specific type of imagery. Remote sensing offers the opportunity to study a relatively large region on the Earth by a single image. In addition, satellite remote sensing analysis systems offer efficient and environmentally friendly non-destructive techniques.

IKONOS data, space Imagining, Inc, were selected as the major data source for the analysis for this research. This selection was based on several factors. As, a site-specific EIS, the spatial details have to be high enough. The IKONOS data is relatively high and provide large coverage. The available revisit frequency for collection areas near the equator for an image collected at a ground-sample distance of 1 m in the panchromatic and 4 m in the multi-spectral bands, is every 3.9 days. They provide five spectral bands with wavelengths between 0.5-0.9 micrometers, with a resolution 4*4 meters plus a panchromatic band with a resolution of 1*1 meter.

5.5.4. Image Processing Module

A fact that is not widely known is that the IKONOS applies different preprocessing and image enhancement modules to increase the reliability of the results and test images with varying spectral content. These lead to having too low estimated noise and almost free radiometric effects (Gerlach, 2000).

5.5.4.1. Image Rectification and Restoration

In order to project the data onto a plane and make it conform to the base map projection system, the following steps will be involved. Image-to-image Rectification: In rectifying, some basic steps are used; Record Ground Control Points (GCPs), Compute Transformation matrix, then resample the image. Before starting these steps, it is important that the reference map has a scale similar to the scale at which the image data is considered useful (Richard, 1986); otherwise the control point pairs may be difficult to establish. Then the process starts by selecting and recording the GCPs.

The number of GCPs to be used depended mainly on the cartographic data accuracy: more GCPs than the minimum required reduced the error propagation in the least-squares block bundle adjustment. In addition, GCPs chosed, it has to be points that are easily identifiable in both Images, such as road intersections and land marks. Next, the transformation matrix which contains the coefficients for transforming the reference coordinates system to the input coordinate system. It is recommended to employ three different order polynomial transformation equations (first, second and third order) in order to determine an acceptable RMS error. Then, Re-sample the image to calculate the values for the rectified image. The nearest neighbor re-sampling is recommended algorithm because it uses only the original pixel brightness. One way to verify that the input image has been correctly rectified to the reference image is to display the re-samples image and the reference image and then visually check that they conform to each other.

5.5.4.2. Image Classification

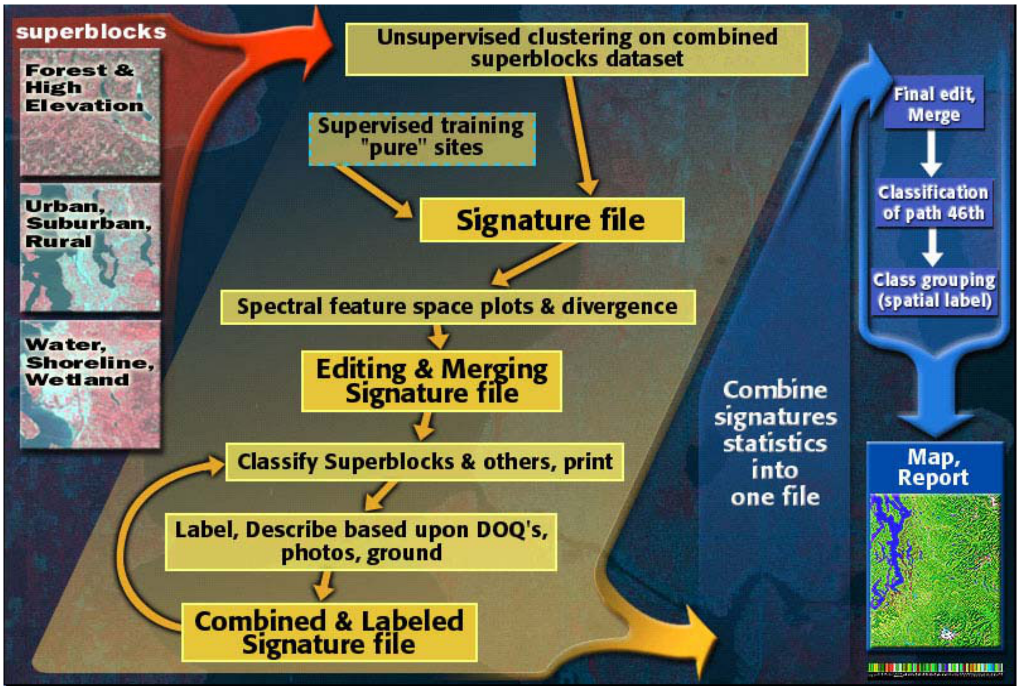


Figure 5.3: The classification process of the Satellite images

The strengths of both the unsupervised and supervised classification approaches are used to derive Land Use/Land Cover of the proposed area of study. Figure 5.3 illustrated the proposed classification process. Unsupervised classification is used to extract the super-block clusters based on natural groupings of spectral data. The area of interest (AOI) was used in each class in an unsupervised classification process using the ISODATA algorithm. The ISODATA procedure creates a signature file for each class that contains more than one sub-class. Also, the supervised classification utilizes priori knowledge from different available sources such as aerial photos, ground truth data or maps to train and extract information from the multi-spectral image.

After creating the initial signature file for the classification categories, these signature files should be evaluated using the "image alarm" command or the contingency matrix in the ERDAS software in order to determine how well the signature in each class would perform for the classification. When the signature is satisfactory, all sub-classes of each signature classes are employed in the next step of classification.

After creating the signature files, the well-known conventional classification algorithm, maximum likelihood decision rule, will be used to classify the images from the parametric signature files. Finally, the classified images were smoothed with a 3x3-majority rule filter. This filter eliminates noise in the classification process and increases the accuracy of the classification (Stiteler, 1995).

5.5.5. Accuracy Assessment

It is necessary to perform accuracy assessment of Land Use/ Land Cover over classification derived from remotely sensed data. Accuracy assessment determines the quality and reliability of information (Congalton and Green, 1999; Stehman, 1996). This is an organized way of comparing the classification with ground truth data, previously tested maps, aerial photos, or other data. This can be done in ERDAS Imagine Accuracy Assessment sub-module by generating random check points throughout the classified image. After the points are generated, the class values for these points, which are the reference points, must be entered. These reference values are compared to the class values of the classified image. To perform a proper accuracy assessment, 250 or more random points have to be generated (ERDAS, 1997).

5.6. Criteria Weighting Module

A novel aspect of the proposed Framework is that it incorporates the spatial variation of impacts by introducing a network approach. This means that evaluation of transportation infrastructures is not limited to a single project or corridor but it can encompass an entire network extending over many different regions or even countries. To accomplish this, the framework employs two sets of: Internal weights: Regional (spatial) weights within the same criteria, Criteria related weights. To determine the weights, one or a combination of the following methods can be used:

1. Direct specification by the DMs,
2. Specification by a panel of experts, (e.g., Delphi technique),
3. By pair-wise comparisons (Yager 1977, Saaty, 1980).

For the measurement of criteria-related weights, the Framework recommends the pair-wise comparison, which is the most efficient weighting method, well established, with a good record of practicality, operational efficiency and reliability, as well as acceptance by the DM; in terms of being short, easy to understand (Saaty, 1980).

The underlying principle is that it is more accurate to estimate the weights by comparing the factors in pairs according to their relative weights than by defining the weights of all factors simultaneously. Hence, when weights of the assessment factors are estimated with the eigenvector methods or the weighted least-square method (Chu et al. 1979), the relative weight of every two factors is compared to define the pair-wise comparison matrix as:

$$A = \lfloor a_{ij} \rfloor, i, j = 1,2,...,n \qquad a_{ij} \succ 0, a_{ij} = 1/a_{ji}, a_{ii} = 1$$

Where a_{ij} is the relative weight of the ith factor and the jth factor.

Pair-wise comparisons become impractical when the number of criteria is large, usually more than 10. Thus it is advisable to keep the number of criteria limited or to group criteria together and apply the method within and among groups of criteria. For the regional weights determination, the framework recommends a direct specification either by the DM or by an expert panel (Delphi method). Regional weights are used to incorporate into the evaluation the relative importance of different regional traversed affected by the proposed project. To accomplish it, a subdivision of the project into segments is required to represent different regions.

5.7. Environmental vulnerability grade map

Developing the Environmental vulnerability grade map for the project under consideration can be represented by the following set of activities:

1. Reclassifying the GIS layers and the classified maps according to the regional weights within the same criteria to develop a criteria vulnerability maps.
2. Rasterizing all the maps and GIS layers using the Spatial Analyst module, which is an extension module within the ArcInfo. The recommended output cell size for the layers is 1m, which is the optimum representation of the pan sharpened image and relatively good for the file sized when we perform the different analyses on the data.
3. Use the Spatial Modeler module to create a script model to combine the criteria vulnerability maps and the criteria related weights to develop the environmental vulnerability map. Figure 5.4 illustrates the concept of combining the criteria vulnerability maps and the criteria related weights to develop the environmental vulnerability map.

5.8. Distribution maps of road impact extent

The road impact on environment depends not only on the environmental vulnerability of the surroundings, but also on the road impact extent. The road impact extent beside the road should be considered to achieve more scientific environmental impact assessment and to select more reasonable optimal alignment. Reviewing the scattered literature indicates that some ecological effects of roads extend outward for >100 m and that the cumulative ecological effect of the road system in the United States is considerable. Two recent studies in the Netherlands and Massachusetts (USA) evaluated several "road-effect-zone" over which significant ecological effects extend outward from a road. The effects of all factors extended > 100 m from the road, and moose corridors, road avoidance by grassland birds, and perhaps road salt in a shallow reservoir extended out-wards > 1 km (Forman and Deblinger, 2000).

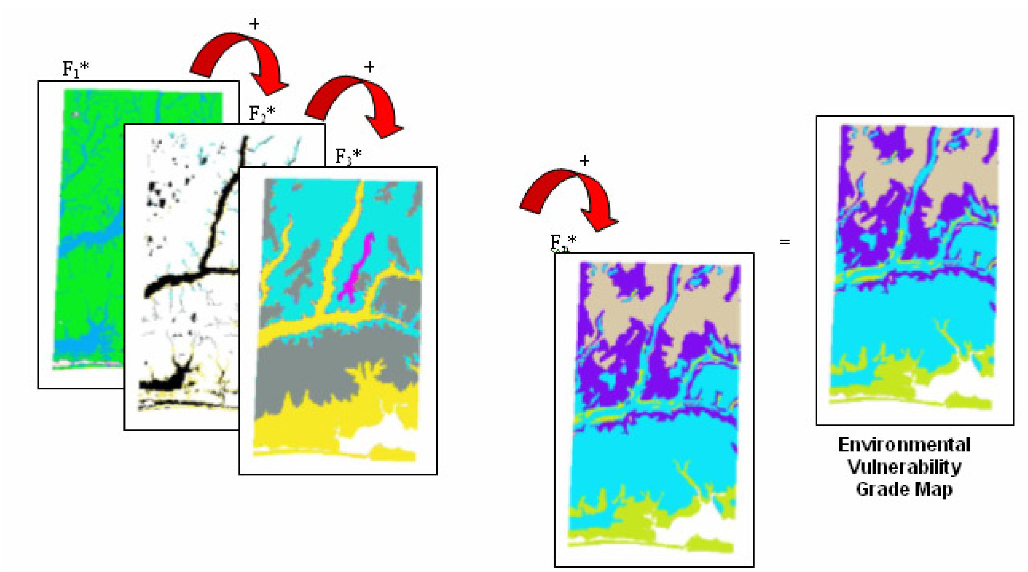


Figure 5.4: the concept of combining the criteria vulnerability maps and the criteria related weights to develop the environmental vulnerability map

Also, the state of the practice depends mainly on the mainly on the factors and the agency that performs the analysis. The framework proposed performing the analysis on four buffer distances from the centerline of the proposed alignment. These distances are 100, 200, 500, and 5280 feet (1Mile) respectively.

5.9. Selection of the best Alternative

The study area can be defined by the different alternatives under consideration for analysis. By analyzing the vulnerability of the road surroundings by analyzing the road impact extent on the surroundings, and with the overlay functions of GIS, the environmental vulnerability grade maps and the road extension limit of I are overlaid to calculate the assessment value E for alternatives as follows:

$$E_i = \sum_{j=1}^{m}\sum_{k=1}^{n}\alpha_{ij} \cdot A_{ijk} \cdot I_{ijk}\ ,\ \alpha_{ij} \in [o-1],\ V_{ijk} \in [0-100],\ I_{ijk} \in [0-1],$$

Where E_i is the assessment value of the ith alignment , m is the number of factors, α_{ij} is the weight of the jth factor, n is the number of cells within the assessment scope of the ith alignment for the jth factor after the overlay of the vulnerability grade maps and the road extension maps of I , A_{ijk} is the number of the Kth cells within the assessment scope of the ith alignment after the overlay, V_{ijk} is the value of V of the Kth cells within the assessment scope of the ith alignment for the jth factor after the overlay and the I_{ijk} is the relative probability between the different road extents within the assessment scope of the ith alignment for the jth factor after the overlay. The best alternative is the minimum value of E.

CHAPTER 6 THE HYBRID FRAMEWORK APPLICATIONS

This chapter describes the Framework application on case studies from transportation projects in the State of Florida to illustrate the use of the proposed framework.

6.1. Introduction

The literature includes three different methods for system validation. First, comparing the solutions provided by different systems that have been in use for many years, second, evaluating the results with solutions provided by domain experts. Last, which is widely used, is to compare the solution with the solutions of real-world cases. A combination between the second and the third method of validation is selected to evaluate the accuracy of the solutions provided by the proposed framework. The Panel of experts selected for providing the data and the validation proof was the Environmental Technical Advisory Team (ETAT), which is established by the State of Florida Department of Transportation (FDOT) for each FDOT district and consists of 12 to 20 representatives from agencies with statutory responsibility for approval and consultation on transportation projects. The ETAT advises the Metropolitan Planning Organizations (MPOs) and/or FDOT regarding the projects' compliance with agency regulatory and planning programs. After contacting the ETAT, only three projects were found to be active at this period so we can get in contact all the time with their members. These projects (Crestview bypass, Okaloosa; Willough Boulevard, Martin; and SR87 extension, Santa Rosa) were selected as case studies. The following sections will illustrate in details one of the case studies. Then, exploration and comments for the results of the three projects will be provided.

6.2. Description of the study area

This proposed roadway is located in northern Okaloosa County. This project will be a new roadway. The 2025 Cost Feasible Plan identifies this segment to be a 4-lane divided facility. The Crestview Bypass would provide important regional access with its connections to SR 85 and Interstate 10. This bypass will become an important inter-modal facility by providing improved connection between I-10 and Bob Sikes Airport and Industrial Park. Bob Sikes Airport has experienced strong gains in employment in aircraft-related and military support industries. In Traffic Analysis Zones adjacent to the corridor, population is anticipated to grow by 7,115 from 3,935 to 11,050, or 64.39 percent, between 1997 and 2020. Employment is projected to increase by 154 from 224 to 378, or 40.74 percent. The number of dwelling units is forecasted to rise by 2,728 from 1,501 to 4,229, or 64.51 percent. The planned roadway will maintain existing bicycle and sidewalk facilities in the corridor. The Transit Wave, operated by Okaloosa County Transit, provides public transportation in Crestview. Figure 6.1 shows the different three road alignment proposed for this project.

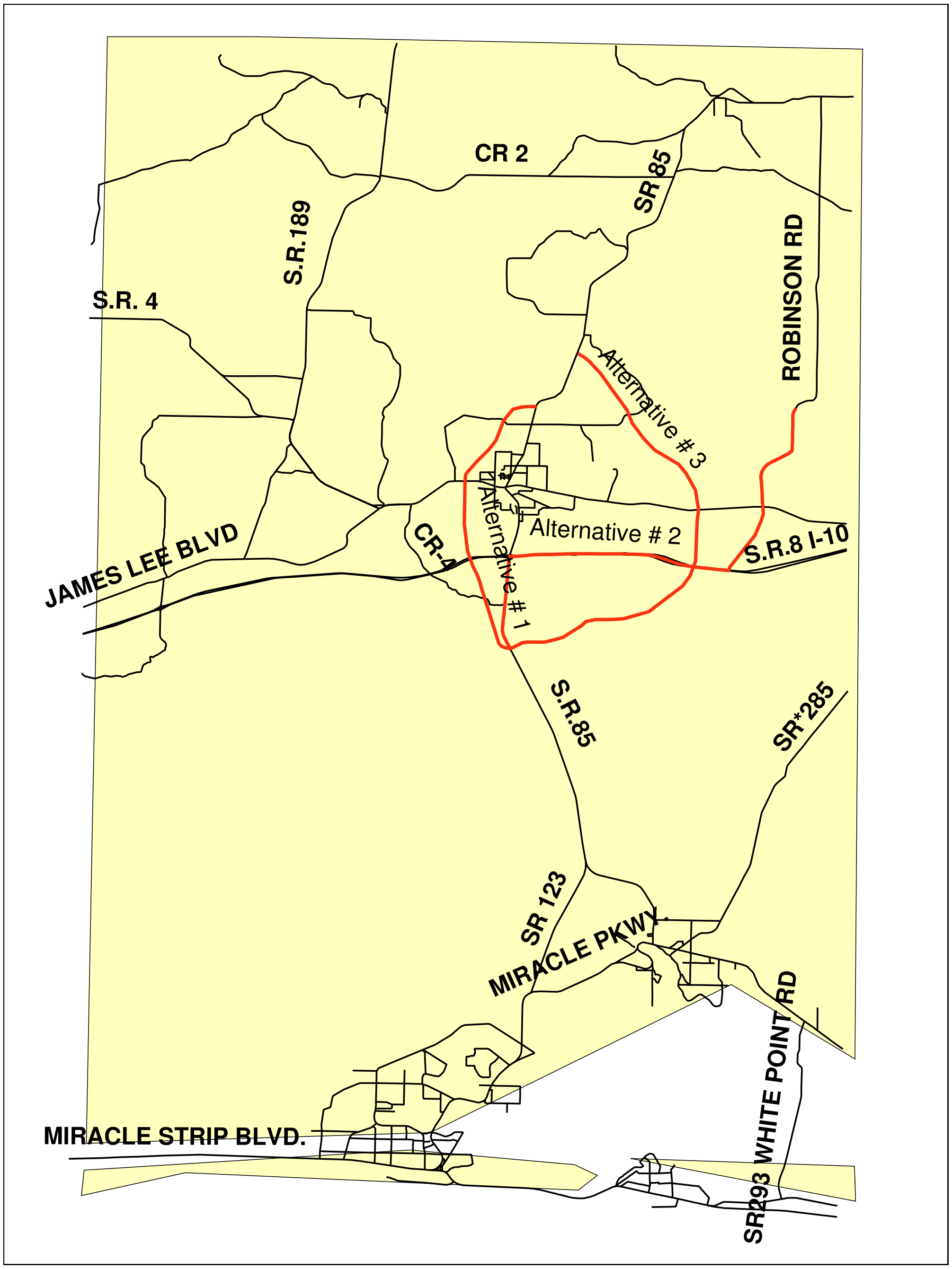


Figure 6.1: Crestview Bypass a Project Location Map

6.3. Problem Structuring

For the current project, In order to define the problem, the above three alternatives were examined. The general objective is the protection of the environment and minimization of negative impacts on the surrounding area. After consulting with the ETAT, The system structure of the assessment factors is defined as in Figure 6.2.

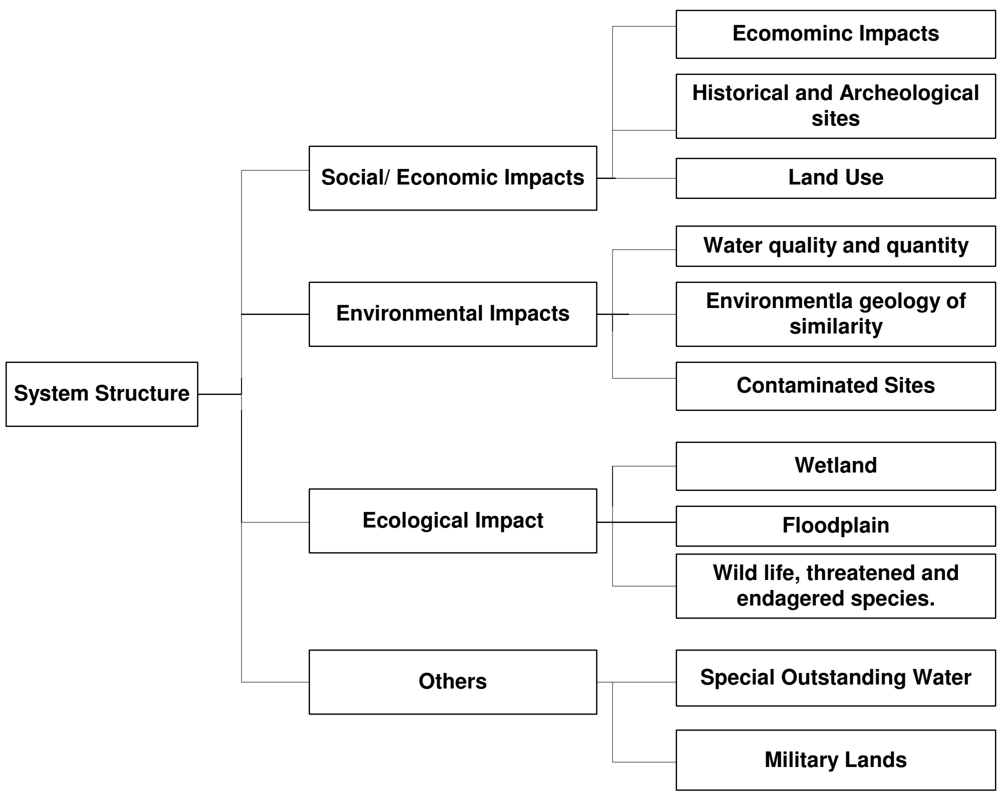


Figure 6.2: System Structure for the Crestview Bypass case

For the determination of the assessment factors, there are many factors that can be involved in the environmental impact assessment. After many trials between the ETAT members, the matrix method was used to relate various factors with the road behavior of construction and operation to reveal the road environmental impact in a selection table. Table 6.1 illustrates the assessment factors for the proposed project.

Table 6.1: the selected assessment factors for the proposed project

System Criterion	Assessment factor
Economic Impact	Population density
Historical and Archeological Sites	Historical and Archeological Sites
Land Use	The land cover and use of the land
Water quality and Quantity	The DRASTIC index for the surface and the aquifer systems
Environmental Geology of Similarity	The sediment type located 10 ft of the land surface
Contaminated Sites	The green project's ecological network model results
Wetland	wetland classification
Flood Plain	Federal Emergency Management Agency's(FEMA) Flood Insurance Rate Maps
Wildlife, threatened, and endangered species	Wild life zones
Special Outstanding Water	Special Outstanding Water
Military Land	Military Land

The degree of environmental protection of each option is expressed on an artificial scale of impact scores, which corresponds to a verbal description as shown in table 6.2. This artificial scale was from 0 for no impact up to 3 for strong negative impact. An artificial scale 100 was used for the regulatory conditions such as the road can't pass over a registered historical place.

Table 6.2: The degree of environmental protection of each option

Score	Verbal Description
100	Extreme Negative Impact
3	Strong Negative Impact
2	Moderate Negative Impact
1	Small Negative Impact
0	No Impact

This scale is used for rating each criterion and the overall alternative options. Then the importance of the criteria was specified on a scale defined, for example in this case, using gradations from 0 to 5 (Table 6.3). These values are used to generate the weights of the evaluation.

Table 6.3: The importance of the criteria

ID	Verbal Description	Value
1	Extreme Negative Impact	5
2	Strong Negative Impact	4
3	Large Negative Impact	3
4	Moderate Negative Impact	2
5	Small Negative Impact	1

6.4. Data Analysis

6.4.1. Data Bank & System Retrieval

As mentioned before, the Florida Geographic Data Library (FGDL) was selected as a mechanism for distributing aerial photographs and spatial (GIS) data throughout the state of Florida. The main reason for choosing it is that this system have been designed carefully and well managed, as well as, the fast track of the updating procedure. Table 6.4 shows the list of aerial photographs and spatial (GIS) data layers used for the proposed project.

Table 6.4: List of data layers required

Description	File Name	Type	Source	Update /New	Extent
2000 Census Blocks	CENBLK	Polygon	USCB	New	COUNTY
Digital Orthophoto Quarter Quads (DOQQ) - 1 meter	DOQQ1M	Image	USGS	Update	COUNTY
Digital Orthophoto Quarter Quads (DOQQ) - 3 meter	DOQQ3M	Image	USGS	New	COUNTY
Drastic Coverage for the Floridian Aquifer System	AQDRFL	Polygon	FDEP	-	COUNTY
Drastic Coverage for the Surficial Aquifer System	AQDRSU	Polygon	FDEP	-	COUNTY
Ecological Regions of Similarity	ECOREG	Polygon	FDEP	-	STATE
Environmental Geology of Florida.	ENVGEO	Polygon	FDEP	New	STATE
FEMA Flood Insurance Rate Maps 1996	FEMA96	Polygon	FEMA	-	COUNTY
Florida County Boundaries - Statewide	CNTBND	Polygon	USCB	Update	STATE
Florida Wildlife Management Areas	WLDMGT	Polygon	FMRI	New	STATE
Greenways Project: Ecological Network Model Results	GWECO	Raster	UF	-	STATE
Historic Bridges	SHPO_BRIDGES	Line	BAR	New	STATE
Historic Cemeteries	SHPO_CEMETERIES	Polygon	BAR	New	STATE
Historic Structure Locations	SHPO_STRUCTURES	Point	BAR	New	STATE
Major Roads	MAJRDS	Line	FDOT	Update	COUNTY
National Register of Historic Places	SHPO_NATL_REGISTER	Polygon	BAR	New	STATE
National Wetlands Inventory - Polygons	NWIP	Polygon	USFW	-	COUNTY
Outstanding Florida Waters	OUTWAT	Polygon	FDEP	New	STATE

Table 6.4 (cont.):

Description	File Name	Type	Source	Update /New	Extent
Pesticide Drastic Vulnerability Areas of the Floridian Aquifer System	AQPSFL	Polygon	FDEP	-	COUNTY
Pesticide Drastic Vulnerability Areas of the Surficial Aquifer System	AQPSSF	Polygon	FDEP	-	COUNTY
Special Outstanding Florida Waters	SPOWTR	Polygon	FDEP	-	STATE
Strategic Habitat and Conservation Areas 2000	SHCA	Polygon	FFWC C	New	STATE
USGS 1:250,000 Landuse/Land Cover from late 1970's /early 1980's	USGSLU	Polygon	USGS	-	COUNTY

6.4.2. GIS Module

Arc Info software was used as a GIS platform to prepare the data processing and preparation such as:

File Format Conversion: the software was used to convert the image data from the Geo Tiff format to the img format, which is the ERDAS IMAGINE format of the picture.

Re-projection: the gathered spatial (GIS) data layers are collected from different sources and they are projected with different projections. All data layers were re-projected to the same geographic reference to establish an implicit spatial-correspondence relationship between themselves, which facilitates subsequent data processing and analysis. Arc Toolbox module, as shown in Figure 6.3, was used to perform the re-projection to the Florida-based (FGDL) Albers Equal Area projection.

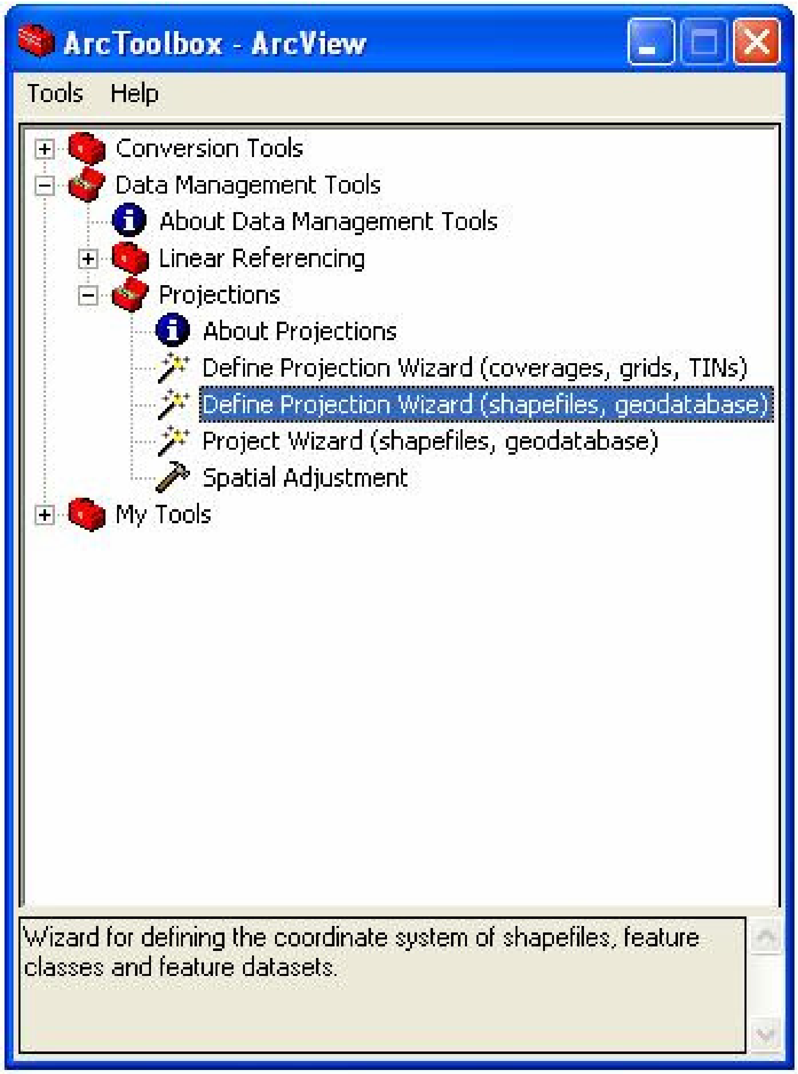


Figure 6.3: ArcTool box used for GIS layers re-projection

Area of Interest Clipping: The satellite image, aerial photographs, and spatial (GIS) data layers are covering different area extents. Arc Info sub-modules, such as the Geo-Processing tool shown in figure 6.4, was use to clip the area of internet that will be use for further analysis. The Area of Interest (AOI) was identified by the boundary limits of Okaloosa County. The actual AOI of the analysis are extending only 1 mile outside the proposed alternatives for the different alignment. The county limits were choose due to the indifference of the calculation time with the available hardware capabilities. For the clipping of the raster data, the spatial Analyst calculator was used to perform this operation.

Figure 6.4: GeoProcessing Wizard used for GIS layers clipping

6.4.3. Acquiring Satellite Images

IKONOS imaginary scenes, space Imagining, Inc, were selected as a data source for this proposed project. The IKONOS data is relatively high and provide large coverage. The available revisit frequency for collection areas near the equator for an image collected at a ground-sample distance of 1 m in the panchromatic and 4 m in the multi-spectral bands, is every 3.9 days. They provide five spectral bands with wavelengths between 0.5-0.9 micrometers, with a resolution 4*4 meters plus a panchromatic band with a resolution of 1*1 meter. The image was "Systematically corrected" which is radio-metrically and geometrically corrected using the satellite model and platform ephemeris information. Rotated and aligned to the user defined map projection. The current output is either UTM or state plane projected, with WGS 84, NAD 83, or NAD 27 datum, so the image has to be reprocessed to Florida-based (FGDL) Albers Equal Area projection.

6.4.4. Image Processing Module

6.4.4.1. Image Rectification & Restoration

Image to Image Rectification was used to rectify the IKONOS map using a geo-referenced Digital Orthophoto Quarter Quads (DOQQ) - 1 meter resolution of the same area. The DOQQ is rectified to the Florida-based (FGDL) Albers Equal Area projection with HPGN datum. Figure 6.5 shows a synopsis of the image rectification and restoration process.

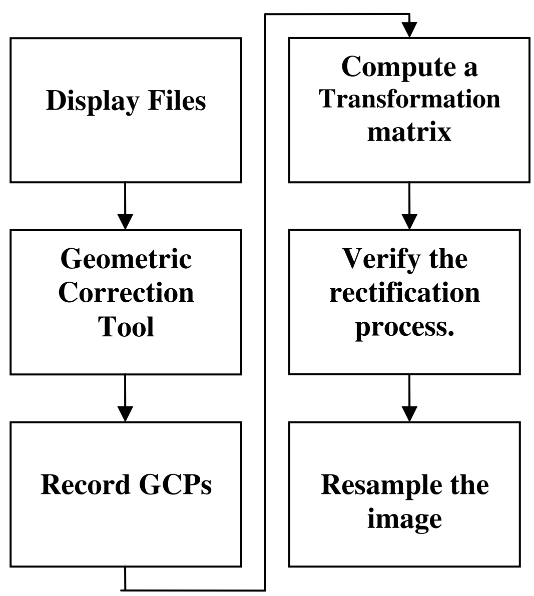


Figure 6.5: Image Rectification and Restoration Synopsis

After opening the two images in two different viewers, the polynomial model option will be selected from the Geo-Correction tool. Selection of the proper properties will lead to the opening of the chip extraction viewers, link box and the GCP tool as shown in Figure 6.6.

By selecting points that are easily identifiable in both images, such as road intersections and land marks GCP points will be edited, and its X and Y inputs are automatically listed in the GCP Tool cell array. The GCPs are choose to spread out across the image to form a large triangle (i.e., they should not form a line). After digitizing the fourth GCP in the first viewer, the subsequent GCPs are automatically matched in the second Viewer. After GCPs digitization in the Viewers, the GCP Tool CellArray will be as in figure 6.7.

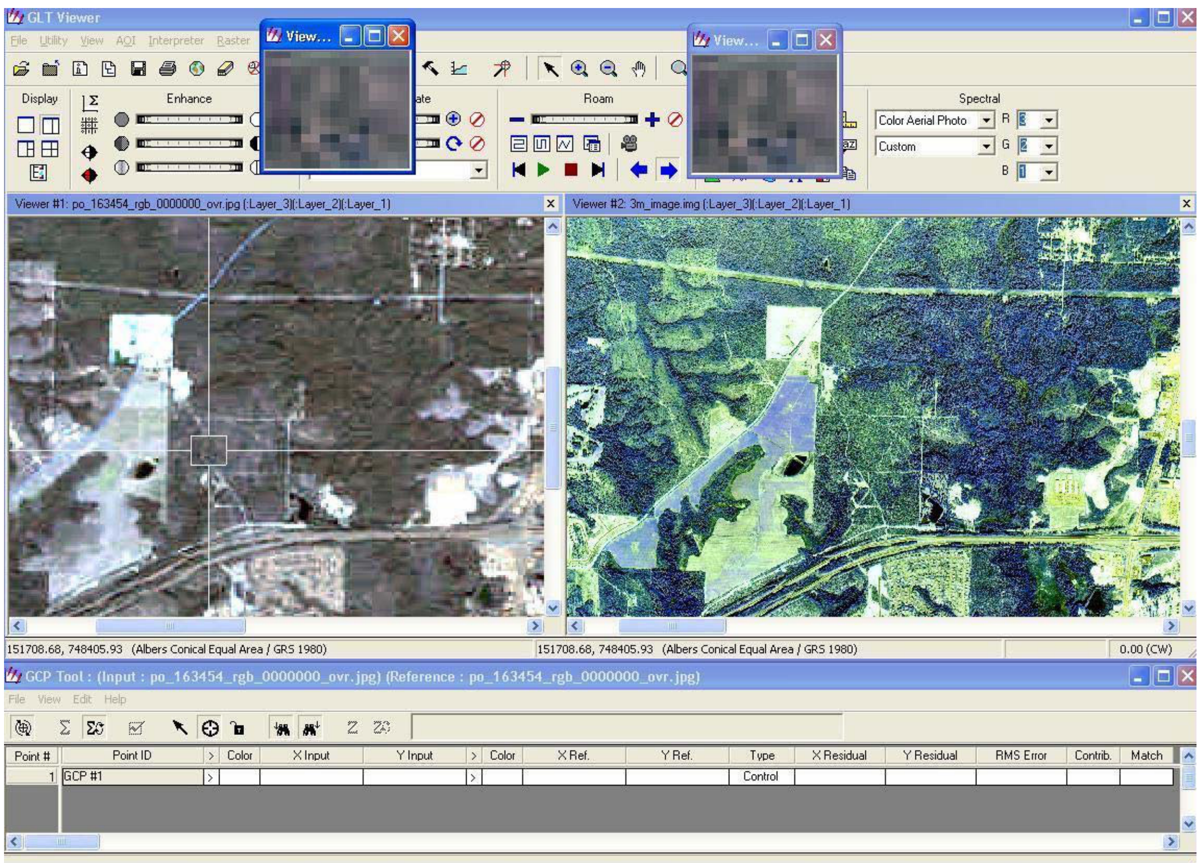
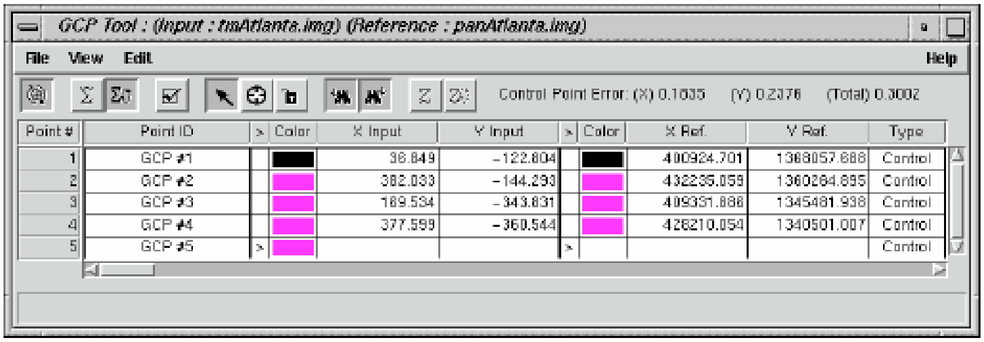


Figure 6.6: Geometric correction window in ERDAS Imagine



Point #	Point ID	>	Color	X Input	Y Input	>	Color	X Ref.	Y Ref.	Type
1	GCP #1			36.849	-122.804			400924.701	1368057.688	Control
2	GCP #2			382.033	-144.293			432235.059	1360264.895	Control
3	GCP #3			169.534	-343.831			409331.888	1345481.938	Control
4	GCP #4			377.599	-360.544			426210.054	1340501.007	Control
5	GCP #5	>				>				Control

Figure 6.7: the GCP Tool CellArray in ERDAS Imagine

In ERDAS Imagine, the transformation matrix is automatically computed in a real time while the GCP editing process. From the Geo-correction tools, resample of the image using the Cubic conversion algorithm, with ignoring the Zero in Stats, to create the new pixel grid. Finally, the re-sampled image and the reference image were visually checked to verify that the input image has been correctly rectified to the reference image.

6.4.4.2. Image Classification

The first step in Land Use/ Land Cover (LULC) classification is to determine the LULC categories. The decision of which land use or land cover categories to use depends on several factors. The first consideration is the needs of the environmental assessment itself. Information required for the EIS process is divided into environmental disciplines.

A second consideration is that LULC categories should generally conform to standard categories. The USGS LULC classification by Anderson et al. (1976) has been widely adopted in the remote sensing and GIS communities, because it was designed specifically for use with remotely sensed data. The Anderson classification is a hierarchical system in which LULC categories are classified on different levels as shown in Table 6.5. For this project, only part of the first level of the classification was used, Urban or built-up land, Agriculture land, Rangeland, forest land, water, and others.

The strengths of both the unsupervised and supervised classification approaches are used to drive Land Use/Land Cover of the proposed area of study. First an unsupervised classification was performed using the ISODATA algorithm to extract the super block clusters based on natural groupings of spectral data. The clustering options used in this project was as shown in figure 6.8: 20 for the number of classes, 30 for the maximum iterations, and 0.950 for the convergence threshold.

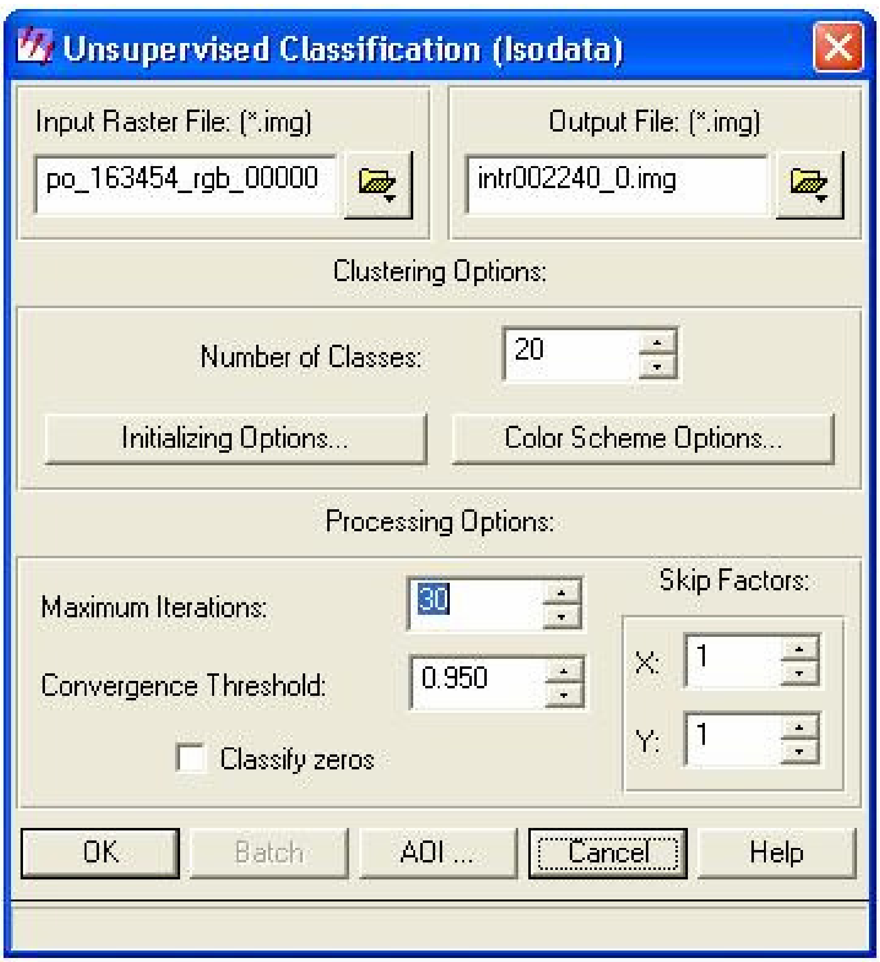
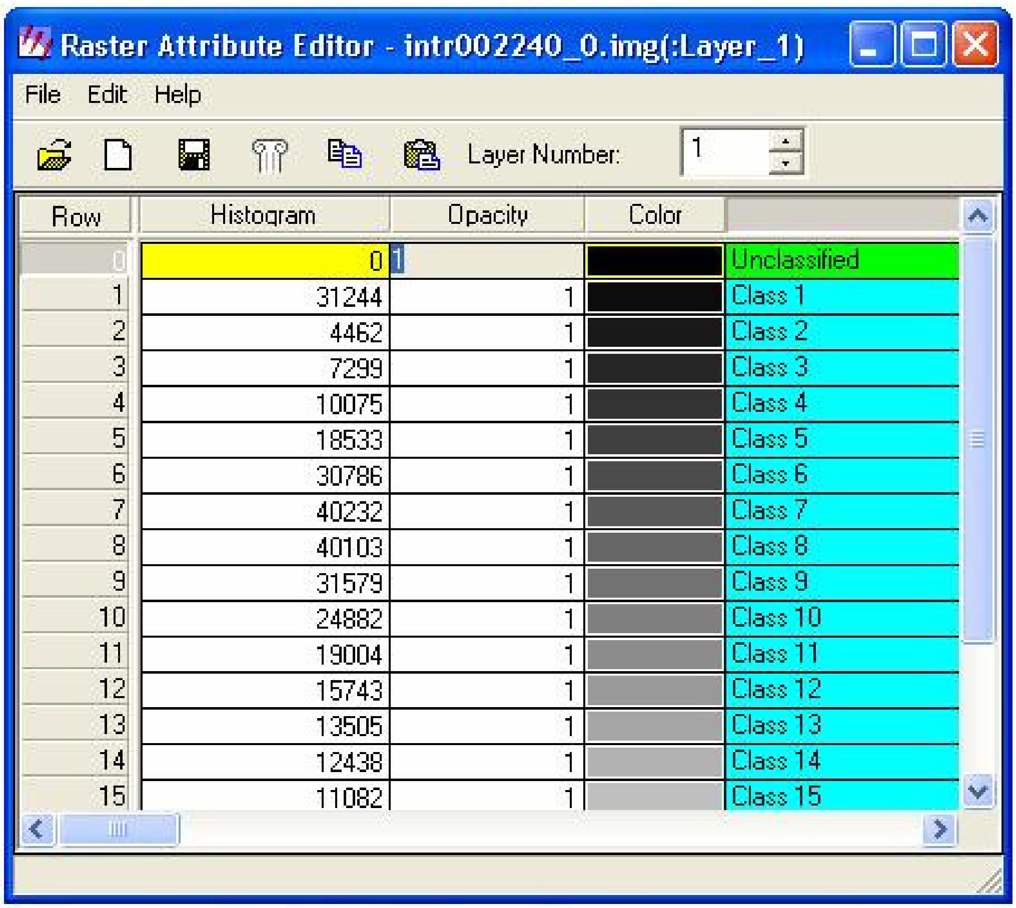


Figure 6.8: The Unsupervised Classification Dialog

Table 6.5: The Anderson Land Use and Land Cover Classification System for Use with Remote Sensor Data

Level I	**Level II**
1 Urban or Built-up Land	11 Residential. 12 Commercial and Services. 13 Industrial. 14 Transportation, Communications, and Utilities. 15 Industrial and Commercial Complexes. 16 Mixed Urban or Built-up Land. 17 Other Urban or Built-up Land.
2 Agricultural Land	21 Cropland and Pasture. 22 Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas. 23 Confined Feeding Operations. 24 Other Agricultural Land.
3 Rangeland	31 Herbaceous Rangeland. 32 Shrub and Brush Rangeland. 33 Mixed Rangeland.
4 Forest Land	41 Deciduous Forest Land. 42 Evergreen Forest Land. 43 Mixed Forest Land.
5 Water	51 Streams and Canals. 52 Lakes. 53 Reservoirs. 54 Bays and Estuaries.
6 Wetland	61 Forested Wetland. 62 Nonforested Wetland.
7 Barren Land	71 Dry Salt Flats. 72 Beaches. 73 Sandy Areas other than Beaches. 74 Bare Exposed Rock. 75 Strip Mines, Quarries, and Grave Pits. 76 Transitional Areas. 77 Mixed Barren Land.
8 Tundra	81 Shrub and Brush Tundra. 82 Herbaceous Tundra. 83 Bare Ground Tundra. 84 Wet Tundra. 85 Mixed Tundra.
9 Perennial Snow or Ice	91 Perennial Snowfields. 92 Glaciers.

After unsupervised classification is performed, the Rater Attribute Editor, shown in Figure 6.9, was used to compare the original image data with the individual classes of the thematic raster layer created from the unsupervised classification to identify the classes.



Row	Histogram	Opacity	Color	
0	0	1		Unclassified
1	31244	1		Class 1
2	4462	1		Class 2
3	7299	1		Class 3
4	10075	1		Class 4
5	18533	1		Class 5
6	30786	1		Class 6
7	40232	1		Class 7
8	40103	1		Class 8
9	31579	1		Class 9
10	24882	1		Class 10
11	19004	1		Class 11
12	15743	1		Class 12
13	13505	1		Class 13
14	12438	1		Class 14
15	11082	1		Class 15

Figure 6.9: The Raster Attribute Editor Dialog

The signature Editor used to create, manage and evaluate and edit the signatures previously created from the unsupervised classification and collect signatures from the image to be classified using the area of interest tools as shown in figure 6.10.

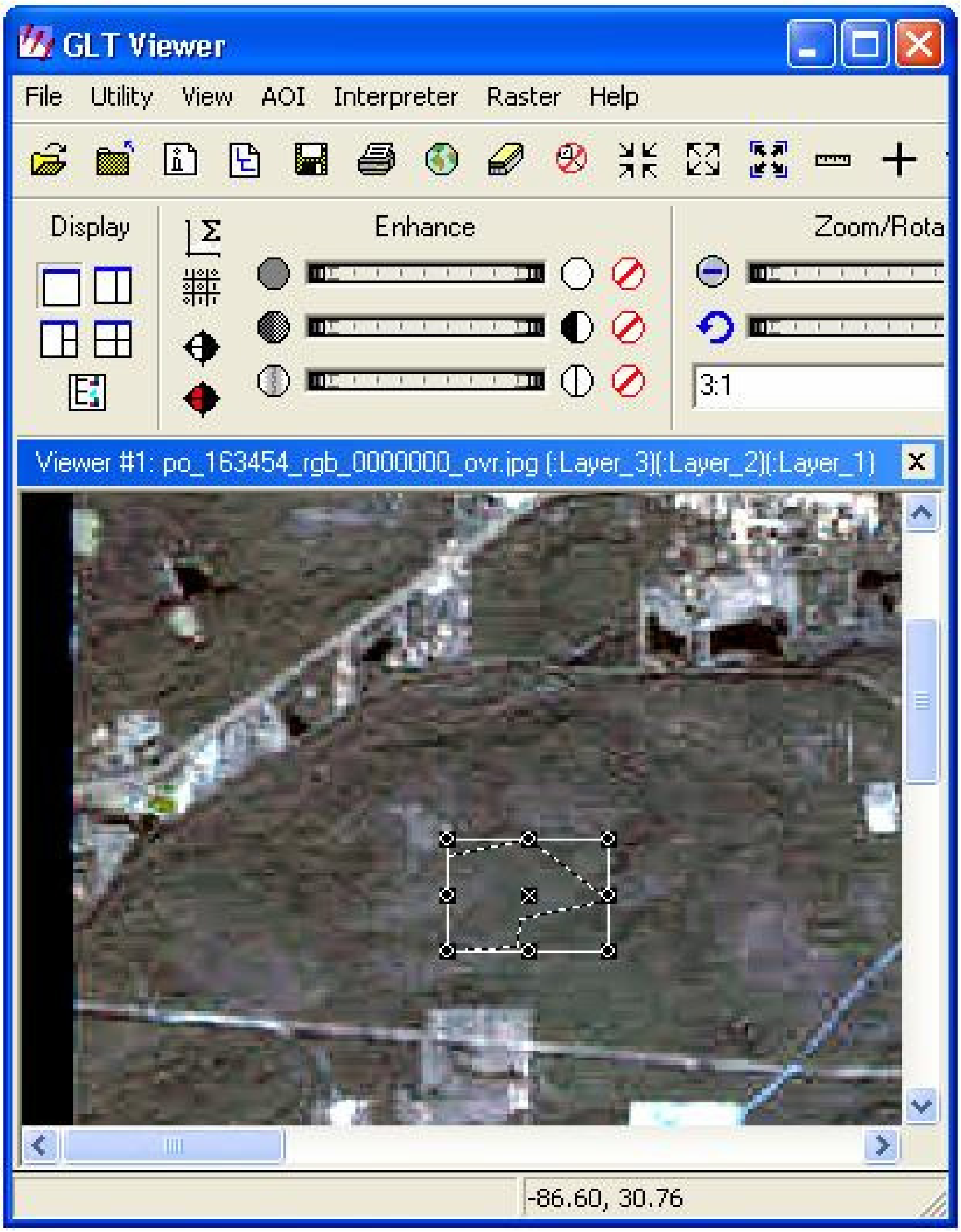


Figure 6.10: Using Area of Interest (AOI) Tool to Collect Signatures

The contingency matrix utility used to evaluate signatures that have been created from AOIs in the image. The output of the contingency matrix of percentages shows how many pixels in each AOI training sample were assigned to each class. The AOI training samples are classified using Feature Space classification algorithms. The contingency Matrix dialog is shown in figure 6.11.

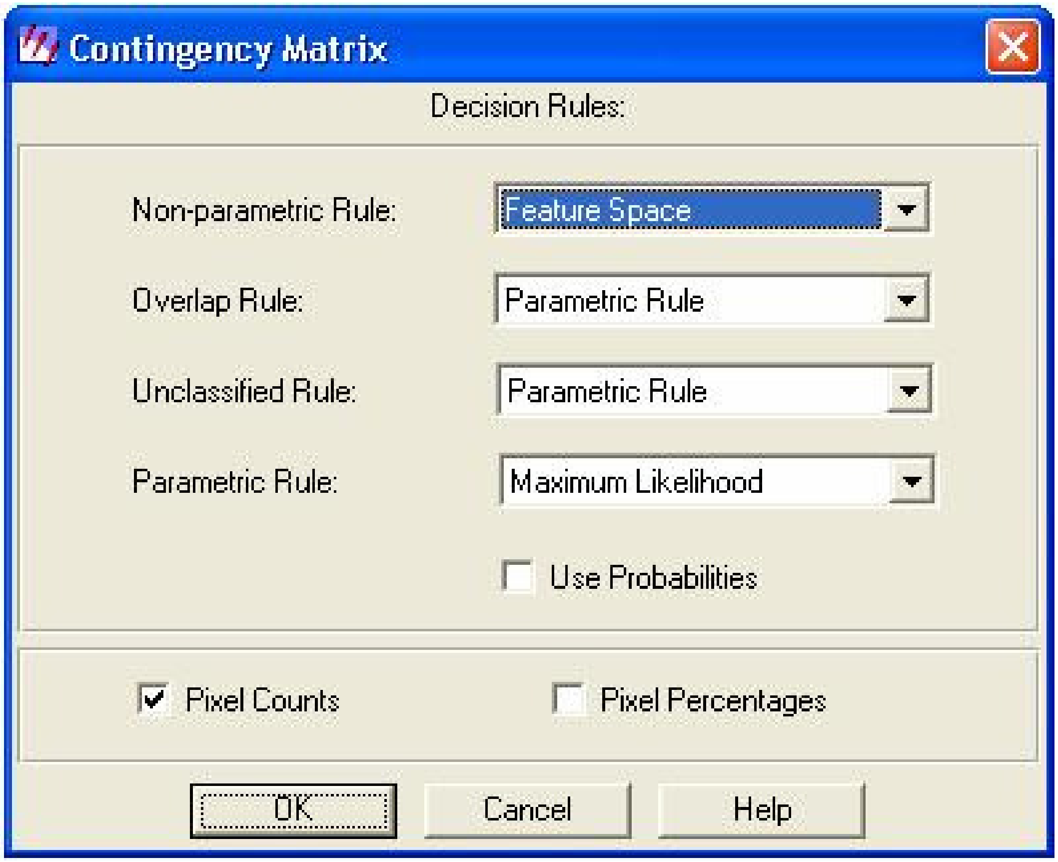


Figure 6.11: The contingency Matrix Dialog

The Feature space to image masking utility used to generate a mask from a Feature Space signature (i.e., the AOI in the Feature Space Image). After final signature file is created, the maximum likelihood classification algorithm was used to classify the images from the parametric signature file. Figure 6.12 shows the Supervised Classification dialog for IRDAS IMAGINE. Finally, the classified image was smoothed with a 3x3- majority rule filter to eliminate the noise in the classification process and increase the accuracy of the classification.

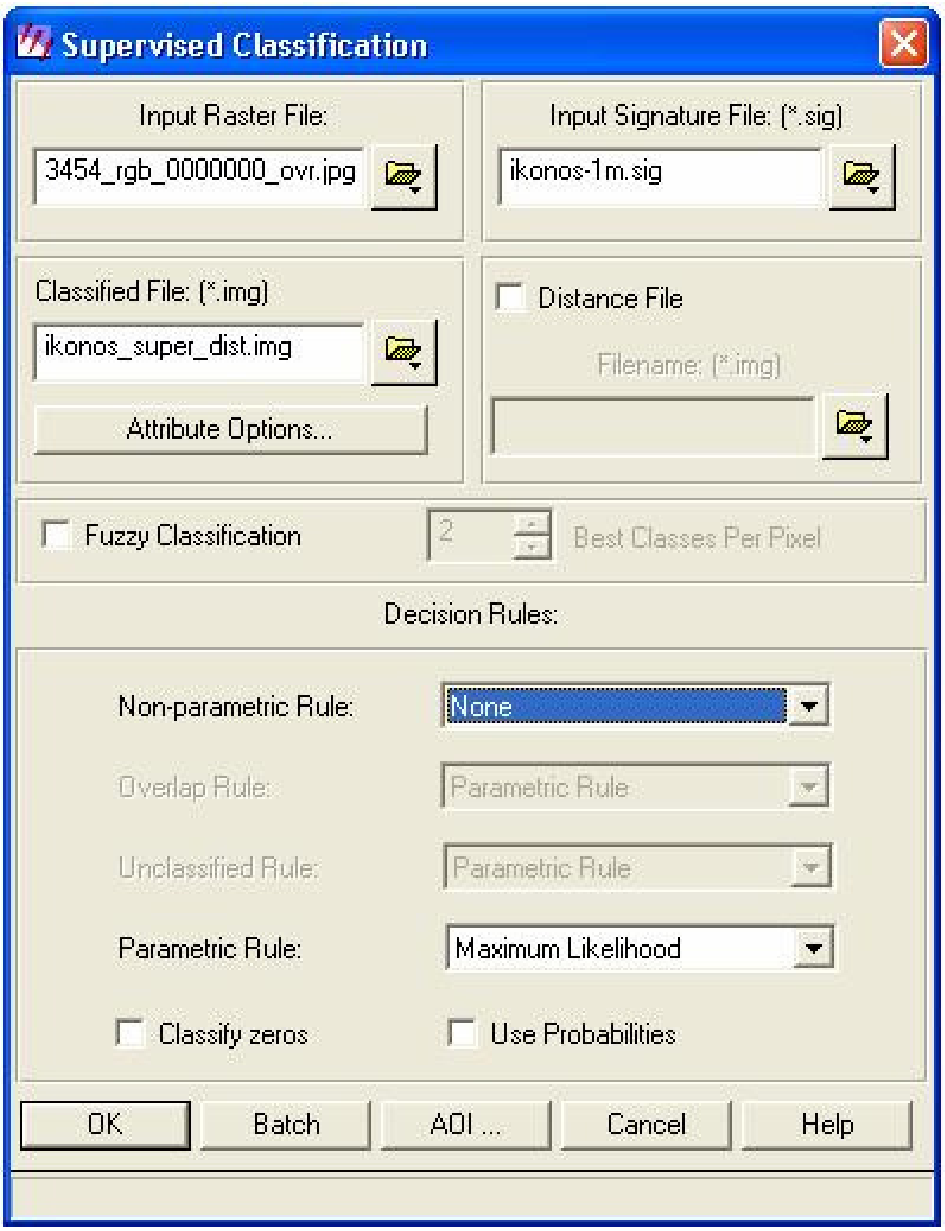


Figure 6.12: The Supervised Classification Dialog

6.4.4.3. Accuracy Assessment

ERDAS Imagine Accuracy Assessment sub-module provides an organized way of comparing the classification with ground truth data, previously tested maps, aerial photos, or other data. This can be done in by generating random check points throughout the Add Random Points utility shown in figure 6.12. After the points are generated, the class values for these points were entered, which are the reference points. These reference values are compared to the class values of the classified image.

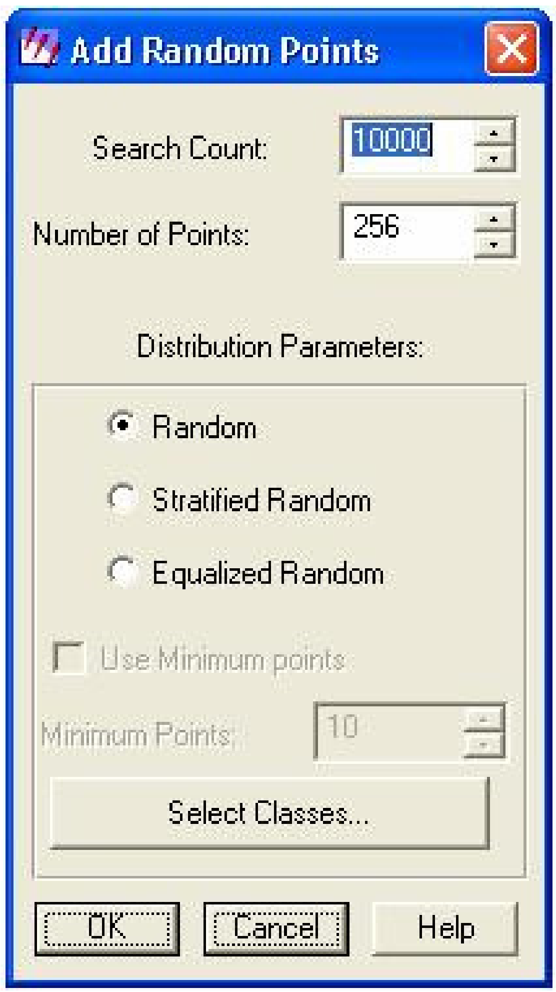


Figure 6.13: The Add Random Points Utility

The number of random points was chosen, such as recommended by the manual, to be 250 points. Also, the Search Count is set to 10000, which means that a maximum of 10000 points are analyzed to see if they meet the predefined requirements in the Add Random Points dialog. The Distribution Parameters should set to Random.

After the process is completed, a list of the points is shown in the Accuracy Assessment CellArray as shown in figure 6.13. The best guess of a reference relating to the perceived class value for the pixel below each reference point is stored in the Accuracy Assessment CellArray Reference Column.

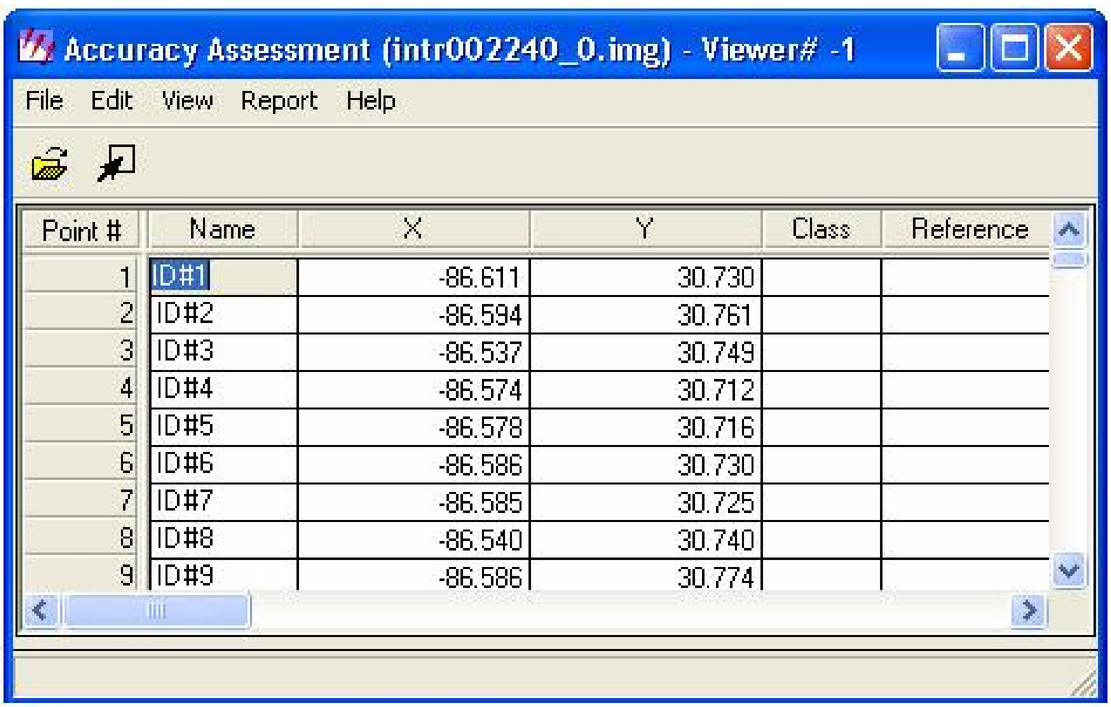
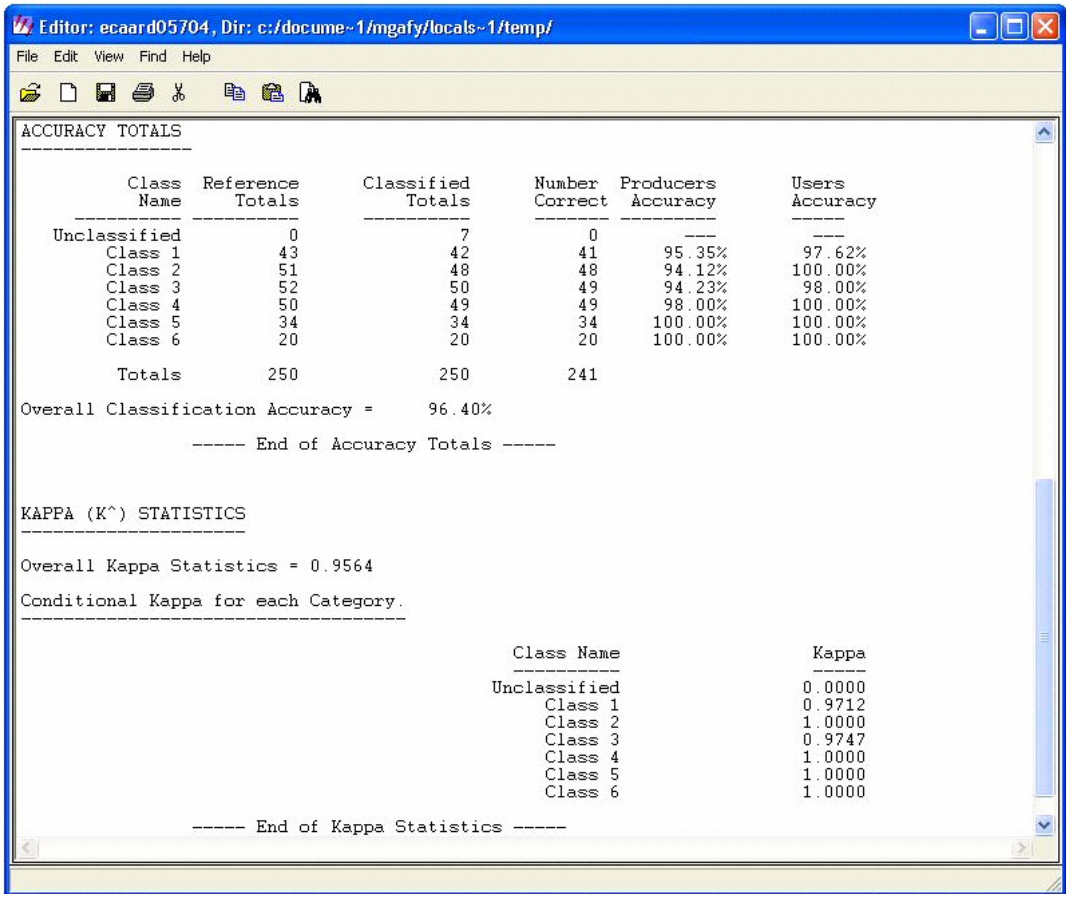


Figure 6.14: The Accuracy Assessment CellArray

In the Accuracy Assessment dialog, the Error Matrix, Accuracy totals, and Kappa Statistics were calculated in the accuracy Report. Figure 6.15 presents the accuracy report of the crestview project.



Editor: ecaard05704, Dir: c:/docume~1/mgafy/locals~1/temp/

File Edit View Find Help

ACCURACY TOTALS

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Unclassified	0	7	0	---	---
Class 1	43	42	41	95.35%	97.62%
Class 2	51	48	48	94.12%	100.00%
Class 3	52	50	49	94.23%	98.00%
Class 4	50	49	49	98.00%	100.00%
Class 5	34	34	34	100.00%	100.00%
Class 6	20	20	20	100.00%	100.00%
Totals	250	250	241		

Overall Classification Accuracy = 96.40%

----- End of Accuracy Totals -----

KAPPA (K^) STATISTICS

Overall Kappa Statistics = 0.9564

Conditional Kappa for each Category.

Class Name	Kappa
Unclassified	0.0000
Class 1	0.9712
Class 2	1.0000
Class 3	0.9747
Class 4	1.0000
Class 5	1.0000
Class 6	1.0000

----- End of Kappa Statistics -----

Figure 6.15: ERDAS Accuracy Report for Crestview Project

6.5. Criteria Weight Module

The ETAT experts were asked to compare all criteria to each other making matrix of values for each comparison pair. The average of all the expert's matrices was used to determine the value of a cell I, j (row I, column J/) of the matrix is the ration Wi/Wj, the main eign vector of the comparison matrix. Then the weights the vector is normalized in the interval [0, 1] to apply Yager's methods (Yager 1977) for calculating the required weights. . Experts determine the pair-wise comparisons matrix, A, as shown in Table 6.6.

Table 6.6: the pair-wise comparisons matrix

	Pop. Den.	Arch	LULC	DRASTIC	Foundation	Eco. model	Wetland	Flood	Wildlife	Spec. Water	Military
Pop. Den.	1	0.91	0.45	0.9	0.23	0.46	1.1	0.45	0.7	0.68	0.23
Arch	1.10	1	0.46	0.91	0.22	0.46	1.14	0.46	0.68	0.7	0.22
LULC	2.22	2.17	1	1.82	0.45	0.91	2.27	0.91	1.3	1.4	0.45
DRASTIC	1.11	1.10	0.55	1	0.22	0.45	1.1	0.45	0.6	0.7	0.23
Foundation	4.35	4.55	2.22	4.55	1	1.8	4.5	1.8	2.7	2.7	0.9
Eco. model	2.17	2.17	1.10	2.22	0.56	1	2.25	0.9	1.3	1.4	0.44
Wetland	0.91	0.88	0.44	0.91	0.22	0.44	1	0.4	0.5	0.6	0.17
Flood	2.22	2.17	1.10	2.22	0.56	1.11	2.50	1	1.3	1.4	0.44
Wildlife	1.43	1.47	0.77	1.67	0.37	0.77	2.00	0.77	1	0.9	0.29
Spec. Water	1.47	1.43	0.71	1.43	0.37	0.71	1.67	0.71	1.11	1	0.29
Military	4.35	4.55	2.22	4.35	1.11	2.27	5.88	2.27	3.45	3.45	1

Factors' weights are calculated by the BLZPACK software, is an implementation of the block Lanczos algorithm intended for the solution of the standard eigenvalue problem $Ax=\mu x$, where A and B are real, sparse symmetric matrices, μ an eigen-value and x an eigenvector, developed by Marques (2000). Results of the eigenvector method are as follows. The weights vector are 0.125, 0.128, 0.069, 0.126, 0.034, 0.064, 0.168, 0.063, 0.099, 0.092, 0.032 and the consistency ratio is 0.038, less than 0.1, which satisfies the consistency criterion.

6.6. Environmental Vulnerability grade Map

In order to develop the vulnerability grade map for each assessment factor, the GIS layers and the classified maps according to the regional weights within the same criteria to. Also, the Spatial Analyst module within ArcInfo was used to Rasterizing all the GIS. 1 m was chosen as output cell size for the layers as shown in Figure 6.16.

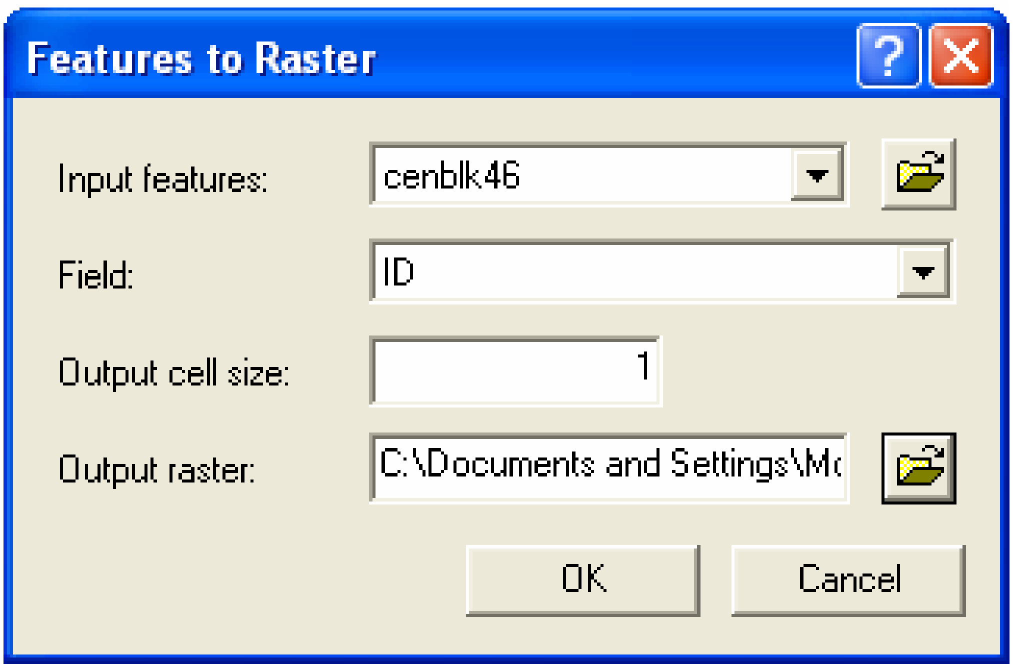


Figure 6.16: GIS layer Rasterization Dialog

Population Density: Table 6.7 was used to estimate the vulnerability score for population density.

Table 6.7: Criteria Vulnerability Score for Population Density

Population Density	**Criteria Vulnerability Score**
92.2368 - 360.7595	3
19.0158 - 92.2367	2
4.5209 - 19.0157	1
0.0000 - 4.5208	0

Figure 6.17 shows the vulnerability map for population density in both raster and vector formats. The same concept was used for the other assessment factors with different conversion tables. Following are the conversion table that used to create the vulnerability maps for the other factors.

Historical and Archeological Sites:

Table 6.8: Criteria Vulnerability Score for Historical and Archeological Sites

Location	**Criteria Vulnerability Score**
Historical and Archeological Site	100
< =100 ft	3
<= 0.50 Mile	2
<= 1.0 Mile	1

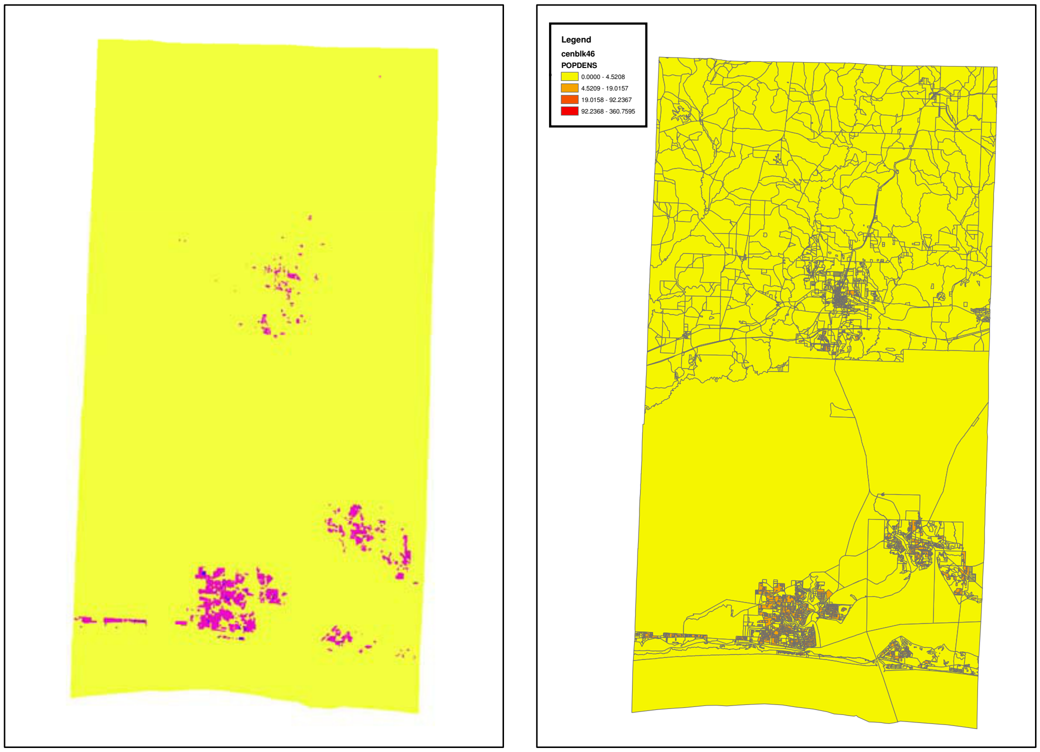


Figure 6.17: Vulnerability map for Population Density in Raster and vector formats

The land cover and use of the land

Table 6.9: Criteria Vulnerability Score for Land Cover/ Land Use

LCLU	Criteria Vulnerability Score
Urban or Built-up Land	3
Agricultural Land	2
Rangeland, Forest Land, and Water	1
Others	0

The DRASTIC index, which is a measure of the pollution potential, for the surface and the aquifer systems

Table 6.10: Criteria Vulnerability Score for surface and the aquifer systems

DRASTIC index	Criteria Vulnerability Score
168-195	3
156-167	2
145-155	1
0-144	0

The sediment type located 10 ft of the land surface

Table 6.11: Criteria Vulnerability Score for foundation type

Foundation Type	Criteria Vulnerability Score
Clay	3
Clayey sand	2
Silt	1
Gravel	0

The green project's ecological network model results

Table 6.12: Criteria Vulnerability Score for ecological network model results

Model Results area	Criteria Vulnerability Score
In	3
Out	0

Wetland classification

Table 6.13: Criteria Vulnerability Score for Wetland classification

Classification	Criteria Vulnerability Score
92.2368 - 360.7595	3
19.0158 - 92.2367	2
4.5209 - 19.0157	1
0.0000 - 4.5208	0

Federal Emergency Management Agency's (FEMA) Flood Insurance Rate Maps

Table 6.14: Criteria Vulnerability Score for Flood Insurance Rate

Flood Insurance Rate	Criteria Vulnerability Score
In	3
Out	0

Wild life zones

Table 6.15: Criteria Vulnerability Score for Wild life zones

Wild life zones	Criteria Vulnerability Score
In	3
Out	0

Special Outstanding Water

Table 6.16: Criteria Vulnerability Score for Special Outstanding Water

Outstanding Water Area	Criteria Vulnerability Score
In	3
Out	0

Military Land

Table 6.17: Criteria Vulnerability Score for Military Land

Military Land	Criteria Vulnerability Score
In	3
Out	0

After creating the Vulnerability grade map for each criteria, the IMAGINE Model Maker is used to construct a script model to combine the criteria vulnerability maps and the criteria related weights to develop the environmental vulnerability map. Figure 6.18 illustrates IMAGINE Model Maker dialog and shows an illustration for the constructed model.

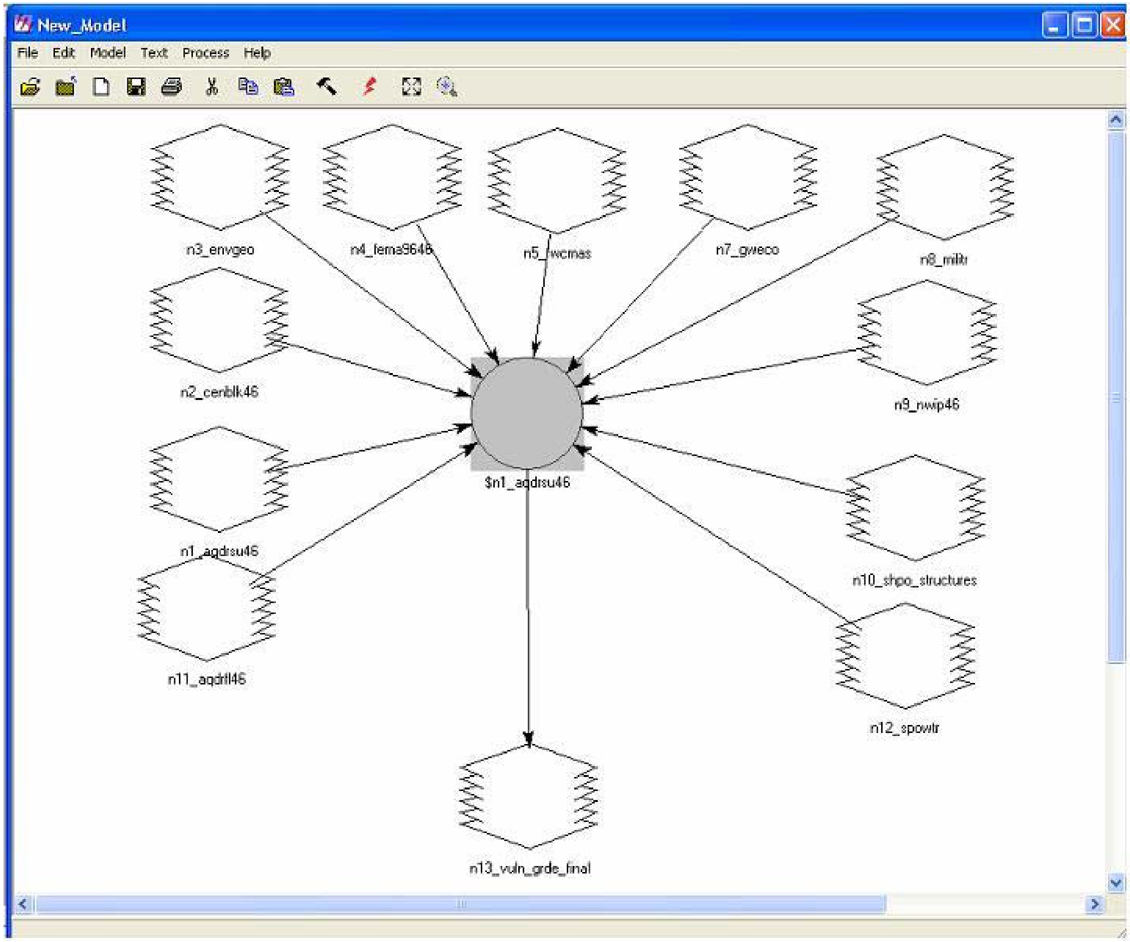


Figure 6.18: The IMAGINE Model Maker Dialog

The criteria function used to construct the model was arithmetic summation function for the multiplying of every vulnerability grade map and the associated criteria weight. Figure 6.19 shows the IMAGINE Model Maker 's Criteria Table Used to Define Rules to Derive the Output Layer Based on Values of the Input Layer(s).

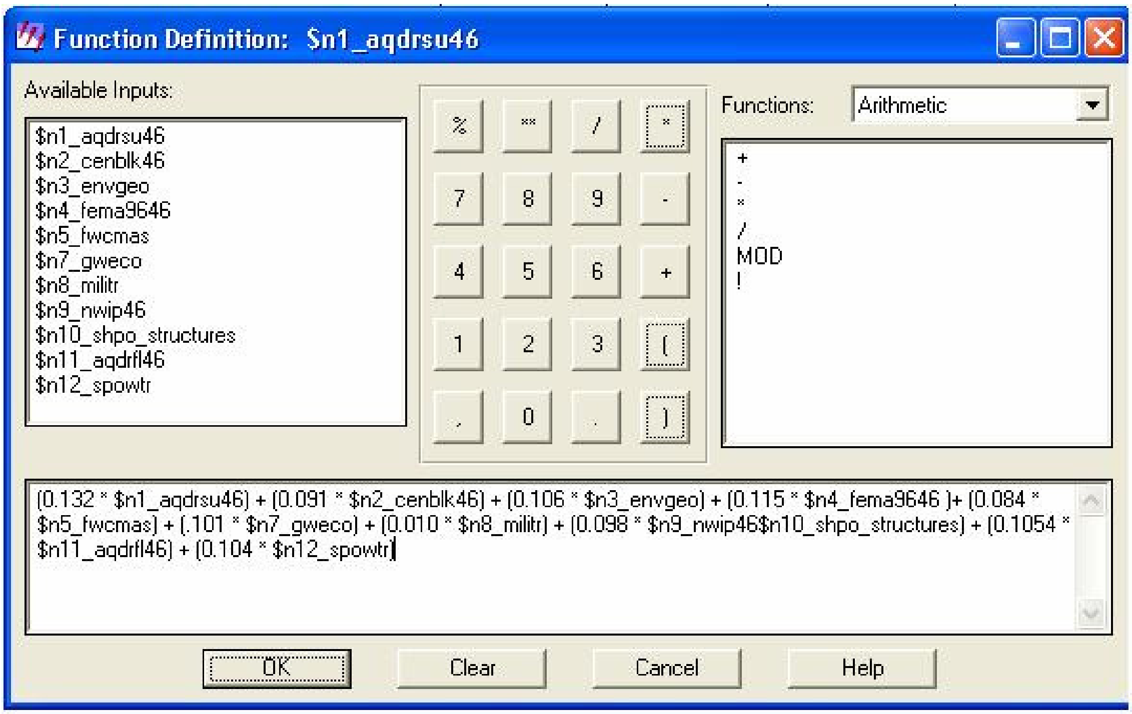


Figure 6.19: The IMAGINE Model Maker's Criteria Table

-

6.1. Selection of the Best Alternative

By buffering a long the road alignment alternatives at the distances of 100, 200, 500, and 5280 feet (1Mile) respectively, the polygons of road impact extent will be created. With PC ARC/INFO we overlay the vulnerability grade map, shown in Figure 6.16, and the road distribution maps. The calculated value of E of the three alternatives are shown in Table 6.20.

Figure 6.20: The Vulnerability grade map for the proposed Project

Table 6.18: Criteria Vulnerability Score

Assessment Value(E) @	Alternative No. 1	Alternative No. 2	Alternative No.3
100 ft	467,064	384,858	98,856
200ft	929,007	784,971	203,571
500ft	2,095,686	1,879,560	582,147
1 Mile	26,291,331	13,484,547	13,216,431

6.1. Exploring the results

From the previous calculations the proposed framework recommends road alignment 3 as a preferred corridor for the study. This result was compatible with endorsing Crestview Bypass Eastern Corridors (E-1), alternative three in this chapter, as the Preferred Corridors for further study in a Project Development and Environmental (PD&E) Study.

The same results were in the two other case studies- Willough Boulevard, Martin; and SR87 extension, Santa Rosa. By representing these results to the ETAT, they agreed that the presented application has demonstrated its advantages, as a qualitative analysis approach, over other conventional quantitative approaches, especially in the comparison of spatial impacts, and that the proposed framework is a comprehensive, generalized methodological framework for environmental assessment of transport projects.

In conclusion, this proposed framework has features, some of which exhibit unique aspects, such as:

• The simplicity in the use and understanding, based on an additive function, and a core approach,

• The use of established techniques for determination of weights, index functions and ranking,

• The use of a hierarchy of criteria, which can be expanded or collapsed accordingly, based on the needs of the evaluation, and

• The explicit incorporation of the spatial distribution of impacts through the use of regional weights.

6.2. Other case studies

6.2.1. Willough Boulevard project, Martin

This project consists of creating a new two lane segment from Cove Road to Bridge Road through south central Martin County. The purpose of this project is to alleviate congestion at two key intersections: Cove Road and US-1 and SR 76 and I-95, to improve safety and increase evacuation options and to accommodate increasing growth in the south central portion of the county. The project would benefit the developments on Seabranch and allow the residents ease of movement to Palm Beach County via I-95 south. The project would greatly relieve congestion on US 1 in the southern portion of the county by creating an additional north south alignment. The project is a county road and is listed in the Cost Feasible of the 2025 Long Range Transportation Plan. The project is estimated to cost approximately $35 million. Figure 6.21 shows the different alignment proposed for this project and the calculated value of E of the two alternatives are shown in Table 6.19.

Table 6.19: Criteria Vulnerability Score

Assessment Value(E) @	Alternative No. 1	Alternative No. 2
100 ft	477,002	548,556
200ft	809,656	931,205
500ft	1,881,333	767,449
1 Mile	23,347,631	26,850,146

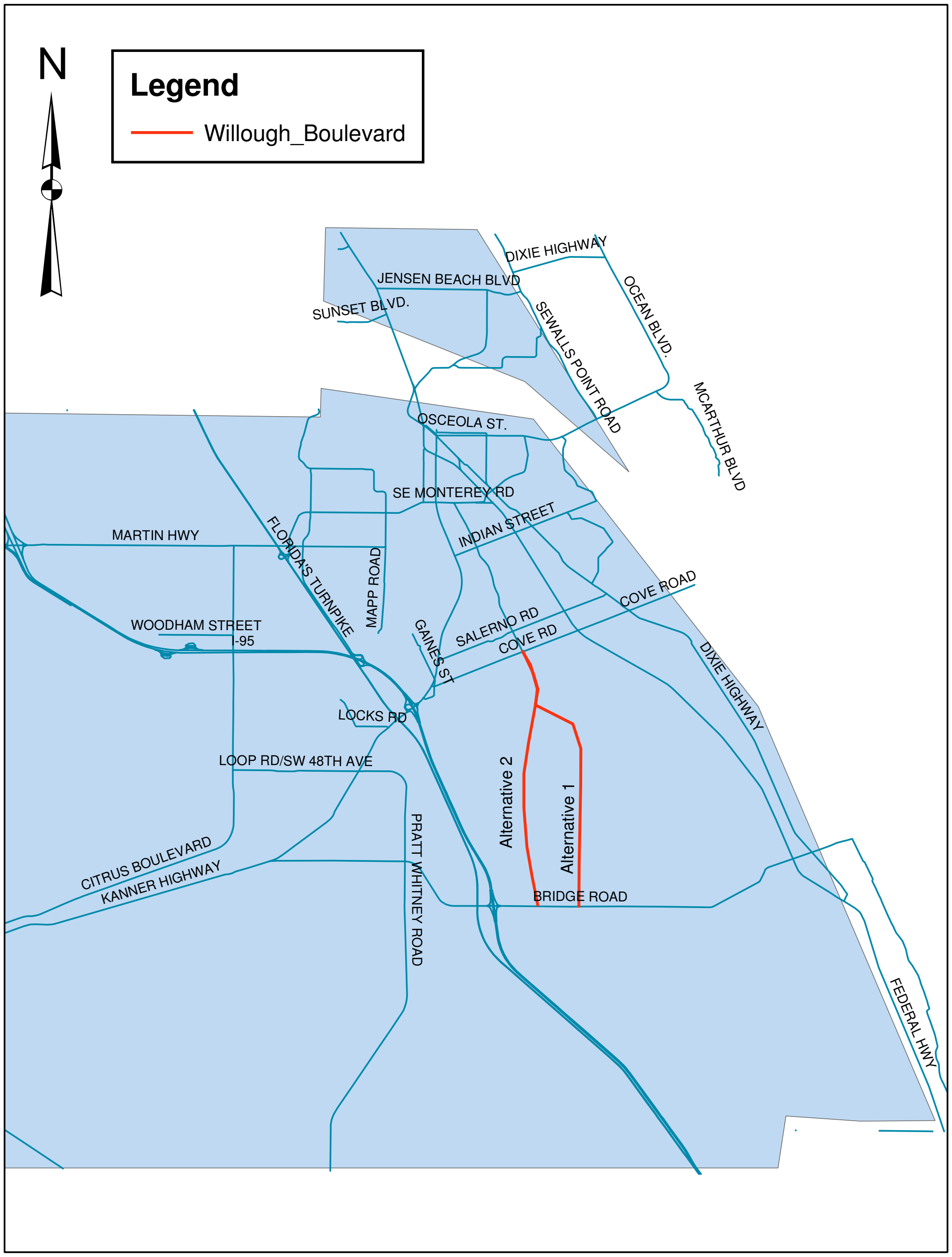


Figure 6.21: Willough Boulevard Project Location Map

6.2.2. SR87 Extension, Santa Rosa.

This proposed roadway is located in central Santa Rosa County. This project will be a new roadway. It will be a 2-lane divided facility with Right-of-Way for a 4-lane divided facility. SR 87S is a north-south minor arterial. It provides important regional access with its connections to Interstate 10, SR 87N, and US 90. In Traffic Analysis Zones adjacent to the corridor, population is anticipated to grow by 2,648 from 2,029 to 4,677, or 56.62 percent, between 1997 and 2020. Employment is projected to increase by 575 from 908 to 1,483, or 38.77 percent. The number of dwelling units is forecasted to rise by 1,114 from 827 to 1,941, or 57.39 percent. No schools are located on this segment. The Raw Model Volume for the 2020 Needs Plan for this segment is 9,472. The construction of the two-lane facility is also intended to provide relief to Ward Basin Road and US 90. When the MPO can show that extension of SR 87 to SR 89 North can be included in the Cost Feasible Plan; rather than stopping at Munson Road, there will be significant relief to congestion on US 90 and the Blackwater River Bridge, because significant growth is occurring along Berryhill Road, northwest of Milton. Also, this facility will provide an additional east-west crossing of Blackwater River.

The construction will maintain existing bicycle and sidewalk facilities in the corridor. Escambia County Area Transit does not provide service to this area of Santa Rosa County. Figure 6.22 shows the different alignments proposed for this project and the calculated value of E of the two alternatives are shown in Table 6.20.

Table 6.20: Criteria Vulnerability Score

Assessment Value(E) @	Alternative No. 1	Alternative No. 2
100 ft	44,152	51,819
200ft	76,467	95,372
500ft	177,681	99,481
1 Mile	2,205,054	1,082,509

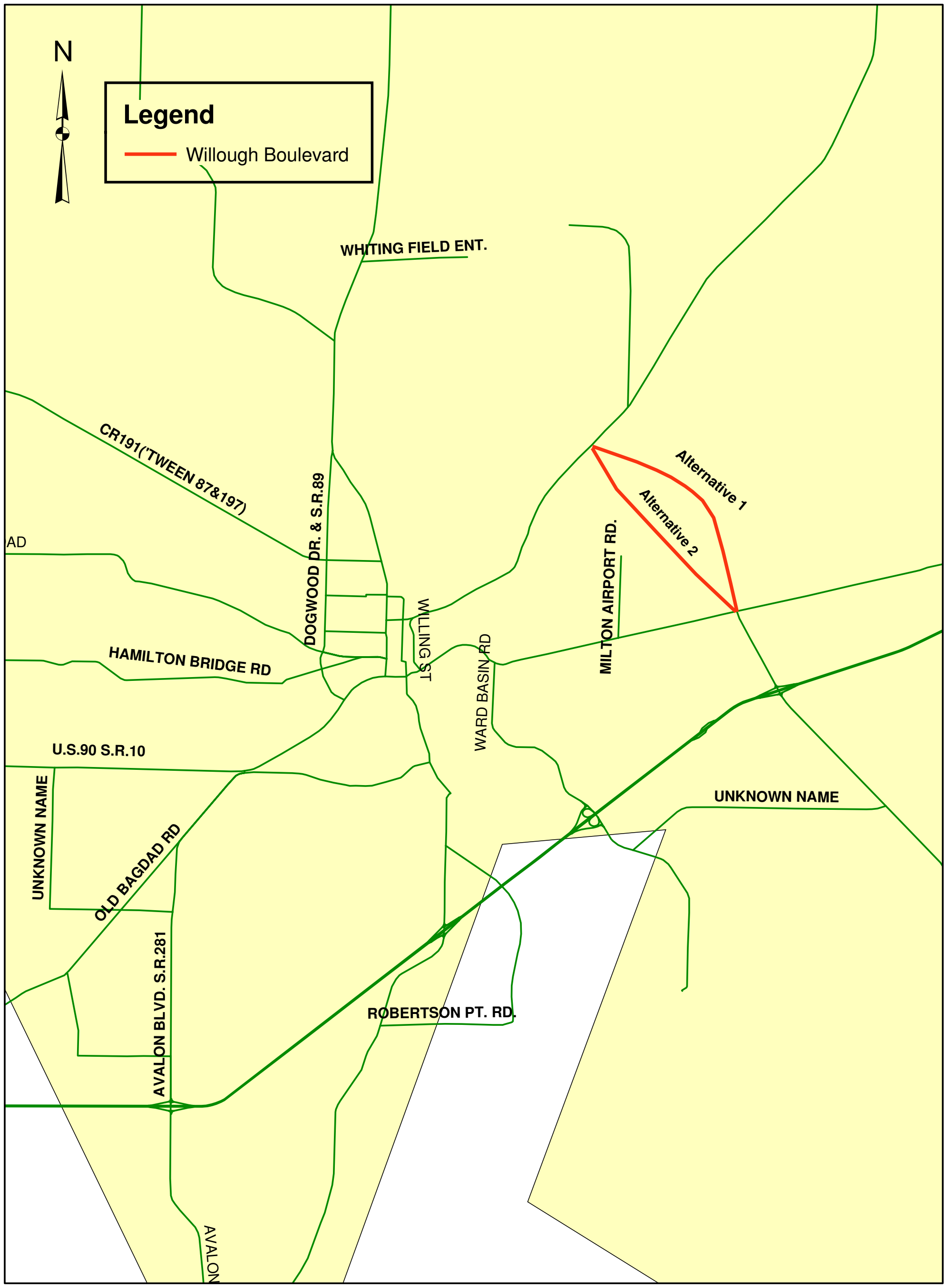


Figure 6.21: SR87 Extension Project Location Map

CHAPTER 7 CONCLUSIONS AND RECOMMENDATIONS

This dissertation has proposed a hybrid decision support framework for conduction the Environmental impact analysis of Transportation projects. This chapter summarizes the research and highlights the research contributions. Subsequently the limitations of the research are discussed. Finally, recommendations for future work are provided.

7.1. Summary of the research

The research proposed a hybrid decision support framework for conduction the Environmental impact analysis of Transportation projects. The methodological framework could be applied both to urban and inter-urban projects, regardless of transport mode, as well as to the development of terminals. Moreover, the methodology handles environmental impacts at any level of detail in the natural and social environment. This framework is easy to be understood, while meeting series efficiency criteria, such as generality, independence, reliability, flexibility, data needs, etc.

The basic concept of the proposed framework is to develop a hierarchal decision-tree structure according to the user objectives to include impacts to the natural and the anthropogenic environment from the construction and operation of transport projects. Moreover, Image processing techniques of the satellite images will be used to acquire the historical environmental data and reconstruction of the missing data. Then, formalize a standard analysis approach based on the integration between GIS and the remote sensed data. Finally, present the data and make the appropriate analysis to support the decision of the decision-makers and allow them to present these data to the public hearings in a simple manner.

This methodological framework is expected to improve the quality of the decision making process for transportation projects regarding the environmental decisions. It can also reduce the assessment and the analysis time. Also, it could be applied both to urban and inter-urban projects, regardless of transport mode, as well as to the development of terminals.

7.2. Research Contribution

The contributions of this research include:

- A decision support system that greatly enhances the ability of transportation agencies to be effective steward of the environment while carrying out its mission is developed. The research will integrate geomorphologic information with data on other environmental resources, opportunities and constraints for land-use planning. Its basis is the belief that adequate EIA can only be obtained through precise and reliable assessments of impacts on the different environmental components (physical, biological, aesthetic, and socio-economic) and through the use of well tested, replicable integration methods.
- Furthermore, updating the GIS legacy data base at the transportation agencies with the useful, well formatted, accurate and timely information driven from the remotely sensed images, using the image processing and data fusion techniques.
- For Framework Implementation, Crestview bypass project is used as an example for the Hybrid methodological framework. A simple

computer implementation for the project was developed. Furthermore, the principles and techniques of EIA were reviewed.

7.3. Limitations

The hybrid decision support framework was developed, conceptually, to be a generic model, which can be tolerated based on the decision maker requirements and the proposed project. However, for the actual implementation in this research, the framework was tailored towards traditional programmatic transportation project. Although applying the framework for other EIA studies for different transportation project types such as Inter-modal Transportation project may be worthwhile, it still requires specific detailed changes for implementation.

Furthermore, the logistics of acquiring data (remote sensing scenes) may affect the performance of the system. For example, the cloud ratio and the sensor inclination can affect the final results. For the purpose of this research, effort was made to find remote sensing scenes with reasonable cloud ratio, less than 10%, and No inclination.

7.4. Recommendation for Future work

- A detailed logistics design is recommended for better performance of the framework. A primary responsibility includes the development of a Long Range Transportation Plan that is consistent with previously determined community goals and objectives. This comprehensive planning role includes ongoing coordination with the DOT, local governments, inter-modal agencies, and the public to develop transportation plans that enhance economic prosperity and preserve the quality of the environment and communities. This proposed framework will greatly expands the role of the Transportation planners for interaction with regulatory and resource agencies and provides tools for more effective communication with the public.

- A hybrid decision support framework is presented. However, the prototype has to be implemented and integrated into a complete computerized system that involves all the EIA steps and allows all the involving agencies that are included in the project to have the same data at the same time and share it. The system will include a central server spatial database, Data entry and remote sensing assessment module, GIS module, Summary report module, and Feedback and communication channel module.

For instance, the integrated computerized framework will be composed of three main basic modules:

- Planning Module: This module will allow agencies to review project Purpose and Need Statements and comment on the potential impact of projects to environmental and community resources very early in the planning process. This opportunity will enable planners to adjust project concepts to avoid or minimize adverse impacts, consider mitigation alternatives, and improve estimation of project costs.
- Programming Module: This module will help before projects are funded in the DOT. This module will initiate the National Environmental Policy Act (NEPA) process for federally funded projects or the State Environmental Impact Process for state-funded projects. Agency input about the potential impact to environmental and community resources is the basis for “agency scoping” efforts to help satisfy NEPA and other applicable federal and state laws that are addressed during the NEPA process
- Development Module. This module will automate the process by which the DOT documents NEPA compliance and obtains required environmental permits. In this module, each project will be developed to the level of detail necessary to accurately assess the socio-cultural and environmental impacts to obtain environmental permits at the conclusion of NEPA. This module will improve the quality of decisions made during planning and reduce legal

challenges during the NEPA and permitting processes by coupling the early agency involvement, continual assessment of socio-cultural effects, and public involvement.

APPENDIX A

GUIDANCE FOR PREPARING AND PROCESSING ENVIRONMENTAL AND SECTION 4(F) DOCUMENTS

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1. PURPOSE. To provide guidance to Federal Highway Administration (FHWA) field offices and to project applicants on the preparation and processing of environmental and Section 4(f) documents.
2. CANCELLATION. Technical Advisory T 6640.8, "Guidance Material for the Preparation of Environmental Documents," dated February 24, 1982, is canceled effective on November 27, 1987.
3. APPLICABILITY
   a. This material is not regulatory. It has been developed to provide guidance for uniformity and consistency in the format, content, and processing of the various environmental studies and documents pursuant to the National Environmental Policy Act (NEPA), 23 U.S.C.109(h) and 23 U.S.C. 138 (Section 4(f) of the DOT Act) and the reporting requirements of 23 U.S.C. 128.
   b. The guidance is limited to the format, content and processing of NEPA and Section 4(f) studies and documents. It should be used in combination with a knowledge and understanding of the Council on Environmental Quality (CEQ) Regulations for Implementing NEPA (40 CFR 1500-1508), FHWA's Environmental Impact and Related Procedures (23 CFR 771) and other environmental statutes and orders (see Appendix A).
   c. This guidance should not be used until November 27, 1987, the effective date of the 1987 revisions to 23 CFR 771.

GUIDANCE FOR PREPARING AND PROCESSING ENVIRONMENTAL AND SECTION 4(F) DOCUMENTS

Background

An earlier edition of this advisory (dated February 24, 1982) placed major emphasis on environmental impact statements (EISs) and provided limited guidance on environmental assessments (EAs) and other environmental studies needed for a categorical exclusion (CE) determination or a finding of no significant impact (FONSI). The revised guidance gives expanded coverage to CE determinations, EAs, FONSIs, EISs, supplemental EISs, reevaluations, and Section 4(f) evaluations. This material is not regulatory. It does, however, provide for uniformity and consistency in the documentation of CEs and the development of environmental and Section 4(f) documents.

The FHWA subscribes to the philosophy that the goal of the NEPA process is better decisions and not more documentation. Environmental documents should be concise, clear, and to the point, and should be supported by evidence that the necessary analyses have been made. They should focus on the important impacts and issues with the less important areas only briefly discussed. The length of EAs should normally be less than 15 pages and EISs should normally be less than 150 pages for most proposed actions and not more than 300 pages for the most complex proposals. The use of technical reports for various subject areas would help reduce the size of the documents.

The FHWA considers the early coordination process to be a valuable tool in determining the scope of issues to be addressed and in identifying and focusing on the proposed action's important issues. This process normally entails the exchange of information with appropriate Federal, State and local agencies, and the public from inception of the proposed action to preparation of the environmental document or to completion of environmental studies for applicable CEs. Formal scoping meetings may also be held where such meetings would assist in the preparation of the environmental document. The role of other agencies and other environmental review and consultation requirements should be established during scoping. The Council on Environmental Quality (CEQ) has issued several guidance publications on NEPA and its regulations as follows: (1) "Questions and Answers about the NEPA Regulations," March 30, 1981; (2) "Scoping Guidance," April 30, 1981; and (3) "GuidanceRegarding NEPA Regulations," July 28, 1983. This nonregulatory guidance is used by FHWA in preparing and processing environmental documents. Copies of the CEQ guidance are available in the FHWA Office of Environmental Policy (HEV-11).

Note, highway agency (HA) is used throughout this document to refer to a State and local highway agency responsible for conducting environmental studies and preparing environmental documents and to FHWA's Office of Direct Federal Programs when that office acts in a similar capacity.

SECTION SUBJECT

I. CATEGORICAL EXCLUSION (CE)

Categorical exclusions are actions or activities which meet the definition in 23 CFR 771.117(a) and, based on FHWA's past experience, do not have significant environmental effects. The CEs are divided into two groups based on the action's potential for impacts. The level of documentation necessary for a particular CE depends on the group the action falls under as explained below.

A. Documentation of Applicability

The first group is a list of 20 categories of actions in 23 CFR 771.117(c) which experience has shown never or almost never cause significant environmental impacts. These categories are non-construction actions (e.g., planning, grants for training and research programs) or limited construction activities (e.g., pedestrian facilities, landscaping, fencing). These actions are automatically classified as CEs, and except where unusual circumstances are brought to FHWA's attention, do not require approval or documentation by FHWA. However, other environmental laws may still apply. For example, installation of traffic signals in a historic district may require compliance with Section 106, or a proposed noise barrier which would use land protected by Section 4(f) would require preparation of a Section 4(f) evaluation (23 CFR 771.135(i)). In most cases, information is available from planning and programming documents for the FHWA Division Office to determine the applicability of other environmental laws. However, any necessary documentation should be discussed and developed cooperatively by the highway agency (HA) and the FHWA.

The second group consists of actions with a higher potential for impacts than the first group, but due to minor environmental impacts still meets the criteria for categorical exclusions. In 23 CFR 771.117(d), the regulation lists examplesof 12 actions which past experience has found appropriate for CE classification. However, the second group is not limited to these 12 examples. Other actions with a similar scope of work may qualify as CEs. For actions in this group, site location is often a key factor. Some of these actions on certain sites may involve unusual circumstances or result in significant adverse environmental impacts. Because of the potential for impacts, these actions require some information to be provided by the HA so that the FHWA can determine if the CE classification is proper (23 CFR 771.117(d)). The level of information to be provided should be commensurate with the action's potential for adverse environmental impacts. Where adverse environmental impacts are likely to occur, the level of analysis should be sufficient to define the extent of impacts, identify appropriate mitigation measures, and address known and foreseeable public and agency concerns. As a minimum, the information should include a description of the proposed action and, as appropriate, its immediate surrounding area, a discussion of any specific areas of environmental concern (e.g., Section 4(f), wetlands, relocations), and a list of other Federal actions required, if any, for the proposal.

The documentation of the decision to advance an action in the second group as a CE can be accomplished by one of the following methods:

1. Minor actions from the list of examples:

   Minor construction projects or approval actions need only minimum documentation. Where project-specific information for such minor construction projects is included with the Section 105 program and clearly shows that the project is one of the 12 listed examples in Section 771.117(d), the approval of the Section 105 program can be used to approve the projects as CEs. Similarly, the three approval actions on the list (examples (6), (7) and (12)) should not normally require detailed documentation, and the CE determination can be documented as a part of the approval action being requested.

2. Other actions from the list of examples:

   For more complex actions, additional information and possibly environmental studies will be needed. This informationshould be furnished to the FHWA on a case-by-case basis for concurrence in the CE determination.

3. Actions not on the list of examples:

   Any action which meets the CE criteria in 23 CFR 771.117(a) may be classified as a CE even though it does not appear on the list of examples in Section 771.117(d). The actions on the list should be used as a guide to identify other actions that may be processed as CEs. The documentation to be submitted to the FHWA must demonstrate that the CE criteria are satisfied and that the proposed project will not result in significant environmental impacts. The classification decision should be documented as a part of the individual project submissions.

4. <u>Consideration of Unusual Circumstances</u>

Section 771.117(b) lists those unusual circumstances where further environmental studies will be necessary to determine the appropriateness of a CE classification. Unusual circumstances can arise on any project normally advanced with a CE; however, the type and depth of additional studies will vary with the type of CE and the facts and circumstances of each situation. For those actions on the fixed list (first group) of CEs, unusual circumstances should rarely, if ever, occur due to the limited scope of work. Unless unusual circumstances come to the attention of the HA or FHWA, they need not be given further consideration. For actions in the second group of CEs, unusual circumstances should be addressed in the information provided to the FHWA with the request for CE approval. The level of consideration, analysis, and documentation should be commensurate with the action's potential for significant impacts, controversy, or inconsistency with other agencies' environmental requirements.

When an action may involve unusual circumstances, sufficient early coordination, public involvement and environmental studies should be undertaken to determine the likelihood of significant impacts. If no significant impacts are likely to occur, the results of environmental studies and any agency and public involvement should adequately support such a conclusion and be included in the request to the FHWA for CE approval. If significant impacts are likely to occur, an EISmust be prepared (23 CFR 771.123(a)). If the likelihood of significant impacts is uncertain even after studies have been undertaken, the HA should consult with the FHWA to determine whether to prepare an EA or an EIS.

II. ENVIRONMENTAL ASSESSMENT (EA)

The primary purpose of an EA is to help the FHWA and HA decide whether or not an EIS is needed. Therefore, the EA should address only those resources or features which the FHWA and the HA decide will have a likelihood for being significantly impacted. The EA should be a concise document and should not contain long descriptions or detailed information which may have been gathered or analyses which may have been conducted for the proposed action. Although the regulations do not set page limits, CEQ recommends that the length of EAs usually be less than 15 pages. To minimize volume, the EA should use good quality maps and exhibits and incorporate by reference and summarize background data and technical analyses to support the concise discussions of the alternatives and their impacts.

The following format and content is suggested:

A. Cover Sheet.

There is no required format for the EA. However, the EIS cover sheet format, as shown in Section V, is recommended as a guide. A document number is not necessary. The due date for comments should be omitted unless the EA is distributed for comments.

B. Purpose of and Need for Action.

Describe the locations, length, termini, proposed improvements, etc. Identify and describe the transportation or other needs which the proposed action is intended to satisfy (e.g., provide system continuity, alleviate traffic congestion, and correct safety or roadway deficiencies). In many cases the project need can be adequately explained in one or two paragraphs. On projects where a law, Executive Order, or regulation (e.g., Section 4(f), Executive Order 11990, or Executive Order 11988) mandates an evaluation of avoidance alternatives, the explanation of the project need should be morespecific so that avoidance alternatives that do not meet the stated project need can be readily dismissed.

C. Alternatives.

Discuss alternatives to the proposed action, including the no-action alternative, which are being considered. The EA may either discuss (1) the preferred alternative and identify any other alternatives considered or (2) if the applicant has not identified a preferred alternative, the alternatives under consideration. The EA does not need to evaluate in detail all reasonable alternatives for the project, and may be prepared for one or more build alternatives.

D. Impacts.

For each alternative being considered, discuss any social, economic, and environmental impacts whose significance is uncertain. The level of analysis should be sufficient to adequately identify the impacts and appropriate mitigation measures, and address known and foreseeable public and agency concerns.

Describe why these impacts are considered not significant. Identified impact areas which do not have a reasonable possibility for individual or cumulative significant environmental impacts need not be discussed.

E. Comments and Coordination.

Describe the early and continuing coordination efforts, summarize the key issues and pertinent information received from the public and government agencies through these efforts, and list the agencies and, as appropriate, members of the public consulted.

F. Appendices (if any).

The appendices should include only analytical information that substantiates an analysis which is important to the document (e.g., a biological assessment for threatened or endangered species). Other information should be referenced only (i.e., identify the material and briefly describe its contents).

G. Section 4(f) Evaluation (if any).

If the EA includes a Section 4(f) evaluation, the EA/Section 4(f) evaluation or, if prepared separately, the Section 4(f) evaluation by itself must be circulated to the appropriate agencies for Section 4(f) coordination (23 CFR 771.135(i)). Section VII provides specific details on distribution and coordination of Section 4(f) evaluations. Section IX provides information on format and content of Section 4(f) evaluation.

If a programmatic Section 4(f) evaluation is used on the proposed project, this fact should be included and the Section 4(f) resource identified in the EA. The avoidance alternatives evaluation called for in Section 771.135(i) need not be repeated in the EA. Such evaluation would be part of the documentation to support the applicability and findings of the programmatic document.

H. EA Revisions.

Following the public availability period, the EA should be revised or an attachment provided, as appropriate, to (1) reflect changes in the proposed action or mitigation measures resulting from comments received on the EA or at the public hearing (if one is held) and any impacts of the changes, (2) include any necessary findings, agreements, or determination (e.g., wetlands, Section 106, Section 4(f)) required for the proposal, and (3) include a copy of pertinent comments received on the EA and appropriate responses to the comments.

III. FINDING OF NO SIGNIFICANT IMPACT (FONSI)

The EA, revised or with attachment(s) (see paragraph above), is submitted by the HA to the FHWA along with (1) a copy of the public hearing transcript, when one is held, (2) a recommendation of the preferred alternative, and (3) a request that a finding of no significant impact be made. The basis for the HA's finding of no significant impact request should be adequately documented in the EA and any attachment(s).

After review of the EA and any other appropriate information, the FHWA may determine that the proposed action has no significant impacts. This is documented by attaching to the EA a separate statement (sample follows) which clearly sets forththe FHWA conclusions. If necessary, the FHWA may expand the sample FONSI to identify the basis for the decision, uses of land from Section 4(f) properties, wetland finding, etc.

The EA or FONSI should document compliance with NEPA and other applicable environmental laws, Executive Orders, and related requirements. If full compliance with these other requirements is not possible by the time the FONSI is prepared, the documents should reflect consultation with the appropriate agencies and describe when and how the requirements will be met. For example, any action requiring the use of Section 4(f) property cannot proceed until FHWA gives a Section 4(f) approval (49 U.S.C. 303(c)).

IV. DISTRIBUTION OF EAs AND FONSIs

A. Environmental Assessment

After clearance by FHWA, EAs must be made available for public inspection at the HA and FHWA Division offices (23 CFR 771.119(d)). Although only a notice of availability of the EA is required, the HA is encouraged to distribute a copy of the document with the notice to Federal, State, and local government agencies likely to have an interest in the undertaking and to the State intergovernmental review contacts. The HA should also distribute the EA to any Federal, State, or local agency known to have interest or special expertise (e.g., EPA for wetlands, water quality, air, noise, etc.) in those areas addressed in the EA which have or may have had potential for significant impact. The possible impacts and the agencies involved should be identified following the early coordination process.

Where an individual permit would be required from the Corps of Engineers (COE) (i.e., Section 404 or Section 10) or from the Coast Guard (CG) (i.e., Section 9), a copy of the EA should be distributed to the involved agency in accordance with the U.S. Department of Transportation (DOT)/Corps of Engineers Memorandum of Agreement or the FHWA/U.S. Coast Guard Memorandum of Understanding, respectively. Any internal FHWA distribution will be determined by the Division Office on a case-by-case basis.

B. Finding of No Significant Impact

Formal distribution of a FONSI is not required. The HA must send a notice of availability of the FONSI to Federal, State, and local government agencies likely to have an interest in the undertaking and the State intergovernmental review contacts (23 CFR 771.121(b)). However, it is encouraged that agencies which commented on the EA (or requested to be informed) be advised of the project decision and the disposition of their comments and be provided a copy of the FONSI. This fosters good lines of communication and enhances interagency coordination.

V. Environmental Impact Statement (EIS) -- FORMAT AND CONTENT

A. Cover Sheet

Each EIS should have a cover sheet containing the following information:

(EIS NUMBER)

Route, Termini, City or County, and State

Draft (Final) (Supplement)

Environmental Impact Statement

Submitted Pursuant to 42 U.S.C. 4332 (2) (c)(and where applicable, 49 U.S.C. 303) by the U.S. Department of Transportation, Federal Highway Administration and State Highway Agency and(As applicable, any other joint lead agency)

Cooperating Agencies (Include List Here, as applicable)

Date of Approval

For (State Highway Agency)

Date of Approval

For FHWA

The following persons may be contacted for additional information concerning this document:

(Name, address, and telephone number of FHWA Division Office contact)

(Name, address, and telephone number of HA contact)

A one-paragraph abstract of the statement.

Comments on this draft EIS are due by (date) and should be sent to (name and address).

The top left-hand corner of the cover sheet of all draft final and supplemental EISs contains an identification number. The following is an example:

FHWA-AZ-EIS-87-01-D(F)(S)

FHWA name of Federal agency

AZ name of State (cannot exceed four characters)

EIS environmental impact statement

87 year draft statement was prepared

01 sequential number of draft statement for each calendar year

D designates the statement as the draft statement

F designates the statement as the final statement

S designates supplemental statement and should be combined with draft (DS) or final (FS) statement designation. The year and sequential number will be the same as those used for the original draft EIS.

The EIS should be printed on 8 1/2 x 11-inch paper with any foldout sheets folded to that size. The wider sheets should be 8 1/2 inches high and should open to the right with the title or identification on the right. The standard size is needed for administrative recordkeeping.

B. Summary

The summary should include:

1. A brief description of the proposed FHWA action indicating route, termini, type of improvement, number of lanes, length, county, city, State, and other information, as appropriate.
2. A description of any major actions proposed by other governmental agencies in the same geographic area as the proposed FHWA action.
3. A summary of all reasonable alternatives considered. (The draft EIS must identify the preferred alternative or alternatives officially identified by the HA (40 CFR 1502.14(e)). The final EIS must identify the preferred alternative and should discuss the basis for its selection (23 CFR 771.125(a)(1)).
4. A summary of major environmental impacts, both beneficial and adverse.
5. Any areas of controversy (including issues raised by agencies and the public).
6. Any major unresolved issues with other agencies.
7. A list of other Federal actions required for the proposed action (i.e., permit approvals, land transfer, Section 106 agreements, etc.).

C. Table of Contents

For consistency with CEQ regulations, the following standard format should be used:

1. Cover Sheet
2. Summary
3. Table of Contents
4. Purpose of and Need for Action
5. Alternatives
6. Affected Environment
7. Environmental Consequences
8. List of Preparers

9. List of Agencies, Organizations, and Persons to Whom Copies of the Statement are Sent
10. Comments and Coordination
11. Index
12. Appendices (if any)

D. <u>Purpose of and Need for Action</u>

Identify and describe the proposed action and the transportation problem(s) or other needs which it is intended to address (40 CFR 1502.13). This section should clearly demonstrate that a "need" exists and should define the "need" in terms understandable to the general public. This discussion should clearly describe the problems which the proposed action is to correct. It will form the basis for the "no action" discussion in the "Alternatives" section, and assist with the identification of reasonable alternatives and the selection of the preferred alternative. Charts, tables, maps, and other illustrations (e.g., typical cross-section, photographs, etc.) are encouraged as useful presentation techniques.

The following is a list of items which may assist in the explanation of the need for the proposed action. It is by no means all-inclusive or applicable in every situation and is intended only as a guide.

1. Project Status - Briefly describe the project history including actions taken to date, other agencies and governmental units involved, action spending, schedules, etc.
2. System Linkage - Is the proposed project a "connecting link?" How does it fit in the transportation system?
3. Capacity - Is the capacity of the present facility inadequate for the present traffic? Projected traffic? What capacity is needed? What is the level(s) of service for existing and proposed facilities?
4. Transportation Demand - Including relationship to any statewide plan or adopted urban transportation plan together with an explanation of the project's traffic forecasts that are substantially different from those estimates from the 23 U.S.C. 134 (Section 134) planning process.
5. Legislation - Is there a Federal, State, or local governmental mandate for the action?
6. Social Demands or Economic Development - New employment, schools, land use plans, recreation, etc. What projected economic

development/land use changes indicate the need to improve or add to the highway capacity?

7. Modal Interrelationships - How will the proposed facility interface with and serve to complement airports, rail and port facilities, mass transit services, etc.?
8. Safety - Is the proposed project necessary to correct an existing or potential safety hazard? Is the existing accident rate excessively high? Why? How will the proposed project improve it?
9. Roadway Deficiencies - Is the proposed project necessary to correct existing roadway deficiencies (e.g., substandard geometrics, load limits on structures, inadequate cross-section, or high maintenance costs)? How will the proposed project improve it?

E. Alternatives

This section of the draft EIS must discuss a range of alternatives, including all "reasonable alternatives" under consideration and those "other alternatives" which were eliminated from detailed study (23 CFR 771.123(c)). The section should begin with a concise discussion of how and why the "reasonable alternatives" were selected for detailed study and explain why "other alternatives" were eliminated. The following range of alternatives should be considered when determining reasonable alternatives:

1. "No-action" alternative: The "no-action" alternative normally includes short-term minor restoration types of activities (safety and maintenance improvements, etc.) that maintain continuing operation of the existing roadway.
2. Transportation System Management (TSM) alternative: The TSM alternative includes those activities which maximize the efficiency of the present system. Possible subject areas to include in this alternative are options such as fringe parking, ridesharing, high-occupancy vehicle (HOV) lanes on existing roadways, and traffic signal timing optimization. This limited construction alternative is usually relevant only for major projects proposed in urbanized areas over 200,000 population.

   For all major projects in these urbanized areas, HOV lanes should be considered. Consideration of this alternative may be accomplished by reference to the regional transportation plan, when that plan considers this option. Where a regional transportation plan does not reflect consideration of this option, it may be necessary to evaluate the feasibility of HOV lanes during early project development. Where a TSM alternative is identified as a reasonable alternative for a "connecting link" project, it should be evaluated to determine the effect that not building a highway link in the transportation plan will have on the remainder of the system. A similar analysis should be made where a TSM element(s) (e.g., HOV lanes) is part of a build alternative and reduces the scale of the highway link.

While the above discussion relates primarily to major projects in urbanized areas, the concept of achieving maximum utilization of existing facilities is equally important in rural areas. Before selecting an alternative on new location for major projects in rural areas, it is important to demonstrate that reconstruction and rehabilitation of the existing system will not adequately correct the identified deficiencies and meet the project need.

3. Mass Transit: This alternative includes those reasonable and feasible transit options (bus systems, rail, etc.) even though they may not be within the existing FHWA funding authority. It should be considered on all proposed major highway projects in urbanized areas over 200,000 population. Consideration of this alternative may be accomplished by reference to the regional or area transportation plan where that plan considers mass transit or by an independent analysis during early project development.

   Where urban projects are multi-modal and are proposed for Federal funding, close coordination is necessary with the Urban Mass Transportation Administration (UMTA). In these situations, UMTA should be consulted early in the project-development process. Where UMTA funds are likely to be requested for portions of the proposal, UMTA must be requested to be either a joint lead agency or a cooperating agency at the earliest stages of project development (23 CFR 771.111(d)). Where applicable, cost-effectiveness studies that have been performed should be summarized in the EIS.

4. Build alternatives: Both improvement of existing highway(s) and alternatives on new location should be evaluated. A representative

number of reasonable alternatives must be presented and evaluated in detail in the draft EIS (40 CFR 1502.14(a)). For most major projects, there is a potential for a large number of reasonable alternatives. Where there is a large number of alternatives, only a representative number of the most reasonable examples, covering the full range ofalternatives, must be presented. The determination of the number of reasonable alternatives in the draft EIS, therefore, depends on the particular project and the facts and circumstances in each case.

Each alternative should be briefly described using maps or other visual aids such as photographs, drawings, or sketches to help explain the various alternatives. The material should provide a clear understanding of each alternative's termini, location, costs, and the project concept (number of lanes, right-of-way requirements, median width, access control, etc.). Where land has been or will be reserved or dedicated by local government(s), donated by individuals, or acquired through advanced or hardship acquisition for use as highway right-of-way for any alternative under consideration, the draft EIS should identify the status and extent of such property and the alternatives involved. Where such lands are reserved, the EIS should state that the reserved lands will not influence the alternative to be selected.

Development of more detailed design for some aspects (e.g., Section 4(f), COE or CG permits, noise, wetlands, etc.) of one or more alternatives may be necessary during preparation of the draft and final EIS in order to evaluate impacts or mitigation measures or to address issues raised by other agencies or the public. However, care should be taken to avoid unnecessarily specifying features which preclude cost-effective final design options.

All reasonable alternatives under consideration (including the no-build) need to be developed to a comparable level of detail in the draft EIS so that their comparative merits may be evaluated (40 CFR 1502.14(b) and (d)). In those situations where the HA has officially identified a "preferred" alternative based on its early coordination and environmental studies, the HA should so indicate in the draft EIS. In these instances, the draft EIS should include a statement indicating that the final selection of an alternative will not be made until the alternatives' impacts and comments on the draft EIS and from the public hearing (if held) have been fully evaluated. Where a preferred alternative has not been identified, the draft EIS should state that all reasonable alternatives are underconsideration and that a decision will be made after the alternatives' impacts and comments on the draft EIS and from the public hearing (if held) have been fully evaluated.

The final EIS must identify the preferred alternative and should discuss the basis for its selection (23 CFR 771.125(a)(1)). The discussion should provide the information and rationale identified in Section VIII (Record of Decision), paragraph (B). If the preferred alternative is modified after the draft EIS, the final EIS should clearly identify the changes and discuss the reasons why any new impacts are not significant.

F. Affected Environment

This section provides a concise description of the existing social, economic, and environmental setting for the area affected by all alternatives presented in the EIS. Where possible, the description should be a single description for the general project area rather than a separate one for each alternative. The general population served and/or affected (city, county, etc.) by the proposed action should be identified by race, color, national origin, and age. Demographic data should be obtained from available secondary sources (e.g., census data, planning reports) unless more detailed information is necessary to address specific concerns. All socially, economically, and environmentally sensitive locations or features in the proposed project impact area (e.g., neighborhoods, elderly/minority/ ethnic groups, parks, hazardous material sites, historic resources, wetlands, etc.), should be identified on exhibits and briefly described in the text. However, it may be desirable to exclude from environmental documents the specific location of archeological sites to prevent vandalism.

To reduce paperwork and eliminate extraneous background material, the discussion should be limited to data, information, issues, and values which will have a bearing on possible impacts, mitigation measures, and on the selection of an alternative. Data and analyses should be commensurate with the importance of the impact, with the less important material summarized or referenced rather than be reproduced. Photographs, illustrations, and other graphics should be used with the text to give a clear understanding of the area and the important issues. Other Federal activities which contribute to the significance of the proposed action's impacts should be described.

This section should also briefly describe the scope and status of the planning processes for the local jurisdictions and the project area. Maps of any adopted land use and transportation plans for these jurisdictions and the project area would be helpful in relating the proposed project to the planning processes.

G. Environmental Consequences

This section includes the probable beneficial and adverse social, economic, and environmental effects of alternatives under consideration and describes the measures proposed to mitigate adverse impacts. The information should have sufficient scientific and analytical substance to provide a basis for evaluating the comparative merits of the alternatives. The discussion of the proposed project impacts should not use the term significant in describing the level of impacts. There is no benefit to be gained from its use. If the term significant is used, however, it should be consistent with the CEQ definition and be supported by factual information.

There are two principal ways of preparing this section. One is to discuss the impacts and mitigation measures separately for each alternative with the alternatives as headings. The second (which is advantageous where there are few alternatives or where impacts are similar for the various alternatives) is to present this section with the impacts as the headings. Where appropriate, a sub-section should be included which discusses the general impacts and mitigation measures that are the same for the various alternatives under consideration. This would reduce or eliminate repetition under each of the alternative discussions. Charts, tables, maps, and other graphics illustrating comparisons between the alternatives (e.g., costs, residential displacements, noise impacts, etc.) are useful as a presentation technique.

When preparing the final EIS, the impacts and mitigation measures of the alternatives, particularly the preferred alternative, may need to be discussed in more detail to elaborate on information, firm-up commitments, or address issues raised following the draft EIS. The final EIS should also identify anynew impacts (and their significance) resulting from modification of or identification of substantive new circumstances or information regarding the preferred alternative following the draft EIS circulation. Note: Where new significant impacts are identified a supplemental draft EIS is required (40 CFR 1502.9(c)).

The following information should be included in both the draft and final EIS for each reasonable alternative:

1. A summary of studies undertaken, any major assumptions made and supporting information on the validity of the methodology (where the methodology is not generally accepted as state-of-the-art).
2. Sufficient supporting information or results of analyses to establish the reasonableness of the conclusions on impacts.
3. A discussion of mitigation measures. These measures normally should be investigated in appropriate detail for each reasonable alternative so they can be identified in the draft EIS. The final EIS should identify, describe and analyze all proposed mitigation measures for the preferred alternative.

In addition to normal FHWA program monitoring of design and construction activities, special instances may arise when a formal program for monitoring impacts or implementation of mitigation measures will be appropriate. For example, monitoring ground or surface waters that are sources for drinking water supply; monitoring noise or vibration of nearby sensitive activities (e.g., hospitals, schools); or providing on-site professional archeologist to monitor excavation activities in highly sensitive archeological areas. In these instances, the final EIS should describe the monitoring program.

4. A discussion, evaluation and resolution of important issues on each alternative. If important issues raised by other agencies on the preferred alternative remain unresolved,the final EIS must identify those issues and the consultations and other efforts made to resolve them (23 CFR 771.125(a)(2)).

   Listed below are potentially significant impacts most commonly encountered by highway projects. These factors should be discussed for each reasonable alternative where a potential for impact exists. This list is not all-inclusive and on specific projects there may be other impact areas that should be included.

5. <u>Land Use Impacts</u>

This discussion should identify the current development trends and the State and/or local government plans and policies on land use and growth in the area which will be impacted by the proposed project.

These plans and policies are normally reflected in the area's comprehensive development plan, and include land use, transportation, public facilities, housing, community services, and other areas.

The land use discussion should assess the consistency of the alternatives with the comprehensive development plans adopted for the area and (if applicable) other plans used in the development of the transportation plan required by Section 134. The secondary social, economic, and environmental impacts of any substantial, foreseeable, induced development should be presented for each alternative, including adverse effects on existing communities. Where possible, the distinction between planned and unplanned growth should be identified.

6. Farmland Impacts

Farmland includes 1) prime, 2) unique, 3) other than prime or unique that is of statewide importance, and 4) other than prime or unique that is of local importance.

The draft EIS should summarize the results of early consultation with the Soil Conservation Service (SCS) and, as appropriate, State and local agriculture agencies where any of the four specified types of farmland could be directly orindirectly impacted by any alternative under consideration. Where farmland would be impacted, the draft EIS should contain a map showing the location of all farmlands in the project impact area, discuss the impacts of the various alternatives and identify measures to avoid or reduce the impacts. Form AD 1006 (Farmland Conversion Impact Rating) should be processed, as appropriate, and a copy included in the draft EIS. Where the Land Evaluation and Site Assessment score (from Form AD 1006) is 160 points or greater, the draft EIS should discuss alternatives to avoid farmland impacts.

If avoidance is not possible, measures to minimize or reduce the impacts should be evaluated and, where appropriate, included in the proposed action.

7. <u>Social Impacts</u>

Where there are foreseeable impacts, the draft EIS should discuss the following items for each alternative commensurate with the level of impacts and to the extent they are distinguishable:

(a) Changes in the neighborhoods or community cohesion for the various social groups as a result of the proposed action. These changes may be beneficial or adverse, and may include splitting neighborhoods, isolating a portion of a neighborhood or an ethnic group, generating new development, changing property values, or separating residents from community facilities, etc.

(b) Changes in travel patterns and accessibility (e.g., vehicular, commuter, bicycle, or pedestrian).

(c) Impacts on school districts, recreation areas, churches, businesses, police and fire protection, etc. This should include both the direct impacts to these entities and the indirect impacts resulting from the displacement of households and businesses.

(d) Impacts of alternatives on highway and traffic safety as well as on overall public safety.

(e) General social groups specially benefitted or harmed by the proposed project. The effects of a project on the elderly, handicapped, nondrivers, transit-dependent, and minority and ethnic groups are of particular concern and should be described to the extent these effects can be reasonably predicted. Where impacts on a minority or ethnic population are likely to be an important issue, the EIS should contain the following information broken down by race, color, and national origin: the population of the study area, the number of displaced residents, the type and number of displaced businesses, and an estimate of the number of displaced employees in each business sector. Changes in ethnic or minority employment opportunities should be discussed and the relationship of the project to other Federal actions which may serve or adversely affect the ethnic or minority population should be identified.

The discussion should address whether any social group is disproportionally impacted and identify possible mitigation measures to avoid or minimize any adverse impacts. Secondary sources of information such as census and personal contact with community leaders supplemented by visual inspections normally should be used to obtain the data for this analysis. However, for projects with major community impacts, a survey of the affected area may be needed to identify the extent and severity of impacts on these social groups.

8. <u>Relocation Impacts</u>

The relocation information should be summarized in sufficient detail to adequately explain the relocation situation including anticipated problems and proposed solutions. Project relocation documents from which information is summarized shouldbe referenced in the draft EIS. Secondary sources of information such as census, economic reports, and contact with community leaders, supplemented by visual inspections (and, as appropriate, contact with local officials) may be used to obtain the data for this analysis. Where a proposed project will result in displacements, the following information regarding households and businesses should be discussed for each alternative under consideration commensurate with the level of impacts and to the extent they are likely to occur:

(a) An estimate of the number of households to be displaced, including the family characteristics (e.g., minority, ethnic, handicapped, elderly, large family, income level, and owner/tenant status). However, where there are very few displacees, information on race, ethnicity and income levels should not be included in the EIS to protect the privacy of those affected.

(b) A discussion comparing available (decent, safe, and sanitary) housing in the area with the housing needs of the displacees. The comparison should include (1) price ranges, (2) sizes (number of bedrooms), and (3) occupancy status (owner/tenant).

(c) A discussion of any affected neighborhoods, public facilities, non-profit organizations, and families having special composition (e.g., ethnic, minority, elderly, handicapped, or other factors) which may require special relocation considerations and the measures proposed to resolve these relocation concerns.

(d) A discussion of the measures to be taken where the existing housing inventory is insufficient, does not meet relocation standards, or is not within the financial capability of the displacees. A commitment to last resort housing should be includedwhen sufficient comparable replacement housing may not be available.

(e) An estimate of the numbers, descriptions, types of occupancy (owner/tenant), and sizes (number of employees) of businesses and farms to be displaced. Additionally, the discussion should identify (1) sites available in the area to which the affected businesses may relocate, (2) likelihood of such relocation, and (3) potential impacts on individual businesses and farms caused by displacement or proximity of the proposed highway if not displaced.

(f) A discussion of the results of contacts, if any, with local governments, organizations, groups, and individuals regarding residential and business relocation impacts, including any measures or coordination needed to reduce general and/or specific impacts. These contacts are encouraged for projects with large numbers of relocatees or complex relocation requirements. Specific financial and incentive programs or opportunities (beyond those provided by the Uniform Relocation Act) to residential and business relocatees to minimize impacts may be identified, if available through other agencies or organizations.

(g) A statement that (1) the acquisition and relocation program will be conducted in accordance with the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, as amended, and (2) relocation resources are available to all residential and business relocatees without discrimination.

9. Economic Impacts

Where there are foreseeable economic impacts, the draft EIS should discuss the following for each alternative commensurate with the level of impacts:

(a) The economic impacts on the regional and/or local economy such as the effects of the project on development, tax revenues and public expenditures, employment opportunities, accessibility, and retail sales. Where substantial impacts on the economic viability of affected municipalities are likely to occur, they should also be discussed together with a summary of any efforts undertaken and agreements reached for using the transportation investment to support both public and private economic development plans. To the extent possible, this discussion should rely upon results of coordination with and views of affected State, county, and city officials and upon studies performed under Section 134.

(b) The impacts on the economic vitality of existing highway-related businesses (e.g., gasoline stations, motels, etc.) and the resultant impact, if any, on the local economy. For example, the loss of business or employment resulting from building an alternative on new location bypassing a local community.

(c) Impacts of the proposed action on established business districts, and any opportunities to minimize or reduce such impacts by the public and/or private sectors. This concern is likely to occur on a project that might lead to or support new large commercial development outside of a central business district.

10. Joint Development

Where appropriate, the draft EIS should identify and discuss those joint development measures which will preserve or enhance an affected community's social, economic, environmental, and visual values. This discussion may be presented separately or combined with the land use and/or social impacts presentations. The benefits to be derived, those who will benefit (communities, social groups, etc.), and the entities responsible for maintaining the measures should be identified.

11. Considerations Relating to Pedestrians and Bicyclists

Where current pedestrian or bicycle facilities or indications of use are identified, the draft EIS should discuss the current and anticipated use of the facilities, the potential impacts of the affected alternatives, and proposed measures, if any, to avoid or reduce adverse impacts to the facility(ies) and its users. Where new facilities are proposed as a part of the proposed highway project, the EIS should include sufficient information to explain the basis for providing the facilities (e.g., proposed bicycle facility is a link in the local plan or sidewalks will reduce project access impact to the community). The final EIS should identify those facilities to be included in the preferred alternative. Where the preferred alternative would sever an existing major route for non-motorized transportation traffic, the proposed project needs to provide a reasonably alternative route or demonstrate that such a route exists (23 U.S.C. 109(n)). To the fullest extent possible, this needs to be described in the final EIS.

8. Air Quality Impacts

The draft EIS should contain a brief discussion of the transportation-related air quality concerns in the project area and a summary of the project- related carbon monoxide (CO) analysis if such analysis is performed. The following information should be presented, as appropriate.

(a) Mesoscale Concerns: Ozone (O_3), Hydrocarbons (HC), and Nitrogen Oxide (NO_x) air quality concerns are regional in nature and as such meaningful evaluation on a project-by-project basis is not possible. Where these pollutants are an issue, the air quality emissions inventories in the State Implementation Plan (SIP) should be referenced and briefly summarized in the draft

EIS. Further, the relationship of the project to the SIP should be described in the draft EIS by including one of the following statements:

> 1 This project is in an area where the SIP does not contain any transportation control measures. Therefore, the conformity procedures of 23 CFR 770 do not apply to this project.
>
> 2 This project is in an area which has transportation control measures in the SIP which was (conditionally) approved by the Environmental Protection Agency (EPA) on (date). The FHWA has determined that both the transportation plan and the transportation improvement program conform to the SIP. The FHWA has determined that this project is included in the transportation improvement program for the (indicate 3C planning area). Therefore, pursuant to 23 CFR 770, this project conforms to the SIP.
>
> Under certain circumstances, neither of these statements will precisely fit the situation and may need to be modified. Additionally, if the project is a Transportation Control Measure from the SIP, this should be highlighted to emphasize the project's air quality benefits.

(b) Microscale Concerns: Carbon monoxide is a project- related concern and as such should be evaluated in the draft EIS. A microscale CO analysis is unnecessary where such impacts (project CO contribution plus background) can be judged to be well below the 1- and 8-hour National Ambient AirQuality Standards (or other applicable State or local standards). This judgment may be based on (1) previous analyses for similar projects; (2) previous general analyses for various classes of projects; or (3) simplified graphical or "look-up" table evaluations. In these cases, a brief statement stating the basis for the judgment is sufficient.

For those projects where a microscale CO analysis is performed, each reasonable alternative should be analyzed for the estimated time of completion and design year. A brief summary of the methodologies and assumptions used should be included in the draft EIS. Lengthy discussions, if needed, should be included in a separate technical report and referenced in the EIS. Total CO concentrations (project contribution plus estimated background) at identified reasonable receptors for each alternative should be reported. A comparison should be made between alternatives and with applicable State and national standards. Use of a table for this comparison is recommended for clarity.

As long as the total predicted 1-hour CO concentration is less than 9 ppm (the 8-hour CO standard), no separate 8-hour analysis is necessary. If the 1-hour CO concentration is greater than 9 ppm, an 8-hour analysis should be performed. Where the preferred alternative would result in violations of the 1 or 8-hour CO standards, an effort should be made to develop reasonable mitigation measures through early coordination between FHWA, EPA, and appropriate State and local highway and air quality agencies. The final EIS should discuss the proposed mitigation measures and include evidence of the coordination.

12. Noise Impacts

The draft EIS should contain a summary of the noise analysis including the following for each alternative under detailed study:

(a) A brief description of noise sensitive areas (residences, businesses, schools,parks, etc.), including information on the number and types of activities which may be affected. This should include developed lands and undeveloped lands for which development is planned, designed, and programmed.

(b) The extent of the impact (in decibels) at each sensitive area. This includes a comparison of the predicted noise levels with both the FHWA noise abatement criteria and the existing noise levels. (Traffic noise impacts occur when the predicted traffic noise levels approach or exceed the noise abatement criteria or when they substantially exceed the existing noise levels). Where there is a substantial increase in noise levels, the HA should identify the criterion used for defining "substantial increase." Use of a table for this comparison is recommended for clarity.

(c) Noise abatement measures which have been considered for each impacted area and those measures that are reasonable and feasible and that would "likely" be incorporated into the proposed project. Estimated costs, decibel reductions and height and length of barriers should be shown for all abatement measures.

Where it is desirable to qualify the term "likely," the following statement or similar wording would be appropriate. "Based on the studies completed to date, the State intends to install noise abatement measures in the form of a barrier at (location(s)). These preliminary indications of likely abatement measures are based upon preliminary design for a barrier of _______ high and ______ long and a cost of $______ that will reduce the noise level by ______ dBA for ________ residences (businesses, schools, parks, etc.). (Where there is more than one barrier, provide information for each one.) If during final design these conditions substantially change, the abatement measures might not be provided. A final decision onthe installation of abatement measure(s) will be made upon completion of the project design and the public involvement process."

(d) Noise impacts for which no prudent solution is reasonably available and the reasons why.

13. Water Quality Impacts

The draft EIS should include summaries of analyses and consultations with the State and/or local agency responsible for water quality. Coordination with the EPA under the Federal Clean Water Act may also provide assistance in this area. The discussion should include sufficient information to describe the ambient conditions of streams and water bodies which are likely to be impacted and identify the potential impacts of each alternative and proposed mitigation measures. Under normal circumstances, existing data may be used to describe ambient conditions. The inclusion of water quality data spanning several years is encouraged to reflect trends.

The draft EIS should also identify any locations where roadway runoff or other nonpoint source pollution may have an adverse impact on sensitive water resources such as water supply reservoirs, ground water recharge areas, and high quality streams. The 1981 FHWA research report entitled "Constituents of Highway Runoff," the 1985 report entitled "Management Practices for Mitigation of Highway Stormwater Runoff Pollution," and the 1987 report entitled "Effects of Highway Runoff on Receiving Waters" contain procedures for estimating pollutant loading from highway runoff and would be helpful in determining the level of potential impacts and appropriate mitigative measures. The draft EIS should identify the potential impacts of each alternative and proposed mitigation measures.

Where an area designated as principal or sole-source aquifer under Section 1424(e) of the Safe Drinking Water Act may be impacted by a proposed project, early coordination with EPA will assist in identifying potential impacts. The EPA will furnish information on whether any of the alternatives affect the aquifer. This coordination should also identify any potential impacts to the critical aquifer protection area (CAPA), if designated, within affected sole-source aquifers. If none of thealternatives affect the aquifer, the requirements of the Safe Drinking Water Act are satisfied. If an alternative is selected which affects the aquifer, a design must be developed to assure, to the satisfaction of EPA, that it will not contaminate the aquifer (40 CFR 149). The draft EIS should document coordination with EPA and identify its position on the impacts of the various alternatives. The final EIS should show that EPA's concerns on the preferred alternative have been resolved.

Wellhead protection areas were authorized by the 1986 Amendments to the Safe Drinking Water Act. Each State will develop State wellhead protection plans with final approval by EPA. When a proposed project encroaches on a wellhead protection area, the draft EIS should identify the area, the potential impact of each alternative and proposed mitigation measures. Coordination with the State agency responsible for the protection plan will aid in identifying the areas, impacts and mitigation. If the preferred alternative impacts these areas, the final EIS should document that it complies with the approved State wellhead protection plan.

14. Permits

If a facility such as a safety rest area is proposed and it will have a point source discharge, a Section 402 permit will be required for point source discharge (40 CFR 122). The draft EIS should discuss potential adverse impacts resulting from such proposed facilities and identify proposed mitigation measures. The need for a Section 402 permit and Section 401 water quality certification should be identified in the draft EIS.

For proposed actions requiring a Section 404 or Section 10 (Corps of Engineers) permit, the draft EIS should identify by alternative the general location of each dredge or fill activity, discuss the potential adverse impacts, identify proposed mitigation measures (if not addressed elsewhere in the draft EIS), and include evidence of coordination with the Corps of Engineers (in accordance with the U.S. DOT/Corps of Engineers Memorandum of Agreement) and appropriate Federal, State and local resource agencies, and State and local water quality agencies. Where the preferred alternative requires an individual Section 404 or Section 10 permit, the final EIS should identify for eachpermit activity the approximate quantities of dredge or fill material, general construction grades and proposed mitigation measures.

For proposed actions requiring Section 9 (U.S. Coast Guard bridge) permits, the draft EIS should identify by alternative the location of the permit activity, potential impacts to navigation and the environment (if not addressed elsewhere in the document), proposed mitigation measures and evidence coordination with the U.S. Coast Guard (in accordance with the FHWA/U.S. Coast Guard Memorandum of Understanding). Where the preferred alternative requires a Section 9 permit, the final EIS should identify for each permit activity the proposed horizontal and vertical navigational clearances and include an exhibit showing the various dimensions.

For all permit activities the final EIS should include evidence that every reasonable effort has been made to resolve the issues raised by other agencies regarding the permit activities. If important issues remain unresolved, the final EIS must identify those issues, the positions of the respective agencies on the issues and the consultations and other efforts made to resolve them (23 CFR 771.125(a)).

15. <u>Wetland Impacts</u>

When an alternative will impact wetlands the draft EIS should (1) identify the type, quality, and function of wetlands involved, (2) describe the impacts to the wetlands, (3) evaluate alternatives which would avoid these wetlands, and (4) identify practicable measures to minimize harm to the wetlands. Wetlands should be identified by using the definition of 33 CFR 328.3(b) (issued on November 13, 1986) which requires the presence of hydrophytic vegetation, hydric soils and wetland hydrology. Exhibits showing wetlands in the project impact area in relation to the alternatives, should be provided.

In evaluating the impact of the proposed project on wetlands, the following two items should be addressed: (1) the importance of the impacted wetland(s) and (2) the severity of this impact. Merely listing the number of acres taken by the various alternatives of a highway proposal does not provide sufficient information upon which to determine the degree ofimpact on the wetland ecosystem. The wetlands analysis should be sufficiently detailed to provide an understanding of these two elements.

In evaluating the importance of the wetlands, the analysis should consider such factors as: (1) the primary functions of the wetlands (e.g., flood control, wildlife habitat, ground water recharge, etc.), (2) the relative importance of these functions to the total wetland resource of the area, and (3) other factors such as uniqueness that may contribute to the wetlands importance.

In determining the wetland impact, the analysis should show the project's effects on the stability and quality of the wetland(s). This analysis should consider the short- and long-term effects on the wetlands and the importance of any loss such as: (1) flood control capacity, (2) shore line anchorage potential, (3) water pollution abatement capacity, and (4) fish and wildlife habitat value. The methodology developed by FHWA and described in reports numbered FHWA-IP-82-23 and FHWA IP-82-24, "A Method for Wetland Functional Assessment Volumes I and II," is recommended for use in conducting this analysis. Knowing the importance of the wetlands involved and the degree of the impact, the HA and FHWA will be in a better position to determine the mitigation efforts necessary to minimize harm to these wetlands. Mitigation measures which should be considered include preservation and improvement of existing wetlands and creation of new wetlands (consistent with 23 CFR 777).

If the preferred alternative is located in wetlands, to the fullest extent possible, the final EIS needs to contain the finding required by Executive Order 11990 that there are no practicable alternatives to construction in wetlands. Where the finding is included, approval of the final EIS will document compliance with the Executive Order 11990 requirements (23 CFR 771.125(a)(1)). The finding should be included in a separate subsection entitled "Only Practicable Alternative Finding" and should be supported by the following information:

(a) a reference to Executive Order 11990;

(b) an explanation why there are no practicable alternatives to the proposed action;

(c) an explanation why the proposed action includes all practicable measures to minimize harm to wetlands; and

(d) a concluding statement that: "Based upon the above considerations, it is determined that there is no practicable alternative to the proposed construction in wetlands and that the proposed action includes all practicable measures to minimize harm to wetlands which may result from such use."

16. Water Body Modification and Wildlife Impacts

For each alternative under detailed study the draft EIS should contain exhibits and discussions identifying the location and extent of water body modifications (e.g., impoundment, relocation, channel deepening, filling, etc.). The use of the stream or body of water for recreation, water supply, or other purposes should be identified. Impacts to fish and wildlife resulting from the loss degradation, or modification of aquatic or terrestrial habitat should also be discussed. The results of coordination with appropriate Federal, State and local agencies should be documented in the draft EIS. For example, coordination with FWS under the Fish and Wildlife Coordination Act of 1958.

17. Floodplain Impacts

National Flood Insurance Program (NFIP) maps or, if NFIP maps are not available, information developed by the highway agency should be used to determine whether an alternative will encroach on the base (100-year) floodplain. The location hydraulic studies required by 23 CFR 650, Subpart A, must include a discussion of the following items commensurate with the level of risk or environmental impact, for each alternative which encroaches on base floodplains or would support base floodplain development:

(a) The flooding risks;

(b) The impacts on natural and beneficial floodplain values;

(c) The support of probable incompatible floodplain development (i.e., any development that is not consistent with a community's floodplain development plan);

(d) The measures to minimize floodplain impacts; and

(e) The measures to restore and preserve the natural and beneficial floodplain values.

The draft EIS should briefly summarize the results of the location hydraulic studies. The summary should identify the number of encroachments and any support of incompatible floodplain developments and their potential impacts. Where an encroachment or support of incompatible floodplain development results in substantial impacts, the draft EIS should provide more detailed information on the location, impacts and appropriate mitigation measures. In addition, if any alternative (l) results in a floodplain encroachment or supports incompatible floodplain development having significant impacts, or (2) requires a commitment to a particular structure size or type, the draft EIS needs to include an evaluation and discussion of practicable alternatives to the structure or to the significant encroachment. The draft EIS should include exhibits which display the alternatives, the base floodplains and, where applicable, the regulatory floodways.

If the preferred alternative includes a floodplain encroachment having significant impacts, the final EIS must include a finding that it is the only practicable alternative as required by 23 CFR 650, Subpart A. The finding should refer to Executive Order 11988 and 23 CFR 650, Subpart A. It should be included in a separate subsection entitled "Only Practicable Alternative Finding" and must be supported by the following information.

(a) The reasons why the proposed action must be located in the floodplain;

(b) The alternatives considered and why they were not practicable; and

(c) A statement indicating whether the action conforms to applicable State or local floodplain protection standards.

For each alternative encroaching on a designated or proposed regulatory floodway, the draft EIS should provide a preliminary indication of whether the encroachment would be consistent with or require a revision to the regulatory floodway. Engineering and environmental analyses should be undertaken, commensurate with the level of encroachment, to permit the consistency evaluation and identify impacts. Coordination with the Federal Emergency Management Agency (FEMA) and appropriate State and local government agencies should be undertaken for each floodway encroachment. If the preferred alternative encroaches on a regulatory floodway, the final EIS should discuss the consistency of the action with the regulatory floodway. If a floodway revision is necessary, the EIS should include evidence from FEMA and local or State agency indicating that such revision would be acceptable.

18. <u>Wild and Scenic Rivers</u>

If the proposed action could have foreseeable adverse effects on a river on the National Wild and Scenic Rivers System or a river under study for designation to the National Wild and Scenic Rivers System, the draft EIS should identify early coordination undertaken with the agency responsible for managing the listed or study river (i.e., National Park Service (NPS), Fish and Wildlife Service (FWS), Bureau of Land Management (BLM), or Forest Service (FS)). For each alternative under consideration, the EIS should identify the potential adverse effects on the natural, cultural, and recreational values of the listed or study river. Adverse effects include alteration of the free-flowing nature of the river, alteration of the setting or deterioration of water quality. If it is determined that any of the alternatives could foreclose options to designate a study river under the Act, or adversely affect those qualities of a listed river for which it was designated, to the fullest extent possible, the draft EIS needs to reflect consultation with the managing agency on avoiding or mitigating the impacts (23 CFR 771.123(c)). The final EIS should identify measures that will be included in the preferred alternative to avoid or mitigate such impacts.

Publicly owned waters of designated wild and scenic rivers are protected by Section 4(f). Additionally, public lands adjacent to a Wild and Scenic River may be subject to Section 4(f) protection. An examination of any adopted or proposed management plan for a listed river should be helpful in making the determination on applicability of Section 4(f). For each alternative that takes such land, coordination with the agency responsible for managing the river (either NPS, FWS, BLM, or FS) will provide information on the management plan, specific affected land uses, and any necessary Section 4(f) coordination.

19. Coastal Barriers

The Coastal Barrier Resources Act (CBRA) establishes certain coastal areas to be protected by prohibiting the expenditure of Federal funds for new and expanded facilities within designated coastal barrier units. When a proposed project impacts a coastal barrier unit, the draft EIS should: include a map showing the relationship of each alternative to the unit(s); identify direct and indirect impacts to the unit(s), quantifying and describing the impacts as appropriate; discuss the results of early coordination with FWS, identifying any issues raised and how they were addressed, and; identify any alternative which (if selected) would require an exception under the Act. Any issues identified or exceptions required for the preferred alternative should be resolved prior to its selection. This resolution should be documented in the final EIS.

20. Coastal Zone Impacts

Where the proposed action is within, or is likely to affect land or water uses within the area covered by a State Coastal Zone Management Program (CZMP) approved by the Department of Commerce, the draft EIS should briefly describe the portion of the affected CZMP plan, identify the potential impacts, and include evidence of coordination with the State Coastal Zone Management agency or appropriate local agency. The final EIS should include the State Coastal Zone Management agency's determination on consistency with the State CZMP plan. (In some States, an agency will make a consistency determination only after the final EIS is approved, but will provide a preliminary indication before the final EIS that the project is "not inconsistent" or "appears to be consistent" with the plan.) (Fordirect Federal actions, the final EIS should include the lead agency's consistency determination and agreement by the State CZM agency.) If the preferred alternative is inconsistent with the State's approved CZMP, it can be Federally funded only if the Secretary of Commerce makes a finding that the proposed action is consistent with the purpose or objectives of the CZM Act or is necessary in the interest of national security. To the fullest extent possible, such a finding needs to be included in the final EIS. If the finding is denied, the action is not eligible for Federal funding unless modified in such a manner to remove the inconsistency finding. The final EIS should document such results.

21. Threatened or Endangered Species

The HA must obtain information from the FWS of the DOI and/or the National Marine Fisheries Service (NMFS) of the Department of Commerce to determine the presence or absence of listed and proposed threatened or endangered species and designated and proposed critical habitat in the proposed project area (50 CFR 402.12(c)). The information may be (1) a published geographical list of such species or critical habitat; (2) a project-specific notification of a list of such species or critical habitat; or (3) substantiated information from other credible sources. Where the information is obtained from a published geographical list the reasons why this would satisfy the coordination with DOI should be explained. If there are no species or critical habitat in the proposed project area, the Endangered Species Act requirements have been met. The results of this coordination should be included in the draft EIS.

When a proposed species or a proposed critical habitat may be present in the proposed project area, an evaluation or, if appropriate, a biological assessment is made on the potential impacts to identify whether any such species or critical habitat are likely to be adversely affected by the project. Informal consultation with FWS and/or NMFS should be undertaken during the evaluation. The draft EIS should include exhibits showing the location of the species or habitat, summarize the evaluation and potential impacts, identify proposed mitigation measures, and evidence coordination with FWS and/or NMFS. If the project is likely to jeopardize the continued existence of any proposed species or result in the destruction oradverse modification of proposed critical habitat, the HA in consultation with the FHWA must confer with FWS and/or NMFS to attempt to resolve potential conflicts by avoiding, minimizing, or reducing the project impacts (50 CFR 402.10(a)). If the preferred alternative is likely to jeopardize the continued existence of any proposed species or result in the destruction or adverse modification of proposed critical habitat, a conference with FWS and/or NMFS must be held to assist in identifying and resolving potential conflicts. To the fullest extent possible, the final EIS needs to summarize the results of the conference and identify reasonable and prudent alternatives to avoid the jeopardy to such proposed species or critical habitat. If no alternatives exist, the final EIS should explain the reasons why and identify any proposed mitigation measures to minimize adverse effects.

When a listed species or a designated critical habitat may be present in the proposed project area, a biological assessment must be prepared to identify any such species or habitat which are likely to be adversely affected by the proposed project (50 CFR 402.12). Informal consultation should be undertaken or, if desirable, a conference held with FWS and/or NMFS during preparation of the biological assessment. The draft EIS should summarize the following data from the biological assessment:

> (a) The species distribution, habitat needs, and other biological requirements;
>
> (b) The affected areas of the proposed project;
>
> (c) Possible impacts to the species including opinions of recognized experts on the species at issue;
>
> (d) Measures to avoid or minimize adverse impacts; and
>
> (e) Results of consultation with FWS and/or NMFS.
>
> In selecting an alternative, jeopardy to a listed species or the destruction or adverse modification ofdesignated critical habitat must be avoided (50 CFR 402.01(a)). If the biological assessment indicates that there are no listed species or critical habitat present that are likely to be adversely affected by the preferred alternative, the final EIS should evidence concurrence by the FWS and/or NMFS in such a determination and identify any proposed mitigation for the preferred alternative.
>
> If the results of the biological assessment or consultation with FWS and/or NMFS show that the preferred alternative is likely to

jeopardize the continued existence of a listed species or result in the destruction or adverse modification of designated critical habitat, to the fullest extent possible, the final EIS needs to contain: (l) a summary of the biological assessment (see data above for draft EIS); (2) a summary of the steps taken, including alternatives or measures evaluated and conferences and consultations held, to resolve the project's conflicts with the listed species or critical habitat; (3) a copy of the biological opinion; (4) a request for an exemption from the Endangered Species Act; (5) the results of the exemption request; and (6) a statement that (if the exemption is denied) the action is not eligible for Federal funding.

22. Historic and Archeological Preservation

The draft EIS should contain a discussion demonstrating that historic and archeological resources have been identified and evaluated in accordance with the requirements of 36 CFR 800.4 for each alternative under consideration. The information and level of effort needed to identify and evaluate historic and archeological resources will vary from project to project as determined by the FHWA after considering existing information, the views of the SHPO and the Secretary of Interior's "Standards and Guidelines for Archeology and Historic Preservation." The information for newly identified historic resources should be sufficient to determine their significance and eligibility for the National Register of Historic Places. The information for archeological resources should be sufficient to identify whether each warrants preservation in place or whether it is important chiefly because of what can be learned by data recovery and has minimal value for preservation in place. Where archeological resources are not a major factor in the selection of a preferred alternative, the determination ofeligibility for the National Register of newly identified archeological resources may be deferred until after circulation of the draft EIS.

The draft EIS discussion should briefly summarize the methodologies used in identifying historic and archeological resources. Because Section 4(f) of the DOT Act applies to the use of historic resources on or eligible for the National Register and to archeological resources on or eligible for the National Register <u>and</u> which warrant preservation in place, the draft EIS should describe the historical resources listed in or eligible for the National Register and identify any archeological resources that warrant preservation in place. The draft EIS should summarize the impacts of each alternative on and proposed mitigation measures for each resource. The document should evidence coordination with the SHPO on the significance of newly identified historic and archeological resources, the eligibility of historic resources for the National Register, and the effects of each alternative on both listed and eligible historic resources. Where the draft EIS discusses eligibility for the National Register of archeological resources, the coordination with the SHPO on eligibility and effect should address both historic and archeological resources.

The draft EIS can serve as a vehicle for affording the Advisory Council on Historic Preservation (ACHP) an opportunity to comment pursuant to Section 106 requirements if the document contains the necessary information required by 36 CFR 800.8. The draft EIS transmittal letter to the ACHP should specifically request its comments pursuant to 36 CFR 800.6.

To the fullest extent possible, the final EIS needs to demonstrate that all the requirements of 36 CFR 800 have been met. If the preferred alternative has no effect on historic or archeological resources on or eligible for the National Register, the final EIS should indicate coordination with and agreement by the SHPO. If the preferred alternative has an effect on a resource on or eligible for the National Register, the final EIS should contain (a) a determination of no adverse effect concurred in by the Advisory Council on Historic Preservation, (b) an executed memorandum of agreement (MOA), or (c) in the case of a rare situation where FHWA is unable to conclude the MOA, a copyof comments transmitted from the ACHP to the FHWA and the FHWA response to those comments.

The proposed use of land from an historic resource on or eligible for the National Register will normally require an evaluation and approval under Section 4(f) of the DOT Act. Section 4(f) also applies to all archeological sites on or eligible for the National Register <u>and</u> which warrant preservation in place. (See Section IX for information on Section 4(f) evaluation.)

23. Hazardous Waste Sites

Hazardous waste sites are regulated by the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). During early planning, the location of permitted and nonregulated hazardous waste sites should be identified. Early coordination with the appropriate Regional Office of the EPA and the appropriate State agency will aid in identifying known or potential hazardous waste sites. If known or potential waste sites are identified, the locations should be clearly marked on a map showing their relationship to the alternatives under consideration. If a known or potential hazardous waste site is affected by an alternative, information about the site, the potential involvement, impacts and public health concerns of the affected alternative(s), and the proposed mitigation measures to eliminate or minimize impacts or public health concerns should be discussed in the draft EIS.

If the preferred alternative impacts a known or potential hazardous waste site, the final EIS should address and resolve the issues raised by the public and government agencies.

24. Visual Impacts

The draft EIS should state whether the project alternatives have a potential for visual quality impacts. When this potential exists, the draft EIS should identify the impacts to the existing visual resource, the relationship of the impacts to potential viewers of and from the project, as well as measures to avoid, minimize, or reduce the adverse impacts. When there is potential for visual quality impacts, the draft EIS shouldexplain the consideration given to design quality, art, and architecture in the project planning. These values may be particularly important for facilities located in visually sensitive urban or rural settings. When a proposed project will include features associated with design quality, art or architecture, the draft EIS should be circulated to officially designated State and local arts councils and, as appropriate, other organizations with an interest in design, art, and architecture. The final EIS should identify any proposed mitigation for the preferred alternative.

25. Energy

Except for large scale projects, a detailed energy analysis including computations of BTU requirements, etc., is not needed. For most projects, the draft EIS should discuss in general terms the construction and operational energy requirements and conservation potential of various alternatives under consideration. The discussion should be reasonable and supportable. It might recognize that the energy requirements of various construction alternatives are similar and are generally greater than the energy requirements of the no-build alternative. Additionally, the discussion could point out that the post-construction, operational energy requirements of the facility should be less with the build alternative as opposed to the no-build alternative. In such a situation, one might conclude that the savings in operational energy requirements would more than offset construction energy requirements and thus, in the long term, result in a net savings in energy usage.

For large-scale projects with potentially substantial energy impacts, the draft EIS should discuss the major direct and/or indirect energy impacts and conservation potential of each alternative. Direct energy impacts refer to the energy consumed by vehicles using the facility. Indirect impacts include construction energy and such items as the effects of any changes in automobile usage. The alternative's relationship and consistency with a State and/or regional energy plan, if one exists, should also be indicated.

The final EIS should identify any energy conservation measures that will be implemented as a part of the preferred alternative. Measures to conserve energy include theuse of high-occupancy vehicle incentives and measures to improve traffic flow.

26. Construction Impacts

The draft EIS should discuss the potential adverse impacts (particularly air, noise, water, traffic congestion, detours, safety, visual, etc.)

associated with construction of each alternative and identify appropriate mitigation measures. Also, where the impacts of obtaining borrow or disposal of waste material are important issues, they should be discussed in the draft EIS along with any proposed measures to minimize these impacts. The final EIS should identify any proposed mitigation for the preferred alternative.

27. <u>The Relationship Between Local Short-term Uses of Man's Environment and the Maintenance and Enhancement of Long-term Productivity</u>

The EIS should discuss in general terms the proposed action's relationship of local short-term impacts and use of resources, and the maintenance and enhancement of long-term productivity. This general discussion might recognize that the build alternatives would have similar impacts. The discussion should point out that transportation improvements are based on State and/or local comprehensive planning which consider(s) the need for present and future traffic requirements within the context of present and future land use development. In such a situation, one might then conclude that the local short-term impacts and use of resources by the proposed action is consistent with the maintenance and enhancement of long-term productivity for the local area, State, etc.

28. <u>Any Irreversible and Irretrievable Commitments of Resources Which Would be Involved in the Proposed Action</u>

The EIS should discuss in general terms the proposed action's irreversible and irretrievable commitment of resources. This general discussion might recognize that the build alternatives would require a similar commitment of natural, physical, human, and fiscal resources. An example of such discussion would be as follows:

"Implementation of the proposed action involves a commitment of a range of natural, physical, human, and fiscal resources. Land used in the construction of the proposed facility is considered an irreversible commitment during the time period that the land is used for a highway facility. However, if a greater need arises for use of the land or if the highway facility is no longer needed, the land can be converted to another use. At present, there is no reason to believe such a conversion will ever be necessary or desirable.

Considerable amounts of fossil fuels, labor, and highway construction materials such as cement, aggregate, and bituminous material are expended. Additionally, large amounts of labor and natural resources are used in the fabrication and preparation of construction materials. These materials are generally not retrievable. However, they are not in short supply and their use will not have an adverse effect upon continued availability of these resources. Any construction will also require a substantial one-time expenditure of both State and Federal funds which are not retrievable.

The commitment of these resources is based on the concept that residents in the immediate area, State, and region will benefit by the improved quality of the transportation system. These benefits will consist of improved accessibility and safety, savings in time, and greater availability of quality services which are anticipated to outweigh the commitment of these resources."

H. List of Preparers

This section should include lists of:

1. State (and local agency) personnel, including consultants, who were primarily responsible for preparing the EIS or performing environmental studies, and a brief summary of their qualifications, including educational background and experience.
2. The FHWA personnel primarily responsible for preparation or review of the EIS and their qualifications.
3. The areas of EIS responsibility for each preparer.

I. List of Agencies, Organizations, and Persons to Whom Copies of the Statement are Sent

Draft EIS: List all entities from which commentsare being requested (40 CFR 1502.10). Final EIS: Identify those entities that submitted comments on the draft EIS and those receiving a copy of the final EIS (23 CFR 771.125(a) and (g)).

J. Comments and Coordination

1. The draft EIS should contain copies of pertinent correspondence with each cooperating agency, other agencies and the public and summarize: 1) the early coordination process, including scoping; 2) the meetings with community groups (including minority and non-minority interests) and individuals; and 3) the key issues and pertinent information received from the public and government agencies through these efforts.
2. The final EIS should include a copy of substantive comments from the U.S. Secretary of Transportation (OST), each cooperating agency, and other commentors on the draft EIS. Where the response is exceptionally voluminous the comments may be summarized. An appropriate response should be provided to each substantive comment. When the EIS text is revised as a result of the comments received, a copy of the comments should contain marginal references indicating where revisions were made, or the response to the comments should contain such references. The response should adequately address the issue or concern raised by the commentor or, where substantive comments do not warrant further response, explain why they do not, and provide sufficient information to support that position.

   The FHWA and the HA are not commentors within the meaning of NEPA and their comments on the draft EIS should not be included in the final EIS. However, the document should include adequate information for FHWA and the HA to ascertain the disposition of the comment(s).

3. The final EIS should (1) summarize the substantive comments on social, economic, environmental, and engineering issues made at the public hearing, if one is held, or the public involvement activities or which were otherwise considered and (2) discuss the consideration given to any substantive issue raised and provide sufficient information to support that position.
4. The final EIS should document compliance with requirements of all applicable environmental laws, Executive Orders, and other related requirements, such as Title VI of the Civil Rights Act of 1964. To the extent possible, all environmental issues should be resolved prior to the submission of the final EIS. When disagreement on project issues exists with another agency, coordination with the agency should be undertaken to resolve the issues. Where the issues cannot be resolved, the final EIS should identify any remaining unresolved issues, the steps taken to

resolve the issues, and the positions of the respective parties. Where issues are resolved through this effort, the final EIS should demonstrate resolution of the concerns.

K. Index

The index should include important subjects and areas of major impacts so that a reviewer need not read the entire EIS to obtain information on a specific subject or impact.

L. Appendices

The EIS should briefly explain or summarize methodologies and results of technical analyses and research. Lengthy technical discussions should be contained in a technical report. Material prepared as appendices to the EIS should:

1. consist of material prepared specifically for the EIS;
2. consist of material which substantiates an analysis fundamental to the EIS;
3. be analytic and relevant to the decision to be made; and
4. be circulated with the EIS within FHWA, to EPA (Region), and to cooperating agencies and be readily available on request by other parties. Other reports and studies referred to in the EIS should be readily available for review or for copying at a convenient location.

VI. OPTIONS FOR PREPARING FINAL EISs

The CEQ regulations place heavy emphasis on reducing paperwork, avoiding unnecessary work, and producing documents which are useful to decisionmakers and to the public. With these objectives in mind, three different approaches to preparing final EISs are presented below. The first two approaches can be employed on any project. The third approach is restricted to the conditions specified by CEQ (40 CFR 1503.4(c)).

A. Traditional Approach

Under this approach, the final EIS incorporates the draft EIS (essentially in its entirety) with changes made as appropriate throughout the document to reflect the selection of an alternative, modifications to the project, updated information on the affected environment, changes in the assessment of impacts, the selection of mitigation measures, wetland and floodplain findings, the results of coordination, comments received on the draft EIS and responses to these comments, etc. Since so much information is carried over from the draft to the final, important changes are sometimes difficult for the readerto identify. Nevertheless, this is the approach most familiar to participants in the NEPA process.

B. Condensed Final EIS

This approach avoids repetition of material from the draft EIS by incorporating, by reference, the draft EIS. The final EIS is, thus, a much shorter document than under the traditional approach; however, it should afford the reader a complete overview of the project and its impacts on the human environment.

The crux of this approach is to briefly reference and summarize information from the draft EIS which has not changed and to focus the final EIS discussion on changes in the project, its setting, impacts, technical analysis, and mitigation that have occurred since the draft EIS was circulated. In addition, the condensed final EIS must identify the preferred alternative, explain the basis for its selection, describe coordination efforts, and include agency and public comments, responses to these comments, and any required findings or determinations (40 CFR 1502.14(e) and 23 CFR 771.125(a)).

The format of the final EIS should parallel the draft EIS. Each major section of the final EIS should briefly summarize the important information contained in the corresponding section of the draft, reference the section of the draft that provides more detailed information, and discuss any noteworthy changes that have occurred since the draft was circulated.

At the time that the final is circulated, an additional copy of the draft EIS need not be provided to those parties that received a copy of the draft EIS when it was circulated. Nevertheless, if, due to the passage of time or other reasons, it is likely that they will have disposed of their original copy of the draft EIS, then a copy of the draft EIS should be provided with the final. In any case, sufficient copies of the draft EIS should be on hand to satisfy requests for additional copies. Both the draft EIS and the condensed final EIS should be filed with EPA under a single final EIS cover sheet.

C. Abbreviated Version of Final EIS

The CEQ regulation (40 CFR 1503.4(c)) provides the opportunity to expedite the final EIS preparation where the only changes needed in the document are minor and consist of factual corrections and/or an explanation of why the comments received on the draft EIS do not warrant further response. In using this approach, care should be exercised to assure that the draft EIS contains sufficient information to make the findings in (2) below and that the number of errata sheets used to make required changes is small and that these errata sheets together with the draft EIS constitute a readable, understandable, full disclosure document. The final EIS should consist of the draft EIS and an attachment containing the following:

1. Errata sheets making any necessary corrections to the draft EIS;
2. A section identifying the preferred alternative and a discussion of the reasons it was selected. The following should also be included in this section where applicable:

    (a) final Section 4(f) evaluations containing the information described in Section IX of these guidelines;

    (b) wetland and finding(s);

    (c) floodplain finding(s);

    (d) a list of commitments for mitigation measures for the preferred alternative; and

3. Copies (or summaries) of comments received from circulation of the draft EIS and public hearing and responses thereto.

    Only the attachment need be provided to parties who received a copy of the draft EIS, unless it is likely that they will have disposed of their original copy, in which case both the draft EIS and the attachment should be provided (40 CFR 1503.4(c)). Both the draft EIS and the attachment must be filed with EPA under a single final EIS cover sheet(40 CFR 1503.4(c)).

VII. DISTRIBUTION OF EISs AND SECTION 4(f) EVALUATIONS

A. Environmental Impact Statement

1. After clearance by FHWA, copies of all draft EISs must be made available to the public and circulated for comments by the HA to: all public officials, private interest groups, and members of the public known to have an interest in the proposed action or the draft EIS; all Federal, State, and local government agencies expected to have jurisdiction, responsibility, interest, or expertise in the proposed action; and States and Federal land management entities which may be affected by the proposed action or any of the alternatives (40 CFR 1502.19 and 1503.1). Distribution must be made no later than the time the document is filed with EPA for Federal Register publication and must allow for a minimum 45-day review period (40 CFR 1506.9 and 1506.10). Internal FHWA distribution of draft and final EISs is subject to change and is noted in memorandums to the Regional Administrators as requirements change.
2. Copies of all approved final EISs must be distributed to all Federal, State, and local agencies and private organizations, and members of the public who provided substantive comments on the draft EIS or who requested a copy (40 CFR 1502.19). Distribution must be made no later than the time the document is filed with EPA for Federal Register publication and must allow for a minimum 30-day review period before the Record of Decision is approved (40 CFR 1506.9 and 1506.10). Two copies of all approved EISs should be forwarded to the FHWA Washington Headquarters (HEV-11) for recordkeeping purposes.
3. Copies of all EISs should normally be distributed to EPA and DOI as follows, unlessthe agency has indicated to the FHWA offices the need for a different number of copies:

    (a) The EPA Headquarters: five copies of the draft EIS and five copies of the final EIS (This is the "filing requirement" in Section 1506.9 of the CEQ regulation.) to the following address:

    Environmental Protection Agency
    Office of Federal Activities
    (A-104), 401 M Street, SW
    Washington, D.C. 20460

    (b) The appropriate EPA Regional Office responsible for EPA's review pursuant to Section 309 of the Clean Air Act: five copies of the draft EIS and five copies of the final EIS.

(c) The DOI Headquarters to the following address:

U.S. Department of the Interior
Office of Environmental Project Review
Room 4239
18th and C Streets, NW
Washington, DC 20240

(i) All States in FHWA Regions 1, 3, 4, and 5, plus Hawaii, Guam, American Samoa, Virgin Islands, Arkansas, Iowa, Louisiana, and Missouri: 12 copies of the draft EIS and 7 copies of the final EIS.

(ii) Kansas, Nebraska, North Dakota, Oklahoma, South Dakota, and Texas: 13 copies of the draft EIS and 8 copies of the final EIS.

(iii) New Mexico and all States in FHWA Regions 8, 9, and 10,except Hawaii, North Dakota, and South Dakota: 14 copies of the draft EIS and 9 copies of the final EIS.

Note: DOI Headquarters will make distribution within its Department. While not required, advance distribution to DOI field offices may be helpful to expedite their review.

B. Section 4(f) Evaluation

If the Section 4(f) evaluation is included in a draft EIS, the DOI Headquarters does not need additional copies of the draft or final EIS/Section 4(f) evaluation. If the Section 4(f) evaluation is processed separately or as part of an EA, the DOI should receive seven copies of the draft Section 4(f) evaluation for coordination and seven copies of the final Section 4(f) evaluation for information. In addition to coordination with DOI, draft Section 4(f) evaluations must be coordinated with the officials having jurisdiction over the Section 4(f) property and the Department of Housing and Urban Development (HUD) and the United States Department of Agriculture (USDA) where these agencies have an interest in or jurisdiction over the affected Section 4(f) resource (23 CFR 771.135(i)). The point of coordination for HUD is the appropriate Regional Office and for USDA, the Forest Supervisor of the affected National Forest. One copy should be provided to the officials with jurisdiction and two copies should be submitted to HUD and USDA when coordination is required.

VIII. RECORD OF DECISION--FORMAT AND CONTENT

The Record of Decision (ROD) will explain the reasons for the project decision, summarize any mitigation measures that will be incorporated in the project, and document any required Section 4(f) approval. While cross-referencing and incorporation by reference of the final EIS (or final EIS supplement) and other documents are appropriate, the ROD must explain the basis for the project decision as completely as possible, based on the information contained in the EIS (40 CFR 1502.2). A draft ROD should be prepared by the HA and submitted to the Division Officewith the final EIS. The following key items need to be addressed in the ROD:

A. Decision.

Identify the selected alternative. Reference to the final EIS (or final EIS supplement) may be used to reduce detail and repetition.

B. Alternatives Considered.

This information can be most clearly organized by briefly describing each alternative and explaining the balancing of values which formed the basis for the decision. This discussion must identify the environmentally preferred alternative(s) (i.e., the alternative(s) that causes the least damage to the biological and physical environment) (40 CFR 1505.2(b)). Where the selected alternative is other than the environmentally preferable alternative, the ROD should clearly state the reasons for not selecting the environmentally preferred alternative. If lands protected by Section 4(f) were a factor in the selection of the preferred alternative, the ROD should explain how the Section 4(f) lands influenced the selection.

The values (social, economic, environmental, cost-effectiveness, safety, traffic, service, community planning, etc.) which were important factors in the decisionmaking process should be clearly identified along with the reasons some values were considered more important than others. The Federal-aid highway program mandate to provide safe and efficient transportation in the context of all other Federal requirements and the beneficial impacts of the proposed transportation improvements should be included in this balancing. While any decision represents a balancing of the values, the ROD should reflect the manner in which these values were considered in arriving at the decision.

C. Section 4(f).

Summarize the basis for any Section 4(f) approval when applicable (23 CFR 771.127(a)). The discussion should include the key information supporting such approval. Where appropriate,this information may be included in the alternatives discussion above and referenced in this paragraph to reduce repetition.

D. Measures to Minimize Harm.

Describe the specific measures adopted to minimize environmental harm and identify those standard measures (e.g., erosion control, appropriate for the proposed action). State whether all practicable measures to minimize environmental harm have been incorporated into the decision and, if not, why they were not (40 CFR 1505.2(c)).

E. Monitoring or Enforcement Program.

Describe any monitoring or enforcement program which has been adopted for specific mitigation measures, as outlined in the final EIS.

F. Comments on Final EIS.

All substantive comments received on the final EIS should be identified and given appropriate responses. Other comments should be summarized and responses provided where appropriate.

For recordkeeping purposes, a copy of the signed ROD should be provided to the Washington Headquarters (HEV-11). For a ROD approved by the Division Office, copies should be sent to both the Washington Headquarters and the Regional Office.

IX. SECTION 4(f) EVALUATIONS--FORMAT AND CONTENT

A Section 4(f) evaluation must be prepared for each location within a proposed project before the use of Section 4(f) land is approved (23 CFR 771.135(a)). For projects processed with an EIS or an EA/FONSI, the individual Section 4(f) evaluation should be included as a separate section of the document, and for projects processed as categorical exclusions, as a separate Section 4(f) evaluation document. Pertinent information from various sections of the EIS or EA/FONSI may be summarized in the Section 4(f) evaluation to reduce repetition. Where an issue on constructive use Section 4(f) arises and FHWA decides that Section 4(f) does not apply, the environmental document should contain sufficientanalysis and information to demonstrate that the resource(s) is not substantially impaired.

The use of Section 4(f) land may involve concurrent requirements of other Federal agencies. Examples include consistency determinations for the use of public lands managed by the Bureau of Land Management, compatibility determinations for the use of land in the National Wildlife Refuge System and the National Park System, determinations of direct and adverse effects for Wild and Scenic Rivers, and approval of land conversions under Section 6(f) of the Land and Water Conservation Fund Act. The mitigation plan developed for the project should include measures which would satisfy the various requirements. For example, Section 6(f) directs the Department of the Interior (National Park Service) to assure that replacement lands of equal value, location, and usefulness are provided as conditions to approval of land conversions. Therefore, where a Section 6(f) land conversion is proposed for a highway project, replacement land will be necessary. Regardless of the mitigation proposed, the draft and final Section 4(f) evaluations should discuss the results of coordination with the public official having jurisdiction over the Section 4(f) land and document the National Park Service's position on the Section 6(f) land transfer, respectively.

A. Draft Section 4(f) Evaluation

The following format and content are suggested. The listed information should be included in the Section 4(f) evaluation, as applicable.

1. Proposed Action.

Where a separate Section 4(f) evaluation is prepared, describe the proposed project and explain the purpose and need for the project.

2. Section 4(f) Property.

Describe each Section 4(f) resource which would be used by any alternative under consideration. The following information should be provided:

(a) A detailed map or drawing of sufficient scale to identify the relationship of the alternatives to the Section 4(f) property.

(b) Size (acres or square feet) and location (maps or other exhibits such as photographs, sketches, etc.) of the affected Section 4(f) property.

(c) Ownership (city, county, State, etc.) and type of Section 4(f) property (park, recreation, historic, etc.).

(d) Function of or available activities on the property (ball playing, swimming, golfing, etc.).

(e) Description and location of all existing and planned facilities (ball diamonds, tennis courts, etc.).

(f) Access (pedestrian, vehicular) and usage (approximate number of users/visitors, etc.).

(g) Relationship to other similarly used lands in the vicinity.

(h) Applicable clauses affecting the ownership, such as lease, easement, covenants, restrictions, or conditions, including forfeiture.

(i) Unusual characteristics of the Section 4(f) property (flooding problems, terrain conditions, or other features) that either reduce or enhance the value of all or part of the property.

3. Impacts on the Section 4(f) Property(ies).

Discuss the impacts on the Section 4(f) property for each alternative (e.g., amount of land to be used, facilities andfunctions affected, noise, air pollution, visual, etc.). Where an alternative (or alternatives) uses land from more than one Section 4(f) property, a summary table would be useful in comparing the various impacts of the alternative(s). Impacts (such as facilities and functions affected, noise, etc.) which can be quantified should be quantified. Other impacts (such as visual intrusion) which cannot be quantified should be described.

4. Avoidance Alternatives.

Identify and evaluate location and design alternatives which would avoid the Section 4(f) property. Generally, this would include alternatives to either side of the property. Where an alternative would use land from more than one Section 4(f) property, the analysis needs to evaluate alternatives which avoid each and all properties (23 CFR 771.135(i)). The design alternatives should be in the immediate area of the property and consider minor alignment shifts, a reduced facility, retaining structures, etc. individually or in combination, as appropriate. Detailed discussions of alternatives in an EIS or EA need not be repeated in the Section 4(f) portion of the document, but should be referenced and summarized. However, when alternatives (avoiding Section 4(f) resources) have been eliminated from detailed study the discussion should also explain whether these alternatives are feasible and prudent and, if not, the reasons why.

5. Measures to Minimize Harm.

Discuss all possible measures which are available to minimize the impacts of the proposed action on the Section 4(f) property(ies). Detailed discussions of mitigation measures in the EIS or EA may be referenced and appropriately summarized, rather than repeated.

6. Coordination.

Discuss the results of preliminary coordination with the public official having jurisdiction over the Section 4(f) property and with regional (or local) offices of DOI and, as appropriate, the Regional Office of HUD and the Forest Supervisor of the affected National Forest. Generally, the coordination should include discussion of avoidance alternatives, impacts tothe property, and measures to minimize harm. In addition, the coordination with the public official having jurisdiction should include, where necessary, a discussion of significance and primary use of the property.

Note:The conclusion that there are no feasible and prudent alternatives is not normally addressed at the draft Section 4(f) evaluation stage. Such conclusion is made only after the draft Section 4(f) evaluation has been circulated and coordinated and any identified issues adequately evaluated.

B. Final Section 4(f) Evaluation

When the preferred alternative uses Section 4(f) land, the final Section 4(f) evaluation must contain (23 CFR 771.135(i) and (j)):

1. All the above information for a draft evaluation.
2. A discussion of the basis for concluding that there are no feasible and prudent alternatives to the use of the Section 4(f) land. The supporting information must demonstrate that "there are unique problems or unusual factors involved in the use of alternatives that avoid these properties or that the cost, social, economic, and environmental impacts, or community disruption resulting from such alternatives reach extraordinary magnitudes" (23 CFR 771.135(a)(2)). This language should appear in the document together with the supporting information.
3. A discussion of the basis for concluding that the proposed action includes all possible planning to minimize harm to the Section 4(f) property. When there are no feasible and prudent alternatives which avoid the use of Section 4(f) land, the final Section 4(f) evaluation must demonstrate that the preferredalternative is a feasible and prudent alternative with the least harm on the Section 4(f) resources after considering mitigation to the Section 4(f) resources.
4. A summary of the appropriate formal coordination with the Headquarters Offices of DOI (and/or appropriate agency under that Department) and, as appropriate, the involved offices of USDA and HUD.
5. Copies of all formal coordination comments and a summary of other relevant Section 4(f) comments received an analysis and response to any questions raised. Where new alternatives or modifications to existing alternatives are identified and will not be given further consideration, the basis for dismissing these alternatives should be provided and supported by factual information. Where Section 6(f) land is involved, the National Park Service's position on the land transfer should be documented.
6. Concluding statement as follows: "Based upon the above considerations, there is no feasible and prudent alternative to the use of land from the (identify Section 4(f) property) and the proposed action includes all

possible planning to minimize harm to the (Section 4(f) property) resulting from such use."

X. OTHER AGENCY STATEMENTS

A. The FHWA review of statements prepared by other agencies will consider the environmental impact of the proposal on areas within FHWA's functional area of responsibility or special expertise (40 CFR 1503.2).

B. Agencies requesting comments on highway impacts usually forward the draft EIS to the FHWA Washington Headquarters for comment. The FHWA Washington Headquarters will normally distribute these EISs to the appropriate Regional or Division Office (per Regional Office request) and will indicate where the comments should be sent. The Regional Office may elect to forward the draft statement to the Division Office for response.

C. When a field office has received a draft EIS directly from another agency, it may comment directly to that agency if the proposal does not fall within the types indicated in item (d) of this section. If more than one DOT Administration is commenting at the Regional level, the comments should be coordinated by the DOT Regional Representative to the Secretary or designee. Copies of the FHWA comments should be distributed as follows:

1. Requesting agency--original and one copy.
2. P-14--one copy.
3. DOT Secretarial Representative--one copy.
4. HEV-11--one copy.

D. The following types of actions contained in the draft EIS require FHWA Washington Headquarters review and such EISs should be forwarded to the Director, Office of Environmental Policy, along with Regional comments, for processing:

1. actions with national implications, and
2. legislation or regulations having national impacts or national program proposals.

XI. REEVALUATIONS

A. Draft EIS Reevaluation

If an acceptable final EIS is not received by FHWA within 3 years from the date of the draft EIS circulation, then a written evaluation is required to determine whether there havebeen changes in the project or its surroundings or new information which would require a supplement to the draft EIS or a new draft EIS (23 CFR 771.129(a)). The written evaluation should be prepared by the HA in consultation with FHWA and should address all current environmental requirements. The entire project should be revisited to assess any changes that have occurred and their effect on the adequacy of the draft EIS.

There is no required format for the written evaluation. It should focus on the changes in the project, its surroundings and impacts, and any new issues identified since the draft EIS. Field reviews, additional studies (as necessary), and coordination (as appropriate) with other agencies should be undertaken and the results included in the written evaluation. If, after reviewing the written evaluation, the FHWA concludes that a supplemental EIS or a new draft EIS is not required, the decision should be appropriately documented. Since the next major step in the project development process is preparation of a final EIS, the final EIS may document the decision. A statement to this fact, the conclusions reached, and supporting information should be briefly summarized in the Summary Section of the final EIS.

B. Final EIS Reevaluation

There are two types of reevaluations required for a final EIS: consultation and written evaluation (23 CFR 771.129(b) and (c)). For the first, consultation, the final EIS is reevaluated prior to proceeding with major project approval (e.g., right-of-way acquisition, final design, and plans, specifications, and estimates (PS&E)) to determine whether the final EIS is still valid. The level of analysis and documentation, if any, should be agreed upon by the FHWA and HA. The analysis and documentation should focus on and be commensurate with the changes in the project and its surroundings, potential for controversy, and length of time since the last environmental action. For example, when the consultation occurs shortly after final EIS approval, an analysis usually should not be necessary. However, when it occurs nearly 3 years after final EIS approval, but before a written evaluation is required, the level of analysis should be similar to what normally would be undertaken for a written evaluation. Although written documentation is left to the discretion of the DivisionAdministrator, it is suggested that each consultation be appropriately documented in order to have a record to show the requirement was met.

The second type of reevaluation is a written evaluation. It is required if the HA has not taken additional major steps to advance the project (i.e., has not received from FHWA authority to undertake final design, authority to acquire a significant portion of the right-of-way, or approval of the PS&E) within any 3-year time

<u>period</u> after approval of the final EIS, the final supplemental EIS, or the last major FHWA approval action.

The written evaluation should be prepared by the HA in consultation with FHWA and should address all current environmental requirements. The entire project should be revisited to assess any changes that have occurred and their effect on the adequacy of the final EIS.

There is no required format for the written evaluation. It should focus on the changes in the project, its surroundings and impacts, and any new issues identified since the final EIS was approved. Field reviews, additional environmental studies (as necessary), and coordination with other agencies should be undertaken (as appropriate to address any new impacts or issues) and the results included in the written evaluation. The FHWA Division Office is the action office for the written evaluation. If it is determined that a supplemental EIS is not needed, the project files should be documented appropriately. In those rare cases where an EA is prepared to serve as the written evaluation, the files should clearly document whether <u>new</u> significant impacts were identified during the reevaluation process.

XII. <u>SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENTS (EISs)</u>

Whenever there are changes, new information, or further developments on a project which result in significant environmental impacts not identified in the most recently distributed version of the draft or final EIS, a supplemental EIS is necessary (40 CFR 1502.9(c)). If it is determined that the changes or new information do not result in new or different significant environmental impacts, the FHWA Division Administrator should document the determination. (After final EIS approval, this documentation could take the form of notationto the files; for a draft EIS, this documentation could be a discussion in the final EIS.)

A. <u>Format and Content of a Supplemental EIS</u>

There is no required format for a supplemental EIS. The supplemental EIS should provide sufficient information to briefly describe the proposed action, the reason(s) why a supplement is being prepared, and the status of the previous draft or final EIS. The supplemental EIS needs to address only those changes or new information that are the basis for preparing the supplement and were not addressed in the previous EIS (23 CFR 771.130(a)). Reference to and summarizing the previous EIS is preferable to repeating unchanged, but still valid, portions of the original document. For example, some items such as affected environment, alternatives, or impacts which are unchanged may be briefly summarized and referenced. New environmental requirements which became effective after the previous EIS was prepared need to be addressed in the supplemental EIS to the extent they apply to the portion of the project being evaluated and are relevant to the subject of the supplement (23 CFR 771.130(a)). Additionally, to provide an up-to-date status of compliance with NEPA, it is recommended that the supplement summarize the results of any reevaluations that have been performed for portions of or the entire proposed action. By this inclusion, the supplement will reflect an up-to-date consideration of the proposed action and its effects on the human environment. When a previous EIS is referenced, the supplemental EIS transmittal letter should indicate that copies of the original (draft or final) EIS are available and will be provided to all requesting parties.

B. Distribution of a Supplemental EIS

A supplemental EIS will be reviewed and distributed in the same manner as a draft and final EIS (23 CFR 771.130(d)). (See Section VII for additional information.)

XIII. Appendices

Two appendices are included as follows:

Appendix A:Environmental Laws, Authority, and Related Statutes and Orders

Appendix B:Preparation and Processing of Notices of Intent.

ENVIRONMENTAL LAWS, AUTHORITY, AND RELATED STATUTES AND ORDERS

AUTHORITY:

42 United States Code (U.S.C.) 4321 et seq., National Environmental Policy Act of 1969, as amended.

23 U.S.C. 138 and 49 U.S.C. 303, Section 4(f) of the Department of Transportation (DOT) Act of 1966.

23 U.S.C. 109(h), (i), and (j) standards.

23 U.S.C. 128, Public Hearings.

23 U.S.C. 315, Rules, Regulations, and Recommendations.

23 Code of Federal Regulations (CFR), Part 771, Environmental Impact and Related Procedures.

40 CFR 1500 et seq., Council on Environmental Quality, Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act.

49 CFR 1.48(b), DOT Delegations of Authority to the Federal Highway Administration.

DOT Order 5610.1c, Procedures for Considering Environmental Impacts, September 18, 1979, and subsequent revisions.

<u>RELATED STATUTES AND ORDERS</u>: The following is a list of major statutes and orders on the preparation of environmental documents.

7 U.S.C. 4201 et seq., Farmland Protection Policy Act of 1981.

16 U.S.C. 461 et seq., Archaeological and Historic Preservation Act; and 23 U.S.C. 305.

16 U.S.C. 470f, Sections 106, 110(d), and 110(f) of the National Historic Preservation Act of 1966.

16 U.S.C. 662, Section 2 of the Fish and Wildlife Coordination Act.

16 U.S.C. 1452, 1456, Sections 303 and 307 of the Coastal Zone Management Act of 1972.

16 U.S.C. 1271 et. seq., Wild and Scenic Rivers Act.

16 U.S.C. 1536, Section 7 of the Endangered Species Act of 1973.

33 U.S.C. 1251 et seq., Clean Water Act of 1977.

33 U.S.C 1241 et seq., Resource Conservation and Recovery Act.

42 U.S.C. 300(f) et seq., Safe Drinking Water Act.

42 U.S.C. 4371 et seq., Environmental Quality Improvement Act of 1970.

42 U.S.C. 4601 et seq., Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970.

42 U.S.C. 4901 et seq., Noise Control Act of 1972.

42 U.S.C. 9601 et seq., Comprehensive Environmental Response, Compensation, and Liability Act of 1980.

42 U.S.C. 7401 et seq., Clean Air Act.

42 U.S.C. 2000d-d4, Title VI of the Civil Rights Act of 1964.

43 U.S.C. Coastal Barriers Resources Act of 1982.

Executive Order 11514, Protection and Enhancement of Environmental Quality, as amended by Executive Order 11991, dated May 24, 1977.

Executive Order 11593, Protection and Enhancement of the Cultural Environment, dated May 13, 1971, implemented by DOT Order 5650.1, dated, November 20, 1972.

Executive Order 11988, Floodplain Management, dated May 24, 1977, implemented by DOT Order 5650.2, dated April 23, 1979.

Executive Order 11990, Protection of Wetlands, dated May 24, 1977, implemented by DOT Order 5660.1A, dated August 24, 1978.

<u>Preparation and Processing of Notices of Intent</u>

The CEQ regulations and Title 23, Code of Federal Regulations, Part 771, Environmental Impact and Related Procedures, require the Administration to publish a notice of intent in the Federal Register as soon as practicable after the decision is made to prepare an environmental impact statement (EIS) and before the scoping process (40 CFR 1501.7). A notice of intent will also be published when a decision is made to supplement a final EIS, but will not be necessary when preparing a supplement to a draft EIS (23 CFR 771.130(d)). The responsibility for preparing notices of intent has been delegated to Regional Federal Highway Administrators and subsequently redelegated to Division Administrators. The notice should be sent directly to the Federal Register at the address provided in Attachment 1 and a copy provided to the Project Development Branch (HEV-11), Office of Environmental Policy, and the appropriate Region Office.

In cases where a notice of intent is published in the Federal Register and a decision is made not to prepare the draft EIS or, when the draft EIS has been prepared, a decision is made not to prepare a final EIS, a revised notice of intent should be published in the Federal Register advising of the decision and the reasons for not preparing the EIS. This applies to future and current actions being processed.

Notices of intent should be prepared and processed in strict conformance with the guidelines in Attachment 1 in order to ensure acceptance for publication by the Office of the Federal Register. A sample of each notice of intent for preparation of an EIS and a supplemental EIS is provided as Attachment 2.

The Project Development Branch (HEV-11) will serve as the Federal Register contact point for notice of intent. All inquiries should be directed to that office.

GUIDELINES FOR PREPARATION AND PROCESSING OF NOTICES OF INTENT

<u>FORMAT</u>

1. Typed in black on white bond paper.
2. Paper size: 8 1/2" x 11".
3. Margins: Left at least 1 1/2", all others 1".
4. Spacing: All material double spaced (except title in heading).
5. Heading: Four items on first page at head of document (see Attachment 2):
    - Billing Code No. 4910-22 typed in brackets or parentheses
    - DEPARTMENT OF TRANSPORTATION (all upper case)
    - Federal Highway Administration
    - ENVIRONMENTAL IMPACT STATEMENT; COUNTY OR CITY, STATE (all upper case; single space)
6. Text: Five sections - AGENCY, ACTION, SUMMARY, FOR FURTHER INFORMATION CONTACT, AND SUPPLEMENTARY INFORMATION; each section title in upper case followed by colon (see Content (below) and Samples 1 and 2).
7. Closing:
    - Include the Catalog of Federal Domestic Assistance number and title
    - Issued on:

      (indent 5 spaces and type or stamp in date <u>when document</u> <u>is</u> signed)

    - Signature line

(begin in middle of page; type name, title, and city under the signature; use name and title of the officialactually signing the document (e.g., "John Doe, District Engineer," not "John Doe, for the Division Administrator"))

8. Document should be neat and in form suitable for public inspection. Two or more notices of intent can be included in a single document by making appropriate revisions to the heading and text of the document.

CONTENT

1. AGENCY: Federal Highway Administration (FHWA), DOT.
2. ACTION: Notice of Intent.
3. SUMMARY: The FHWA is issuing this notice to advise the public that an environmental impact statement will be prepared for a proposed highway project in . . . .
4. FOR FURTHER INFORMATION CONTACT: This section should state the name and address of a person or persons within the FHWA Division Office who can answer questions about the proposed action and the EIS as it is being developed. The listing of a telephone number is optional. State and/or local officials may also be listed, but always following the FHWA contact person.
5. SUPPLEMENTARY INFORMATION: This section should contain:
    a. a brief narrative description of the proposed action (e.g., location of the action, type of construction, length of the project, needs which will be fulfilled by the action);

       For a supplement to a final EIS add: the original EIS number and approval date, and the reason(s) for preparing the supplement;

    b. a brief description of possible alternatives to accomplish the goals of the proposed action (e.g., upgrade existing facility, do nothing (should always be listed), construction on new alignment, mass transit, multi-modal design); and
    c. a brief description of the proposed scoping process for the particular action including whether, when, and where any scoping meeting will be held.

       For a supplement to a final EIS: the scoping process is not required for a supplement; however, scoping should be discussed to the extent anticipated for the development of the supplement;

       In drafting this section -

- use plain English
- avoid technical terms and jargon
- always refer to the proposed action or proposed project (e.g., the proposed action would . . .)
- identify all abbreviations
- list FHWA first when other agencies (State or local) are listed as being involved in the preparation of the EIS

PROCESSING

1. Send three (3) duplicate originals each signed in ink by the issuing officer to:

    Office of the Federal Register
    National Archives and Records Administration
    Washington, DC 20408

2. The duplicates must be identical in all respects. The Federal Register will accept electrostatic copies as long as they are readable and individually signed.
3. Three (3) additional copies are required if material is printed on both sides. If a single original and two certified copies are sent, the statement "CERTIFIED TO BE A TRUE COPY OF THE ORIGINAL" and the signature of a duly authorized certifying officer must appear on each certified copy.
4. A record should be kept of the date on which each notice is mailed to the Federal Register.
5. Send one (1) copy each to the Project Development Branch (HEV-11) and the Regional office.

APPENDIX B

FLORIDA APPLICABLE FEDERAL AND STATE LAWS, RULES, REGULATIONS AND GUIDANCE

Applicable Federal and State Laws, Rules, Regulations and Guidance		
Agency Order	Title Procedures for Considering Environmental Impacts)	Cite DOT Order 5610.1c
Code of Federal Regulations	Consistency for Federal Assistance to State and Local Governments [16 U.S.C.1456(d)]	15 Code of Federal Regulations Part 930, Subpart F
Code of Federal Regulations	Environmental Impact and Related Procedures	23 Code of Federal Regulations 771
Code of Federal Regulations		23 Code of Federal Regulations 771.117(d)(12)
Code of Federal Regulations	Statewide Planning	23 Code of Federal Regulations Part 450 Subparts B &C and 49 Code of Federal Regulations Part 613
Code of Federal Regulations		23 Code of Federal Regulations Part 650
Code of Federal Regulations	Procedures for the Protection of Historic and Cultural Properties	36 Code of Federal Regulations Part 800
Code of Federal Regulations		36 Code of Federal Regulations Parts 60 and 63
Code of Federal Regulations	Designation of Areas for Air Quality Planning Purposes	40 Code of Federal Regulations 81
Code of Federal Regulations	Conformity to State or Federal Implementation Plans for Transportation Plans	40 Code of Federal Regulations 93, Subpart T
Code of Federal Regulations	Clean Air Act, as amended	40 Code of Federal Regulations Part 93, Title 1
Code of Federal Regulations	CEQ Regulations for Implementing the Procedural Provisions of the National Environmental Protection Act	40 Code of Federal Regulations Parts 1500-1508
Code of Federal Regulations		FR Vol 48 No 163, 38139-381410
Code of Federal Regulations		FR Vol. 52 No 160, 31116-31119
Code of Federal Regulations	Transportation for Individuals with Disabilities	
Code of Federal Regulations	EPA NPDES Permit for Stormwater from Construction Activities	
Code of Federal Regulations	NPDES General Permit for Stormwater Discharge from Construction Sites	
Code of Federal Regulations	Procedures for Abatement of Highway Traffic and Construction Noise	23 Code of Federal Regulations 772
Code of Federal Regulations	Airport Noise Compatibility Planning	14 Code of Federal Regulations Part 150
Code of Federal Regulations	Railroad Noise Emission Compliance Regulations	49 Code of Federal Regulations Part 210
Code of Federal Regulations	Mitigation of Impacts to Privately Owned Wetlands	23 Code of Federal Regulations 777.11(f)
Code of Federal Regulations	Regulatory Programs of the USACE	33 Code of Federal Regulations 328.3(b)
Code of Federal Regulations	MOA: Clean Water Act Section 404(b)(1) Guidelines	Federal Register Vol. 55 No 48
Code of Federal Regulations		Title 40 Part 261, et seq.
Code of Federal Regulations		Title 42 Section 300 et seq.
Code of Federal Regulations	Consistency for Activities Requiring a Federal License or Permit [16 U.S.C. 1456(c)(3)(A)]	15 Code of Federal Regulations 930, Subpart D

Applicable Federal and State Laws, Rules, Regulations and Guidance

Agency Order	Title Procedures for Considering Environmental Impacts)	Cite DOT Order 5610.1c
Code of Federal Regulations	Coastal Barriers Resources Act [16 U.S.C.3501, et seq.]: Advisory Guidelines, Final Rule	FR Vol. 48, No 195
Code of Federal Regulations	Coastal Barrier Resources Act [16 U.S.C.3501, et seq.]: Delineation Criteria	FR Vol. 47 No 148
Code of Federal Regulations	Interagency Coordination-Endangered Species Act of 1973, as amended	50 Code of Federal Regulations Part 402
Code of Federal Regulations		7 Code of Federal Regulations 658
Executive Order	Protection and Enhancement of the Cultural Environment	Executive Order 11593
Executive Order	Floodplain Management	Executive Order 11988
Executive Order	Protection of Wetlands	Executive Order 11990
Executive Order	Intergovernmental Coordination	Executive Order 12372
Executive Order	Environmental Justice	Executive Order 12898
Guidance Document	Guidance for Preparing and Processing Environmental and Section 4(f) Documents	Technical Advisory 6640.8a
Florida Statutes	Administrative Procedures Act	Chapter 120
Florida Statutes	State Lands: State-owned lands; Uses	Chapter 253.034
Florida Statutes		Chapter 267.061
Florida Statutes	Water Resources	Chapter 373
Florida Statutes	Environmental Land & Water Management/Developments of Regional Impact	Chapter 380, Part I
Florida Statutes	Environmental Control	Chapter 403
Florida Statutes		Section 286.26
Florida Statutes		Section 334.30
Florida Statutes		Section 337.243
Florida Statutes		Section 337.243
Florida Statutes		Section 338.22
Florida Statutes		Section 338.223
Florida Statutes		Section 338.224
Florida Statutes		Section 338.251
Florida Statutes		Section 339.125
Florida Statutes		Section 339.135
Florida Statutes		Section 339.155
Florida Statutes		Section 339.155(6)
Florida Statutes	Metropolitan Planning Organization	Chapter 339.175
Florida Statutes		Section 335.17

Applicable Federal and State Laws, Rules, Regulations and Guidance		
Agency Order	**Title Procedures for Considering Environmental Impacts)**	**Cite DOT Order 5610.1c**
Florida Statutes	Florida Aquatic Preserve Act of 1975	Sections 258.35 through 258.46
Florida Statutes	Environmental Control: Dept. Powers/Duties	Section 403.061 Subsection (27)
Florida Statutes		Chapter 337
Florida Statutes	Coastal Planning and Management/Florida Coastal Management Act	Chapter 380 Part II
Florida Statutes	Beach & Shore Preservation: Coastal Zone Protection	Sections 161.54(1) and 161.54(5)
Florida Statutes	Areas of Critical State Concern and Coastal Infrastructure Policy	Sections 380.045, 380.05 and 380.27
Florida Statutes	Local Government Comprehensive and land Development Regulation Act	Section 163, Part II
Florida Statutes		Section 334.044(25)
Florida Statutes		Section 336.045(1)
Florida Statutes		Section 336.045(6)
Florida Statutes		Section 339.155(2)(k)
Florida Statutes		Section 335.093
Guidance Document	District Review of Conformity Determinations	FDOT Procedure No 525-010-014
Guidance Document	Applying the Section 404 Permit Process to Federal Aid Highway Projects	FHWA-RE-88-028
Guidance Document	Transportation Enhancement Projects	Procedure 525-030-300
Guidance Document	Environmental Policy	Topic # 000-625-001
Guidance Document	Transportation Design for Livable Communities	Topic # 000-625-060
Guidance Document	Corridor Planning and Design Report	Topic # 525-030-137
Guidance Document	Right-of-Way Corridor Mapping	Topic # 550-030-015
Guidance Document	Exception Agreement and 23 United States Code 106 Exception Process	Topic # 625-010-000
Guidance Document	NPDES Permits for Stormwater Discharge from Highway Construction Sites	Topic # 650-040-003-d
Guidance Document	Federal-Aid Policy Guide	
Guidance Document	Analysis of Highway Construction Noise	FHWA Technical Advisory T6160.2
Guidance Document	Preservation of the Nation's Wetlands	USDOT Order 5660.1A
Guidance Document	Local Operating Agreement "Merging the Section 404 and NEPA Process in Florida	
Guidance Document		USDOT Order 5650.2
Governor's Order		SExecutive Order 95-359
State Rule		14-107

Applicable Federal and State Laws, Rules, Regulations and Guidance

Agency Order	Title Procedures for Considering Environmental Impacts)	Cite DOT Order 5610.1c
State Rule	Air Pollution Control: Conformity	FDEP Rule 62.204.500
State Rule		Rule 14-88
State Rule	Florida Aquatic Preserves	Chapter 18-20, Florida Administrative Code
State Rule	Organization and Procedure (St. Johns WMD)	Chapter 40C-1
State Rule	Consumptive Use	Chapter 40C-2
State Rule	Environmental Resource Permits, Surface WM Systems	Chapter 40C-4
State Rule	Standard General Environmental Resource Permits	Chapter 40C-40
State Rule	Surface Water Management Basin Criteria	Chapter 40C-41
State Rule	Noticed General Environmental Resource Permits	Chapter 40C-400
State Rule	Minimum Flows and Levels	Chapter 40C-8
State Rule	Environmental Resource Permits: Regulation of Stormwater Management Systems	Chapter 40C-42
State Rule	Sovereignty Submerged Lands Management	Chapter 18-21
State Rule	FDEP Rule; regulation of stormwater discharge	Chapter 62-25 Florida Administrative Code
State Rule	Water Quality Standards	Chapter 62-3 Florida Administration Code
State Rule	Delineation of the Landward Extent of Wetlands and Surface Waters	Chapter 62-340
State Rule	FDEP Rule; Water Policy	Chapter 62-40 Florida Administrative Code
State Rule	Permits: Permits for Water Pollution Sources	Chapter 62-4.242 Florida Administration Code
State Rule		Chapter 17-3.041 Florida Administrative Code
State Rule		Chapter 17-4.242 Florida Administrative Code
State Rule		Chapter 17-25 Florida Administrative Code
State Rule	Florida Wildlife Code Title 39, T & E Species	Chapter 39-27 Florida Administrative Code
State Rule		Florida Administrative Code 14-12.021
United States Code	Wild and Scenic Rivers Act	16 United States Code 1271
United States Code	Coastal Zone Management Act of 1972	16 United States Code 1451 *et seq.*
United States Code	Sections 303 and 307 of the Coastal Zone Management Act of 1972	16 United States Code 1452 and 1456
United States Code	Section 7 of the Endangered Species Act of 1973	16 United States Code 1536
United States Code	Archaeological and Historic Preservation Act	16 United States Code 461 and 23 United States Code 305
United States Code	Sections 106, 110(d), and 110(f) of the National Historic Preservation Act of 1966	16 United States Code 470(f)
United States Code	National Historic Preservation Act of 1966	16 United States Code 470(f), Public Laws 89-665, 91-243, 93-54, 94-422, 94-458, 96-515

Applicable Federal and State Laws, Rules, Regulations and Guidance		
Agency Order	Title Procedures for Considering Environmental Impacts)	Cite DOT Order 5610.1c
United States Code	Section 2 of the Fish and Wildlife Coordination Act	16 United States Code 662
United States Code	Standards	23 United States Code 109
United States Code	Public Hearings	23 United States Code 128
United States Code	Section 4(f) of the Department of Transportation Act of 1966	23 United States Code 138 and 49 United States Code 303
United States Code	Resource Conservation and Recovery Act	33 United States Code 1241
United States Code	Clean Water Act of 1977	33 United States Code 1251
United States Code	Title VI of the Civil Rights Act of 1964	42 United States Code 2000-d4
United States Code	Safe Drinking Water Act	42 United States Code 300(f)
United States Code	Environmental Quality Improvement Act of 1970	42 United States Code 4371
United States Code	Uniform Relocation and Real Property Acquisition Policies Act of 1970, as amended	42 United States Code 4601
United States Code	Noise Control Act of 1972	42 United States Code 4901
United States Code	Clean Air Act, as amended	42 United States Code 7401
United States Code	Comprehensive Environmental Response, Compensation and Liability Act of 1980	42 United States Code 9601
United States Code	Coastal Barriers Resource Act of 1982	16 United States Code 3501, et seq.
United States Code	Farmland Protection Act of 1981	7 United States Code 4201
United States Code	National Environmental Policy Act of 1969	Public Law 91-190
United States Code	Acquisition of Right-of-way	Section 1017, ISTEA
United States Code	American with Disabilities Act of 1990	
United States Code	Title VIII of the Civil Rights Act of 1968	
United States Code	TEA-21	Public Law 105-178
United States Code	Fish and Wildlife Coordination Act of 1934	Public Law 85-624
United States Code	Federal Water Pollution Control Act, as amended by the Clean Water Act of 1977	Public Law 92-500
United States Code	Safe Drinking Water Act, as amended	Section 1424(e) and 1427 Public Law 93-523
United States Code	The Wild and Scenic Rivers Act	Public Law 90-542
United States Code	Coastal Barrier Resources Improvement Act of 1990	Public Law 101-591, 104 Stat. 2931
United States Code	Endangered Species Act of 1973, as amended 1978, 1979 and 1982	
United States Code		Title 23 United States Code 109(h)

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BIOGRAPHICAL SKETCH

Education

2003–2005 Ph.D., Civil Engineering, Florida State University, Tallahassee, FL.
Dissertation: Environmental Impact Assessment of Transportation Projects: An Analysis using an Integrated GIS, Remote Sensing, and Spatial Modeling Approach.

1999–2002 M.S., Civil Engineering, Cairo University, Cairo, Egypt.

Thesis: Neural Network Model for Parametric Cost Estimation of Sewer Projects

1994–1999 B.S., Civil Engineering, Cairo University, Cairo, Egypt.

Academic Experience

2003–2005 *Graduate Student Teaching Assistant, Florida State University, Tallahassee, FL.*
Assisted the Instructor with class presentations, class planning, grading papers, and preparing student evaluations. At Instructor's discretion, made instructional presentations. Provided individualized instruction during the office hours. Assisted Instructor with management and discipline in the classroom and on field trips. Performed other duties assigned by the Instructor for the following classes:
CCE4004 “Construction Engineering” (35 students),
CEG2202C “Site Investigation” (53 students), and
TTE3004 “Transportation Engineering” (36 students.)

2003-2005 *Graduate Student Research Assistant, Florida State University, Tallahassee, FL.*
Conducted the research work on a project funded by the FSU Research Foundation, titled “Emerging Imaging and GPS/GIS Civil Technologies Applications for Civil Infrastructure Assessments and Management”; Prepared the progress reports, and presentations ; attended the research meetings with the funding agency.
Assisted in preparing and successfully securing grant funding to Florida A & M University and Florida State University.
Worked on a project funded by Federal Highway Administration (FHWA) to identify processes to reduce highway construction project times during spring 2003.

2004 *Class Grader. Florida State University, Tallahassee, FL.*

Graded papers and prepared student evaluations for the EGM3512 "Engineering Mechanics" class (56 students) for the summer 2004.

1999-2002 Recitation Instructor, Cairo University, Cairo, Egypt.

50% course teaching responsibility including class instruction, computer lab instruction, developing assignments and projects, student evaluations, and grading for the following classes:
CEM 2016 "Introduction to Construction Management" (72 students),
CEM 4009 "Cost Estimation and Control" (28 students),
CEE 1004 "Engineering Economics" (32 students), and
CEM 3029 "Scheduling and Planning Techniques" (64 students.)

2002 *Research Assistant, Cairo University, Cairo, Egypt.*
Provided a professional practice advice, for the senior students in their graduation project, in a variety of non-technical issues, such as safety, reliability, aesthetics, ethics, and social impact. Tutored in preparing the final written report and the oral presentation.

2000-2002 *Instructor, Construction Management Computer Laboratory. Cairo University, Cairo, Egypt.* Contracted to provide professional software training classes and business services for outreach groups and government agencies for the following software packages: Primavera Project Planner, Primavera Expedition, SAP 2000, STAAD 3.

2001-2002 *Visiting Teaching Assistant (Part-Time). Modern Academy, Cairo, Egypt.* Assisted the Instructor with class presentations, class planning, and grading papers and preparing student evaluations. Performed other duties assigned by the Instructor for the Arch 318 "Theory of Structures" class (38 students.)

2002 *Visiting Teaching Assistant (Part-Time). Misr International University (MIU), Cairo, Egypt.* Assisted the Instructor with class presentations, class planning, and grading papers and preparing student evaluations. Performed other duties assigned by the Instructor for the following classes:
Arch 1004 "Structural Engineering" (62 students),
Arch 3005 "Reinforced Concrete" (39 students), and
Arch 2004 "Construction Materials & Tests" (42 students.)

Honors and Notable Recognitions

Listed in the Chancellor List, 2005

Dissertation Research Grant, Florida State University, Spring 2004

Best Overall performance prize, Faculty of Engineering, Cairo University Egypt, 1999.

First Place Prize in 4th year Civil Engineering Class (Highest GPA). Presented by the Soil & Foundation Lab, Faculty of Engineering, Cairo University, Egypt, 1999.

First place prize in 3rd year Civil Engineering Class (Highest GPA). Presented by the Soil & Foundation Lab, Faculty of Engineering, Cairo University, Egypt, 1998.

Soil & Foundation Lab Prize for the highest grades in Soil Mechanics Course, 1998.

Selected by the College of Engineering, Cairo University, to participate in the funded training at water treatment plant construction site, Trabzon, Turkey, 1997.

Publications

El-Gafy, M., and AbdelRazig, Y.; "Ant Colony Optimization for Dynamic Construction Site Layout"; International Journal of Computational Intelligence, Vol. 2, No. 1, 2004.

AbdelRazig, Y. and El-Gafy M., "Computer Simulation Analysis to Reduce Asphalt Paving Process Duration"; Proceeding of the Fourth International Conference on Information Systems in Engineering and Construction (ISEC 2004), Cocoa Beach, Florida, 2004.

AbdelRazig, Y. and El-Gafy M., "Networked Computer Integrated Construction Environment Strategy"; Proceeding of the Fourth International Conference on Information Systems in Engineering and Construction (ISEC 2004), Cocoa Beach, Florida, 2004.

El-Gafy M. and AbdelRazig, Y., "Parametric cost estimation for Transportation projects: Principal component regression vs. neural networks"; Proceeding of the Fourth International Conference on Information Systems in Engineering and Construction (ISEC 2004), Cocoa Beach, Florida, 2004.

El-Gafy M. and AbdelRazig, Y., "Web-based Construction Supply Chain Management: A Research Framework"; Proceeding of the Fourth International Conference on Information Systems in Engineering and Construction (ISEC 2004), Cocoa Beach, Florida, 2004.

El-Gafy, M., and AbdelRazig, Y., " Remote Sensing Framework for Transportation Infrastructure Environmental Assessment", proceeding of the 9th International Conference on Engineering, Construction and Operations in Challenging Environments, Houston, Texas, March, 2004.

El-Gafy, M. A., Taha, M. A., and El-Said, M., "Neural Network Model for Parametric Cost Estimation of Sewer Projects" Proceedings of the 10th International Conference on Artificial Intelligence Applications, Cairo, Egypt, Feb. 6-9, 2002.

El-Gafy, M., and AbdelRazig, Y.; "Facilities Survey Feasible With GIS and GPS ", Arc-User Magazine, ESRI, Winter Issue, 2004.
http://www.esri.com/news/arcuser/0104/facilities.html

El-Gafy, M., and AbdelRazig, Y.; "Managing the University Facilities Using GPS and GIS", GIS Educator, ESRI, 2005 (Invited Paper to be published in the new edition of the GIS Educator newsletter.)

Professional Experience

2002 *Civil Engineer. Yotopia Residential and Touristic Investment Co., Egypt.* Performed construction supervision and contract administration on five residential buildings to ensure the sub-contractor's compliance with the owner plans and specifications. Projects included measuring quantities, preparing pay estimates, reviewing contract change orders, inspecting quality of work done, and monitoring the sub-contractor's overall performance. Enforcement of CPM scheduling clauses in contract specifications. Developed plans, specifications, estimates, and other contract documents.

2001-2002 *Civil Engineer. El-Robia Contracting Co., ISO 9002 certified, Egypt.* Performed the structural analysis and design of steel and reinforced concrete buildings on two projects (Dreamland, Beverly Hills.) Prepared working drawings and shop drawings for designed projects. Performed project management activities as an assistant resident engineer on Dream Land project for one month; and worked closely with construction people involved in design projects to assure that plans were followed, quality was upheld and correct procedures and materials were used.

2000 *Civil Engineer (Part-Time), Design Consulting Inc. (DCI), (Dr. Mohamed El-Zanaty &Dr. Ashraf El-Zanaty), Egypt.*
Assisted in the structural analysis, design, and preparation of working drawings for one of the biggest Underground projects in Egypt (Omar Makram Underground Garage)[30hrs/week, 9 weeks.]

1999-2000 *Civil Engineer (Part-Time), Misr Consults (Dr. Mokhtar Sedik), Egypt.* Performed the structural analysis and design of reinforced concrete building (Dr. Anwar El – Nady's Mansion) [20hrs/week, 10 months.]

1997 *Engineer Trainee, Akeer Insaat, Trabzon, Turkey.* Assisted the project manger to perform office and field work in the construction of a water treatment plant. Performed field land surveying including: drafting; use of theodolite for traversing; and transit leveling to obtain contour plots.

Professional Development Activities

University-wide Teaching Conferences (spring 2004, fall 2004, spring 2005)

Workshops & Seminars

- Using Group Activities
- Advanced PowerPoint
- Mentor Training Workshop
- Designing and Using Games, Role-plays, and Simulations in Instruction
- Using Feedback to Improve Teaching Skills
- Designing New Courses
- Leading Class Discussions
- Aligning Your Teaching Philosophy with Learning Objectives
- Developing a Learner-Centered Syllabus
- Applying Creative Thinking Techniques in the Classroom
- Cultural, Instructional, and Language Issues in the Classroom

Preparing Future Faculty (PFF)

Electronic Campus

- New Features in Blackboard
- Blackboard Uploading Content
- Advanced PowerPoint
- Blackboard Communication
- Blackboard Grading and Assessments

Auditing class STA 5934: Becoming an educator (spring 2004 and spring 2005).

FAMU Researchers workshop series

- Elements of Proposal Development
- A Primer for a Successful Grant
- Do's and Don'ts of Collaboration
- Elements of Proposal Development

Memberships and Professional Affiliations

Member, the International Computational Intelligence Society, (2004-present)

Student Member, American Society of Civil Engineers, (2003-present)

Member, Egypt Engineers Syndicate, Egypt, (1999-present)

Member, Egyptian Society of Engineers, (1999-present)

Member, the Society of Management Engineers, Egypt, (1999-present)