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Potential Value Extraction from TxDOT's Right of Way and Other Property Assets

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Potential Value Extraction from TxDOT's Right of Way and Other Property Assets

by

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Dedication

First and foremost, I dedicate this thesis to my parents Vilma and Wanderlan, who are my inspiration and mirror, who always encourage me to pursue my dreams, and who taught me the greatest values of my life. I also dedicate this thesis to my sister Mariana and my brothers Diego and Fabio, who are my best friends and who are always available to help and support me. Finally, I dedicate this thesis to my family and friends, who have always cheered and prayed for my success.

Primeiramente, eu dedico esta tese à meus pais Vilma e Wanderlan, que são minha inspiração e espelho, que sempre me incentivaram a buscar meus sonhos, e que me ensinaram meus maiores valores. Dedico também esta tese a minha irmã Mariana e meus irmãos Diego e Fábio, que são meus melhores amigos e que estão sempre disponíveis para me ajudar e me apoiar. Finalmente, dedico esta tese a minha famila e amigos, que sempre torceram e rezaram para meu sucesso.

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Abstract

Potential Value Extraction from TxDOT's Right of Way and Other Property Assets

by

Thiago Mesquita Paes, M.S.E.

The University of Texas at Austin, 2011

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Many Departments of Transportation (DOTs), including Texas Department of Transportation (TxDOT), have been challenged by inadequate funding from traditional federal and state fuel taxes, increasing construction cost, aging highway system, traffic congestions, and recent natural disasters, compromising their primary mission to provide safe vehicle transportation routes with adequate capacity. Furthermore, environmental awareness and sustainability concept have strengthened and sparked debates in Congress, culminating with several regulatory policies that affect, inclusively, transportation projects. This scenario has prompted DOTs to pursue innovative ways to reduce maintenance cost (at minimum) and generate revenue (at maximum) exploiting their assets, and to meet the new regulations. Likewise, the Center of Transportation Research at The University of Texas at Austin undertook a comprehensive research study to identify and determine when, where, and under what circumstances TxDOT should pursue the implementation of which Value Extraction Application (VEA), and how to effectively recognize and involve key stakeholders. As a result, 11 VEAs were identified. In addition, a methodological framework – embedding a multi-attribute criteria analysis matrix as the decision making method - was devised to guide TxDOT throughout the

process of identifying, evaluating, comparing, and selecting the most appropriate VEA while a list of stakeholders associated with each VEA and a stakeholder analysis framework was provided to help TxDOT to identify and reach out key stakeholders.

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CHAPTER 1: INTRODUCTION

1.1 BACKGROUND MOTIVATION, AND RESEARCH NEED

Many State Departments of Transportation (State DOTs), including the Texas Department of Transportation (TxDOT), are increasingly challenged by inadequate revenue from traditional federal and state fuel taxes. These fuel taxes – that comprise about 50% of the Texas highway fund receipts (see Figure 1.1) - were conceived in the 1950s as an indirect charge to recover the costs of vehicle travel on the U.S. highway system. Fuel taxes have, however, not increased with the inflation rate and, given increasing maintenance and construction costs (see Figure 1.2), and more fuel-efficient vehicles, the vehicle per mile tax has become largely inadequate. Inadequate funding from the traditional fuel tax together with increased demand for transportation and increasing maintenance needs, resulting from an aging highway system, have thus resulted in significant deficits. This has been compounded by the fact that State DOTs have also had to deal with rescissions implemented to fund unexpected expenditures, including the relief efforts and reconstruction after Hurricane's Katrina, Rita, and Ike, over the past 6 years.

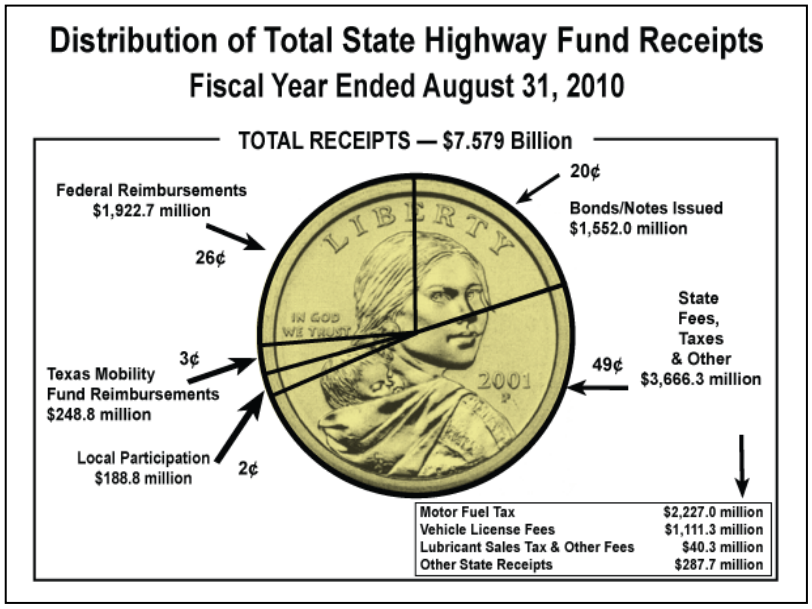

Figure 1.1 – 2010 Total State Highway Fund Receipts
Source: Susan Combs Texas Controller of Public Accounts (2001)

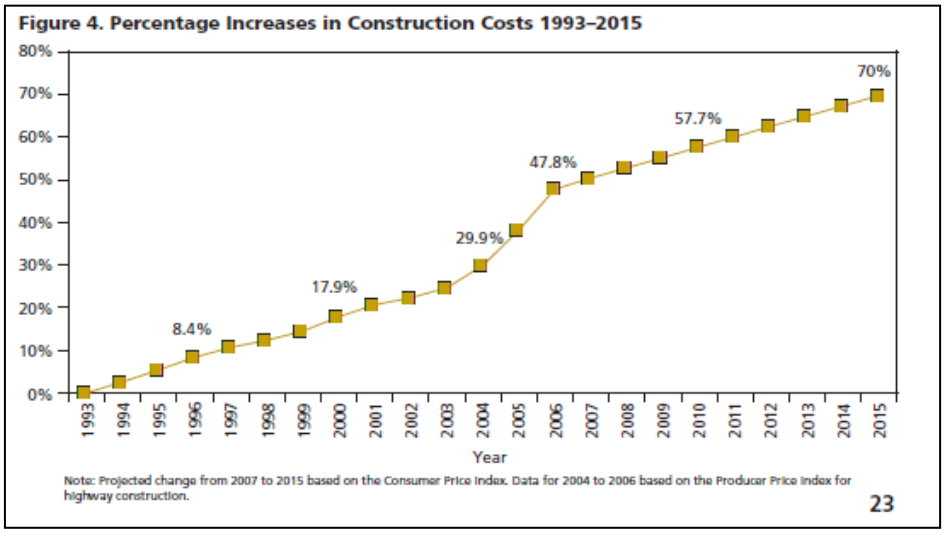

Figure 1.2 – Trends in Construction Costs
Source: AASHTO (2007)

In Texas, a number of recent analyses, including the 2030 Committee report, have consistently pointed to significant deficits and an increasing gap between available funding and increasing maintenance and capacity needs. The 2030 Committee recommended a minimum investment of $14.3 billion per year by TxDOT to attain the agency's goals (see Figure 1.3) - nearly double Texas's highway fund receipts (see Figure 1.1). Furthermore, the Joint Analysis Using Combined Knowledge (J.A.C.K.) model, a financial planning and forecasting tool developed by TxDOT, predicted that by 2016 there will be no funds for highway expansion

TOTAL INVESTMENT NEEDED (2008 $)

	2009-2030	Per Year
Pavements	$ 89 Billion	$ 4.0 Billion
Bridges	$ 36 Billion	$ 1.6 Billion
Urban Mobility	$171 Billion*	$ 7.8 Billion*
Rural Mobility & Safety	$ 19 Billion	$ 0.9 Billion
TOTAL	**$315 Billion**	**$14.3 Billion**

Figure 1.3 – Total Investment Needed by TxDOT until 2030
Source: TxDOT 2030 Committee (2009)

(see Figure 1.4). Inadequate funding and increased funding needs have thus sparked interest in the extraction of additional value from TxDOT's right-of-way (ROW) and other land holdings.

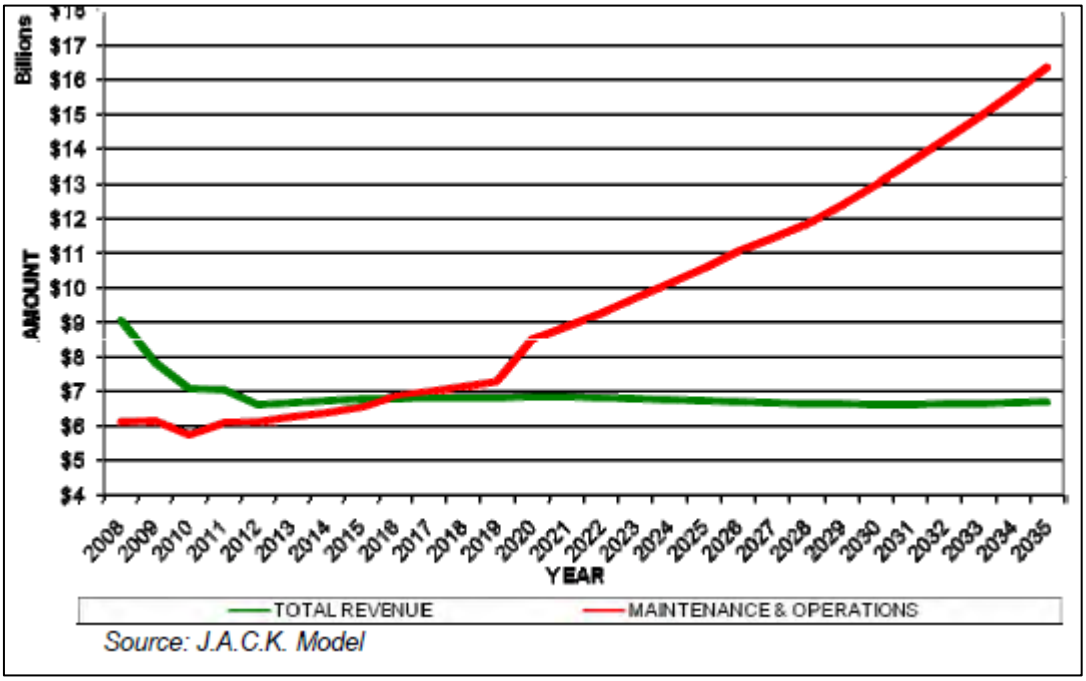

Figure 1.4 – TxDOT Total Revenue vs. Maintenance & Operation Costs
Source: Persad (2009)

State and Federal legislation, regulations, and guidelines; however, limit or prevent TxDOT from implementing potential value extraction applications (VEAs) that may interfere in the Department's primary mission of providing safe vehicle transportation routes with adequate capacity. Any proposed value extraction or value capture strategy must thus comply with such regulations. Furthermore, the potential applications are not necessarily equal in their revenue/cost-saving potential, nor are they necessarily feasible in all geographic/spatial contexts (e.g., urban and rural locations) or given available land uses (e.g., ROW, buildings, or vacant land).

Furthermore, environmental concerns – e.g., climate change and wildlife protection - have increasingly gained attention from Federal and State Government and agencies. Green engineering and sustainability concepts have entered political debates

about GHG emission goals, global warming potential (GWP), environmental life cycle cost assessments, energy conservation, and a reduction of U.S. fossil fuel dependence. In the case of transportation agencies, the need for a stronger commitment to sustainability has resulted in several DOTs embarking on pilot and/or research projects to evaluate the feasibility, requirements, and consequences of accommodating renewable energy projects in highway ROW and on DOT properties.

In August 2010, TxDOT funded the Center for Transportation Research (CTR) at The University of Texas at Austin to conduct a research study to identify and determine when, where, and under what circumstances TxDOT should pursue the implementation of which value extraction applications (VEAs).

1.2 RESEARCH OBJECTIVES

The primary objective of this research study was to identify ways for TxDOT to extract value[1] from its highway ROW and assets (i.e., buildings, and other land holdings) without compromising the Department's primary mission to provide safe vehicle transportation routes with adequate capacity. This study aimed to provide TxDOT with information and guidance in determining when, where, and under what circumstances to pursue the implementation of which VEAs, as well as structured guidance on identifying and involving key stakeholders in the implementation of feasible VEAs. Specifically, the primary goals were:

- Compile and synthetize consultancy reports, documented research, and other publicly available information regarding potential VEAs;
- Examine the requirements, barriers, and challenges associated with implementing potential VEA in Texas;
- Evaluate the impacts (i.e., positive or negative) associated with the implementation of each identified VE; and

[1] Value is here understood as: (1) revenue streams, (2) cost savings, and (3) societal benefits, including environmental benefits, which are not necessarily quantifiable in monetary terms.

- Develop a framework and assessment matrix to guide and assist TxDOT in identifying and implementing the most promising VEAs given the TxDOT asset and objective.

The research conducted to meet these objectives culminated in this thesis.

1.3 RESEARCH SCOPE AND LIMITATION

This research analyzed and evaluated identified VEAs given TxDOT's objectives and its properties and ROW being considered (see Figure 1.5). The research revealed 11 potential VEAs, as follows:

- Property Management;
- Airspace Leasing – Buildings;
- Airspace Leasing – Parking Lot;
- Right-of-Way Leasing – Utilities and Telecommunication;
- Advertising;
- Solar Panels;
- Wind Turbines;
- Geothermal Energy;
- Special Roads (Solar Road and Piezoelectric Energy);
- Carbon Sequestration and Biomass; and
- Wildlife Crossing.

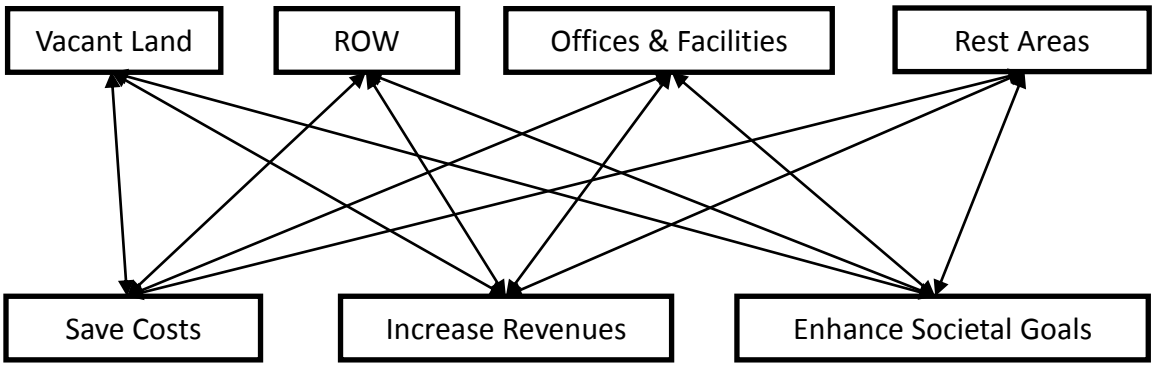

Figure 1.5 – Interaction of TxDOT's Assets and Objectives

The research was limited to examining and assessing the VEAs within the Texas context (e.g., needs, market, culture, climate, geography, legislation, and regulations). Specifically, the research was presented and input was obtained from TxDOT's Dallas, El Paso, Houston, Paris, Tyler, Pharr, and Yoakum Districts. Seven criteria were explored:

- Technical Feasibility;
- Political/Public Concerns;
- Legal Considerations;
- Financial/Economic Feasibility;
- Environmental Considerations;
- Potential Social Impacts/Benefits; and
- Safety Considerations.

Moreover, the information and data considered and presented in this report reflect current available technologies, current costs, current political considerations, existing Federal and State legislation, and existing TxDOT policies and regulations. Not only can changes to any of these parameters influence and modify the consideration and feasibility of the identified VEAs, but new technologies can emerge, thereby resulting in new opportunities and potential VEA. Despite these restrictions and limitations, general findings and recommendations were extracted from several references that seem applicable and transferable to Texas.

1.4 REPORT STRUCTURE

This thesis consists of six chapters. Following this introduction, Chapter 2 presents the research methodology, including the literature review and an overview of the interviews conducted, as well as an introduction to multi-attribute criteria analysis and the evaluation matrix that were used to evaluate and compare VEAs. Chapter 3 provides a detailed review of each VEA in terms of the seven evaluation criteria, as well as identified best practices and concluding remarks. Chapter 4 presents the methodological framework and VEA evaluation matrix developed to assist TxDOT in identifying and implementing feasible VEAs. Chapter 5 describes the stakeholder analysis framework and public outreach plan. Finally, Chapter 6 provides conclusions and recommendations, as well as presents the research contributions and offer final remarks.

This thesis also includes seven appendices. Appendix I illustrates the inputs and outputs of the methodological framework developed. Appendix II presents the questionnaire used to characterize TxDOT's assets and filter potential VEAs. Appendix III summarizes the advantages and disadvantages/requirements of each VEA. Appendix IV presents the questions that are used to evaluate each VEA in terms of the seven criteria identified. Appendix V provides examples and best practices pertaining to each VEA. Appendix VI lists potential stakeholders that should be involved when considering for each VEA. Finally, Appendix VII provides the questionnaires used to facilitate research interviews.

CHAPTER 2: RESEARCH METHODOLOGY, BACKGROUND REVIEW, AND EVALUATION MATRIX

This chapter compromises three sections: (1) an overview of the research methodology that briefly details the tasks undertaken; (2) a detailed discussion on how the background review was conducted, including main sources of information; and (3) an explanation of the multi-attribute criteria (MAC) analysis theory used to evaluate and compare potential VEAs.

2.1 RESEARCH METHODOLOGY

This research comprised seven major tasks:

1. Conduct literature and background review;
2. Identify best practice Value Extraction Applications;
3. Assess legal issues and concerns;
4. Develop stakeholder analysis framework;
5. Develop Value Extraction Application methodological framework;
6. Conduct public outreach and finalize Value Extraction Application methodological framework; and
7. Document research.

Figure 2.1 depicts the research methodology while the ensuing sub-sections briefly describe each of the aforementioned tasks.

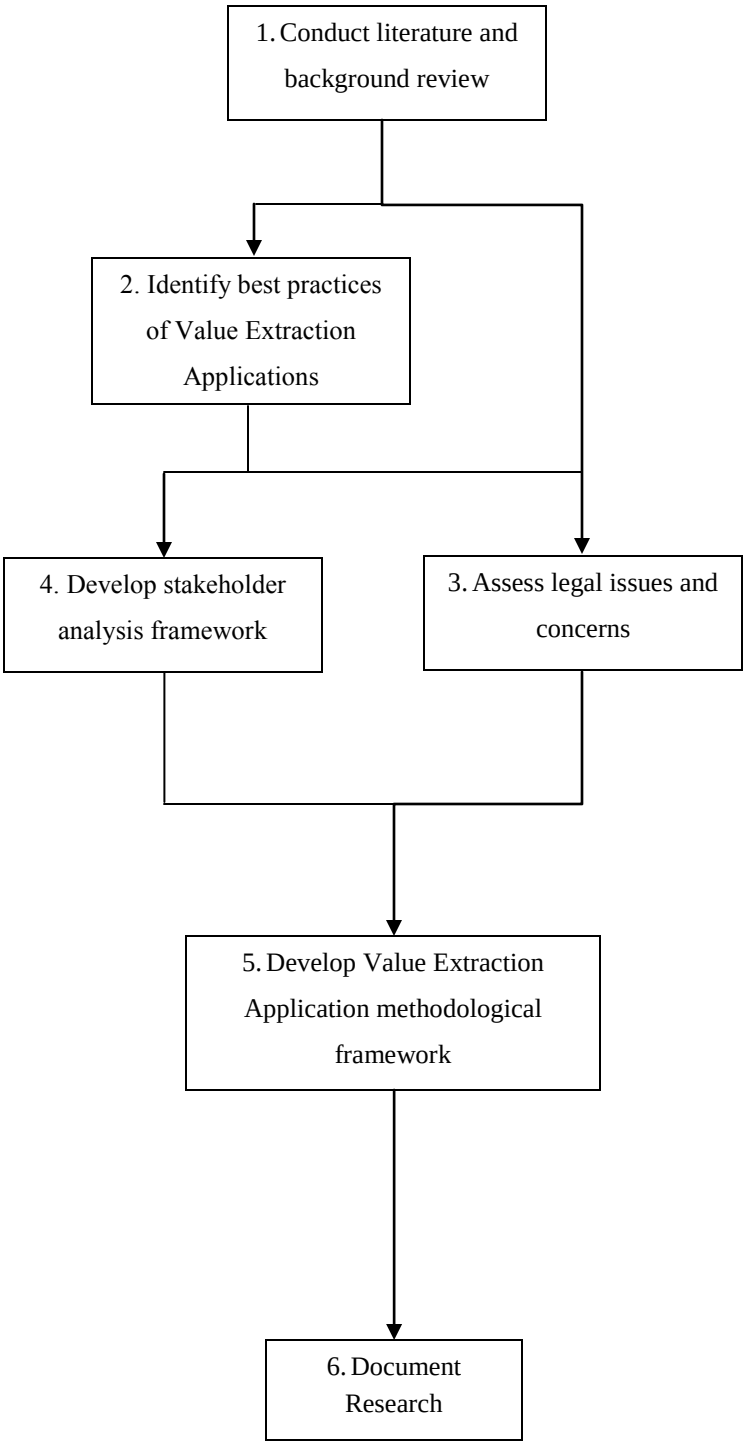

Figure 2.1 – Flow chart of the research methodology

2.1.1 Conduct Literature and Background Review

This research project was initiated with an extensive literature review to gather information about value extraction applications (VEAs) that have been implemented nationally and internationally. The research team also reviewed relevant studies conducted for TxDOT to better understand the agency's needs, resources, expenses, and goals. A series of interviews was conducted with strategic TxDOT personnel and national leaders on different value extraction applications to complement and further discuss the literature findings. Questionnaires were developed to guide the interviews (see Appendix VI. Members of the research team also attended conferences, webinars, and a peer-exchange to share experiences and supplement information and findings about VEAs. Chapter 3 presents and discusses the information gathered.

2.1.2 Identify Best Practice Value Extraction Applications

From the literature review, it was possible to identify and understand the factors that drive the feasibility of VEAs such as, geographic and spatial context, site characteristics, and legal constraints. Moreover, each VEA potentially contributes differently to the fulfillment of TxDOT's objectives (i.e., revenue, cost savings, and/or societal goals), but includes inherent trade-offs. To identify which VEA would be the most appropriate and suitable to attain TxDOT's specific goal(s) in a specific location and with a specific property, two sequential approaches were followed. First, Best Practices – herein defined as established projects or procedures, as well as case studies that can be used as a reference for successful implementation model – were identified, reviewed, and analyzed. This allowed for the identification of "success" – i.e., factors that can increase the likelihood of successful implementation of a specific VEA – and necessary conditions – that would hinder or preclude the achievement of the intended objective if absent. Though the best practices were identified from the lessons learned by early adopters and the initial findings and conclusions of ongoing pilot projects, the best practices may not be applicable in all cases. The 11 identified VEAs were thus evaluated

in terms of the type of assets and primary objectives. Questions regarding conditional aspects were developed for each asset type to function as a first filter in identifying potential VEAs[2]. The questions aim to determine whether the asset's characteristics are compatible with the necessary conditions to achieve a specific objective. The identified best practices are discussed in detail in Chapter 3 and summarized in Appendix V. Chapter 4 provides the methodological framework for identifying the most appropriate VEAs given the asset type and agency objective. Appendix II presents the questionnaire used to determine the feasibility of potential VEAs. An evaluation matrix was developed – using multi-attribute criteria analysis – to guide TxDOT in comparing potential VEAs and their respective trade-offs, thereby facilitating the identification and selection of the most appropriate VEA(s). The research team selected seven criteria that cover different aspects and impacts associated with the implementation of any VEA. Section 2.3 discusses the theory behind the multi-attribute criteria technique and introduces the evaluation matrix, while Appendix IV describes each component of the matrix in detail.

2.1.3 Assess Legal Issues and Concerns

Legal issues and concerns are an important consideration when implementing any sort of activity on a public asset. In the case of the transportation sector, State and Federal legislation, Federal Highway Administration (FHWA) and American Association of State Highway and Transportation Officials (AASHTO) regulations, and internal DOT policies govern the types of activities that can and cannot occur on ROW and properties held or purchased by DOTs, thus playing a crucial role in the feasibility of VEAs. The research team thus assessed the legal framework and legal constraints under which TxDOT can potentially extract additional value from its ROW and other land holdings. Chapter 3 highlights the major legal consideration regarding each VEA.

[2] Potential VEAs are any Value Extraction Application that can be implemented in a certain type to fulfill a specific TxDOT objective (i.e., generate revenue, save cost, or enhance societal goals).

2.1.4 Develop Stakeholder Analysis Framework

In any public project, especially transportation projects, a diversified and large group of stakeholders[3] is typically involved. However, the level of interest and influence vary among the different groups and largely depend on the type and location of the project. While failing to reach out specific stakeholders can jeopardize a project's implementation and progress, an extensive outreach program to stakeholders that are not interested in or affected by the project can be very costly and inefficient for the DOT. Therefore, effectively identifying, reaching out to, and involving key stakeholders[4] not only can save cost and resources, but can also be crucial to ensure the successful implementation of a VEA. The research team thus developed a stakeholder analysis framework to assist TxDOT in identifying key stakeholders and selecting the most effective outreach technique to engage these stakeholders.

The stakeholder analysis framework is described in Chapter 5. Furthermore, a part of the stakeholder analysis framework - as an important component of the methodological framework developed in this research – is briefly presented in Chapter 4, while a list of stakeholders pertaining to each VEA is provided in Appendix VI.

2.1.5 Develop VEA Methodological Framework

The Value Extraction Application methodological framework is based on information, findings, and outcomes of all the previous tasks. The VEA methodological framework is intended to assist and guide TxDOT in identifying the most feasible VEAs given the agency's objective and the characteristics of the asset. Chapter 4 presents the VEA methodological framework and explains each step in detail through a hypothetical case study. Appendix I provides the inputs and outputs for the steps of the

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[3] Stakeholders: persons, groups, or institutions with interest in a project or policy or who may be directly or indirectly affected by the process or the outcome (World Health Organization, ND).

[4] Key Stakeholders: those who can significantly influence, or are important to the success of the project. (World Health Organization, ND)

methodological framework while Appendices II to III provide the detailed information presented in Appendix I that are embedded within the methodological framework.

2.2 BACKGROUND REVIEW

This section provides information on how the background review was organized and conducted. First, the methodology adopted is introduced, including important definitions. The literature review is then described, highlighting main information sources consulted. Finally, the interviews conducted and seminars attended are listed.

2.2.1 Methodology

The background review was divided into three main steps as follows:

- Conduct literature review by
  - reviewing consultancy reports, documented research, and other publicly available information about potential VEAs; and
  - reviewing TxDOT studies of VEAs or related subjects.
- Conduct interviews and attend seminars. The interviews comprised two groups:
  - interviews with key TxDOT personnel to understand internal limitations and capabilities, as well as to learn about barriers and challenges in pursuing the implementation of each VEA; and
  - interviews with leaders and experts on each VEA to obtain specific and detailed information regarding the implementation of identified VEAs, main challenges and barriers, current results and impacts, lessons learned, and recommendations for implementation.
- Synthetize the information gathered in a technical memorandum (see Chapter 3) and summarize main findings and considerations (see Chapter 6 and Appendices III and V).

2.2.2 Literature Review

The literature review comprised a comprehensive and in-depth review of TxDOT studies and other published reports, articles, and documents to identify potential VEAs and to understand their respective challenges, barriers, benefits, and requirements. Also, the term VEA had to be clearly defined, understood, and agreed upon by TxDOT and the research team prior to initiating the literature review. Ultimately, VEA was defined as

any activity that can be implemented on TxDOT properties (i.e., ROW, buildings, and land holdings) to (1) increase revenue streams, (2) save costs, or (3) provide societal benefits, including environmental benefits, which are not necessarily quantifiable in monetary terms.

During the literature review, the research team identified 11 VEAs as follows:

- Property Management,
- Airspace Leasing – Buildings,
- Airspace Leasing – Parking Lot,
- Right-of-Way Leasing – Utilities and Telecommunication,
- Advertising,
- Solar Panels,
- Wind Turbines,
- Special Roads (Solar Road and Piezoelectric Energy),
- Geothermal Energy,
- Carbon Sequestration and Biomass, and
- Wildlife Crossing.

2.2.2.1 General References

Several references were consulted, mostly comprising published articles and papers. Although some research reports were also reviewed, most of the VEAs lacked

comprehensive research and data. Wildlife crossings are perhaps the only VEA that have been the topic of extensive research with conclusive results regarding cost-effectiveness, benefits, and challenges. In the case of the renewable energy applications (i.e., solar panels, wind turbines, geothermal, and biomass & biofuel), comprehensive work has been done to assess and analyze the requirements, barriers, impacts, and cost-effectiveness of these applications. The studies; however, did not consider and represent implementation on highway ROW and DOT properties and, thus, the conclusions may not be entirely applicable. On the other hand, some DOTs have been conducting pilot projects to evaluate the potential application of these renewable energy technologies in highway ROW. These pilot projects have provided important insights and information for this research project and were essential in developing the methodological framework (see Chapter 4). The literature review was also important in identifying leaders and experts on each VEA and for the development of questionnaires to guide the interviews (see Appendix VII).

2.2.2.2 TxDOT Relevant Reports

Past TxDOT research studies and reports provided the research team with insight and knowledge about the functions and expectations of the agency, potential challenges and barriers to pursuing VEAs, internal organization and structure, and available resources. For example, in 1993 TxDOT funded Research Project 0-1329, titled "*Leasing of TxDOT's Right-of-Way*", to study, expand, and develop TxDOT's airspace leasing program. In 2005, TxDOT Research Project 0-4609, titled "*Options for Outsourcing Outdoor Advertising Control in Texas*", looked at TxDOT's advertising program. In 2008, TxDOT Research Project 0-5788, titled *"Right-of-Way Real Property Asset Management – Prototype Data Architecture",* was undertaken to assess existing ROW management practices – i.e., at TxDOT and other DOTs - develop a Geographic Information System (GIS) ROW architecture, conduct a few case studies, and make a number of implementation recommendations for a GIS ROW inventory database. In

2001, the General Land Office (GLO) published a list of recommendations and suggestions for TxDOT to implement an efficient property management system/program. This report stated that TxDOT has an inefficient property management system and need to invest in information systems (i.e., GIS), training, and staff resources.

2.2.2.3 Interviews

The literature review acquainted the research team with potential VEAs and helped to identify implemented projects. The information; however, was not sufficient to thoroughly understand and evaluate the barriers, challenges, requirements, and potential impacts of each VEA. The research team thus conducted a series of interviews with leaders and experts concerning each VEA to complement the findings of the literature review. Specifically, the research team obtained insights and current results that have not been published, as well as a better understanding of the implementation process and main obstacles encountered and addressed. The interviews were conducted with TxDOT personnel and DOT representatives that have implemented pilot projects or are recognized as leaders on a specific VEA. All interviews with TxDOT were conducted face-to-face, while telephone interviews were conducted with other DOT representatives. Some members of the research team also participated in meetings and webinars concerning the research topic or a specific VEA. These meetings and webinars usually pertained to recent and ongoing initiatives on the concepts of sustainable and environmentally-friendly highway projects. These meetings and webinars were mostly administrated by the FHWA and/or the Volpe Center to share information and discuss manners to enhance highway projects and minimize impacts on the environment and natural habitats. The main topics were wildlife crossings, renewable energy, and carbon sequestration. Table 2.1 and Table 2.2 list the interviews conducted with TxDOT personnel and with other DOT representatives, respectively. The tables also include the VEA discussed and the main goals and topics. Table 2.2 also provides meetings and

webinars attended. The questionnaires used to guide the interviews are included in Appendix VII.

Table 2.1 – Summary of TxDOT Interviews

Date	Participant	Value Extraction Application	Goal / Discussed Topics
12/12/10	TxDOT - Maintenance Division	Property Management (i.e., Rest Areas) and Advertising	Discuss management of TxDOT's rest areas.
12/19/10	TxDOT - ROW Maintenance Division and Grass Management	Carbon Sequestration and Biomass	Understand how vegetation and ROW management are performed.
5/3/11	TxDOT - ROW Acquisition	Excess Land (i.e., swap and sell) and ROW leasing (i.e, utilities, communication towers, and advertising)	Understand how TxDOT manages excess lands and ROW, as well as its current procedures, policies, and contracts.
5/4/11	TxDOT - Maintenance Facilities Management	Property Management (i.e., swap, lease, and sell) and Communication Towers	Understand how TxDOT manages its facilities and seek opportunities for implementing VEAs
6/7/11	TxDOT - Maintenance Division	Airspace Leasing - Utilities	Main barriers for implementing VEA, potential sites, current use of ROW by utility agencies.
6/27/11	TxDOT - Traffic Operation and Safety Division	Airspace Leasing - Utilities	Main concerns and barriers to implementing shared resources and leasing airspace on TxDOT's communication towers.

Table 2.2 – Summary of Other Interviews, Meetings, and Webinars

Date	Participant	Value Extraction Application	Goal / Discussed Topics
1/21/11	Caltrans - Property Management Division	Property Management (i.e., leasing, communication towers, utilities, parking lot, and swap and sell)	Understand how Caltrans conducts property management, airspace leasing, and ROW leasing.
1/20/11	Utah State University and Utah DOT	Biomass (i.e., oilseed crops)	Improved understanding of the Biofuel pilot project and research being conducted by USU and Utah DOT.
1/22/11	2011 Annual TRB Meeting	Public Outreach	Attend public engagement sessions at the 2011 Annual TRB meeting.
1/31/11	University of Tennessee and Tennessee DOT	Biomass (i.e., switchgrass)	Discuss the Switchgrass pilot project for biofuel being conducted in Tennessee.
2/3/11	Volpe Center - FHWA	Carbon Sequestration	Discuss the main findings of the TxDOT and FHWA research projects.

Date	Participant	Value Extraction Application	Goal / Discussed Topics
2/4/11	Oregon DOT - Solar Roadway Project	Solar Panels	Discuss lessons learned from the solar panel pilot project.
2/4/11	Solarways	Solar Roads	Explore the idea and feasibility of the solar road concept. Obtain information from solar road idea developer on the main characteristics of the project.
3/24/11	Peer-Exchange Meeting	Renewable Energy (i.e., Solar Panels, Biomass, Biofuel, Wind Turbine, and Geothermal) and Sustainability (i.e., carbon sequestration and wildlife crossings)	Attend a Peer Exchange Meeting that aims to share information, lessons learned, results, and challenges.
5/10/11	University of Minnesota	Piezoelectric Cells (Energy Generation)	WIM device, Weight Station, Power Source for Bridge Monitoring & WIM
5/24/11	FHWA, Colorado DOT, Western Transportation Institute, and Normadeau Associates	Wildlife Crossings	Webinar on the importance of Wildlife, Congressional Study, Hotspot Identification, Design Cost-Effectiveness, and The I-70 Mountain Corridor

2.3 MULTI-ATTRIBUTE CRITERIA ANALYSIS & EVALUATION MATRIX

A further decision analysis framework was required to assist TxDOT in evaluating and comparing potential VEAs and, consequently, identifying the most appropriate VEA given the asset type and the agency's objective. This sub-section therefore introduces introducing the concept of multi-attribute criteria analysis, which is used to compare different possible alternatives or solutions to a problem. Each criterion embedded in the decision analysis framework is defined and the evaluation matrix developed to assess and compare potential VEAs is presented.

2.3.1 Multi-Attribute Criteria Analysis

Multi-attribute criteria (MAC) analysis is a decision making technique commonly used to assess solutions that involve trade-offs (e.g., cost and schedule) or compare alternatives that are seemingly not comparable. Typically, the decision making involves several attributes or impacts that pertain to potential alternatives. This attributes usually

have different scales (i.e., units of measurement) or are merely qualitative (i.e., cannot be quantified) and can therefore not be directly compared or combined into a unique measure (e.g., monetary). Furthermore, the level of importance of each attribute may differ given the goal of the decision maker. In the case of VEAs, seven criteria were identified to comprise and represent the universe of impacts and benefits that should be considered when implementing a VEA. The seven criteria are:

- Technical Feasibility;
- Political/Public Concerns;
- Legal Considerations;
- Financial/Economic Feasibility;
- Environmental Considerations;
- Potential Social Impacts/Benefits; and
- Safety Considerations.

By analyzing and evaluating potential VEAs according to these seven criteria, TxDOT can consider and apply the information gathered (i.e., best practices and pilot projects) to the Texas case at hand, thereby considering the actual features and challenges of the project location (e.g., legal, political, cultural, and technical attributes). Furthermore, all the potential VEAs can be assessed given the same baseline and criteria, thereby enabling direct comparison.

2.3.2 Criteria Definition

To evaluate and compare potential VEAs, it is essential to have a clear understanding of the meaning of each criterion. This sub-section provides a description and examples for each criterion included in the MAC analysis.

2.3.2.1 Technical Feasibility

Technical Feasibility refers to the technical requirements for the successful implementation of a VEA. For example, a site's characteristic is a major factor for

several VEAs such as, solar panels (e.g., proximity to transmission lines, slope of terrain, and minimum of five acres of available land) and biomass (e.g., minimum 15 inches of rainfall, soil characteristics, distance to biorefineries, and minimum of one acre of available land). Technical feasibility also concerns engineering and construction standards and requirements. For example, to construct a building over a highway the distance between columns (i.e., free span), minimal clearance, construction methods, and access to the jobsite can impose challenges that can prevent project execution.

2.3.2.2 Political/Public Concerns

The political and public concerns criterion refers to how the VEA will likely be perceived by the general public and politicians. In other words, political and public concerns assess whether the VEA is controversial, the potential impacts on nearby communities and businesses, the likelihood of resulting in public opposition, and the potential impacts on TxDOT's image. For example, the selling or leasing of vacant land for a new business development can negatively impact neighboring communities (e.g., increase traffic congestion and decrease property values) and existing businesses (e.g., concurrence), thereby causing public dissatisfaction. Some VEAs can, on the other hand, enhance TxDOT's image and receive support from nearby communities, as well as local politicians. These positive perceptions will likely occur if the VEA enhances public goodwill and/or social benefits without increasing tax payments. For example, wildlife crossings can integrate habitats, protect endangered species, enhance road safety, create jobs, and, even, reduce car insurance premiums. Another example is parking lots that can alleviate traffic congestion, stimulate business development, and secure revenue for TxDOT.

2.3.2.3 Legal Considerations

Legal considerations include Federal and State legislation, FHWA policies and regulations, the National Environmental Policy Act (NEPA) and other environmental regulations, Federal Aviation Association (FAA) regulations, and AASHTO policies,

which can directly or indirectly affect and/or drive the implementation of a potential VEA. Legal considerations also include studies and analysis that must be conducted, as well as permits and licenses that must be obtained. Finally, legal considerations pertain to written agreements, liabilities, business models, and responsibilities. For example, Federal and State regulations govern the types of activities that can and cannot occur on ROW held by DOTs or purchased by the DOTs. 23 Code of Federal Regulations (CFR) Chapter 1, for the most part, regulates the activities and opportunities that DOTs are granted vis-à-vis the federal system of interstate highways. Moreover, Federal law currently prohibits DOTs from privatizing and commercializing rest areas along interstate highways. In Texas, Texas Transportation Code and Texas Administrative Code govern the activities and opportunities surrounding TxDOT's ROW and real estate assets. Furthermore, Transportation Code Sub-chapter C of Chapter 202 governs leases, easements, and agreements that concern highway property. Section 202.052 *allows the department to lease a highway asset, part of the ROW, or airspace above or underground a highway, if the department determines that the interest to be leased will not be needed for a highway purpose during the term of the lease*. Also in Texas, *"TxDOT regulates the display of off-premise outdoor advertising signs along highways regulated by the Highway Beautification Act (HBA) and all other highways and roads located outside of the corporate limits of cities, towns and villages in Texas under the State Rural Roads Act (RRA)"*. In some cases, a lack of zoning law can defer or even impair the implementation of a VEA such as, solar, wind, and geothermal. Also, environmental analysis is a requirement for any project on public land. A solar project, for example, must comply with NEPA – either the FHWA or the DOE process, if not both – to receive an environmental permit. Finally, any construction exceeding 200ft requires the filling of form "74601-Notice of Proposed Construction or Alteration" with the Federal Aviation Administration (FAA) prior to its outset. The FAA and the Department of Defense (DOD) will review the form and issue a permit.

2.3.2.4 Financial/Economic Feasibility

The implementation of any VEA requires an upfront investment by TxDOT and/or private investors. The financial/economic feasibility criterion evaluates the upfront investment and the consequential payback period, as well as the potential financial and economic benefits that the implementation of a VEA can bring to TxDOT and society. For example, wildlife crossings typically require an investment of $1 to $3 million by the DOT, but the investment can be recovered through cost savings from eliminating the need to remove animal carcasses and vehicle wrecks caused by animal-vehicle-crash incidents (AVC). Wildlife crossings also Economically benefit the society by preventing human fatalities from AVC (i.e., value of human life), reducing vehicle insurance premiums, and creating temporary jobs (i.e., construction jobs). Another example is the property management VEA, which can generate revenue for TxDOT (e.g., selling or leasing land lots or properties) and/or save costs (e.g., swap transaction that result in the DOT acquiring a new facility). Furthermore, property management applications that result in TxDOT selling land in prime real estate locations can stimulate economic development (i.e., creation of business opportunities and jobs in urban areas) and raise tax revenues for the state (i.e., payment of land taxes by private owners).

2.3.2.5 Environmental Considerations

Highway are and have been criticized for their associated environmental impacts, including habitat fragmentation, deforestation, noise and dust during and after construction, vehicle emissions (e.g., NOx, SOx CO, and CO_2), and threats to endangered species (e.g., animal-vehicle-crashes). The environmental considerations criterion assesses a VEA's potential impact on the environment. Wind turbines, for example, are a renewable and non-pollutant energy source. Wind turbines can thus contribute to reduce GHG emissions from power generation and help to combat global warming. On the other hand, wind turbines can be detrimental to nearby communities – because of noise and shade – and endanger bird and bat populations.

2.3.2.6 Potential Social Impacts/Benefits

The social impacts and/or benefits criterion assesses a potential VEA's impact on business opportunities, economic development, job creation, and general societal welfare. For example, the implementation of a telecommunication tower in rural areas can enhance internet and cell-phone signals. This type of infrastructure can be essential for economic development in these areas. Moreover, the internet plays an important role in education and professional development. On the other hand, privatizing rest areas may result in competition with local businesses in small communities, hence negatively impacting social welfare. Or seen differently, well served and interactive rest areas and welcome centers can potentially enhance tourism and create jobs in rural areas. Renewable energy projects (i.e., solar, wind, geothermal, and biomass energy) can be scaled (i.e., can be implemented with different sizes and capacities) and implemented close to end-users. This can reduce the cost of transmission lines, and supply electricity to remote and rural areas, thereby promoting economic development, jobs, and societal welfare. On the other hand, renewable energy systems can impact nearby communities negatively (e.g., noise, shade, and property value reduction).

2.3.2.7 Safety Considerations

TxDOT's primary mission is to provide safe vehicle transportation routes with adequate capacity. The safety considerations criterion considers the potential impact of a VEA on the safety of road users and the general public. This criterion thus considers clear zones[5], obstacles and obstructions created, access needs, risks imposed during

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5 "The clear zone (also called the clear recovery area) is an area provided along highways to allow vehicles veering off the travel lane opportunity for safe recovery or stopping. The clear zone width (always measured from the edge of the travel lane) depends on several roadway factors, including: whether the surrounding area is rural or urban, the functional classification of the highway, the design speed, and average daily traffic (ADT)" (TxDOT glossary). For example, freeways shall have minimum 30ft of clear zone (Table 2-11: Horizontal Clearances, TxDOT design manual).

implementation or maintenance of the VEA, and the likelihood of increasing accidents. Rest areas, for example, are essential to road safety. Privatizing and/or offering enhanced services at rest areas can motivate drivers to stop, avoid rest areas closures, and, even, increase the availability of rest stops. Consequently, road accidents caused by "drowsy driving" - a serious problem that leads to thousands of automobile crashes each year – can be reduced and road safety can be enhanced. Another example is wildlife crossings. Several studies have demonstrated that a well-designed wildlife crossing can effectively enhance road safety and reduce the occurrence of animal-vehicle accidents. On the other hand, safety concerns may arise whenever a wildlife crossing is planned for an existing road. Safety is also a major concern when using advertising in highway ROW. FHWA and the AAA Foundation for Traffic Safety argue that advertising can distract drivers, thereby causing accidents. Furthermore, signs and billboards must be located outside the clear zone to protect drivers that run off the road.

2.3.3 Evaluation Matrix

An evaluation matrix was devised and delivered by this research effort to guide TxDOT in the assessment and comparison of VEAs in determining the most appropriate VEA to be implemented in a specific context (i.e., asset, objective, and location). The evaluation matrix embeds MAC analysis as the decision making technique to compare potential VEAs in terms of feasibility and impacts scores. Figure 2.2 presents the steps undertaken to develop the evaluation matrix, as well as the criteria, calculations, and outcomes pertaining to the VEA evaluation process. Table 2.3 provides the composition of the feasibility and impact scores.

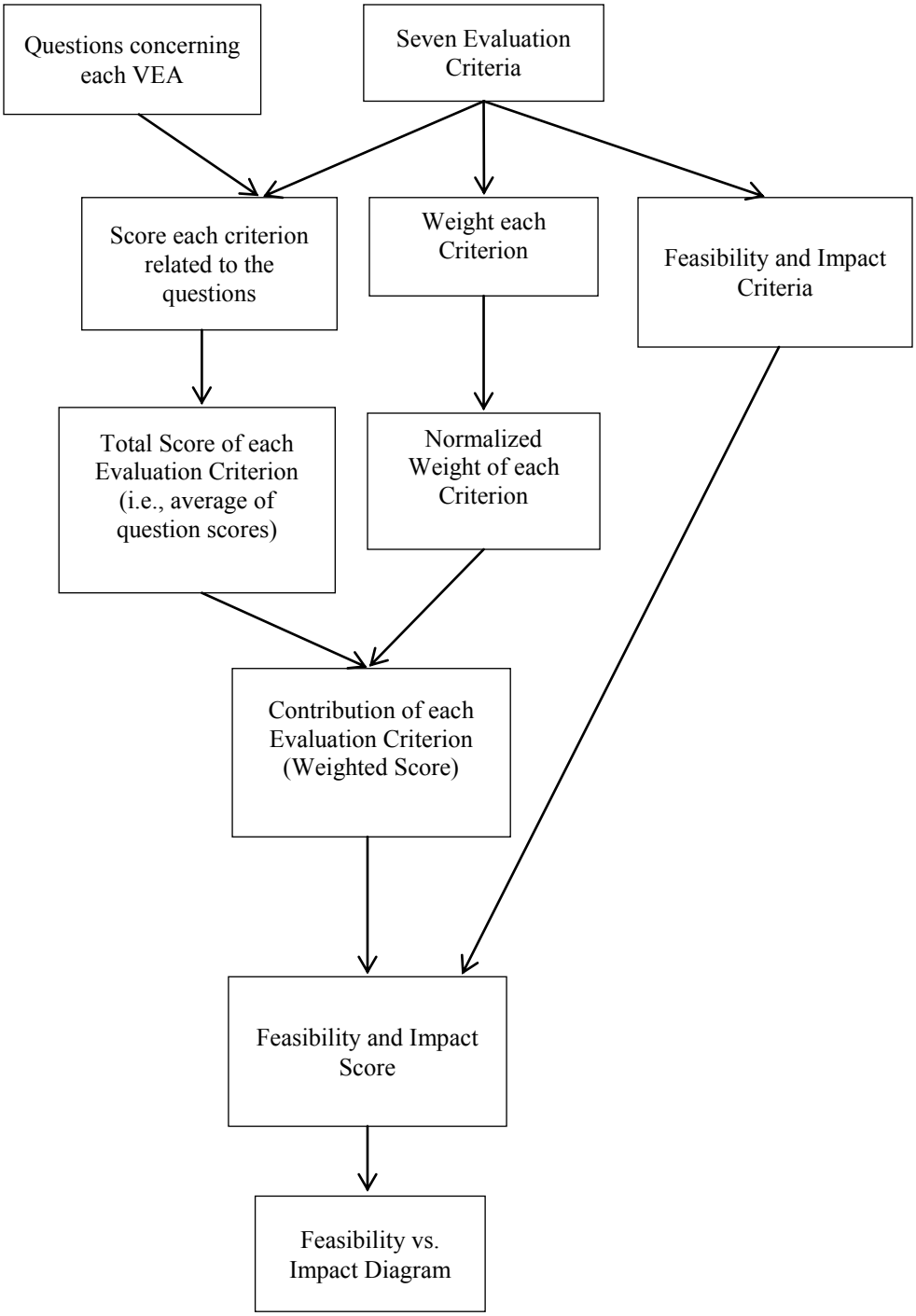


Figure 2.2: Flowchart of Multi-attribute and Evaluation Matrix Analysis

Table 2.3: Composition of Feasibility and Impact Scores

Feasibility Score	**Impact Score**
Technical Feasibility	Political/Public Concerns
Legal Considerations	Environmental Considerations
Financial/Economic Feasibility	Potential Social Impacts/Benefits
	Safety Considerations

The evaluation matrix includes a series of questions that were developed based on information gathered during the background review. The questions address one or more of the identified criteria and are intended to help TxDOT consider the various factors that can influence the implementation of each potential VEA. Figure 2.3 shows the evaluation matrix template.

		FEASIBILITY			IMPACT					
		Technical	Legal	Economical	Political/ Public	Environmental	Safety	Social		
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19									Feasibility Score	Impact Score
20										
	TOTAL CONTRIBUTION OF EACH CRITERION	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 2.3: Evaluation Matrix Template

The user is required to evaluate each potential VEA separately, scoring each criterion (i.e., question) on a scale from -2 to 2 (see Table 2.4). The scores are used to convert a qualitative attribute into a quantitative measurement, thereby allowing direct

comparison. The total score of each criterion (S) is given by the average of the partial score (s) (i.e., the scores given to each question associated with a criterion), as shown in the formula below. Therefore, a positive criterion score does not necessarily imply no concerns or negative impacts.

$$Criterion\ Score\ (Sj) = \frac{\sum_{i=1}^{i=n} Question\ Score\ (si)}{n}$$

Where,

n is the number of questions related to the criterion.

Table 2.4: Criteria Score Scale

Score Scale		
Negative Impact	-2	Major Concern or Barrier
	-1.5	
Somewhat Negative Impact	-1.0	Minor Concern or Barrier
	-0.5	
Neutral	0	Neutral
	0.5	
Somewhat Positive Impact	1.0	Minor Benefits or Driver
	1.5	
Positive Impact	2.0	Major Benefits or Driver

As previously mentioned, each criterion may also have a different level of significance (i.e., weight) in the decision process, depending on the intended objective, project location, and type of asset. To reflect and incorporate the importance of each criterion in the decision analysis, the user can use to criteria weights techniques. Different methods can be used to assign criteria weights. For example, a maximum score (e.g., 1, 10, or 100) can be assigned to the criterion with the highest importance and the other criteria can then be assessed relative to the most important criterion. Alternatively, the criteria can be ranked and the rank position can be related to a specific weight.

Regardless of the approach or scale adopted to weigh the criteria, the weights (w_i) will be normalized. The normalized weight (W_i) is determined by dividing the criterion weight (wi) by the sum of the criteria weights that comprise the feasibility or impact score (see formula below).

$$Wi = \frac{wi}{\sum_{j=1}^{j=n} wj}$$

Where,

w_i or w_j is the weight scale of a criterion (e.g., technical, environmental, and safety);

n is the number of criterion pertaining to feasibility or impact.

Table 2.5: Example of Weight Scale and Normalized Weight

		Normalized Weight	Weight Scale
Feasibility	Technical	0.23	5
	Legal	0.45	10
	Economic	0.32	7
Impact	Political/Public	0.21	6
	Environmental	0.24	7
	Safety	0.34	10
	Social	0.21	6

For example, in Table 2.5 a scale of 1 to 10 was used to weigh the criteria. The normalized weight of the economic criterion (i.e., 0.32) was calculated by dividing 7 (i.e., economic criterion weight) by 22 (i.e., sum of the weights of technical (5), legal (10), and Economic (7) criteria). It is important to point out that the sum of normalized weights of a major criterion must be equal to 1 (e.g., 0.23+0.45+0.32=1).

Finally, the feasibility (fs) and impact (Is) scores of each potential VEA are calculated by adding the product of the normalized criterion weights and the total criterion scores (see formula below). The fs and Is scores are subsequently plotted (see Figure 2.4). The fs and Is scores are the VEA X-axis and Y-axis coordinates, respectively. The chart is divided in four quadrants to help the user identify the most appropriate VEA to be implemented (i.e., inside the green quadrant and closer to the upper right corner) (see Figure 2.4). Chapter 4 provides an example of how the evaluation matrix, the scores, the weights, and the chart can be used in identifying the most appropriate VEA(s) to be implemented.

$$fs\ or\ Is = \sum_{i=1}^{i=n} Wi\ x\ Si$$

Where,

W_i is the normalized weight of criterion I;

S_i is the total score of criterion i.

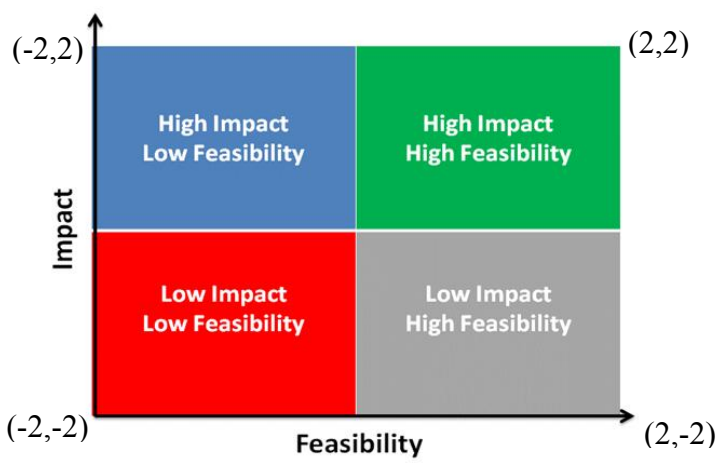


Figure 2.4: Example of Impact vs. Feasibility Diagram

2.3.4 Concluding Remarks

The MAC analysis is an efficient technique to evaluate solutions that involve trade-offs (e.g., cost and schedule) and compare alternatives that are seemingly not comparable – i.e., conditions that typically pertain to potential VEAs. The MAC analysis used in the evaluation of potential VEA incorporates seven criteria (i.e., technical, legal, economic, political/public, environment, safety, and social) to comprise and represent the universe of impacts and benefits that should be considered when implementing a VEA. These criteria may have different levels of significance (i.e., weight) in the decision process, depending on the intended objective (i.e., increase revenue, save cost, and enhance societal goals), project location, and type of asset. Therefore, different weight scores can be assigned to each criterion – using different methods – to incorporate the importance of each criterion in the decision analysis.

In addition, an evaluation matrix – which embeds MAC analysis as the decision making technique - was developed to assist and guide TxDOT in the assessment and comparison of VEAs in determining the most appropriate VEA to be implemented in a specific context (i.e., asset, objective, and location). The evaluation matrix is a straightforward and simple mechanism that includes a series of questions – which address one or more of the identified criteria - to help TxDOT consider the various factors that can influence the implementation of each potential VEA. Potential VEAs are ultimately compared in terms of feasibility and impacts scores.

CHAPTER 3: VALUE EXTRACTION APPLICATIONS

This Chapter contains a summary of the information and findings acquired during the background review on each of the identified VEAs. Each sub-section introduces and discusses in detail one of the eleven identified VEAs in terms of the seven criteria mentioned in Chapter 2. Examples and best practices are also provided before the chapter concludes with some brief remarks.

3.1 PROPERTY MANAGEMENT

This VEA has been commonly used by several U.S. Departments of Transportation (DOTs). In essence, the DOTs operate as a real estate agency selling, bartering, or leasing their property (i.e., land lots and buildings). These DOTs have internal departments that manage the properties and use the web primarily to disseminate information.

The property management applications are discussed by property type: rest areas, land lots, and buildings (i.e., offices, warehouses, storage yards, etc.). The approaches for addressing these different asset categories differ and are therefore discussed separately.

3.1.A Property Management of Excess land

Land lots are valuable assets to the DOTs and need to be carefully managed, as the majority of land owned by the DOTs is for future use, such as road expansion. However, these land lots also represent a considerable investment if unused. For example, in 1999, the Texas DOT's (TxDOT) land ownership amounted to an investment of nearly $161 million (see Table 3.1.1). In addition, these land holdings need to be monitored and maintained, entailing therefore extra expenditures and investments by the DOT.

Buildings are also strategic business assets for the DOTs and are sometimes located in desirable and valuable areas. Buildings are; however, essential for a DOT to perform its role and promote public service. Buildings are typically used to house a

DOT's personnel, but in some occasions they can be leased and thereby generate revenue for public services. Moreover, instances exist where DOT buildings in highly desirable locations can be swapped with a property in a less desirable location or even sold to the private sector.

Table 3.1.1: GLO Recommendations and TxDOT Action
Source: General Land Office, Real Property Evaluation Reports, TxDOT

Comparison of GLO recommendations and TxDOT action, 1996 to 1999

	1996		1999	
	# of Sites	Value of Land*	# of Sites	Value of Land*
Total number of sites owned by TxDOT	382	$201,910,000	432	$160,341,000
GLO Recommendations				
Sites recommended to retain	339	$63,284,000	385	$72,414,000
Sites recommended to sell or lease	43	$138,626,000	47	$87,927,000
TxDOT Action				
Sites sold or transferred	9	$652,536	15	$2,646,000
Partial sites sold or transferred	2	$127,900,000**		
Sites reclassified	5	$970,250	12	$26,333,000
Sites where no action was taken	32	$9,091,000	20	$58,948,000

* "This number is the GLO estimate of the value of land only. It does not include the value of facilities or represent the sale price" (TxDOT, 2001).

** "GLO estimated the total value of the land was $ 127,900,000. Part of the Leander site was sold for more than $ 18 million and part of the Sugarland site was transferred to other entitles" (TxDOT, 2001).

3.1.1.A Technical Feasibility

This VEA does not present any substantial technical challenges. A well-designed and updated website is potentially a valuable technical tool to facilitate a property management program, but it is not mandatory. An effective marketing and advertising program is; however, essential to disseminate information about available properties and to engage interested entities. A representative of the California Department of Transportation (Caltrans) explained that Caltrans employs tools such as email, local newspapers, Craigslist, and its website to disseminate information and reach out to likely buyers or lessees. Caltrans had also used E-bay, but encountered some legislative issues. Craigslist and email lists have proven to be very effective for selling properties. Properties with a value of less than $1,000 can be sold without a bidding process. Two major concerns when selling DOT properties are the evaluation of future highway network needs and the fair appraisal of the property. The intended use of the property and the impacts on nearby businesses, communities, traffic, and possible future road expansion also need to be assessed.

TxDOT's ability to manage its assets has been questioned and it has been recommended that a strategic master plan with an annual review process be developed (Susan Combs, 2001). The General Land Office (GLO) evaluated in 1996 and reviewed in 1999 TxDOT's land assets and needs and recommended several land sales, leases, and barters (see Table 3.1.1). The GLO also highlighted several issues concerning TxDOT's process for evaluating property for retention or surplus. One of the issues was that the evaluation processed occurred infrequently. TxDOT did not have a mandate or the staff assets to evaluate the agency's property use annually. A holistic review of TxDOT's land only happens when the GLO performs its evaluation of TxDOT's properties every four years (Susan Combs, 2001). For TxDOT to conduct its own property evaluation to facilitate timely and coherent management decisions, it requires in-house staff with :

knowledge of best practices in efficient, least-cost space utilization and functional adjacencies, real estate market interaction for acquisition/disposition pricing, financial feasibility determinations, transaction structuring (where values and complexities warrant), strategic plan preparation that is proactive and anticipatory of future needs, and financial optimization (Susan Combs, 2001).

The right-of-way (ROW) agents (i.e., the personnel who are responsible for assessing, negotiating, selling, leasing, and acquiring lands, ROW, and properties) in Caltrans have backgrounds in business administration, construction management, economics, and real estate. Caltrans discourages the hiring of engineers for these positions. Furthermore, the ROW agents undergo a systematic internal academy training administered by the International ROW Association (IRWA). Caltrans pays for two training courses per year (Personal Communication with Caltrans, 2010).

3.1.2.A Political/Public Concerns

Transparency is critical for the implementation of this VEA. TxDOT has to carefully conduct the process of announcing and negotiating its properties. Therefore, auctions should be widely used to ensure equal opportunities and transparency, as well as to set a fair market value for the asset, even though other ways of negotiating are also options. Moreover, the property or land's ultimate use may cause some concern for the public (neighbors), such as when a new business will be opened, a tall building will be constructed, or industrial facility will be developed.

3.1.3.A Legal Considerations

Both Federal and State laws govern the disposal or lease of a real estate property interest that is deemed to be in excess of the transportation needs.

At the Federal level, for property acquired with Federal funds 23 CFR §710.409 deals with the disposal of real property interests that is deemed in excess to transportation needs. Under §710.409 (a) real property can be sold or conveyed to a public entity or a

private party. Sub-section (b) requires that Federal, State, and local agencies shall be given an opportunity to acquire property if it has a potential use for parks, conservation, recreational or other related purposes, and if State law allows such transfers. The State DOT is required to notify the appropriate resource agencies regarding the disposal intention. This can be accomplished through placing of the notice in the state's regular disposal notification listing. The DOT is; however, allowed to retain excess property to restore, preserve, or improve the scenic beauty and environmental quality adjacent to the transportation facility.

If a property is transferred at less than fair market value for a public purpose interest approved and determined by FHWA, the deed must provide for the property to revert back to the DOT given failure to continue public ownership and use. If the property is sold at a fair market value no reversion clause is required.

At the State level, segments of Texas's Transportation Code (TC) govern the control (sale or lease) of real property assets. TC Chapter 202 lays out the control of transportation assets and under 202.021's provisions real property that is no longer needed –including ROW – can be transferred or sold if it was acquired for a highway purpose and is determined it is no longer needed for a state highway. The real property can be transferred or sold to a governmental entity with condemnation powers or to the general public (TC §202.021(b)). Highway ROW shall be transferred or sold given the following priorities: to a governmental entity with condemnation authority, to abutting or adjoining landowners, or to the general public.

202.024 provides for the exchange of real property that is not needed for highway purposes, as a whole or as a partial consideration for another interest in real property needed for a state highway purpose.

Under TC § 202.058 the department may also allow the owner of real property abutting or adjoining property acquired by the department for the ROW of a road in the state highway system, to use or cultivate a portion of the ROW not required for immediate use by the department. The agreement (in writing) may provide for:

1. use or cultivation of the property;
2. construction of improvements on the property;
3. placement of fences on the property; and
4. other matters.

The department may not execute an agreement that would impair or relinquish the state's right to use the property for ROW when needed to construct or reconstruct the road for which it was acquired (§ 202.058 (d)). The use by the owner of adjoining or abutting property does not constitute abandonment of the property by the department.

TC 201.1055 governs the exchange of department-owned real property. Under 201.1055 (c) the Transportation Commission may authorize the director to exchange department-owned real property under Sub-section (a)(2). 201.1055 (d) requires that the Commission shall notify the Bond Review Board and Texas Public Finance Authority of the proposed transaction not less than 45 days before the date the Commission signs an agreement under this section providing for the exchange of department-owned real property under Sub-section (a)(2). The agreement for the exchange of department-owned real property under Sub-section (a)(2) that has an appraised value greater than the appraised value of real property and improvements acquired by the department under the agreement, must require the private entity to compensate the department for the difference.

Finally, a new consideration that may also have to be taken into account is if the property has been acquired through eminent domain, will be the need to ensure that it does not fall foul of new provisions enacted as a consequence of SB 18 from the 82nd Legislature.[6] Specifically, the right of repurchase set out in the amendment of Property Code 21.101 if a property is not used for public use within 10 years of the taking. So TxDOT will need to ensure that any excess property - that has been acquired through eminent domain and has not been put to a public use (under a series of criteria set out in the new bill) by the 10th anniversary of the date of acquisition - has been offered in good

[6] For example, one could envisage the scenario where property is taken by eminent domain for a new highway route, and remainder property not utilized for the highway is now owned by TxDOT. This remainder property could be subject to this new requirement.

faith to the previous owner for right of repurchase and that this offer has been extinguished as the agency has not received notice that the previous owner wants to purchase the real property. This provision would apply to any of the VEA discussed in this thesis.

Involvement of the State Department of Justice (DOJ), as well as legal counsels, is always recommended to advise and review the written agreements with private parties to minimize any potential risks and undesired liability.

3.1.4.A Financial/Economic Feasibility

The implementation of an effective property management system requires an initial investment in information systems (e.g., website, GIS, database, etc.) and resources (i.e., management personnel). However, this VEA can potentially reduce maintenance costs and even generate revenue. Selling off land assets that do not have a current or future use helps a DOT to reduce its maintenance cost and a state to receive property taxes. According to a GLO study, TxDOT had nearly $88 million (in 1999 dollars) of sites (lands) that could be sold or leased (see Table 3.1.1). It is worth mentioning that this amount represents only the value of the land itself. The costs of relocating and replacing the district office, warehouse, and maintenance facilities need to be factored in by TxDOT.

3.1.5.A Environmental Considerations

When conducting bartering transactions or land leases, or when selling properties, TxDOT should consider how the future owner or lessee will use the land asset to avoid environmental contamination or any polluting activity. Furthermore, Federal and State legislation prohibit lease or sale of public land for certain types of use. Besides, the new use must comply with the National Environmental Policy Act (NEPA) and other relevant environmental regulations. For example, TxDOT has invested in a number of innovative projects to mitigate environmental concerns at its rest areas such as, a rain water

harvesting system (to use for irrigation), a waste water treatment system, solar panels, and wind towers.

TC Section 202.061 allows the Commission to enter into an environmental covenant for the purpose of subjecting real property - it has an ownership interest in – for environmental remediation if this is approved by the Texas Commission on Environmental Quality or a federal agency with authority to approve such.

3.1.6.A Potential Social Impacts/Benefits

Agreements or trades involving public land and building assets with private entities will likely result in new business opportunities and, consequently, new jobs. Furthermore, public agencies and services could promote the value and development of surrounding areas. Therefore, moving TxDOT's offices or warehouses from more valuable areas—usually close to urban centers—to more distant sites can potentially aid in the development of the new nearby communities. TxDOT can also pursue agreements with cities to allow the cities to use TxDOT's vacant land lots for temporary public parks or other community attractions in exchange for maintaining the land.

3.1.7.A Safety Considerations

The major safety issue concerns the availability of resources (i.e., funding) for road maintenance, snow plows, and crash responses. It has been argued that the maintenance cost of rest areas and non-used land lots reduces the budget available for other priority services that affect the road condition and, ultimately, road safety.

3.1.8.A Examples

In terms of property management programs, many states have well-developed websites to announce auctions, post available assets, publish guidelines and requirements, and manage the interface between the DOT and the public. The Iowa DOT presents a good example of how to generate revenue from property management. The Iowa DOT leases, sells, and swaps properties for different purposes, such as agriculture, residential housing, commercial buildings, and parking lots. The Iowa DOT uses a website (see Figure 3.1.1) as the main means of communication between the agency and the public. The website provides access and allows for the download of manuals, guidelines, forms, and all documents related to an agreement (e.g., lease, sale, and swap), the property type (land, building, row), and utilization.

Figure 3.1.1: Iowa DOT's Property Management Website
Source: Iowa DOT (May 2010)

The best example in terms of the property management application; however, is the Caltrans program. Caltrans's property management website contains detailed information regarding auction procedures, leasing guidelines, and property announcements. It is easy to navigate and is constantly updated (see Figure 3.1.2). In an interview with Caltrans Real Property Services division, employees explained that the property management program is divided into three value extraction functions: airspace and ROW leasing, property management, and excess land sales (see Figure 3.1.2).

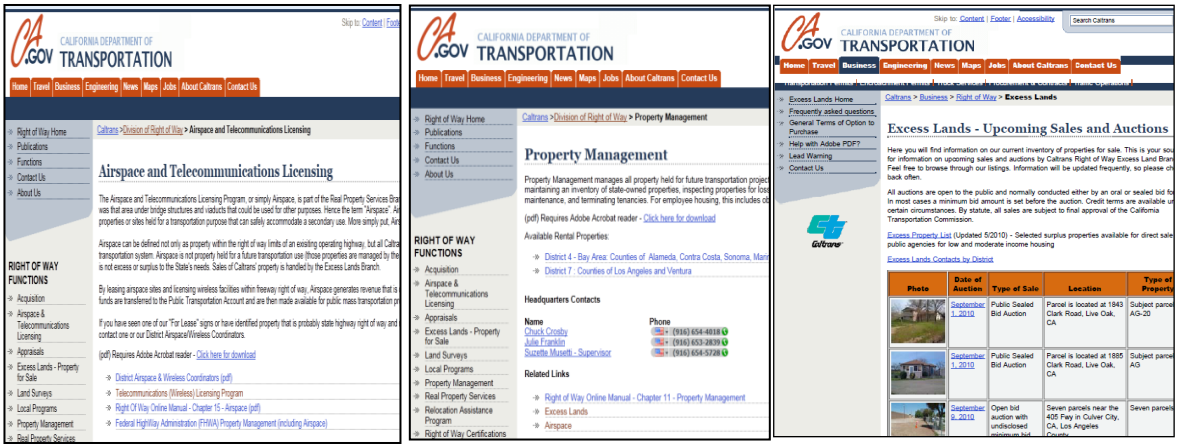


Figure 3.1.2: California DOT's Property Management Website
Source: Caltrans (2010)

Caltrans's airspace and ROW leasing program was created in 1961 as a first trial when the Federal Highway Administration (FHWA) gave Caltrans airspace leasing permission. This program is responsible for managing the airspace rights of the Caltrans's properties. The airspace leasing component generated about $25 million last year with the leasing of airspace beneath viaducts for parking lots, leasing airspace over freeways, and leasing ROW for telecommunication antennas. Revenues from this program component have increased 7% over the last 10 years. The telecommunication program started in 1991, making Caltrans one of the pioneers in the United States. The property management division was set up seven years ago. This division is in charge of acquiring and managing land that will not be used immediately for Caltrans projects. This division has secured about $12 million in revenue per year, mostly from the leasing of property in two significant corridors owned by Caltrans. One of these corridors—which has about 400–500 housing units—is located in Los Angeles and has been owned by Caltrans since the 1970s. Finally, the excess land component is responsible for lands or properties that are not needed or will not be used within 20 years. In 2010, this component secured nearly $11.5 million in revenue that came from selling 290 parcels. Excess land or properties are identified through an annual systematic review of all

land/property inventories relative to the land/property requirements included in Caltrans's 20 year construction plan. Caltrans is also not allowed to purchase any excess property besides what is required for a specific project. Furthermore, the California legislature passed AB 1020 about three years ago, which establish a 10-year window for Caltrans to hold a property for a project. If the project is not developed in 10 years, negotiations concerning excess land or properties are conducted at the district/regional level.

Caltrans has about 12 managers and 48 employees in 12 districts involved in property management. The staff and the managers; however, are not dedicated 100% to the property management program as they have other administrative duties as well. Caltrans does have a property database developed in 1982, but the database is neither user-friendly (i.e., Cobalt-based) nor easily updated. Therefore, it is not widely used in the day-to-day property management program.

Caltrans currently has about 3,500 parcels that were acquired for future projects. Of these 3,500 parcels, 1,500 parcels are cleared and not available, 1,000 are residential properties, and 1,500 comprise residential and parking leases. In addition, Caltrans have identified 1,500 airspaces for leasing, of which 1,200 are being leased. Regarding the negotiation process, Caltrans is only allowed to consider market value for cost-benefit analysis and no social or environmental benefit can be converted into monetary value. Then, both FHWA and Caltrans have to approve the process and the site license agreement, which typically guarantees the site for five years and allows for five year-renewals. Furthermore, any agreement that would last for over 5 years has to be approved by the California Transportation Commission (CTC).

In terms of major barriers and difficulties in implementing a successful property management program, Caltrans emphasized that the major objective of the agency is to promote an efficient and safe transportation system. Therefore, any ROW or airspace usage that may jeopardize road safety and create a hazardous situation would not be considered. Prior to any agreement, Caltrans looks to the district advisor for help identifying and assessing potential risks.

In the case of land swap transactions, Caltrans has the authority to swap only land lots. The agency swaps about 10–20 lots per year. California legislators have attempted to pass a bill that will allow Caltrans to barter maintenance facilities through a competitive bidding process. Caltrans is very supportive of this legislation. Caltrans has 350 maintenance facilities of which 25 have been identified as potential barter transactions. In general, these facilities are old and on sites with access problems. If the bill passes, Caltrans will specify the design of the new maintenance facility. The private party will be required to construct the new facility according to Caltrans's design guidelines and the exchange will be conducted upon completion of the facility. Caltrans will benefit from acquiring a new and updated facility. On the other hand, when Caltrans sells properties, the revenue goes to the Public Transportation Account and not to the department. A barter transaction; however, can be very complex and complicated.

In Texas, a number of successful facility barter transactions have been performed by TxDOT. For example, one of the barter transactions occurred in San Antonio and took two years to complete. The transaction involved the 7-acre Boerne Maintenance Facility (TxDOT) that was located in an incompatible "industrial" area and adjacent to a supermarket and apartment complex. The supermarket wanted the Boerne site to expand the supermarket and construct a parking lot. The supermarket proposed to swap the Boerne site for a maintenance office and storage facility located on a 13-acre lot in an outlying region and adjacent to an industrial/business park. The supermarket paid for the construction of the office improvements. The only costs incurred by TxDOT were $30,000–$40,000 for remediating hazardous materials. The new TxDOT facility would have cost $1.7–$1.8 million given site acquisition and office improvements. Furthermore, TxDOT could remain in the Boerne facility until the new facility was completed to TxDOT's satisfaction. The City of Boerne had to make a few minor utility investments to serve the new TxDOT facility (Susan Combs, 2001).

Another barter transaction was initiated in 1991 when the TxDOT Laredo area and maintenance offices received nine responses to a request for proposal (RFP),

specifically looking for a barter transaction. TxDOT wanted to replace an existing facility and secure sufficient space to build a new district office. TxDOT finally exchanged 11.7 acres and a maintenance facility for 32 acres in an outlying location and an improved $1.0 million maintenance office (Susan Combs, 2001).

In these cases, all risks associated with the transaction and the facility—e.g., procurement of zoning, permits, and utility extension—were defrayed by TxDOT and the agency also incurred no cash costs (Susan Combs, 2001). The TxDOT engineers emphasized the importance of having a strong and well-financed counter party with proven capability to conduct the transaction to ensure a successful outcome.

In addition, TxDOT had about 130 active lease agreements associated with temporarily surplus ROW during FY2009-FY2010. The lease agreements comprised different uses and generated about $1.1 million in revenues (Personal Communication with TxDOT, 2011).

3.1.9.A Concluding Remarks

To implement an asset management program, TxDOT needs to:

a. Develop and establish a systematic and comprehensive property evaluation process,
b. Train staff,
c. Invest in information systems (e.g., website, database, and GIS) capable of rendering real-time information and analysis to facilitate decision-making processes,
d. Involve of the State Department of Justice (DOJ), as well as legal counsels, to advise and review the written agreements with private parties and to minimize any potential risks and undesired liability.

Furthermore, some properties' and buildings' features determine the feasibility of and interest in this VEA. It is important, but not imperative, that the asset involved in the possible transaction has the following characteristics:

a. Prime location for investor (i.e., dense urban center),

b. out-of-date facility with inefficient operation or high cost of maintenance, and

c. compatible surrounding land uses given the proposed new development.

3.1.B Rest areas

Rest areas are a component of the highway system, therefore the responsibility for these facilities lies primarily with the DOTs. A survey conducted by the American Association of State Highway and Transportation Officials (AASHTO) revealed that significant maintenance costs are obligating several DOTs (e.g., Arizona, New Mexico, California, Colorado, Georgia, Kentucky, and Virginia) to close some of their rest areas. Moreover, some rest areas have raised concerns about security and hygiene. In these cases the value of the rest areas in ensuring a safe and quality road trip is questionable. Thus, funding for rest area improvements is fundamental. Privatization or leasing some areas to allow for vending and advertising could provide some funding. TxDOT owns 92 facilities (i.e., rest areas and information centers) that cost $17,000/month to operate (Personal Communication with TxDOT, 2010). TxDOT makes every effort to maintain its rest areas, ensuring that they are open and providing good services to the traveling public.

3.1.1.B Technical Feasibility

Rest area commercialization or privatization is a relatively simple VEA and does not demand any complex technical solution or investment. It is essential, however, that TxDOT has data available regarding usage of and traffic passing by existing rest areas in order to attract investors. In the case of new rest areas, location and site characteristics are fundamental. A good location can significantly reduce construction costs, ease the construction process, and impact the facility utilization and effectiveness. Access is also crucial and, thus, has to be studied and assessed. Another important factor is the availability of in-house staff to conduct and oversee the entire process.

3.1.2.B Political/Public Concerns

Rest area commercialization or privatization is very controversial and has resulted in many discussions and debates in the federal legislature. Some DOTs have tried to convince law makers to change the legislation and allow for commercial and private activities at the rest areas along federal and state highways to guarantee good service and comfort for the users. On the other hand, business owners and communities along the highways have pressured lawmakers to maintain the status quo, alleging that the privatization of rest areas would ruin their businesses and only source of income.

3.1.3.B Legal Considerations

The privatization of and commercialization at rest areas, unlike property management, involve major legal issues and considerations. Federal law currently prohibits TxDOT from privatizing and commercializing rest areas along the interstate highways. According to TxDOT, the Department of Assistive and Rehabilitative Services is the only agency that can use federal properties for vending (e.g., blind vendors). As mentioned before, this topic has been debated extensively. Legislators have expressed concern that by allowing business opportunities at rest areas, the DOT's focus would change from efficient transportation to real estate business profitability. In addition, the public may perceive the privatization or commercialization of rest areas as unfair competition with local business – potentially affecting these businesses negatively.

Finally, the Randolph Sheppard Act does not apply turnpikes (toll roads) and state roads. Basically, safety rest areas located on non-interstate highways that, therefore, were built using state and/or private funds (i.e., without federal funds) can be commercially exploited. TC Section 202.055 allows the DOT to lease a rest area along a toll road or state highway to a person engaging in sales, services, or other commercial activities that serve the travelling public.

3.1.4.B Financial/Economic Feasibility

In the case of rest areas, TxDOT estimated that one pair of facilities cost about $12–$15 million to build and on average of $17,000 per facility to operate. The number of cars passing by and stopping determines the feasibility of attracting private sector investments. According to TxDOT, rest areas in remote areas will thus not be financially attractive to private investors because of the potentially low patronage coupled with high operation and maintenance costs (e.g., relocation of people, materials, electricity, etc.).

3.1.5.B Environmental Considerations

TxDOT should ensure that the design of "private" rest areas complies with the agency and state environmental standards and sustainability goals, as well as the National Environmental Policy Act (NEPA). Because the majority of TxDOT rest areas are located in remote or semi-rural locations, attention must be paid to water use, such as wasted and storm water treatment, reuse, and disposal. TxDOT should not only provide guidelines for and requirement of compliance but also oversee the design and construction or retrofit of the facilities. Furthermore, as will be further discussed, TxDOT can employ other VEAs such as renewable energy and advertising to reduce its carbon footprint and promote an educational program of clean energy sources, sustainability, and environmental protection. For example, TxDOT has invested in a number of innovative projects to mitigate environmental concerns at its rest areas such as, a rain water harvesting system (to use for irrigation), a waste water treatment system, solar panels, and wind towers.

3.1.6.B Potential Social Impacts/Benefits

The privatization and commercialization of rest areas may result in competition between the privatized rest area and nearby businesses. Small roadside communities that rely on travelers' expenditure (e.g., for gas and food, lodging, etc.) may be financially impacted, consequently affecting their social conditions. On the other hand, well served

and interactive rest areas and welcome centers can potentially enhance the tourism market, creating jobs, and therefore helping to develop rural regions (FHWA, 1996).

3.1.7.B Safety Considerations

Rest areas are essential to the safety of road users. Caltrans states that

rest areas are an important part of Caltrans' efforts to ensure traveler safety. They provide clean, safe and comfortable places for travelers to rest and manage their needs. Attractive and useful, rest areas encourage travelers to use a safe location off the roadway to take a break and return more alert to the highway (Personal Communication with Caltrans, 2010).

In addition, the research conducted by the National Center on Sleep Disorders Research (NCSDR) and show the National Highway Traffic Safety Administration (NHTSA) that "drowsy driving is a serious problem that leads to thousands of automobile crashes each year" (NCSDR/NHTSA, 2010) Furthermore, a study conducted by Michigan State University and confirmed by the Minnesota DOT showed a direct relation between safety rest area spacing and vehicle crashes (SRF, 2007). It was thus recommended that rest areas should provide good service to ensure that they are attractive, that closed ones should be re-opened, and investments in new ones should be made. Allowing private and commercial rest areas would not only raise the availability of these facilities (i.e., number of rest areas) but enhance the service and increase the attractiveness, thereby contributing to a better and safer highway system.

3.1.8.B Examples

An important example of how to extract value from rest areas is presented by the Oasis complex in Illinois, which is composed of seven private and commercialized rest areas spread out along the I-294/94, I-90, and I-88 tollways. The O'Hare Oasis (see

Figure 3.1.4), located on the I-294 tollway at milepost 38, offers several services, such as a gas station, car wash, food court, shopping, and an ATM.

In Delaware, a 42,000 square foot welcome center (see Figure 3.1.5) is part of the busy I-95 corridor. The construction of the center, which includes an integrated mini-mall, rest area, and gas station, cost about $35 million (2010) and was totally paid for by the developer. Furthermore, the 35-year lease contract provides the State of Delaware a percentage of the revenues from gas, food, and other goods sold, with $1.6 million in revenue guaranteed.

Figure 3.1.4: O'Hare Rest Area in Illinois
Source: Wikipedia – "Illinois Tollway oasis" (2010)

Photo courtesy of HMSHost Corporation

Figure 3.1.5: IH 95 Rest Area in Delaware
Source: Stateline (2010)

To overcome the problem of a lack of rest areas and the barriers to rest area privatization, as well as to reduce the financial and administrative costs to the state DOTs, the FHWA launched the Interstate Oasis Program (see Figure 3.1.6), a public-private partnership in 2006. The Interstate Oasis is defined by FHWA as an off-freeway facility that aims to supplement the public rest area. To qualify as an Interstate Oasis, the facility has to comply with a list of requirements and specifications, including a standardized design, offering of products and services to the public, 24-hour access to restrooms, and parking for autos and heavy trucks. Furthermore, a specific and unique logo has to be adopted to identify the units that are part of the program. The blue signs that indicate the location of the Oasis facilities also have to meet certain requirements (see Figure 3.1.7).

Figure 3.1.6: Example of FHWA Interstate Oasis Program
Source: Kalla (2006)

Figure 3.1.7: Blue Sign Template of FHWA Interstate Oasis Program
Source: Kalla (2006)

A new opportunity for exploring rest areas is brought by electrical vehicles (EV) and plug-in hybrid electrical vehicles (PHEV). Charging facilities could be installed at rest areas to meet the increasing demand for and availability of EV and PHEV, thereby incentivizing, and supporting the road users of "green" cars. To conclude, this VEA, however, faces some legal barriers that prohibit most commercial activities on public lands and properties.

3.1.9.B Concluding Remarks

Rest areas have been proved to be fundamental and critical to drivers' safety. On the other hand, rest area maintenance and construction account for a portion of the budget and resources that could be spent on road maintenance and improvement. Rest area privatization and/or commercialization could alleviate some budget concerns, but more importantly promote better service and more attractive rest stops, thereby creating positive tourism and job impacts.

While privatization and commercialization on the federal interstate system are prohibited by law, TxDOT can employ some sort of advertising/sponsorship and renewable energy sources as means to reduce maintenance cost and promote sustainability. The FHWA Interstate Oasis Program also offers an alternative to overcome legal barriers and help TxDOT to reduce its investments in and maintenance costs of rest areas.

In the case of state and toll highways, although there are no major legal issues that prevent TxDOT from privatizing and commercializing rest areas along these roads, it is important to consider the following factors:

a. Impacts on nearby community's business;
b. Existing social projects, such as "blind vendor support";
c. Traffic flow and best sites for new rest areas;
d. Minimum design requirements and specifications for private rest areas; and
e. Liabilities and responsibilities of all parties involved.

3.2 AIRSPACE LEASING—BUILDINGS

The term airspace refers here to the available space over a highway or freeway that can be used for construction purposes without interfering or hampering the main goal of TxDOT in promoting a safe and efficient transportation system—specifically, the highway's capacity has to be protected and preserved (FHWA, 2010).

In 1993, research conducted by the Texas Transportation Institute (TTI) reported that right-of-way airspace leasing programs formally began across the country in the 1970s. Since then several states have explored using the airspace above highways/freeways for revenue purposes. This VEA can be implemented in both urban and rural settings, but their characteristics and considerations deviate from each other (TTI, 1993). The FHWA remarked that "airspace leasing activities tend to be concentrated in states with high population densities and high land values in urban areas" (TTI, 1993). The railroad mode typically implements airspace leasing above their passenger stations (TTI, 1993).

In summary, airspace leasing is a complex agreement that concerns legal, planning, environmental, design, construction, maintenance, safety, insurance, and security requirements to be successfully implemented (FHWA, 2010).

3.2.1 Technical Feasibility

The usage of space over freeways for any construction project imposes several technical challenges that have to be addressed by DOTs prior to the leasing agreement. Unforeseen future needs, such as lane expansions and clearances under the likely permanent structure, may be the primary challenge when assessing the feasibility of leasing any area over highways. Thus, it is recommended that any lease proposal be shared with all disciplines responsible for the highway system, including design, maintenance, and planning (TTI, 1993). The traffic engineers also have to review the airspace leasing proposal early on and carefully assess the future capacity of the highway (Savvides, 2005). Another concern involves the design requirements of the new structure.

The road lanes dictate or at least restrain the location of the future building's foundation and columns. The design of the structure has to be conservative and cross long spans with transition beams and supports to withstand possible collisions, explosions, or terrorism attacks (Savvides, 2005). Moreover, AASHTO and FHWA have stricter design requirements for construction over roads (TTI, 1993). The leasing agreement—and consequently the building's design and construction—has to address safety concerns about public health, aesthetics, lighting, ventilation/exhaustion, drainage, vibration, noise, traffic capacity, clearance, maintenance, fire resistance, emergency services, and compatibility with surrounding environment (Savvides, 2005). Limited access to new projects—i.e., buildings—can also hinder the viability of the project and, therefore, accessibility has to be incorporated to the project design.

Finally, construction is a challenge. The existing traffic, safety issues, and site constraints have to be analyzed and considered. Airspace leases for buildings are typically applied in areas with intense traffic volumes and congestion. Any traffic disruption would impact drivers and communities negatively. A constructability study has to be conducted, as well as early planning and a detailed scheduling routine (Savvides, 2005). TxDOT has to be aware of the potential concerns and address these as obligations and requirements in contract clauses.

3.2. 2 Political/Public Concerns

Construction over freeways can be controversial, resulting in political and public opposition. Visual pollution, disturbances during construction (i.e., traffic interference), impacts on the neighborhood (e.g., privacy, congestion, etc.), and a lack of transparency during the planning may cause public and political opposition. It is therefore important that public outreach be conducted during the planning and construction phases to avoid or minimize opposition to the project. Transparency is also essential.

On the other hand, projects such as rest areas over highways can provide entertainment for travelers, especially for kids and can therefore enhance the relationship between the DOT and the public.

3.2.3 Legal Considerations

The FHWA's Airspace Guideline (23 CFR Section 713.203) clarifies the major considerations for airspace leasing agreements. For interstate facilities, the FHWA has to approve all airspace leases (FHWA, 2010).

TC Sub-chapter C of Chapter 202 governs leases, easements, and agreements that concern highway property. Section 202.052 *allows the department to lease a highway asset, part of the ROW,* ***or airspace above*** *or underground a highway, if the department determines that the interest to be leased will not be needed for a highway purpose during the term of the lease*. The lease may be for any purpose that is *not inconsistent* with applicable highway use under sub-section 202.052 (b), and must charge *not less than fair market value* for the highway asset in cash, services, tangible or intangible property, or any combination thereof under Sub-section 202.052 (c). Exceptions for the charges under sub-section d can be made for lease to a public utility provider, leases for a social, environmental, or economic mitigation purpose, or for leases to an institution of higher education.

TC § 202.053 (a) provides that TxDOT may determine all terms of the lease except:

- the tenant may not be required to post a bond/security in excess of six months lease rental;
- the lease must allow the tenant to mortgage or other pledge or grant a security interest in the leasehold to secure financing for the acquisition of the leasehold, or construction or operations of an improvement that the lease allows (§202.053 (a) (1) and (2)).

TxDOT may not convey title to, or sever from the real property, any permanent improvement constructed on the area leased under this sub-chapter (§202.053 (b)).

Texas Administrative Code (TAC) requires in Chapter 43, Sub-chapter 21 Right of Way that structures built over the ROW shall occupy no more length of highway than authorized by the department (Rule21.605 (i)). Rule 21.605 (j) requires that the design and occupancy of such a structure over or under the ROW shall not affect safety, appearance, or enjoyment of the highway through the spillage of fumes, vapors, odors, droppings, or discharge from the structure. Signs and displays developed or maintained by the lessee are restricted to those indicating ownership or on-premise activities and must be authorized by the department subject to the Highway Beautification Act.

Because air space leasing involves a public asset, transparency is critical in the appraisals, negotiation, and bid lease valuations.

Involvement of the State Department of Justice (DOJ), as well as legal counsels is always recommended to advise and review the written agreements with private parties, and minimize any potential risks and undesired liability.

3.2.4 Financial/Economic Feasibility

Financial consideration is an important factor in determining the attractiveness of applying this application. The technical issues highlighted previously can impose significant additional construction costs that have to be offset by the revenue generated. Although, from a DOT's perspective, this VEA does not demand major expenditures, besides the administration costs, the leasing price charged by the DOT to the developers will often determine the financial feasibility of the project. Both the FHWA Guidelines and Senate Bill 352 (TTI, 1993) mandate the charging of a minimal fair market price in airspace leasing agreements. The DOT has to demonstrate and FHWA has to approve the potential social, environment, or economic benefits accrued if a lower charge is levied. Most of the successful airspace leasing programs for buildings have been in urban areas, where real estate is very valuable. In rural areas, on the other hand, the construction features can be attractive and enhance business development. A long-term leasing agreement is, however, usually necessary to secure a return on investment (TTI, 1993). A

great example can be found in Boston, where the economic feasibility of three airspace leasing projects was only ensured by an airspace premium funding granted by the city. This funding was needed because the land value in Boston at the outset of the projects was not yet high enough to spark and encourage private investment. In terms of benefits, the City of Boston could reconnect the neighbors that have been divided by the highway corridor, generate new tax revenue, and create permanent jobs with the economic development (Savvides, 2005).

3.2.5 Environmental Considerations

The environmental considerations are largely a function of the location of the lease. In dense urban areas with a high level of buildings, the construction of additional buildings can cause a heat island and visual pollution. A minimum distance as determined by wind flow and heat simulation thus has to be maintained between buildings. In rural areas, no additional considerations or impacts besides what already applies to buildings or constructions have to be accounted for. This includes sewage, water, electricity, trash, and construction disposal that have to be carefully analyzed, assessed, and included in the design and specifications of all buildings and construction projects. In both cases, on the other hand, constructing over highways reduces the building and city's footprint, once construction (i.e., highway) already exists in place. Furthermore, occupying airspace minimizes the utilization of and need for green fields – one of the points of consideration for green buildings and green engineering.

3.2.6 Potential Social Impacts/Benefits

An airspace leasing program provides an opportunity for financial investment and business expansion; and thereby promoting economic development (Iacono et al.) to the benefit of the city and the community. Constructing buildings over freeways can also link and integrate communities that were divided by road construction (Savvides, 2005). On the other hand, if the airspace right is conceived and granted without a comprehensive study that includes the mitigation of potential negative impacts, it can cause significant

negative impacts on nearby neighborhoods and road users. These impacts include traffic disruption (e.g., access and directions), shadows on neighboring facilities, visual intrusion, loss of neighbor's privacy, heat island, and a decrease in property value.

3.2.7 Safety Considerations

Traffic safety is a primary factor and objective of the DOTs. After 9/11, terrorism attacks that potentially entail catastrophe have also become a major consideration. Infrastructure assets are potential targets of terrorists. Therefore, whenever a leasing agreement is negotiated, a risk assessment has to be conducted (Broils-Cox, 2008). The FWHA has highlighted the importance of state agencies with security expertise or those responsible for critical infrastructure protection to assess and approve the airspace leasing request. When no expert is available in-house, it is recommended that an independent safety and security assessment be conducted to advise the DOT during the decision making process (FHWA, 2010). The risk assessment must cover, among other areas, the vulnerability of the structure, consequences of an attack, and the importance of the transportation facility. In response, preventive and protective measures must be considered and included within the agreement. FHWA also stated that under no circumstances can the airspace be used for manufacturing or storing flammable, explosive, or hazardous substances (FHWA, 2010).

For airspace leasing of buildings, the tunnels are the most vulnerable in terms of safety and security. Lighting, evacuation routes, monitoring against terrorism, an effective air exchange system (e.g., exhaust emissions), explosions, car accidents, safe access, and fire protection systems (i.e., sprinklers) are important considerations in the planning and evaluation process. Furthermore, a safety analysis and plan is very important during the construction phase, as the road facility will still be opened to traffic (TTI, 1993). Finally, the building design has to prevent the ability to throw objects out of windows on to the highway (TTI, 1993).

3.2.8 Examples

Most of the existing airspace leases are in dense urban areas, where the airspace is leased for residential and commercial buildings, hotels, supermarkets, and garages. A few examples exist in rural or semi-rural locations, but these are less prevalent.

Caltrans has reportedly used ROW for restaurants, manufacturing, parking, mini-storage, boat launching, and community park facilities. In 1993, it was estimated that the program generated more than $12 million per year (TTI, 1993). However, according to Caltrans, all the revenue generated by the airspace leasing program goes to the Public Transportation Account and, thus, not to Caltrans. In addition, the state of Washington has one of the most publicized airspace leasing programs as a result of the construction of the Washington State Convention and Trade Center (see Figure 3.2.1) over the IH 5 in Seattle. Phoenix, Denver, and Montreal (Canada) also have convention centers over freeways (TTI, 1993). In Boston (see Figure 3.2.2), the airspace over the Massachusetts Turnpike holds at least three formalized airspace leasing agreements for buildings. The first is the Copley Place, a 3.5 million square-feet complex constructed in 1986 that comprises hotel, retail store, office, parking, and housing. The second is Columbus Center, a complex of buildings that occupies 7 acres divided into 4 parcels of air rights and total 1.4 million square-feet of construction. The Columbus Center consists of hotel, restaurant, retail store, health club, residential building, and parking. The last is the One Kenmore that occupies 1 parcel of airspace and is still under development. When concluded, the One Kenmore will have 1.2 million square-feet of construction, including office, health club, grocery store,

Figure 3.2.1: Washington State Convention & Trade Center
Source: Courtesy of Washington State
Convention & Trade Center

community center, and parking. The economic feasibility of all three projects was ensured by a grant from the City of Boston. This funding was needed because the land value in Boston was not yet high enough to spark and encourage private investment at the outset of the projects. In terms of benefits, the City of Boston could reconnect the neighborhoods that have been divided by the highway corridor, generate new tax revenue, and create permanent jobs with the economic development (Savvides, 2005).

Another international example is the Malietoren edifice over the Utrechtsebaan in the Netherlands (see Figure 3.2.3). This building is an important architectural landmark for the city of Den Haag as it represents the city gate, where the arterials once entered the inner city (Savvides, 2005). Finally, in Illinois a number of commercial rest areas (see Figure 3.2.4) that comprise the Oasis complex (total of seven rest areas) are all built over different tollways. Five of the seven rest areas were constructed back in 1958 at the same time the highway was constructed. All the rest areas were redeveloped and renovated between 2003 and 2005 by a private developer. The redevelopment cost of approximately $95 million was all incurred by the developer and represented no risk and no cost to the Illinois State Toll Highway Authority (ISTHA). The deal comprises a 25 year leasing agreement in which the developer has to pay ISTHA a percentage of the vendor sales with $750,000 per year guaranteed (Joseph Ryan and John Patterson for Daily Herald, 2009). The particular architectural characteristic of the rest areas—i.e., over the highway—helps to attract visitors and customers, thereby benefiting the businesses and vendors.

Figure 3.2.2: Hancock Garage—Boston
Source: Savvides (2005)

Figure 3.2.3: Malietoren—Netherlands
Source: Savvides (2005)

Figure 3.2.4: Belvedere Oasis, Illinois
Source: Wikipedia-"Illinois Tollwas oasis" (2010)

3.2.9 Concluding Remarks

Using an airspace leasing agreement for a building is a complex VEA that requires a comprehensive assessment of impacts on nearby communities and traffic. The site selection is crucial for determining the feasibility of this VEA. In addition, some points have to be carefully regarded, assessed, and addressed, such as the following:

a. The traffic and highway future needs (i.e., road expansion and clearance).

b. Construction and safety considerations:

- Structural design requirements and constraints (e.g., free span and clearance);
- Other design requirements (e.g., accessibility, ventilation, drainage, emergency services, and fire resistance);
- Tunnel safety (e.g., lighting, ventilation, evacuation access, drainage, and fire protection);
- The building/facility cannot be used for flammable, hazardous, or explosive substance storage; and
- FHWA and AASHTO guidelines and requirements.

c. Environmental and social impacts:

- Disturbance during construction (e.g., noise, dust, and traffic congestion);
- After construction (e.g., privacy, traffic congestion, noise, property value, shadow, heat island/wind current, and visual pollution); and
- Compliance with NEPA and environmental regulations.

d. Cost of evaluation, negotiation, and legal processes:

- Prime location (the value of the land has to offset the high investment cost).

e. Involvement of the State Department of Justice (DOJ), as well as legal counsel, is always recommended to advise and review the written agreements with private parties, and minimize any potential risks and undesired liability.

3.3 AIRSPACE LEASING—PARKING LOT

Many urban areas (e.g., financial districts, commercial areas, and downtown areas) have inadequate parking to satisfy demand. Existing garage parking tends to be very expensive and insufficient. In addition, curb parking not only interferes with and impedes traffic flow, but also represents unsafe conditions as drivers tend to look for a parking space while driving at low speeds and making sudden maneuvers, thereby increasing the likelihood of crashes and accidents (Box, 2004). Box (2004) reported that curb parking is directly related to 20% of all accidents on urban streets. Furthermore, studies conducted by FHWA in 1978 found that 20% of pedestrian accidents involve people entering the street from behind parked cars. It was found that by prohibiting parking on main streets, accidents can be reduced 12% to 90% (Box, 2004). This VEA explores the use of existing areas beneath viaducts and ramps, as well as DOT land lots, as parking lots.

3.3.1 Technical Feasibility

Using airspace for a parking lot is a relatively simple application in terms of technical feasibility. This VEA may only require studies regarding information

technology and system implementation (e.g., parking meters or another system) and the parking design and arrangement to ensure orderly and functional access. Vehicle access is, however, a major concern and often determines the viability of the application. Other factors that have to be evaluated are traffic flow and people access (FHWA, 2010).

The technical requirements of the parking lot application can be easily incorporated in the planning and design of a new viaduct project without adding significant cost.

One concern about this application relates to the future need for the space or land for expansion or other uses. To avoid any inconvenience to private parties, 3- to 5-year leasing contracts are recommended, because they reflect the changes in traffic demand and needs, and thus in highway systems (TTI, 1993).

3.3.2 Political/Public Concerns

Because parking availability is a common concern in congested areas, any approach or step towards increasing available parking will probably be well received by the general public. A partnership between the cities and TxDOT to assess the needs and opportunities for this application would be beneficial. If the airspace is leased to a private entity, it is essential to use public bidding to promote transparency and equal opportunity, as well as to effectively establish a fair market price for the leasing arrangement.

On the other hand, there is a portion of the general public (i.e., environmentalists and transit providers) that views "parking unavailability" as a way to manage (i.e., reduce) single vehicle occupant use.

3.3.3 Legal Considerations

In addition to the FHWA requirements under 23 CFR Section 1.23, Section 710.407, and the AASHTO guidelines mentioned earlier, the leasing agreement and contract have to clearly state responsibilities, liabilities vis-à-vis conforming to current design standards, and provisions to insure the safety and integrity of any federally funded facility, leasing period, leasing price, price adjustment base, insurance, and other

considerations. Although these leasing contracts are typically short- or mid-term agreements, the price adjustment base has to be negotiated. An escalator factor has typically been used by most DOTs, as well as the GLO, for price adjustments. Involvement of the State Department of Justice (DOJ), as well as legal counsels, is always recommended to advise and review the written agreements with private parties, and minimize any potential risks and undesired liability.

As noted in chapter 2 on air space lease for buildings, Sub-chapter C of Chapter 202 governs leases, easements, and agreements that concern highway property. Section 202.052 *allows the department to lease a highway asset, part of the ROW, or airspace above or underground a highway, if the department determines that the interest to be leased will not be needed for a highway purpose during the term of the lease*. The lease may be for any purpose that is *not inconsistent* with applicable highway use under sub-section 202.052 (b), and must charge *not less than fair market value* for the highway asset in cash, services, tangible or intangible property, or any combination thereof under Sub-section 202.052 (c).

3.3.4 Financial/Economic Feasibility

The implementation of this VEA is relatively simple and straightforward. It involves neither TxDOT investment nor substantial expenditures by a third party. Two different approaches are typically used: (1) entering into a partnership with cities and (2) entering into a leasing agreement with the private sector. When entering into a leasing agreement with the private sector, a fair market price has to be determined. Therefore, the financial and economic feasibility of the application will depend on the demand for parking space and the market value of the land. In general, the areas under highways used for parking are in very dense urban locations where space is scarce and land is valuable. In an economic analysis, the benefits in the terms of savings resulting from more available parking spaces and less traffic interference have to be considered, as well as cost savings in land maintenance, fewer traffic accidents, and more “taxable” lands.

3.3.5 Environmental Considerations

This VEA does not impose substantial environmental impacts. However, some precautions have to be taken to avoid soil and water contamination from the cars' oil, as well as to drain the rain water to a public rainwater system. On the other hand, this VEA can potentially be combined with other VEAs that are environmentally friendly, such as solar panels (Solarhighways, 2011).

3.3.6 Potential Social Impacts/Benefits

Parking availability is one of the factors that could directly influence the economic development in urban areas. Therefore, this VEA can be used as leverage to attract businesses to areas where a lack of parking impairs the growth of commercial activities. Economic development is associated with several social benefits, including the creation of jobs for nearby communities.

3.3.7 Safety Considerations

In general, parking lots can improve traffic safety and reduce accidents related to curb parking. However, some security measures should be implemented to protect the integrity of the viaducts and the safety of the pedestrians (users). Hence, restrictions are typically placed on the type of vehicle that can use the parking lot beneath viaducts and bridges (Broils-Cox, 2008). FHWA prohibits any vehicle or truck carrying flammable, explosive, or hazardous materials from parking in highway airspace areas (FHWA, 2010). The leasing contract must thus contain clauses stating the specific proposed use—i.e., parking lot—and provide for immediate termination in case of violations (Broils-Cox, 2008). Also, security measures and parking design have to be included in the contract and approved by the transportation agency's engineering, operation, and safety personnel. Available safety measures should be considered, such as access to emergency vehicles, fencing, lighting, wheel stop, curbs, and cameras for surveillance (FHWA,

2010). Access for pedestrians is also an important factor. A structure—such as a pedestrian bridge—may be required to avoid interference with the traffic flow.

3.3.9 Examples

Caltrans has extensively used airspace leasing for parking lots as a VEA (see Figure 3.3.1). Caltrans has entered into both long-term and short-term leasing agreements for parking. In general, the private sector has approached Caltrans to lease available spaces. Some parking lot structures are, however, leased to parking companies via a competitive bid for two or three years. To announce the bidding process, Caltrans employs such tools as Craigslist and email. In addition, park-and-ride lots, usually somewhat distant from downtown areas, are typically leased to independent car sellers or for community events on weekends. These park-and-ride leases usually involve community centers that are responsible for providing security and cleaning the area. The community centers typically pay a lower rate for leasing the park-and-ride lot. Caltrans currently has around 400 parking lot leasing agreements that generate a reasonable level of income. However, all revenue generated goes to the Public Transportation Account. Concerns faced by Caltrans regarding parking lot agreements usually involve lawsuits filed against the public agency for damage to vehicles parked in the parking lots. Caltrans, however, has always prevailed over such claims, because the agency not only protects itself through contract clauses, but also partners with third parties that have insurance and the financial capability to compensate the claimant.

Figure 3.3.1: Parking Lot in California
Source: Caltrans (2009)

In Texas, some examples of parking lots beneath TxDOT highways can also be found. However, TxDOT comments that the agreement typically involves another public

agency (e.g., city, court house, and DPS) and does not provide any financial payment or monetary benefit to TxDOT.

3.3.3 Concluding Remarks

Airspace leasing for parking lots is a relatively simple VEA that mostly depends on the location (e.g., business attractiveness, demand, and accessibility) and requires some safety measures (e.g., access, fence, surveillance, curbs, and prohibition of flammable substances and some sorts of vehicles). Other points that should be looked at are:

a. Term commitment (3–5 years of leasing recommended);
b. FHWA and AASHTO guidelines and requirements;
c. Liability over the vehicles parked (contractual agreement). It is recommended to involve the State Department of Justice (DOJ), as well as legal counsels to advise and review the written agreements with private parties, and minimize any potential risks and undesired liability;
d. Reduce congestion and accidents (relative to curb side parking); and
e. Economic and business development.

3.4 AIRSPACE LEASING - UTILITIES AND TELECOMMUNICATION TECHNOLOGIES

The utilization of ROW for utility accommodation has been extensively studied by researchers and federal agencies such as, the FHWA and AASHTO. "Accommodating public utilities on highway right-of-way has traditionally been at no cost to the utility or only involves direct cost reimbursement for replacement ROW" (FHWA). However, renewable energy sources, such as wind turbines and photovoltaic solar panels, have provided an opportunity for states to consider the longitudinal accommodation of these technologies. In addition, new telecommunication technologies (e.g., fiber optics, cell phones, and internet wireless) have resulted in discussions and opportunities for exploring this potential VEA. In 1996, Congress passed the Telecommunication Act, allowing free competition between telecommunication providers (e.g., cable, telephone, and cell phone). This competition has resulted in telecommunication providers seeking to access available strategic space to install their infrastructure. Telecommunication providers use mainly two ways to furnish their service: fiber optics and wireless. Fiber optics can be placed underground in conduits or above ground through poles, whereas wireless is transmitted by fixed antennas (FHWA—Public Roads, 2000). Because TxDOT owns ROW throughout the state, utility companies will be interested in entering into multiple leasing agreements with the agency. Multiple leasing negotiations are typically simpler and cheaper to negotiate and allow for bargaining. AASHTO also introduced the concept of shared resources as an alternative means for funding transportation projects. Shared resources is defined as "private donations of telecommunication technology (principally fiber optic communications), and sometimes cash, in exchange for access to public right of way" (AASTHO—Shared Resources). Shared resources agreements are attractive because of the potential for additional revenues and because they can provide states with access to technological management tools such as, Information Technology Systems (ITS).

Another example is the installation of cell-phone and wireless internet antennas along highways (mainly in rural or semi-urban areas). To furnish internet and cell-phone

coverage along highways, individual wireless antennas do not need to be affixed to a tower, but can be placed on highway sign supports, light posts, roofs of buildings, bridges, and viaducts. In the case of bridges and viaducts, they can be a strategic and inexpensive solution for telecommunication and utility providers to overcome challenges and obstacles of crossing rivers, creeks, valleys, and oceans.

3.4.1 Technical Feasibility

Similar to leasing airspace for buildings, the major technical obstacle for leasing ROW for accommodating utilities and telecommunication technologies is future expansion of the road—specifically for buried and/or robust utility infrastructure. Furthermore, accommodating utilities crossing under highways require special considerations such as buried depth, concrete coat, and reinforcement. Hence, the implementation of this VEA along existing roads may be prohibitively expensive.

Similar to the other VEAs, the efforts and challenges are fewer when the use of ROW for utilities (e.g., underneath) is incorporated in new project planning and design. Finally, the following table (see Table 3.4.1) highlights other likely technical issues that can be faced during the implementation of utilities in ROW.

Table 3.4.1: Project Structure Issues
Source: U.S. DOT (1996)

Project Structure Issues	
*Exclusivity**	Shared resource arrangements may limit access to public right-of-way to a single private sector partner in any specific segment, that is, grant exclusivity. From the public sector point of view, exclusive arrangements have both advantages (administrative ease) and disadvantages (potential constraints on competition among service providers, lower total compensation received by public sector).
Form of real property right	Shared resource arrangements can be structured in any of several legal formats (easement, lease, franchise, license) with variations in the property rights conveyed. Moreover, the property right may involve access to the right-of-way itself for privately owned infrastructure, or be limited to access to (or use of) publicly owned infrastructure.
Type of consideration	Compensation to the public sector may in the form of goods (in-kind), cash, or combinations of both. Moreover, in-kind compensation can include not only basic fiber-optic cable but also equipment to "light" the fiber, maintenance, and even operation and upgrading.
Geographic scope	Projects can be extensive in scope, covering long segments of roadway, or more focused on specific areas. The option that is best in any individual context depends on other factors, such as considerations of administrative burden, service interests of potential bidders, and private sector willingness to install infrastructure in an area larger than their primary area of interest.

3.4.2 Political/Public Concerns

A major public concern is the potential traffic disruption imposed by the construction and maintenance of the infrastructure along the ROW that is almost always perceived negatively by road users and nearby communities. Another issue is the "free" and at any time access to TxDOT's ROW, property, or infrastructure by the private entity to perform construction, maintenance, repair, and updates on its system. The following table (see Table 3.4.2) points out other political and legal concerns that this VEA can generate or face. On the other hand, this VEA can enhance the services (i.e., telecommunication) provided by utility companies, mainly in rural and semi-urban areas. Therefore, not only will public acceptance likely be forthcoming, but political support can also be potentially generated. Finally, a better telecommunication network can help TxDOT and other public agencies improve their information management systems and, consequently, yield an enhanced service, an efficient maintenance program, and a better decision making process (i.e., wise use of public money).

Table 3.4.2: Threshold Legal and Political Issues
Source: U.S. DOT (1996)

Threshold Legal and Political Issues	
*Public sector authority to receive and/or earmark compensation:**	The public sector may be precluded from receiving cash payments, but may still be free to engage in barter arrangements, particularly if they are structured as procurements. In general, state departments of transportation (DOTs) have less flexibility; municipalities and authorities such as turnpike and transit agencies have greater flexibility in dealing with cash flows.
Authority to use public right-of-way for telecommunications	Shared resource arrangements may be precluded if state law mandates free access for utilities or if public agencies are not allowed to discriminate among utilities (e.g., permit access for telecommunications but disallow access for gas and sewerage).
Authority to participate in public-private partnerships	Because shared resource arrangements are a form of public-private partnering, legal authority to enter into such agreements is a basic requirement. In some cases, "implied authority" is not considered sufficient and specific legislation or "express authority" must be passed.
Political opposition from private sector competitors	Shared resource arrangements may trigger political opposition, though not necessarily prohibition, from private sector companies resisting the establishment of bypass networks that they perceive as competing with the services they offer. Opposition may be slight when the bypass system is limited to transportation needs, but it is likely to be stronger if the system supplies a greater range of public sector communications needs.
Inter-agency and political coordination	In addition to investing effort in coordination among agencies in the same political jurisdiction, the lead public agency may also have to orchestrate agreements between geographically proximate political jurisdictions to ensure continuity of fiber for their private partner(s).
Lack of private sector interest in shared resources	At its core, shared resource arrangements depend on private sector interest in expanding telecommunications infrastructure. Reluctance to enter into partnerships with public agencies for access to right-of-way may stem from insufficient market demand for increased communications capacity, cost factors such as more stringent installation specifications along roadway right-of-way, and administration or managerial burden of compliance.

3.4.3 Legal Considerations

The FHWA provides detailed guidance regarding the utilization of highway ROW for longitudinal accommodation of utilities on the federally funded interstate system. Also, federal resolution determines that public utilities can be treated differently than private utilities when using this ROW. In other words, public utilities are treated under the accommodation resolution, while private utilities fall under the airspace leasing regulation. The major point of distinction is the "intended use" and "public interest." The FHWA permits states to decide whether or not to utilize the utility accommodation program, as well as to develop their own accommodation policy. The FHWA, however, has to approve the state's accommodation. It is also considered essential that a DOT provides equal opportunities for all utility providers or interested entities (FHWA and Public Roads, 2000).

Similar to other VEAs, the leasing agreement and contract have to clearly state responsibilities, liabilities, leasing period, leasing price, and price adjustment factor among other considerations. Furthermore, for long-term leasing contracts, the price adjustments are typically based on an escalator factor (TTI, 1993). Escalator factors have been used by most DOTs, as well as the GLO, for price adjustments. Leasing agreements also typically include a protective clause that comes into effect when the agreement or contract has to be terminated (TTI, 1993). The following table (see Table 3.4.3) describes some of the common and important issues concerning shared resource contracts. However, state and federal utility accommodation policies may be out of date and not address new technologies and their requirements. Therefore, some reformulation may be required. In addition, involvement of the State Department of Justice (DOJ), as well as legal counsels, is always recommended to advise and review the written agreements with private parties, and minimize any potential risks and undesired liability.

Table 3.4.3: Contract Issues
Source: U.S. DOT (1996)

Contract Issues	
*Relocation**	Allocation of responsibility for infrastructure relocation in case of roadway improvements affects private partner willingness to pay for right-of-way insofar as it carries a financial responsibility as well.
*Liability**	Similarly, allocation of legal liability among partners affects the financial risks assumed by each one. Liability includes responsibility for system repair, consequential damages (economic repercussions), and tort actions.
Procurement issues	Shared resource arrangements face many of the same issues as other procurements regarding selection and screening of private vendors or partners.
System modification	Shared resource arrangements may or may not include explicit provisions for system modification; that is, technological upgrading to keep abreast of technical improvements and expansion of capacity to meet subsequent needs.
Intellectual property	Intellectual property involves intangible components (e.g., software programs) of the operating system that might not be available to the public sector partner when the partnership is dissolved after the lease period unless specifically addressed in the contract.
Social-political issues	Social-political issues involve equity among political jurisdictions or population segments within the right-of-way owner's domain. More specifically, two issues may affect how shared resource arrangements are structured: most-favored community issues—comparable compensation for all communities engaging in shared resource arrangements, and geographic and social equity—equitable access to and benefit from shared resource arrangements.

In Texas, Transportation Code sets out the regulations for utility accommodation. Under TC Section 202.092 telecommunication providers cannot place or maintain their

facilities or otherwise use improvements, including structures, medians, conduits or lines, constructed or installed by the state as components of the highway system, except by lease under Section 202.052's provisions or an agreement under Section 202.093.

Section 202.093 allows TxDOT to enter into an agreement with a telecommunications provider, to place their telecommunication facilities for a commercial purpose within the median of a divided state highway, or place lines within or otherwise use telecommunication facilities owned or installed by the state in or on the improved portion of the state highway, including a median, structures, equipment, conduits or any other component of the highway facility. TxDOT can enter into an agreement that provides for cash compensation or the shared use of facilities. Section 202.094 requires that before TxDOT enters into any such agreement that they follow a procedure using competitive sealed proposals. Section 202.093(b) also notes that this sub-chapter does not limit a telecommunications provider from placing lines or facilities in the unimproved portion of state highway ROW.

One of the major considerations for a utility location airspace lease VEA in or adjacent to the ROW is that the DOT is responsible for the cost of utility relocation (TC Section 203.092) if the utility is required to move – which is set out in a series of criteria. Section 203.092 (d) notes that the cost of relocation includes the entire amount paid by the utility properly attributable to the relocation less:

1. any increase in the value of the new facility;
2. the salvage value derived from the old facility; and
3. any other deduction established by regulations for federal cost participation.

Finally, environmental analysis is also a requirement for any project or activity on public land. Any project must be in compliance with NEPA – either FHWA or DOE process, if not both – to receive an environmental permit. Ultimately, FHWA has to review all documents (e.g., permits, drawings, analysis of impacts, and contractual agreements) from the project – if located in highway ROW - to issue a final permit, allowing the project to move forward.

3.4.4 Financial/Economic Feasibility

The costs associated with accommodating utilities along the ROW varies depending on how the utility will be placed (e.g., buried, tower, etc.); if it is to be accommodated in the ROW of an existing road or a new project; the technical requirements; and if it will be located in a remote or urban area. In addition, the maintenance cost has to be factored in depending on the type of utility. All these costs are incurred by the utility provider or investor. Finally, intangible benefits such as social development, telecommunication coverage, and safety have to be appraised and considered in the economic analysis. In addition, the following table (see Table 3.4.4) summarizes some financial issues involved in applying shared resources and ROW lease for utilities.

As previously mentioned, DOTs have to charge the fair market price (at a minimum) when it allows private entities to use public land. Federal regulations (23 CFR 710), however, provide an exception when the DOT demonstrate and FHWA approves that the activity is in the public interest, i.e., has social, environmental, or economic benefits.

Table 3.4.4: Financial Issues
Source: U.S. DOT (1996)

Financial Issues	
*Valuation of public resources**	Before entering into shared resource agreements, the public sector needs to have some idea of the value of the assets it brings to the partnership; that is, continuous or sporadic access to its right-of-way for placement of private (communications) infrastructure.
*Tax implications of shared resource projects**	Partnerships between public and private entities may pose unique tax issues, particularly bond eligibility for tax-exempt status when proceeds may benefit profit-making private organizations.
Valuation of private resources	Valuation of the private resources provided in barter arrangements helps the public sector determine whether it is receiving a fair market "price" for its resource.
Public sector support costs	Although shared resource arrangements provide cash revenue or telecommunications infrastructure without public sector cash outlays, such compensation is not without cost since the public sector must use agency labor hours for administration, coordination, and oversight.

3.4.5 Environmental Considerations

An assessment of the environmental impacts is essential and has to consider the type of utility that is going to be accommodated within the ROW. For example, gas and oil pipelines may pose a risk of contamination when leaking. Other applications such as

energy or telecommunication can be dangerous for livestock and wildlife, mainly if not buried. The FHWA, through 23 CFR Section 771, obligates a state to submit environmental documentation describing the purpose of using the ROW to the FHWA Division office. This documentation has to comply with the NEPA requirements (FHWA, Utility Guidelines, 2009).

3.4.6 Potential Social Impacts/Benefits

The availability of wireless and cell-phone services in remote and rural areas can have an important social role in the development of remote and rural communities. Most utility services are essential and critical for social development and welfare. Furthermore, telecommunication and internet availability can play an important and beneficial role in providing education, information, and safety (e.g., tornado warning). Finally, Intelligent Transportation Systems are facilitated by robust IT networks, thus contributing to more effective and efficient infrastructure management and better decision making (FHWA and Public Roads, 2000).

3.4.7 Safety Considerations

Regardless of whether the utility is accommodated under or above ground, implementing this VEA along existing roads always raises safety concerns. If the application does not involve the installation of a fixed structure such as towers, the major issues revolve around construction and maintenance. It is important to develop a construction plan and anticipate likely hazardous situations during construction (if the road exists already) and during maintenance. TxDOT, as the owner of the ROW and the responsible party for promoting road safety, has to require and evaluate the execution plan. Access for maintenance purposes is potentially critical and has to be considered and assessed. Antennas along the ROW may also pose some hazardous obstacles for drivers. Therefore, precautionary measures have to be undertaken such as designation of an installation location (i.e., the most appropriate place for installing towers) and protection barriers. On the other hand, for buried utilities, there is no safety risk associated with car

crashes. Nonetheless, it is fundamental to consider and evaluate maintenance accessibility, security precautions, potential risks (e.g., explosions, fire, and leaks), and overall highway safety (FHWA guideline, 2009).

Having a wireless signal for cell phones along highways allows drivers to communicate accidents, animal carcasses, obstruction, and severe weather conditions, thereby enhancing the safety environment of the highway system. In addition, a wireless communication infrastructure facilitates the implementation of the Advanced Rural Transportation System (ARTS) that uses information technology (FHWA and Public Road, 2000). ARTS aims to improve safety and transportation services in rural areas (FHWA and Public Road, 2000). The Central Federal Lands Highway Division (CFLHD) defines the main objective of ARTS technologies as to "provide information about remote road and other transportation systems. Examples include automated road and weather conditions reporting and directional information," which can be disseminated by several methods, such as Dynamic Message Signs (DMS), 511 travel information, and Highway Advisory Radio (HAR). CFLHD also highlights the importance and value of this type of information to motorists traveling to remote and rural locations.

3.4.8 Examples

The New York State Thruway Authority uses two different types of shared resource agreements. The first involves the design, construction, maintenance, and operation of six ducts of fiber optics along its ROW. The second type of agreement is with the wireless companies that pay a monthly leasing fee in exchange for being allowed to install antennas on towers, buildings, sign posts, bridges, and undeveloped ROW of the Authority (AASHTO—Shared Resources Website).

Figure 3.4.1: Wireless antennas attached to FDOT Tower
Source: Florida ITS (2001)

In 1999, "The Florida DOT reached a 30-year lease agreement with Lodestar Towers, Inc., allowing Lodestar Towers, Inc. to lease access to the Department's limited access rights-of-way in return for compensation formulated as a percentage of the gross revenues received from renting antenna space to commercial wireless service providers". The public private lease agreement was developed in compliance with the Department's Telecommunications Policy, whose goal is "to consolidate wireless tower use to the Department's limited access rights-of-way by providing equal access and opportunity to all wireless service providers. This strategy encourages wireless service providers to collocate on towers located on the Department's limited access rights-of-way instead of developing numerous new tower sites in local communities. The resulting reduction of the number of towers and the location of needed towers as far from residential areas as possible facilitates the intent of the

Figure 3.4.2: Wireless Monopole with Electrical Vault and Fencing
Source: U.S. DOT (2000)

lease to support the wireless service providers while minimizing wireless tower proliferation". "To date, Lodestar Towers, Inc. has constructed 26 towers on the Department's rights-of-way. Another 22 proposed towers are under siting and design review by the Department" (Florida ITS, 2001).

Caltrans received $7.3 million in revenue in FY 2008 from its airspace leasing program, of which $1.3 million came from 52 cell towers (Caltrans, 2009). Caltrans's Leasing Program Administration personnel regard the cost-effectiveness of cell towers to be a major benefit. Cell towers do not require extensive on-site maintenance and generate reasonable revenues (Caltrans, 2009). All revenue generated by the Caltrans leasing program, however, goes to the Public Transportation Account and the only benefit to the Department is thus shared resources (i.e., reserved fiber optic or wire rack space on ROW required by agreement). In addition, an old bill (i.e., legislation determination) requires Caltrans to incur the cost of managing and administrating the program. Caltrans's airspace program for telecommunications is administered by an agent and five-person team responsible for managing the relationship with renters, those seeking business opportunities, and implementing the procedures needed for leasing (Caltrans, 2009). Most of the airspace leasing agreements involve telecommunication providers, which encompass 20 different companies. Most of the telecommunication leasing agreements are located in urban areas (about 90%) and all of them are in accordance with Caltrans's master license agreement that grants a 5-year license for a specific site, with the option to renew the license five times for five years each. According to Caltrans, the utility agreements have to clearly state responsibilities and liabilities for road expansion and utility relocation. If not, the transportation agency has to cover the cost. Caltrans used to be able to charge for accommodating fiber optics in ROW, but the previous legislature removed that ability. It is estimated that the state is not receiving approximately $5 million per year for not charging for accommodating fiber optics in Caltrans's ROW.

In Texas, TxDOT estimates that the agency is receiving between $2 and $4 million from an informal and inactive program. Some TxDOT representatives also

believes that formalizing this program could bring more management efficiency and income to the state.

3.4.9 Concluding Remarks

Airspace leasing for accommodating utilities and telecommunication technologies has a diversified application. New communication technologies (e.g., fiber optics, cell phones, and wireless internet), as well as new renewable energy technologies (e.g., solar panels and wind turbines), potentially raise new opportunities to maximize the benefits of implementing this VEA. However, this VEA has some characteristics and considerations that have to be account for and/or addressed such as:

a. importance of assessing possible future road expansions (i.e., relocation cost);
b. public-private partnership (i.e., liabilities and responsibilities);
c. need for private access to the ROW for construction and maintenance;
d. involvement of telecommunication hardware such as fiber optic lines and cell/internet wireless towers;
e. although very important and beneficial to remote areas, it is more attractive and used in urban areas;
f. need for careful contractual considerations;
g. compensation options for TxDOT include barter (i.e., use of the infrastructure by TxDOT in exchange for the ROW access) and/or cash;
h. FHWA provides thorough guidance regarding the utilization of highway ROW for longitudinal accommodation of utilities and airspace leasing;
i. different approach for public utilities and private facilities (i.e., accommodation vs. airspace leasing);
j. involvement of the State Department of Justice (DOJ), as well as legal counsels, is always recommended to advise and review the written agreements with private parties, and minimize any potential risks and undesired liability;

k. TxDOT and public agencies can take advantage and improve their IMS (shared resources and telecommunication services) (e.g., ARTS);

l. the FHWA, through 23 CFR Part 771, obligates the state to submit environmental documentation describing the purpose of using the ROW to the FHWA Division office. This documentation also has to comply with NEPA; and

m. wireless and cell signals covering the highway network can help drivers to communicate accidents, animal carcasses, obstacles, and bad condition, thereby enhancing road safety.

3.5 ADVERTISING

Advertising by transportation agencies has been widely discussed. For example, AASHTO acknowledges the potential and attractiveness of advertising revenue for transportation agencies (AASHTO—Advertising, 2010). Therefore, many DOTs have thus pursued the implementation of this VEA. The implementation of an advertising program, however, has many dimensions in terms of where and what type of advertising to use.

To offset the high cost of maintaining rest areas, several states have explored alternatives to generate revenue at their rest areas. Advertising at rest areas and kiosks (i.e., electronic signs, brochures, and billboards) and wireless internet sponsorship have been explored as potential revenue sources. The Georgia DOT, for example, is looking for private partners to maintain rest areas in return for the right to exploit advertising space and sponsorship at the rest areas (Stateline.org, 2010). California has been considering the approval of a controversial state bill allowing advertisements on Caltrans's vehicle license plates (i.e., electronic license plates) (CSG, 2010). AASTHO has recommended and some DOTs have sold naming rights for toll roads and plazas, highway corridors, and concession areas (AASHTO—Naming Rights, 2010). Finally, some DOTs, such as Pennsylvania, California, and Florida, have pursued the use of

electronic signs that alert drivers about traffic conditions, accidents, and work on the road for advertising, but this required a prior waiver of FHWA regulations.

3.5.1 Technical Feasibility

There are no major technical concerns or impediments that hinder the implementation of advertising as a VEA. A marketing analysis and traffic flow evaluation to assess the viability and impact of the advertising location is recommended to optimize the advertising effectiveness of the advertisement and maximize the revenue generated. If electronic devices or the internet is used for advertisements in very rural and remote areas, it is important to determine the availability and adequacy of telecommunication signals and electricity sources.

3.5.2 Political/Public Concerns

Misinterpretation of advertising by state agencies can generate controversy and discussion by the public and political officials. TxDOT thus has to carefully assess and determine acceptable advertisements (i.e., content, images, and message) to preclude any negative reactions. These concerns are exacerbated whenever it involves generated revenue. On the other hand, state DOTs and federal agencies have successfully used advertisement signs, posters, billboards, and other channels to share information about public services, conduct public outreach, and educate the public (e.g., "Don't Drink and Drive" in Texas) (FHWA, 1996).

3.5.3 Legal Considerations

Different advertising regulations pertain to interstate highways, state roads, and turnpikes (i.e., toll roads). For example, FHWA regulates the number, size, and location of advertisement signs through its advertising control program. In addition, several FHWA regulations prevent advertisement on overhead and roadside signs. Furthermore, state laws can yet exacerbate the challenges and obstacles in implementing an advertising program (CSG, 2010). In Texas, "TxDOT regulates the display of off-premise outdoor

advertising signs along highways regulated by the Highway Beautification Act (HBA) and all other highways and roads located outside of the corporate limits of cities, towns and villages in Texas under the State Rural Roads Act (RRA)" (TxDOT, 2010).

Section 391.001 TC sets out the definitions and regulations for highway beautification in Texas. Section 391.002 describes the purpose of the chapter, which was to comply with – and is conditioned on– the Highway Beautification Act of 1965 (23 U.S.C. Sections 131, 136, 319). Section (b) (1) notes the need to regulate the erection and maintenance of outdoor advertising, adjacent to the interstate and primary system to promote the health, safety, welfare, morals, convenience, and enjoyment of the traveling public, as well as to protect the public investment in the interstate and primary systems.

TC Section 202.060 also allows the Commission to adopt rules to implement a pilot project for leasing state highway ROW, subject to federal regulation of outdoor advertising, for *commercial advertising by means of a floral mosaic living logo* in a county with a population of over 500,000.

Parties interested in outdoor advertising should review all regulations pertaining to signs on the specific site and then obtain the appropriate license and permit, if necessary. In addition, some modes of advertising require approval from the federal government before they can be used, such as electronic highways signs (CSG, 2010).

Photo by John Wilcox

HIGHWAY ROBBERY: Due to regulations prohibiting advertising on federal highways, the state will lose $500,000 in a Citizens Bank sponsorship when Fast Lane merges with E-ZPass. The change will also necessitate replacing 275 signs.

Figure 3.5.1: Fast Lane Sponsorship of Massachusetts Turnpike
Source: Chabot (2010)

On the other hand, some sponsorships on federal highways are illegal, because they may be perceived as government endorsement (FHWA, 1996). In general, some states allow only sponsorship for littering removal, under a well-established program (i.e., Adopt-A-Highway Litter Removal Service of America, Inc. and Adopt-A-Highway Maintenance Corporation). An example of how legislative considerations can impact the implementation of this VEA occurred in Boston where a turnpike became part of the Massachusetts DOT, which require "the state to end Citizens Bank's $500,000-a-year Fast Lane sponsorship, because the Massachusetts Turnpike now falls under federal guidelines that forbid advertising on federal highways" (see Figure 3.5.1) (Chabot, 2010). Similarly, some naming rights of public assets may also face legal barriers and considerations because of sponsorship concerns.

3.5.4 Financial/Economic Feasibility

Research conducted by AASTHO and TTI highlighted the importance of including the costs of administering and regulating advertising programs in the feasibility study to determine the fees charged. Some TxDOT representatives, for example, believe that the administration cost of advertisements at rest areas alone is prohibitive. It is believed that the cost associated with the staff required to manage several small advertising contracts will not be offset by the revenue and profits from the advertisements. Furthermore, the technology or means used to advertise can increase costs substantially. For example, rest area panels and brochures are less expensive than TV screens and electronic boards. The revenue generated by the former is, however, also less than the latter. Pennsylvania DOT estimated that approximately $150 million could be generated annually through advertising on electronic highway signs that inform drivers of accidents, traffic congestion, and construction (CSG, 2010).

Naming rights and sponsorships can also generate substantial revenues and have lower cost per number views (see Figure 3.5.2). Although the revenue generated through naming rights is likely insufficient to fund large transportation capital projects, their stability and predictability make this application attractive for DOTs. In addition, the revenue can be used to fund a portion of the operation and maintenance of the transportation system (AASTHO—Naming Rights, 2010). Another benefit of these programs (e.g., litter removal sponsorship) is the cost savings that can be generated through reduced mowing activities and roadside maintenance.

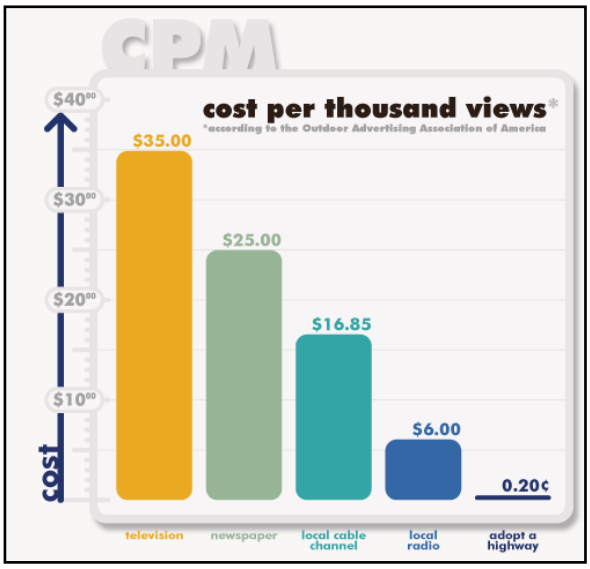


Figure 3.5.2: Cost of Advertising per Thousand Views
Source: Adopt-a-Highway Program (2011)

Finally, the visibility along highways for advertising can help promote businesses in rural areas–thereby helping the development of these communities. This benefit has to be appraised and accounted for in an economic analysis.

3.5.5 Environmental Considerations

In general, advertising does not impose substantial environmental impacts besides the aesthetic impacts associated with certain types of advertising (e.g., billboards). This application, however, can be used for educational purposes such as environmental conservation, wildlife preservation, and global warming awareness. Furthermore, some advertising means can be linked to sustainable resource usage. For example, electronic panels can be connected to a renewable energy source, brochures can be made from

recycled paper, and signs and billboards can be constructed with recycled materials (e.g., wood and aluminum).

3.5.6 Potential Social Impacts/Benefits

In general, advertising can be used to share ideas, integrate communities, engage public participation in social projects, and conduct public outreach. Especially in semi-rural and rural locations, advertising can help small communities to promote their points of interest (i.e., tourist attractions, and typical activities and businesses in their community), thus helping local development.

Litter removal sponsorship is also a great example of how advertising can promote social and environmental benefits. Making roadside litter-free helps to preserve the fauna and flora, prevent soil and water contamination, prevent proliferation of insects and, consequently, diseases, and generate local employment.

3.5.7 Safety Considerations

Safety is a major concern when using advertising in highway ROW. FHWA and AAA Foundation for Traffic Safety argue that advertising can distract drivers and, consequently, cause accidents (CSG, 2010). Furthermore, the signs and billboards have to be located outside the safety zone for cars to protect drivers. On the other hand, brochures, web sites, and other advertising means can be used to educate, warn, and guide drivers toward safer behavior (e.g., “don’t drink and drive,” “no texting,” “buckle up,” and car maintenance).

3.5.8 Examples

Advertising on highway assets—i.e., non-federal highway ROW, bridges, and rest areas—has been implemented in some areas. Several examples thus exist that illustrate the applicability of different advertising means as a VEA. The Pennsylvania Turnpike, for example, has permitted advertisements on tollbooth windows and ticket machines, which generated about $519,000 in 2009 alone (CSG, 2010). Miami-Dade Transit

implemented a naming program for toll plazas and subway stations. Similarly, DOTs can implement naming rights for rest areas, kiosks, and rest stops that will allow companies or individuals to have their names associated with the asset in lieu of paying for maintaining (i.e., sponsorship) or even constructing and retrofitting the asset. Florida DOT has recently started to manage its own advertising program in house, after the contract with Florida Interstate Logos expired. To reflect a more realistic value of advertisement for business, FDOT increased the price of blue signs by nearly 200% in some cases. The new price varies according to location, traffic volume, and market condition (AASHTO—Journal, 2010). The Georgia DOT (GDOT) has sought opportunities to raise revenue through advertising and has estimated that more than $1.4 million can be generated. The intention is to place advertisements on kiosks, TVs, backlit signs, and electronic posters at rest areas. GDOT, however, regards wireless internet sponsorship as the most lucrative application. The idea is that travelers would watch commercials and advertisements on their computer in exchange for free internet access. These websites can be used to inform and help travelers plan their trip and stops, as well as provide information about points of interest and attractions. The websites can also contain advertising for lodging, restaurants, and gas stations along a specific route.

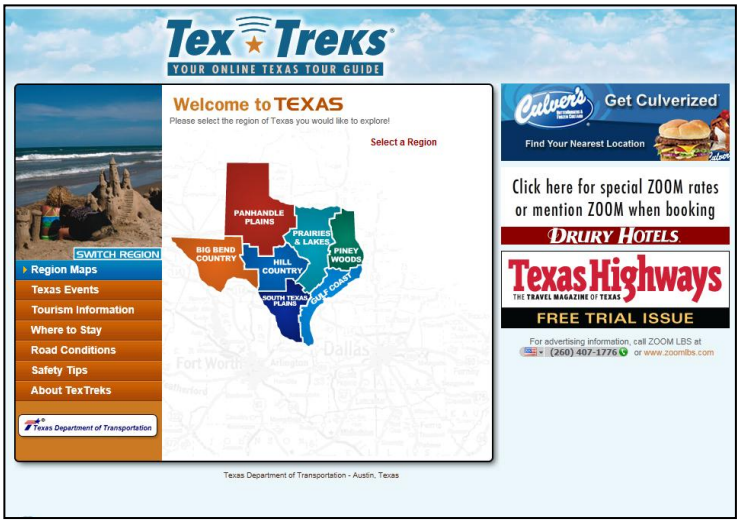


Figure 3.5.3: Tex Treks Website
Source: TexTrek (2010)

In Texas, all rest areas and travel information centers currently provide free wireless access to travelers as an incentive to stop along the highway and rest for a while. The wireless service is provided and

managed by a third party that receives $100,000 per month for the service and maintenance from TxDOT. TxDOT measures and monitors the quality and usage of the service, penalizing the provider if the service is unavailable or decreases in quality for more than five days. TxDOT also has a website (i.e., Tex Treks) (see Figure 3.5.3) that appears when travelers access the wireless service and informs users about, for example, road conditions, provides travel tips, and suggests places to stay. The wireless service provider currently has ownership over all advertisements on the website and receives all advertising revenue. TxDOT is exploring different options to share in the advertising revenue generated. One option is to offset the costs of providing and maintaining the internet service with advertising revenue generated.

In Oregon and Washington (see Figures 3.5.4 and 3.5.5, respectively), brochures and panels are used as advertising means. Rest areas are equipped with brochure dispensers that are rented to vendors and companies. The vendor can rent dispenser space at a rest area or at several rest areas (i.e., packages). The rent price varies depending on the number of rest areas in the rent package and/or the size of the panel (see Figure 3.5.5).

Figure 3.5.4: Oregon Travel Information Center
Source: OTIC (2010)

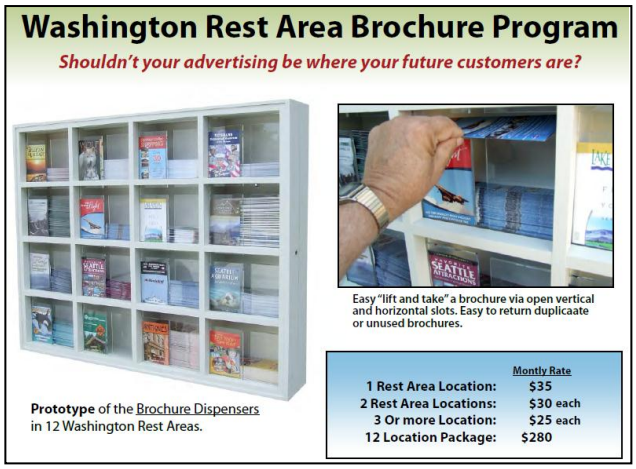


Figure 3.5.5: Example of Washington Rest Area Brochure
Source: Storeyco (2010)

Another interesting application of this VEA option is found in Toronto, Canada, where the vegetation along the highway that links the international airport to downtown is used to advertise companies (see Figure 3.5.6).

Figure 3.5.6: Advertising along ROW in Toronto, Canada

Blue signs (or logo signs), however, are the most common advertising type encountered along U.S. highways (see Figure 3.5.7) and are used mainly to inform travelers about services along the road. There are, however, some other templates of signs that are also used (see Figure 3.5.8). In Texas, TxDOT has a partnership with a Texas-based company called LoneStar Logos & Signs L.L.C. (see Figure 3.5.9) that is responsible for providing motorists "useful information about services and destinations while traveling Texas highways" (LoneStar Logos & Signs). LoneStar Logos & Signs has a diversified portfolio of sign programs (i.e., logo signs, tourism directional signs, and mall/retailer signs), which encompass "companies of all sizes, from small, locally-owned family businesses to large national and international corporations" (LoneStar Logos & Signs). The main objective of this partnership is "to connect motorists with information about nearby services and destinations in an effort to bring comfort to drivers and passengers and make Texas highways safer and easier to navigate" (LoneStar Logos & Signs). LoneStar also highlights the major benefits of this program, as offering more

information and therefore increase safety of drivers, increase business for participant destinations, and provision of the best service and value possible to the State of Texas.

Figure 3.5.7: Illinois IH 80
Source: AARoads (2010)

Figure 3.5.8: New York IH 878
Source: AARoads (2010)

Figure 3.5.9: Blue Sign Template of LoneStart Logos
Source: LoneStar Logo & Signs (2011)

In general, there are two nationwide programs concerning sponsorship for litter removal and roadside maintenance. The first program is called Adopt A Highway Maintenance Corporation (AHMC) and "provides your company or organization the opportunity to brand your company name and logo while supporting the community your customers live and work in. The best part of the Adopt A Highway/Sponsor a Highway program is, AHMC does all the work, while your company gets all the positive recognition" (Adoptahighway.com). The states participating in this program are Arizona, California, Colorado, Connecticut, Delaware, Georgia, Indiana, Kansas, Maryland, Massachusetts, Michigan, Nevada, New Hampshire, New Jersey, New York, Rhode

Island, Utah, and Washington. The second program is called Adopt A Highway—Litter Removal Service of America (AAH-LRSA). It has been in business for 22 years and "provides an opportunity for businesses to financially sponsor litter removal along America's busiest highways while receiving recognition. Companies that make a commitment to finance litter pick up along a stretch of highway, receive a sign that identifies them as a community minded, environmentally conscious business. Our professional crews perform the cleanup of adopted/sponsored segments." AAH-LRSA is in charge of all arrangements, including 1) determination of desirable and available sites, 2) provision of DOT's custom panel for the sign, 3) execution of all work (i.e., cleaning and maintaining), 4) coordination of all activities with the DOT, and 5) documentation of all services (Adoptahighway.net). The states that are participating in this program are Arizona, California, Connecticut, Indiana, Kansas, Maryland, Massachusetts, Missouri, Nevada, New Hampshire, New Jersey, New York, Rhode Island, and Washington. Regardless the program, each DOT has its own sign patterns that are uniquely applied (see Figure 3.5.10 to 3.5.14).

Figure 3.5.10: Arizona's Sign Pattern
Source: Adopt-a-Highway Program (2011)

Figure 3.5.11: California's Sign Pattern
Source: Adopt-a-Highway Program (2011)

Figure 3.5.12: Sponsorship Sign in Arizona
Source: Adopt-a-Highway Program (2011)

Figure 3.5.13: Sponsorship Sign in Massachusetts
Source: Adopt-a-Highway Program (2011)

Figure 3.5.14: Sponsorship Sign in Maryland
Source: Adopt-a-Highway Program (2011)

Another type of sponsorship that can be used by TxDOT is called Adopt-A-Watt. Like Adopt-a-Highway, in an Adopt-a–Watt agreement companies can sponsor or fund clean energy and alternative fuel projects in exchange for having their name advertised and acknowledged. Also, a sign template – that complies with FHWA Acknowledgment Sign Standards - is provided (see Figure 3.5.15). The two most popular programs are Sponsor-able Photo-Voltaic Light (SPVL) and Sponsor-able Photo-Voltaic Display (SPVD). In the case of solar lights, the sponsorship fees start at $2.000 per year, while for solar arrays the sponsorship fees start at $10,000 with a three year minimum commitment in both cases.

Figure 3.5.15: Adopt- a- Watt Sign Template

Source: AAW (2011)

Figure 3.5.16: SPVD at JFK International Airport

Source: AAW (2011)

Several Adopt-a-Watt projects have been implemented nationwide, comprising rest areas, travels plazas, bridges, tunnels, airports, sport/entertainment complexes, and rail/bus stops. Figure 3.5.16 shows an example of SPVD at the JFK International Airport, NY/NJ.

Ultimately, advertising can be employed through naming rights - a very popular advertising program used by the private sector and that has been adopted by the public sector in certain circumstances, such as train stations, airports, toll booths, rest areas, and highway corridors. Here, a private company pays a naming right fee in exchange for having its company name and/or logo associated with the property (e.g., rest area, toll plaza, bridge, or highway).

3.5.9 Concluding Remarks

Advertising as a VEA is very simple and provides several possible means to implement. However, some important concerns need to be addressed and considered. These include:

a. Legal and regulatory barriers such as:
   - Differing regulations for Interstate highways, state roads, and turnpikes (toll roads).
   - Federal law does not allow adverting on interstate ROW.
   - In Texas: the Highway Beautification Act (HBA) and State Rural Roads Act (RRA) regulate the use of billboards and signs.
   - Different legal considerations for advertising and sponsorship.
   - Sponsorship allowed only for litter removal and highway maintenance.

b. Advertisement has a diversified portfolio for application (e.g., brochures, website, signs, and billboards).

c. Some possible advertising means may require some electronic devices or internet signals.

d. Most advertising means involve high administration costs when compared to the revenues generated.

e. It requires a considerable amount of “small” contracts to offset the administration costs. However, some advertising means are more cost-effective than others.

f. Sponsorship can help reduce maintenance cost and/or generate revenue (e.g., naming rights, adopt-a-highway, and wireless).

g. Advertisement has to be implemented in areas with great visibility (e.g., people or vehicles).

h. Advertisement can be used to conduct public outreach and promote public service.

i. In rest areas, wireless sponsorship has been used by some DOTs in a cost-effective way.

j. TxDOT pays $100,000 for the wireless service at rest areas and travel information centers in the state.

k. TxDOT maintains an informative website (i.e., Tex Treks).

l. The major concern of advertising on highways is driver distraction.

3.6 SOLAR PANELS

Solar photovoltaic panels are composed of cells that convert sunlight into electricity through the photoelectric effect (see Figure 3.6.1). In general, solar panels have no moving parts, do not require water, do not make noise, and do not produce any waste or emissions (SECO Website). Solar panels have been widely used on residential and commercial buildings and are a key component of the U.S. national strategy for reducing the nation's carbon footprint and promoting renewable energy (SECO Website). In addition, the increasing costs and price volatility of fossil fuels, concerns about global climate change, lower solar energy equipment and technology prices, and federal and state incentives have enhanced solar activity (SECO, 2008). This has resulted in the construction of many solar power plants nationwide, including in Texas. In terms of energy production, solar energy ranked 10th in the U.S. in 2009 (DOE). Texas is ranked as the 9th state in terms of state solar energy

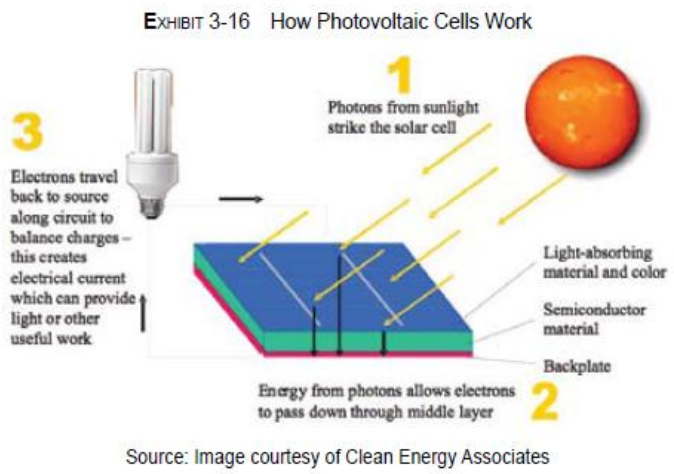


Figure 3.6.1: How Photovoltaic Cells Work
Source: SECO (2008)

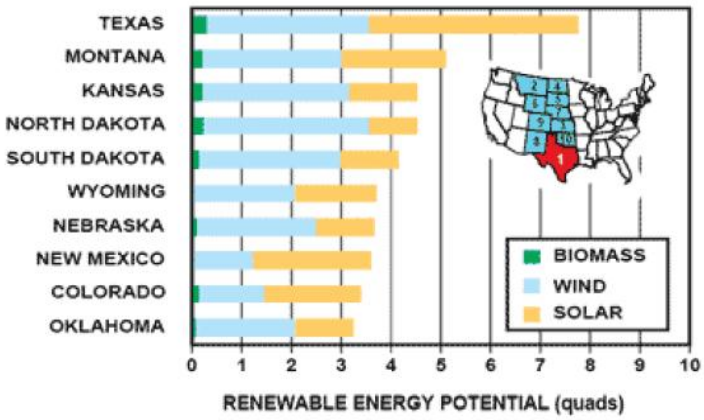


Figure 3.6.2: Renewable Energy Potential by State
Source: SECO (2008)

potential (Engineering News Record, 2010). In terms of new renewable energy sources, solar has the greatest potential in Texas, as shown in Figure 3.6.2.

In both the U.S. and Texas, the interest in renewable energy has gained momentum due to "an increase in environmental awareness, skyrocketing oil and gas prices, and national security concerns" (SECO, 2008). Electricity is essential to economic development and welfare and any shortage or price variation can be catastrophic for an economy. In Texas, these problems are exacerbated as the state consumes nearly 12% of all energy used in the U.S. and ranks 5th in terms of consumption per capita. Most of the energy and electricity used in Texas are from petroleum products, crude oil, and natural gas (see Figure 3.6.3). Although Texas is a national leader in the production of these energy resources, production has significantly decreased while consumption has increased between 1970 and 2005 (see Figure 3.6.4).

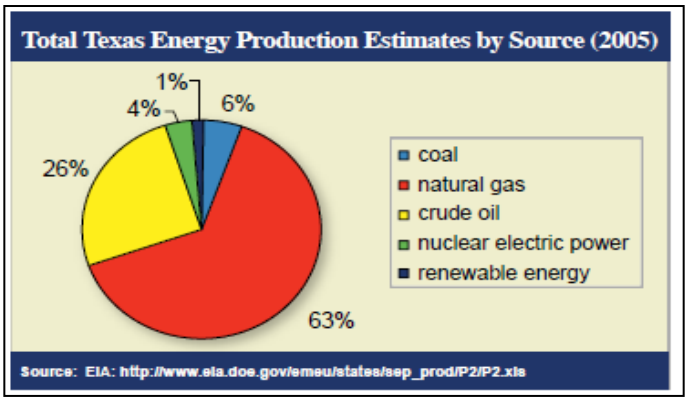
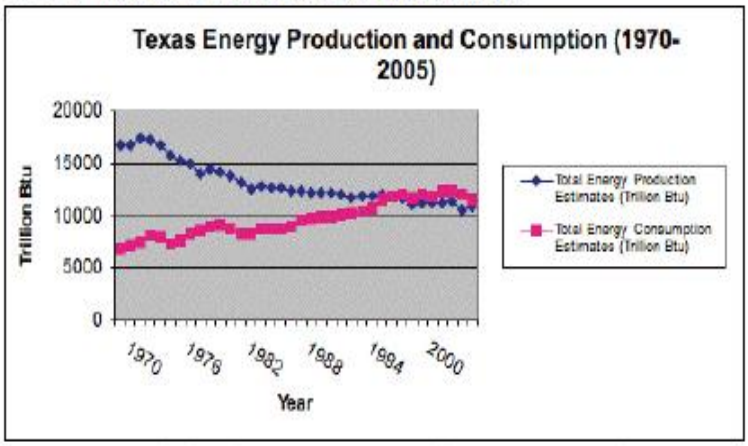


Figure 3.6.3: Texas Energy Production by Source
Source: SECO (2008)



Source: Energy Prod Estimates: http://www.eia.doe.gov/emeu/states/sep_prod/P7/PDF/P7_tx.pdf
Consumption Estimates: http://www.eia.doe.gov/emeu/states/sep_use/total/use_tot_tx.html

Figure 3.6.4: Texas Energy Production and Consumption
Source: SECO (2008)

It has been projected that the traditional energy sources will not be sufficient to meet the growing energy demand. Moreover, the federal government has continuously expressed the need for the country to be less dependent on fossil fuels and foreign energy. In fact, Texas "must rely on a diversity of energy sources to fulfill its ever-growing needs" (SECO, 2008). Furthermore, the projected trends will not only result in higher electricity prices, but could result in electricity shortages (SECO, 2008). For example, the price of natural gas consumed in the U.S. has doubled since 1995 (SECO, 2008).

TxDOT spends more than $200 million annually on electricity (TxDOT, 2009). Renewable energy resources may thus present an option to reduce electricity costs, protect the agency against the volatility of electricity prices, or generate revenues.

Two different approaches are herein envisioned for the use of solar panels. First, solar panels can be installed along highway ROWs to generate electricity for public lighting, houses, or even communities. Second, solar panels can be installed on TxDOT's buildings, such as offices, warehouses, and rest areas. Both these approaches can reduce electricity expenditures, as well as the carbon footprint. The new trend in electric cars also offers a new opportunity for exploring solar panels as a revenue stream. Because electric cars do not have a long range, some DOTs are looking at implementing recharge stations fueled by solar panels along highways and at rest areas to meet electric car demand. At rest areas, solar energy can also be used to provide electricity for recreational vehicles (RVs) and trucks.

3.6.1 Technical Feasibility

The major advantages of solar panel systems are their mobility and scalability. Solar panels can be installed near to the end user and to any desirable scale (SECO, 2008), reducing both the infrastructure investment—e.g., transmission lines—and the loss of electricity due to heating along transmission lines. Moreover, solar panels can operate off-grid—i.e., not connected to the existing electricity grid—as stand-alone systems. As stand-alone systems, solar panels only operate during sunlight and, thus, batteries have to

be incorporated into the system to ensure full independence from the grid (i.e., electricity) at any time. One possibility to reduce or avoid the use of batteries is the adoption of a hybrid and stand-alone electricity generator system—i.e., incorporate solar panels and wind turbines into one integral system (SECO, 2010).

Another benefit of using solar panels is that their production capability—i.e., during the day—corresponds with the daily and seasonal energy demand in Texas, when the price of purchasing electricity from the grid is highest (Borestein, 2008). On the other hand, solar panels have low energy density production. A considerable area is thus required to produce a large amount of electricity (SECO, 2010). This characteristic is one of the three barriers that preclude wide solar utilization (SECO, 2008).

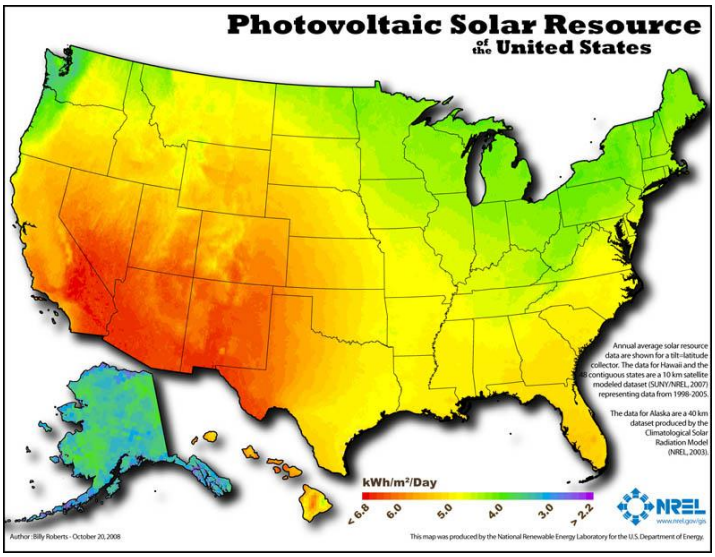


Figure 3.6.5: Potential PV Solar Panel Production in the U.S.
Source: NREL (2010)

Even though technical reports show Texas as one of the U.S. states with high solar potential, studies have to be conducted to determine the best location (i.e., direction and inclination) to ensure efficient electricity production. Indeed, several factors impact the system efficiency, including the average hours of sunlight per year and angle between panels and the sunlight (SolarBuzz). The National Renewable Energy Laboratory (NREL) has developed maps (see Figure 3.6.5) to estimate the average energy production (in KWh/m^2/day) of the solar panels by region. As can be seen, potential solar energy production improves as one moves from east Texas to west Texas. Avoiding fixed and

known obstructions and shadows—e.g., from buildings and trees—is important, however, as the NREL dataset does not account for these location-specific factors. The Oregon DOT (ODOT)—a pioneer in installing solar panels on ROW—points to the importance of site's features and to the feasibility of the project and highlights some technical criteria, such as site terrain (i.e., how flat or level the site is) and existing infrastructure (e.g., fiber optic and wireless signal) to monitor and control production and ensure the integrity of the equipment. Moreover, in the case of ROW, ODOT mentions that a linear site is better.

In addition, research and development centers have been working on improving solar cell efficiency and have achieved promising results in controlled environments (SECO, 2008). As the solar energy technology evolves, more cost-effective solar panels will be developed. Finally, if solar panels can be incorporated early on in the design of new projects (i.e., roads and buildings), lower investment cost would be required. On the other hand, if solar energy systems are installed on existing buildings, the current electrical system has to be considered and analyzed as improvements would likely be needed.

3.6.2 Political/Public Concerns

Initiatives aimed at environmental protection and carbon footprint reduction typically receive attention and support from many organizations and politicians. Texas has enacted legislation to establish a renewable energy resource base and incorporate goals for renewable energy implementation (SECO, 2008). Hence, this VEA has some merit for TxDOT to improve public perception of the agency. Furthermore, a number of federal and state bills have been passed to incentivize and facilitate the implementation of this renewable energy source. For example, the Executive Order 13514 issued by President Obama sets up "an integrated strategy toward sustainability in Federal Government and to make reduction of greenhouse gas emissions a priority of Federal

agencies". Likewise, FHWA is endorsing and promoting the incorporation of climate change considerations into the transportation decision-making process.

An important consideration was pointed out by ODOT in order to avoid or mitigate any public opposition beforehand. ODOT also mentioned additional assessments and research the agency had to carry out in a solar project near a residential area. Although different concerns (e.g., concerns about electromagnetic field, glare, taxes, incentives paid, and property values) may arise, ODOT does recommend undertaking at least public involvement/outreach, visual impact analysis, and noise analysis. Moreover, ODOT cited the importance of a good relationship with the project neighborhood and argued that a majority of the issues were due to a lack of knowledge and awareness about the technology. However, education on these issues may entail extra efforts and work.

3.6.3 Legal Considerations

The Texas legislature passed Senate Bill 20 (SB20) in 2005 to increase Texas's renewable energy goal (SECO, 2008). However, the major legal consideration for this VEA concerns the use of government incentives by a public agency (i.e., non-tax payer). The solution has been to enter into a public private partnership (P3), where the private entity is the investor. Such a partnership (i.e., P3) was used by ODOT to ensure the feasibility of the first solar ROW project. Also the numerous subsidies, rebates, and tax credits have different nuances and legal considerations that have to be understood to prevent misinterpretations and wrong considerations. Tied with SB 20, for example, is the Renewable Portfolio Standard (RPS) that regulates and drives the Renewable Energy Credit (REC) market and the Solar Set-Aside program. Ultimately, the Net Metering Policy—which allows the renewable energy producer to sell back surplus energy produced to the grid at the retail price—could be important to the viability of a solar panel application. In Texas, the Net Metering Policy is not obligatory within the Electric Reliability Council of Texas (ERCOT) competitive area. Rather it is a voluntary program

in which the utility companies buy back the excess of production at a rate negotiated beforehand with the producer/consumer (SECO, 2008).

Another legal issue highlighted by ODOT and which most DOTs are not aware of is existing patents regarding the implementation of renewable energy sources along highway ROW. There are about 20 patents held by Green Highway Company involving public land. Although ODOT has not been ignoring the existing patents, the agency commented the possibility of challenging them and the need for a nationwide movement (i.e., FHWA, AASHTO, and the federal government) to overturn and decline them. Furthermore, ODOT cited that the FHWA regulations (e.g., airspace lease regulation, easement conditions, and accommodation permit) must be considered during the process and must be addressed in legal agreements (e.g., liability, responsibilities, access, maintenance, ownership over incentives and credits, land commitment, and shared risks). For example, ODOT mentioned the need to guarantee long-term commitment to the land. The investor is legally assured that the project can only be removed if transportation need is clearly demonstrated. In addition, the DOT has to share risks with the investor to make the project economically feasible. The DOT must be liable for any damage or theft occurred with the panels. In any case, the investor has to be indemnified from financial loss that is caused by external factors. The investor's responsibilities encompass construction and procurement of the project, maintenance of equipment and infrastructure, restoration, and preservation of the site. In fact, ODOT recommends the involvement of the State Department of Justice (DOJ), as well as legal counsels to advise and review the written agreements with private parties to minimize any potential risks and undesired liability.

In addition, Massachusetts DOT (MassDOT) pointed to the importance of verifying local zoning laws prior to moving forward with a project. MassDOT argues that most cities do not have zoning laws revised to address and regulate renewable projects. The lack of zoning law can defer or even impair the implementation of solar projects. Another issue is the proximity to public and military airports and likely interference or

obstruction with air traffic, aircraft navigation/communication systems, and military radars. For any construction over 200ft, the form "74601-Notice of Proposed Construction or Alteration" must be filed with the Federal Aviation Administration (FAA) prior to its outset. The FAA and the Department of Defense (DOD) will review the form and issue a permit. Typically, sites that are not within three to five miles of an airport are not deemed a hazard to air traffic (Volpe Center, 2011). Environmental analysis is also a requirement for any renewable energy project on public land. Any project must be in compliance with NEPA – either FHWA or DOE process, if not both – to receive an environmental permit. Ultimately, FHWA has to review all documents (e.g., permits, drawings, analysis of impacts, and contractual agreements) from the project – if located in highway ROW - to issue a final permit, allowing the project to move forward.

As has been noted in previous sections of this report any placement of such structures on or adjacent to the ROW (federal and state) will also have to comply with the provisions of CFR, TC, and TAC and not compromise mobility, safety, and the ability of the DOT to control its assets in the best interests of the general public, and will need to be charged at not less than fair market value.

Finally, the placement of any such solar panel technology adjacent to the ROW will need to be compliant with the rules regarding highway beautification. TXDOT would also need to ensure that no stray light or light movement was visible from the solar panels to oncoming motorists.

3.6.4 Financial/Economic Feasibility

The cost of solar energy technology is arguably the major obstacle to the wide application of solar panels. However, several incentives and subsidies, such as rebates and tax credits, are available for this application. The most significant incentives are typically granted by federal and state governments (DSIRE). ODOT, for example, was granted $2 million for its first project that was awarded to its partner (i.e., investor). These incentives, however, vary from year to year. Furthermore, "innovative financing mechanisms using public-private-partnerships" (P3s) allow DOTs to "secure clean renewable energy—without paying a premium—from assets it already owns" (ODOT). These P3s can "utilize state energy tax credits, federal incentives, and utility incentives to finance solar projects, which the DOT—having no tax liability—cannot take advantage of on its own" (ODOT 2010). Another financial consideration is the payback period for the investment (SolarBuzz). In fact, the cost of solar energy production on a large scale is quite high compared to other energy sources (SECO, 2008). Hence, incentive programs reduce the payback period and largely drive and determine the feasibility of solar projects (SolarBuzz). Figure 3.6.6 illustrates the total installed cost of different sizes of solar systems net of the common incentives (Wiser et al., 2009). By comparing the values presented in Figure 3.6.6 with the values in Figure 3.6.7, the influence and importance of the incentives on the economic feasibility of solar projects become evident. The highest cost component is the

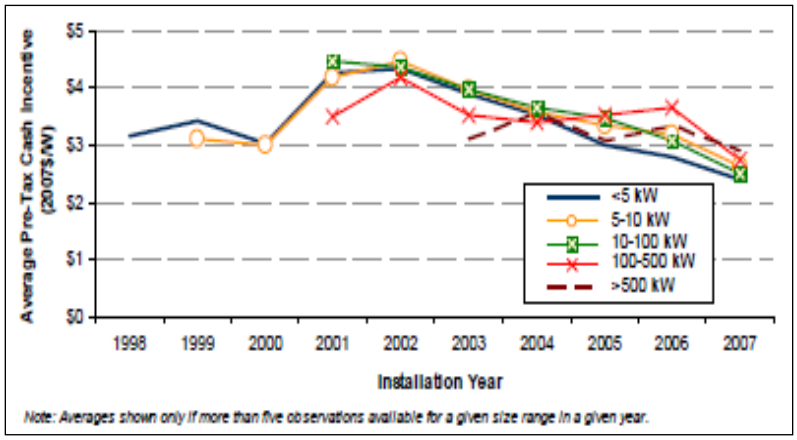


Figure 3.6.6: Trends of Solar Energy Cost According to the Installed Capacity
Source: Wiser et al. (2009)

equipment itself—representing 40–50% of total installed cost (SolarBuzz). Because the technology is evolving and the demand has been increasing, there is an expectation that the overall cost of solar systems and, consequently, the need for incentives will reduce in future (SECO, 2008). Indeed, installed costs have declined over the years (see Figure 3.6.7). From 2005 to 2007, installed cost has, however, remained largely unchanged. The latter has been attributed to solar panel demand, which created a shortage in the supply, and consequently, resulted in higher module prices (Wiser et al., 2009). Furthermore, unlike the module prices that are dictated by the national market, the remaining 50–60% of total installed costs are associated with non-module components and, hence, are driven by local programs (Wiser et al., 2009).

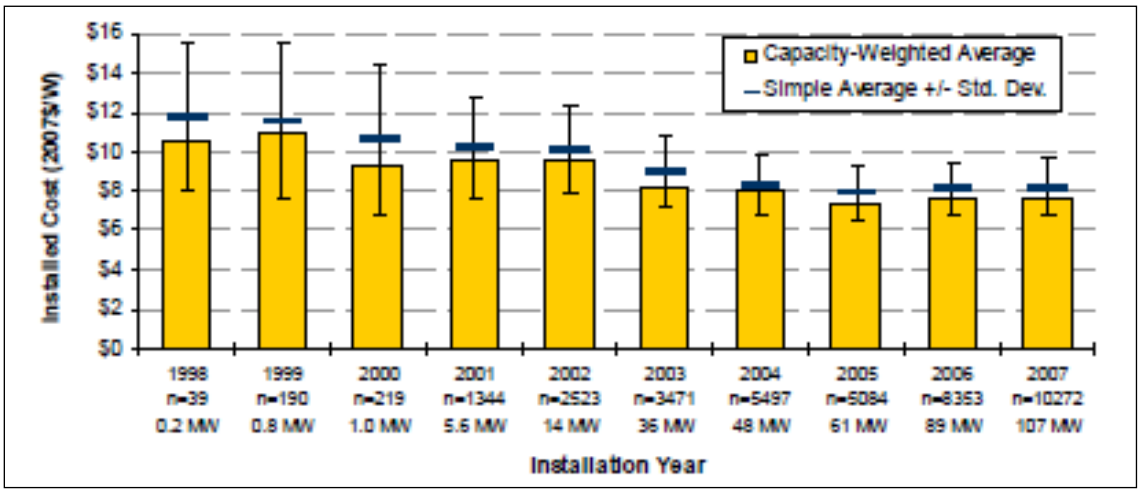


Figure 3.6.7: Installed Cost of Solar Project from 1998 to 2007
Source: Wiser et al. (2009)

Although the maintenance cost of solar panels is important to life-cycle cost analysis, it does not represent a significant cost relative to the initial cost (i.e., installation, site preparation, etc.) and is typically expected to represent 1% of the initial hardware investment annually—i.e., equipment (PVResources, 2010). Also, solar panel maintenance is typically the responsibility of the utility agency, as is any damage due to vandalism or incidents that may occur. ODOT mentioned, on the other hand, that it was crucial to share risks (e.g., vandalism and incidents) with the utility company to make

their first solar project economically feasible. In addition, the majority of solar panel vendors provide a 25-year warranty on the equipment; therefore, this period should be used in the life-cycle cost analysis. ODOT commented, for example, that the maintenance of its pioneer project has been minimal. Thus far, the vendor has changed some cracked panels - without cost to the investor (i.e., warranty coverage). Plus, mowing activities have been performed a couple of times during the summer. Finally, cleaning and washing the panels have not been needed. The rain has been enough to keep the panels clean (Volpe Center, 2011). On the other hand, two additional factors that may impact the feasibility of the solar systems are interest rates and on-grid electricity price growth. These factors are difficult to predict and have to be carefully considered.

If the solar panels are connected to local system grids, potential revenues can be explored. Some electricity providers offer consumers/producers credits for excess electricity produced by the solar system that is fed into the utility grid (SECO Website), i.e., net metering. In fact, ODOT also cites the grid connection as the most cost-effective way to implement solar projects and because of that ODOT recommends sites that are a maximum of half-mile away from transmission lines.

Solar panel owners can also benefit from selling REC generated by their system. This additional income can be added to other incentives granted by utility, state, and federal programs. The potential revenue generated is determined by the type of REC market that exists where the solar energy system is located. A voluntary REC market is characterized by the voluntary nature of the transactions. In the traditional REC market, the RECs created by solar energy systems may be sold to electricity suppliers for meeting renewable portfolio standards (RPS). The latter is the RPS solar set-aside markets that may be limited by the size of the solar energy system (i.e., total electricity generation capacity) (Wiser et al., 2009). In Texas, “the RPS provides for a REC trading program that will continue through 2019” (SECO Website). A REC market promotes greater flexibility and provides an incentive for companies to pursue renewable energy projects because electricity suppliers can resort to the market to meet renewable energy capacity

targets without investing in the new technologies—hence, providing opportunities for trades (SECO). In Texas, the RECs are issued quarterly, based on meter readings. The Texas electric grid operator, ERCOT, is entitled to monitor and control the REC market. Furthermore, the Public Utility Commission of Texas (PUCT) can cap the price of RECs or even suspend the RPS if it is regarded as necessary to maintain the reliability and operation of the grid system (SECO). In Oregon, ODOT mentioned that the RECs were fundamental to the success and viability of the pioneer project. ODOT also argued that in future projects the agency will benefit from a portion of the REC, as opposed to the pioneer project in which the RECs go entirely to the investor (i.e., private partner).

As said, typically in a solar project the DOT will enter in to an agreement/partnership with a utility company and/or private investor. Different business models can be used according to the DOT's goal and the interest of the investor. It is important to bear in mind that the attractiveness and economic feasibility of the project may vary depending on the business model adopted. The four business models generally used for solar projects are:

- The DOT purchase all the renewable energy generated from the project. This model was used by Oregon DOT in its first pilot project;
- The DOT charge a rent fee – following the airspace lease policy – and does not purchase any renewable energy or acquire any RECs. This model is being proposed by Caltrans and Massachusetts DOT;
- The DOT acquires only the RECs from the project and the investor sells the electricity generated as non-renewable;
- The DOT owns and operates the entire solar system. This model is generally used in DOT facilities (i.e., offices, rest areas, and maintenance facilities). In the case of highway ROW, Ohio DOT explored this model in its first project, but afterwards Ohio DOT realized and asserted that owning and operating solar systems is not a sustainable business model for ROW projects, as long as the cost of renewable energy is still high – because DOTs cannot benefit from incentives.

In a remote residential market or industrial application, solar panels can be a less expensive alternative than diesel power or another energy source that requires long transmission lines. Whether required or not, transmission and distribution investment are important factors that have to be considered when analyzing the economic feasibility of solar panels. Disregarding these investments can underestimate and ignore the potential benefits from solar systems (Borenstein, 2008). Most discussions of the real value of solar panels in fact revolve around the savings that can be derived from reduced transmission and distribution infrastructure investments (Borenstein, 2008). Typically, the economic feasibility of solar energy is driven by the considerable initial cost of the system and low operating costs, subsequently (SolarBuzz).

Finally, it is important to highlight that these economic studies typically ignore the monetary benefits of environmental preservation, carbon credits, increased security, and other social benefits.

3.6.5 Environmental Considerations

Solar panels are environmentally friendly, do not produce emissions, and are non-polluting. Therefore, they do not contribute to noise, air, or effluent pollution as well as carbon footprint or waste disposal. Moreover, photovoltaic panels do not need and use water for electricity generation. Solar panels furthermore contribute to reduced water consumption as solar energy offsets the likely energy production from conventional energy sources, which require water, to satisfy the same demand (SECO, 2008). Water is a precious natural resource and has been the subject of many discussions among environmental and political groups. Researchers have argued that clean and drinkable water will be scarce in the future. Given the worldwide preservation and conservation of water using an energy source that does not require water is beneficial.

Despite the environmental benefits of solar panels, some concerns have surged regarding the disposal of these panels at the end of their life (SECO, 2008). Photovoltaic technology uses heavy metals such as cadmium, and improper equipment disposal could

harm the environment. Moreover, whenever batteries are integrated with the solar system considerations regarding disposal and recycling must also be taken into account and addressed. Some solar manufacturers have, however, developed or implemented recycling programs and reprocessing techniques, which can overcome disposal concerns (SECO, 2008).

3.6.6 Potential Social Impacts/Benefits

It has been estimated that the solar industry could create more than 100,000 new jobs in areas such as, technology research and development (R&D), manufacturing, and electrical services (The UT, 2007). In general, researchers have found that renewable energy generates more jobs in construction and manufacturing sectors per megawatt installed, than fossil fuel (SECO, 2008). To ensure that all aforementioned social benefits will be attained and maximized for local communities, ODOT came up with "value based investment in renewable resource development" criteria in lieu of the common procurement practice of lowest cost. ODOT believes that "adopting value-based selection criteria will change the focus of public investments from cost to return on investment." The value-based procurement criteria include 1) use of local manufacturers, 2) long-term warranties, 3) world-class sustainable manufacturing practices, 4) direct and sustained local employment and training, 5) reinvestment in innovative technology and partnership with local universities, 6) guaranteed end-of-useful life product recycling, and 7) training of small local business in product installation. Following these criteria, ODOT can reach benefits beyond the social ones, such as environmental and financial (i.e., higher return on investment).

Perhaps the most important social benefit of solar panels is the system ability to furnish electricity in remote areas where the cost of building transmission lines could be prohibitive. Electricity is fundamental to societal welfare, quality of life, and economic development and it has been argued that solar panels can generate electricity without disturbing and impacting the community. A solar energy program can create public

involvement, increase environmental awareness, and provide an opportunity to educate the public about the importance of reducing the carbon footprint.

3.6.7 Safety Considerations

Solar panels do not pose any risks in terms of explosions, fire, disasters, structural failures, or accidents inherent to most of the other energy sources. The installation of solar panels has, however, raised some safety concerns regarding glint and glare (i.e., light reflectiveness), the clear zone, and protecting solar panels from cars and people (e.g., incidents and vandalism). These concerns can be easily overcome if the implementation of the solar panels is considered and incorporated in the design of new projects. On existing roads, unused terrain near exit ramps is seen as an ideal location to overcome safety problems. Guard rail can also be used as an alternative to minimize and mitigate safety concerns. ODOT reinforced the importance of safety zones and established minimum of 30 feet from the road's shoulders as minimal set-back for solar panels projects – other DOTs have adopted different minimal set-back requirements. Furthermore, the need to access the panels was also remarked on by ODOT as a safety concern in the pioneer project. Vehicles and trucks running in low speed or maneuvering on the highway pose risk for other drivers. To overcome this concern, ODOT mentioned the need for alternative access roads besides major highways (e.g., interstate). For example, for the pioneer solar project ODOT required a traffic control plan to be submitted to the District office prior the Utility Permit could be granted. FHWA has also to review the project characteristics and follow the utility permit process before it being issued. Furthermore, in the specific case of glint and glare issues some pioneer DOTs on solar project have argued, based upon the report issued by FAA in November 2010, entitled as "Technical Guidance for Evaluating Selected Solar Technologies on Airports", and observations from their pilot projects, that solar panels are designed to absorb and use sunlight, and not glint or glare issues have been noticed, reported, and presented on solar project in the ROW (Volpe Center, 2011).

3.6.8 Examples

Figure 3.6.8: Oregon Solar Array Project
Source: ODOT (2009)

ODOT is the pioneer in implementing solar panels in highway ROW. In December 2008, ODOT concluded the installation of the first solar arrays project at the interchange of IH 5 (see Figure 3.6.8). The arrays – consisting of 594 panels, ground-mounted - can produce up to 130 KWh annually, i.e., one-third of the energy needed on the site. The solar arrays feed the grid with the electricity produced during the day whereas at night the grid supplies the electricity for interchange lighting. According to ODOT, the project location was carefully selected and represented a major objective in the ODOT's initiative toward renewable energy and sustainable development. During the project site selection, ODOT developed a list of "Solar Highway Project Sitting General Criteria" that encompasses more than 10 different items that the site must have, such as:

1. at least 5 acres, and less than 20 acres if within rural zoning,
2. full access from a paved or gravel roadway to the array,
3. utility and road access available for at least 35 years,
4. within one-half mile of existing electricity grid,
5. fiber optic connectivity for security and research data transmission,
6. terrain slope lower than 15%, and
7. total solar resource fraction of at least 95% to be Economic.

Moreover, if the site is in ROW, a 30-foot clear zone must be excluded from the edge of the travel lane shoulders due to safety precautions. ODOT pointed to highway interchanges as sites that will likely meet all the previous criteria. In addition, ODOT believes that the most cost-effective solar project— which was the case in the pioneer

project—is when there is a public utility or private investor as partner and the system is connected to the grid, so both net metering policy and REC can be applied. To do so, ODOT developed an innovative business organization model (see Figure 3.6.9) that could best meet the project characteristics and needs. By adopting this business model, ODOT was able to incorporate all tax benefits (i.e., incentives and accelerated depreciation) and RECs with the project; thereby making the project economically feasible. Initially, ODOT partnered with Portland General Electric (PGE) – a local utility company – to develop the solar project. But, since neither ODOT nor PGE could take advantage of the Federal and State incentives – because they do not have tax liability, U.S. Bank was brought in as a tax equity investor (i.e., third party developer). In other words, U.S. Bank owns the solar project and leases the project back to PGE, which is liable for the maintenance, operation, and security of the solar system. In summary, U.S. Bank claimed the following tax benefits:

- State's Business Energy Tax Credit (BETC), which covered 50% of eligible cost (i.e., permit fees, equipment, engineering, design, materials, and installation);
- 30% of Federal Investment Tax Credit, granted by the Energy Policy Act of 2005 (EPACT) and extended by the American Recovery and Reinvestment Act of 2009 (ARRA);
- utility financial incentives; and
- accelerated depreciation.

Figure 3.6.9 clearly shows all parties involved and how the incentives were obtained by the developer.

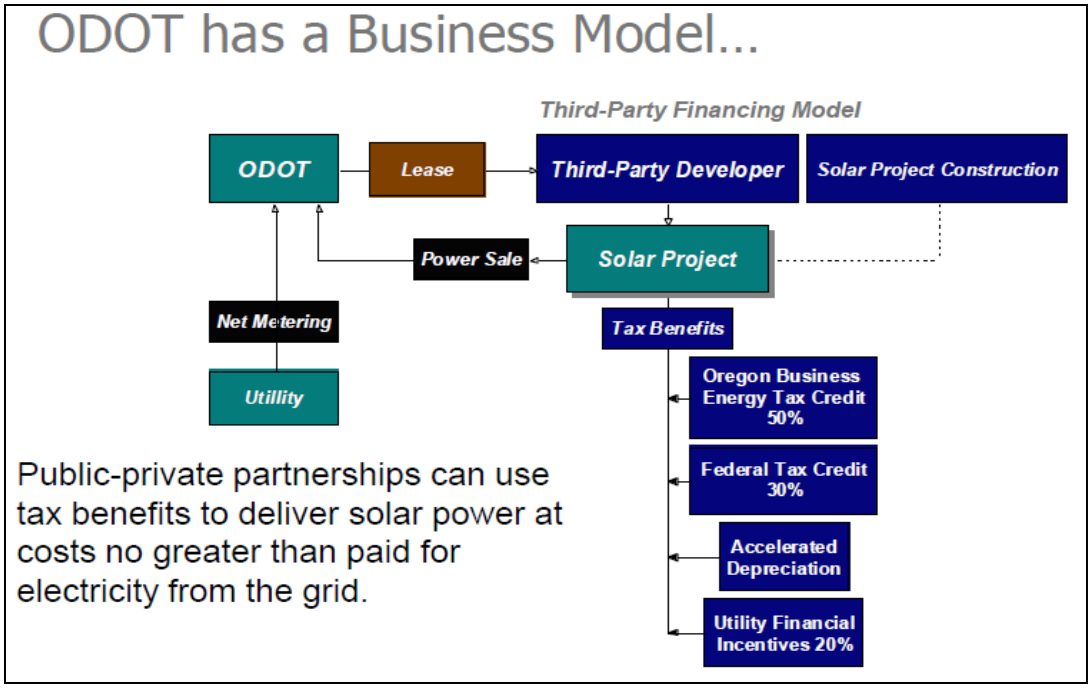


Figure 3.6.9: ODOT Business Model for Solar Array Project
Source: ODOT (2009)

ODOT estimated that installing solar arrays on 120 miles of ROW could supply about 47 million KWh of energy—equivalent to the annual energy consumption by ODOT. Regarding the lessons learned, ODOT pointed out the requirements for safety (e.g., clear zone, reflectivity, alternative site access, and traffic control), grid interconnection, avoiding shading, and security. Also, ODOT mentioned the need for an internal champion, leadership and management support, and commitment over time. However, ODOT asserted that solar resource development still requires incentives (e.g., tax credits)

Figure 3.6.10: Solar Array in Germany
Source: ODOT (2009)

and other financing support from federal and state governments to be financially feasible. For example, ODOT's project received $2 million in federal stimulus funding. Moreover, the carbon offset (i.e., REC) created by the solar energy project was valued at $30 per metric ton by the developers (i.e., PGE).

Besides the technical and economic factors previously mentioned and discussed, ODOT highlighted the importance of public outreach to educate the public on renewable energy technology, and effectively address any concerns raised by the public (Volpe Center, 2011). Finally, ODOT and its partner are planning to implement a new solar project on a 6.4 acre site adjacent to the Baldock Rest Area on IH-5. The project is intended to have 1.75 megawatt (MW) of installed capacity. A third project is also under development and it concerns a 3MW solar panel system on a terraced hillside near I-205 at the ODOT maintenance facility in West Linn (Volpe Center, 2011).

In California, Caltrans is partnering with the Sacramento Municipality Utility District (SMUD) to explore two 594-panel or 1.4MW projects, using photovoltaic and concentrator PV systems simultaneously. The two sites chosen are along the IH-50 and are currently under environmental review. The following sitting criteria were used to select the site:

- southern exposure to maximize generation potential;
- independent access to the site from an entry point other than the road itself;
- compliance with Caltrans's safety requirements (i.e., height and ~50ft of setback);
- close proximity to SMUD electrical facility to minimize transmission line costs;
- size of the land should be enough to guarantee economic feasibility and interest of private developer; and
- any competing commercial or private demand could exist for the land (i.e., developers' interest).

Unlike the ODOT model, in these projects SMUD will enter in to an agreement with a developer to design, construct, operate, and maintain the solar system. SMUD will then purchase the renewable energy generated from the developer and resell it to its

utility customers via its Solar Shares program. SMUD will pay Caltrans a fixed rent for using Caltrans's ROW. Public outreach was also an important step in the project. SMUD held four public workshops in September 2010 and developed visualizations (e.g., conceptual drawings, realistic photos, and 3D animation), to help explain the project (i.e., characteristics and objectives) to the publican. Currently, Caltrans is analyzing the feasibility of installing solar charge stations for electrical vehicles along highways, as well as the installation of solar panels for light poles (Volpe Center, 2011).

Colorado DOT (CDOT) and Ohio DOT have worked with local consulting companies and/or universities to identify opportunity zones and sites suitable for renewable energy and revenue generating projects in highway ROW. The identification has been made by overlaying ROW maps and geographic information system (GIS) data layers of renewable energy source potential (i.e., solar, wind, geothermal, and biomass resource maps). Currently, Ohio has various renewable energy projects going on – in different stages - in the highway ROW and on other real estate holdings (Volpe Center, 2011). For example, in 2010 the Ohio DOT, in conjunction with the University of Toledo, installed a 100KW solar array – composed of 966 rigid solar panels (see Figure 3.6.11) and 198 flexible solar panels (see Figure 3.6.12) – in the ROW of IH-280 and Greenbelt Parkway in Toledo, OH. The solar array supply all the electricity needed of the Veteran's Glass City Skyway Bridge, which has a 196-foot lighted pylon containing 384 light emitting diode fixtures (Volpe Center, 2011).

Figure 3.6.11: Rigid Solar panels installed along I-280 in Toledo, OH
Source: Volpe Center (2011)

Figure 3.6.12: Flexible Solar Panels installed along I-280 in Toledo, OH
Source: Volpe Center (2011)

MassDOT is working with the Town of Carver, Massachusetts, to allow the implementation of a solar array project – with 117 KW installed capacity - along Route 44. MassDOT will concede an easement to The Town of Carver, granting full access to the site, and the Town will be responsible for partnering with a developer to install, own, and operate the solar array. The Town will then purchase the renewable energy from the vendor to provide electricity to its new water treatment facility. MassDOT will receive $880 per year from the Town as payment for the land use. This value was reached after the Town got an appraisal of the value of the land. The site selected has an embankment at a 36-degree pitch, which makes it well suited for a solar array. The solar array will be set back 65 feet from the highway with direct access through the water treatment facility. However, as a condition to the easement the Town or developer will have to install guardrail on the roadside along the entire extension of the solar array. The easement also contains a clause regarding potential future relocation of the solar system. In case MassDOT needs the area for road lane expansion, the Town and developer will be required to remove the system without charging MassDOT (Volper Center, 2011). Furthermore, like CDOT and Ohio DOT, MassDOT has been working with a consulting firm to assess its real estate holdings and identify potential sites for large- and small-wind and solar projects. To do so, MassDOT and the consulting firm have overlaid GIS

data of its real estate holdings and National renewable resource data. MassDOT has come up with a set of criteria to assess the feasibility and suitability of site. The criteria include minimal site acreage, minimal set-back, access, proximity to utility interconnection, environmental issues, and proximity to residential areas and other developments (Volpe Center, 2011).

A number of solar projects can be found in European transportation ROW. Germany, for example, has invested €11 million in a solar panel project on top of a tunnel on highway A3 that has a 2.8 MW capacity (Figure 3.6.10). It is expected that the investment cost will be recovered in 16 years from cost savings. The 16,000 solar modules occupy 2.7 km and will provide electricity to nearly 600 houses (PV-tech.org, 2009). In the United Kingdom (UK), Netherlands, Switzerland, Austria, France, and Germany, as well as in Australia, solar panels have a "dual use." Besides energy generation, the panels also act as sound barriers (see Figure 3.6.13 and 6.14).

Figure 3.6.13: Solar Panels as Sound Barriers in Australia
Source: Chapa (2008)

Figure 3.6.14: Solar PV as Sound Barriers in UK
Source: www.photovoltaik.eu/ (2010)

Finally, solar panels can also be installed on buildings such as, offices, rest areas, and warehouses. The concept of green rest areas has been widely supported by some DOTs such as those in Connecticut, Massachusetts, Colorado, and Wyoming.

Specifically, the Wyoming DOT (WDOT) has 19 rest areas that use solar power to provide an estimated half of the rest areas' energy needs. To bring more attention and curiosity about renewable energy and GHG emission reduction, WDOT installed solar "flowers" at a rest area on Interstate 70 near Parachute in August 2010 (see Figure 3.6.15 and 6.16). In this case, the solar panels have been installed to have additionally an aesthetic function and educational purpose. In Texas, solar panels will be installed at two new rest areas along IH-20. Concerns still persist about the technology and long payback period for solar panels. On the other hand, the great value of a green energy source for environmental awareness, public image, and educational purposes can make this VEA worthwhile. Another example of promising solar technology is found on the Texas Capitol and is referred to as "solar paint," but the price of this technology is still very high.

Figure 3.6.15: Solar Flower in Wyoming Rest Area
Source: Garfield Clean Energy (2010)

Figure 3.5.16: Solar Flower in Wyoming Rest Area
Source: Garfield Clean Energy (2010)

3.6.9 Concluding Remarks

Solar energy technology is evolving. In general, the main barrier and drawback of solar panels is the price that is still high, although decreasing. Several federal and state government incentives have helped the adoption and construction of solar energy projects. In the case of solar panels in highway ROW, the following characteristics and factors have to be considered:

a. importance of site location and its characteristics (e.g., area, plainness, alternative access road, clear zone, avoiding shade, existing zoning laws, aesthetics, and sunlight intensity);
b. most cost-effectives application involves business model (e.g., P3), net-metering policies, and urban centers;
c. in remote areas, solar panels can be a solution to overcome or reduce the cost of transmission lines;
d. in urban areas, the distance from transmission lines is an important factor for the feasibility of the project;
e. Contractual agreements, liabilities, and responsibilities (e.g., site security, maintenance, vacating the site and removing the equipment, termination conditions, and ownership of the REC) are important, as well as shared risk and guaranteed of long-term commitments;
f. Involvement of the State Department of Justice (DOJ), as well as legal counsels is always recommended to advise and review the written agreements with private parties, and minimize any potential risks and undesired liability;
g. permits (i.e., utility accommodation, airspace lease, special use permit, and easement), and legal considerations regarding RECs, incentives, and patents need to be understood;
h. legal considerations, such as zoning laws and FAA permits, pertain in some cases;
i. potential conflicts with Texas's Highway Beautification Act and Wildflower program;

j. a renewable energy source, solar panels can be fundamental to carbon footprint reduction, less dependence on fossil fuels, and sustainability goals;

k. likely issues can arise when installing solar panels close to communities, due to a lack of knowledge and awareness about solar technology;

l. importance of upper-management support and an in-house champion, who would be responsible for leading and managing the entire implementation process;

m. need for effective public involvement and support; and

n. environmental impact analysis and assessment, including hazardous material, water quality, historic resources, and threatened or endangered species, as well as the costs of mitigating and remediating the impacts. Compliance with NEPA and other environmental regulations are essential.

3.7 WIND TURBINE

Wind turbines represent substantial environmental benefits in electricity generation. However, their efficiency depends on weather conditions and is a function of geographical characteristics. Wind energy has been developed rapidly in the U.S. and new types and models of wind turbines have been studied at several technological centers—specifically, the concept of small wind turbines because of reduced costs and ease of installation. Concurrently, new designs have been developed to generate electricity from the air turbulence associated with traffic flow. However, the viability of the latter models has not been proven yet.

3.7.1 Technical Feasibility

Different sizes of wind turbines have different electricity generation capacities. The wind speed—which changes with the altitude—is the major factor that determines the performance and viability of each type of wind turbine (Chapman et al., 2009). Hence, the equipment type has to be selected considering the site characteristics at the location of installation as it directly determines capacity and efficiency. Another point to consider is the available land area for the installation and minimal distance required between two adjacent wind turbines. Relative to other renewable energy sources, wind turbines require a larger area by KWh of electricity generated, but generally less than solar photovoltaic panels. However, new turbine models—called small wind turbines (see Figures 7.1 and 7.2)—have facilitated the use of wind energy in smaller areas.

Figure 3.7.1: Small Wind Turbine Model
Source: DOE (2005)

Figure 3.7.2: Small Wind Turbine Model
Source: DOE (2005)

Unlike solar panels, wind turbines can generate electricity any period of the day, although they are more efficient at night. Nevertheless, a wind energy system cannot be fully independent and reliable. To ensure electricity throughout the day, it is essential that the wind energy system be connected to the grid or backed up by batteries. A hybrid system that consists of a wind and solar system could be an alternative option as solar and wind peak productions occur at different times of the day. The hybrid system can have backup batteries also. The advantage of a hybrid system is that it can provide reliable off-grid energy—hence, saving on transmission line costs.

Figure 3.7.3: Wind Turbines near a Highway
Source: DOE (2005)

Important factors to consider when installing wind turbines are the construction plan, transportation requirements, and impacts on existing roads/traffic. (Figure 3.7.3 depicts wind turbines near a highway.) All analysis has to be done prior to deciding whether to move forward with the project. Furthermore, it is important that the wind system comply with

local electrical code requirements or, at least, with the National Electrical Code (NEC) published by the Fire Protection Association (DOE, 2005). Vendors therefore have to provide proof of certification prior to finalizing the agreement.

Wind turbines require more maintenance and supervision than solar energy systems. However, by investing in good equipment and starting with good design and proper installation, these disadvantages can be overcome (Homepower Magazine).

Figure 3.7.4 shows the estimated annual production capacity per m^2 of wind turbines in Texas. Texas has the best wind power generation potential in the U.S, specifically northern and southwestern Texas, as well as the coastal zones (SECO, 2008).

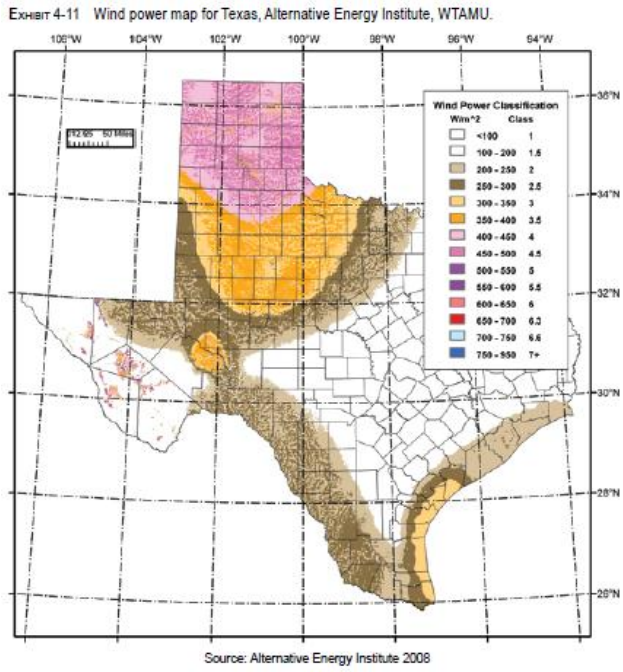


Figure 3.7.4: Wind Power Potential in Texas
Source: SECO (2008)

Novel models of small wind turbines that rely on the air turbulence generated by passing traffic are still largely in the development stage. The efficiency of these systems is largely a function of the traffic density. Moreover, over-the-highway turbines have to

allow trucks to pass under them. Also, the turbulence associated with cars may be insufficient for generating energy.

3.7.2 Political/Public Concerns

Research has shown that wind turbines can negatively affect nearby communities and lands; thereby resulting in concerns from politicians and the public, mostly landlords and farmers. Concerns have been expressed about "visual aesthetics, tourism, property value, public roads, public safety, and quality of life for people living close or at a distance from the developments" (Tillinghast, 2004). In England, for example, a British judge ruled that the wind turbines 0.35 miles away reduced property values by 20% due to noise, visual intrusion, and flickering of light (Tillinghast, 2004). Another study in Denmark also found that windmills decrease housing prices. In the U.S, realtors also believe that windmills impose a negative impact on nearby properties, although the impact on the price cannot be estimated. For the Cape Wind project in Massachusetts, for example, the impact on property values is estimated to range from 4.0% to 10.9% (Tillinghast, 2004). Because wind turbine installation can impact private properties, it is important to conduct public outreach prior to developing wind projects (SECO, 2008) on TxDOT sites. On the other hand, implementing a renewable energy source, such as wind turbines, at rest areas or weigh stations can be highly visible to the travelers and general public. This provides an opportunity to demonstrate environmental responsibility and gain political support (Chapman et al., 2009). For example, Executive Order 13514 issued by President Obama sets up "an integrated strategy toward sustainability in Federal Government and to make reduction of greenhouse gas emissions a priority of Federal agencies". Likewise, FHWA is endorsing and promoting the incorporation of climate change considerations into the transportation decision-making process. Furthermore, mid- and utility-scale wind turbines, as well as site characteristics and location can significantly reduce the common impacts of wind mills, thereby minimizing and/or mitigating any likely public and/or public opposition and concerns.

3.7.3 Legal Considerations

The Texas legislature passed Senate Bill 20 (SB20) in 2005 to increase Texas's renewable energy goal (SECO, 2008). However, the major legal consideration for this VEA concerns the use of government incentives by a public agency (i.e., non-tax payer). The solution has been to enter into a public private partnership (P3), where the private entity is the investor. Such a partnership (i.e., a P3) was used by ODOT to ensure the feasibility of the first solar ROW project. Also the numerous subsidies, rebates, and tax credits have different nuances and legal considerations that have to be understood to prevent misinterpretations and wrong considerations. Tied with SB 20, for example, is the RPS that regulates and drives the REC market and the Set-Aside program. Ultimately, the Net Metering Policy—which allows the renewable energy producer to sell back surplus energy produced to the grid at the retail price—could be important to the viability of the wind turbine VEA. In Texas, the Net Metering Policy is not obligatory within the Electric Reliability Council of Texas (ERCOT) competitive area. Rather it is a voluntary program in which the utility companies buy back the excess of production at a rate negotiated beforehand with the producer/consumer (SECO, 2008).

Another legal issue highlighted by ODOT and which most DOTs are not aware of is existing patents regarding the implementation of renewable energy sources along highway ROW. There are about 20 patents held by Green Highway Company that involve public land. Although ODOT has not been ignoring the existing patents, the agency commented on the possibility of challenging them and the need for a nationwide attempt (i.e., the FHWA, AASHTO, and the federal government) to overturn and decline them. Furthermore, ODOT cited the FHWA regulations (e.g., airspace lease regulation, easement conditions, and accommodation permit) that needed to be considered during the process and legal agreements (e.g., liability, responsibilities, access, maintenance, ownership over incentives and credits, land commitment, and shared risks) that must be negotiated. For example, ODOT mentioned the need to guarantee a long-term commitment to the application. The investor has to be legally assured that the project can

be only be removed if transportation need is clearly demonstrated. In addition, the DOT has to share risks with the investor to make the project economically feasible. The investor's responsibilities encompass construction and procurement of the project, maintenance of equipment and infrastructure, restoration, and preservation of the site. Also, ODOT recommends the involvement of the State Department of Justice (DOJ), as well as legal counsels to advise and review the written agreements with private parties to minimize any potential risks and undesired liability.

In addition, the height of some wind turbines can raise concerns. Some jurisdictions impose a limitation on height of the structures in residential areas because of view obstruction. Other concerns that wind turbine may provoke in residential areas involve noise, shadow, and light reflection. In airport zones (i.e., military or public airport), there are also height thresholds that must be addressed (DOE). This problem is exacerbated because of likely interference or obstruction with air traffic, aircraft navigation/communication systems, and military. Indeed, for any construction over 200ft, the form "74601-Notice of Proposed Construction or Alteration" must be filed with the Federal Aviation Administration (FAA) prior its outset. The FAA and the Department of Defense (DOD) will review the form and issue a permit. Typically, sites that are not within 3-5miles of an airport are not deemed as hazard to air traffic (Volpe Center, 2011). Massachusetts DOT (MassDOT), for example, points out the importance of verifying local zoning laws prior to moving forward with the project. MassDOT argues that most cities do not have zoning laws revised to address and regulate renewable projects. The lack of zoning law can defer or even impair the implementation of wind projects. Environmental analysis is also a requirement for any renewable energy projects on public land. A project must be in compliance with NEPA – either FHWA or DOE process, if not both – to receive an environmental permit. Ultimately, FHWA has to review all documents (e.g., permits, drawings, analysis of impacts, and contractual agreements) from the project – if located in highway ROW - to issue a final permit, allowing the project moves forward.

If wind turbines were placed upon the ROW through a lease, the provisions of Texas Administrative Code (TAC) Title 43, Chapter 21 ROW would set the rules for such asset development. Within Sub-chapter L –leasing of highway assets – under Rule 21.602 the Commission can authorize the lease of a highway asset if the interest to be leased isn't needed for a highway purpose during the life of the lease, and the use of the property will be consistent (and not impede) with safety, maintenance, operation and beautification of the system, plus the lease must be economically beneficial to the department.

Under TAC Rule 21.605 the use of leased ROW beneath the established gradeline of the highway shall provide sufficient vertical and horizontal clearances for the construction, operation, maintenance, ventilation, and safety of highway facilities (Rule 21.605 (b)). The use of leased highway ROW above the established gradeline of the highway shall provide for vertical and horizontal clearances (Rule 21.605(c)). Piers, columns, or any other portion of any improvements to be constructed on the leased ROW cannot be erected in a location that will interfere with visibility (or reduce the sight distance) *or in any other way i*nterfere with the safety and free flow of traffic or level of service on highway facilities. Structural supports for any improvements must be located clear of all horizontal/vertical dimensions specified by the department (Rule 21.605 (e)). All these restrictions and the use of the ROW shall not result in highway and non-highway users being unduly exposed to hazardous conditions (Rule 21.605 (f)). This includes a requirement in Rule 21.605 (g) for appropriate safety precautions and features *necessary* to minimize the possibility of injury to users of the highway or the leased facility be provided. The department will determine the acceptability of these features considering the adequacy for evacuation of structures in case of a major accident.

As has been noted in previous sections of this thesis, any placement of such structures on or adjacent to the ROW (federal and state) will also have to comply with the provisions of CFR, TC and TAC and not compromise, mobility, safety, and the ability of

the DOT to control its assets in the best interests of the general public, and will need to be charged at not less than fair market value.

Finally the placement of any such wind turbines within or adjacent to the ROW will need to be compliant with the rules regarding highway beautification, for example TXDOT would need to ensure that no stray light, or overt movement was visible from the wind blades and turbines to oncoming motorists.

3.7.4 Financial/Economic Feasibility

Wind turbines demand considerable initial investments, but can be, according to the DOE, competitive when compared to conventional energy sources (DOE). Relative to other renewable energy sources, wind turbines also have comparatively higher upfront costs, but the turbines are generally more efficient (i.e., in terms of cost per KWh produced). Moreover, the cost-effectiveness of wind turbines, in general, improves as the size of the rotor increases. For example, it is estimated that a small wind system can lower electricity bill by 50% to 90% (DOE). Nevertheless, wind energy development is still driven by incentives, subsidies, and tax credits. Similar to solar panels, transmission lines can determine the economic viability of the system. For example, if the wind turbines are installed near the end-user, considerable costs can be saved in terms of reduced transmission costs, enhancing the economic feasibility of wind (SECO, 2008).

To measure economic feasibility and compare alternative electricity generating options, the concept of levelized cost of energy (LCOE) is used. The LCOE is the average cost of the energy production by a particular energy system over a specified time period. For wind energy, LCOE includes the cost of turbine, the operation and maintenance expenses, interest rate (cost of money), inflation, cost growth of grid-based electricity, permitting and zoning cost, and life of the equipment—generally estimated as 25 years (Chapman and Wiczkowski, 2009). The main factors, however, are the installed cost and the annual net energy production (SECO, 2008). The installed cost is a function

of commodities' prices, including steel, copper, and cement, as these are the main materials that wind turbines are made of and needed for installation.

Another consideration is whether the system will be tied to the grid. Off-grid wind systems are battery based, which is usually expensive and demands intensive maintenance. The cost of maintaining the batteries must be offset by the cost saving of building transmission lines to connect the wind system to the existing grid. Battery-based systems are usually more feasible in very remote areas or where it is difficult to connect the renewable energy source to the grid (Homepower Magazine Website). For on-grid systems, "net metering" is essential to ensure the economic feasibility of the wind project and to decrease the payback period. Net metering allows the renewable energy producer to sell any surplus electricity generated—and returned to the grid—to the utility company, e.g., deducting any consumption from their electricity bill (DOE). Although federal regulations obligate utility companies to connect with and buy net electricity from small wind turbines, the utility should always be contacted prior to tying the wind system to the grid (DOE).

Finally, similar to solar panels, wind turbine owners can benefit from the REC market and set-aside program. Also, carbon dioxide trading could enhance the feasibility of both solar and wind energy systems. Once it becomes environmental policy in the U.S., these non-carbon emission energy sources will become even more valuable (SECO, 2008).

As previously noted, typically in wind turbine projects the DOT will enter in agreement/partnership with a utility company and/or private investor. Different business model can be used according to the DOT's goal and the interest of the investor. It is important to bear in mind that the attractiveness and economic feasibility of the project may vary depending on the business model adopted. The four business models generally used for wind projects are:

- The DOT purchase the whole renewable energy generated from the project. This model was used by Oregon DOT in its first solar pilot project;

- The DOT charge a rent fee – following the airspace lease policy – and does not purchase any renewable energy or acquire any REC. This model is being used by Caltrans and Massachusetts DOT;
- The DOT acquires only the REC from the project and the investor sells the electricity generated as non-renewable;
- The DOT owns and operates the entire wind system. This model is generally used in DOT's facilities (i.e., offices, rest areas, and maintenance facilities). In the case of highway ROW, Ohio DOT adopted this model in its first renewable project, but afterwards ODOT realized and asserted that owning and operating wind systems is not a sustainable business model for ROW projects, once the cost of renewable energy system is still high – because DOTs cannot be benefited from incentives - and thus prohibitive for DOTs.

3.7.5 Environmental Considerations

Similar to other renewable energy sources, wind energy is environmentally friendly as it reduces the carbon footprint by producing clean energy without emitting CO_2, NO_X, and SO_X. Similar to solar panels, it also does not require water for generating electricity (SECO, 2008). Furthermore, by installing wind turbines in the highway ROW, drivers can be made aware of the importance of renewable energy as an alternative energy source. However, most wind turbines represent a hazard to birds and bats. In Kansas City, however, a new type of turbine was installed on IH 435 that overcomes this problem. The design of this wind turbine was developed by A. L. Huber Construction and is found near the Interstate 435 and Roe Avenue (see Figure 3.7.5). Although, this model does not resemble a traditional wind

Figure 3.7.5: Kansas City Model
Source: KMBC (2009)

mill, it has the most advanced wind technology and is capable of generating 5,000 watts of power (KMBC, 2009). Moreover, this wind turbine model needs only 6 mph of wind to produce energy. Major benefits are decreased or avoided bird kill, noise generation, and ice throw, which are common disadvantages of traditional wind turbines (KMBC, 2009).

Another environmental problem concerns the likelihood of oil leaking or a turbine's motor catching fire. The leaking can contaminate the soil, as can the detergent generally used to clean the turbine. Fire (see Figure 3.7.6) always poses a danger for the environment, especially if it is not controlled early and easily and extinguished. Other environmental concerns entail noise and visual impacts. While the noise from blades and gearboxes has been reduced with newer models of wind turbines, the visual impacts imposed are sensitive to the location of the wind turbine. For example, rural and tourist areas are more sensitive about visual impacts than urban areas (SECO, 2008). Finally, in the case of both solar and wind energy systems, the stand-alone off-grid systems impose environmental concerns because of the batteries. Battery maintenance requires precautions and plans to avoid site contamination, and battery usage and disposal are potentially damaging to the environment. If batteries are used, a disposal plan needs to be developed and implemented. Wind energy systems connected to the grid are thus usually the most cost-effective and environmentally friendly option (Homepower Magazine, 2010).

Figure 3.7.6: Fire on Wind Turbine Rotor
Source: Hoffman (2010)

3.7.6 Potential Social Impacts/Benefits

Wind energy systems can potentially provide electricity to remote areas, thus benefiting distant communities. Also, by installing a renewable energy source, DOTs can make a statement and educate the public about green energy and the importance of reducing the carbon footprint. The installation and maintenance of wind turbines (i.e., aside from the equipment manufacturing and operation) involves a considerable workforce that can benefit rural economic development (SECO, 2008). On the other hand, wind turbines cause noise and shadows, and reflect sunlight. Those that live near wind farms have complained about these impacts. Also, the literature revealed that wind turbines near television antennas, telecommunication towers, or radar can cause interference with the signals, thus directly impacting the quality of life of those who live nearby (Tillinghast, 2004).

As previously mentioned, wind turbines can potentially decrease nearby property values and consequently property tax payments. Cities impacted by wind turbine developments could thus be obligated to raise taxes to recover the revenue lost. Property owners outside the wind turbine impact zone could thus be burdened with raised taxes (Tillighast, 2004). Furthermore, in regions where environmental tourism is an important economic activity, wind developments can be detrimental to tourism and therefore to the businesses that serves these visitors. Surveys and research have demonstrated that people who seek to visit scenic, rural, and pastoral environments are not willing to go to places where the view could be affected by industrial devices such as wind turbines (Tillighast, 2004).

3.7.7 Safety Considerations

Wind turbines along ROW represent a number of risks. Firstly, any structural failure (e.g., blades or any piece falling or flinging) can be disastrous, as Figure 3.7.7 shows. Whenever wind turbines are placed near communities or the road, the consequences are exacerbated and precautions have to be taken. An accident in November 2006 near Oldenburg in northern Germany serves as an example. A sudden gust of wind ripped the tip off of the rotor blade throwing the heavy, 10-meter (32 foot) fragment a distance of 200 meters. Although no injuries or serious damage resulted, the incident raised a new concern. Secondly, in areas with hail and snow (ice), if any piece of ice hits the blade, it can be thrown over a long distance with high intensity, potentially resulting in accidents. In addition, the ice can damage the structural integrity of the wind turbines and, hence, create risk for the surrounded areas. Therefore, a safety radius of 750 to 1,000 feet around the wind turbine is recommended (Tillinghast, 2004). Blade and wind turbine failure is depicted in Figures 7.8 and 7.9.

Figure 3.7.7: Wind Turbine Wreck
Source: Piepkorn (2008)

Figure 3.7.8: Blade Failure
Source: OC Safety News (2011)

Figure 3.7.9: Wind Turbine Failure
Source: Hoffman (2010)

Thirdly, wind turbines along ROW poses the likelihood that oil can spill from the turbine onto the road, which could represent hazardous condition if the oil makes the pavement slippery. Fourthly, wind turbines can be a distraction to drivers and, thus, can provoke accidents. In England, government inspectors withdrew support for a wind power plan, alleging the wind turbines would affect road safety adversely (Tillinghast, 2004). Finally, like solar panels, wind turbines placed along ROW may pose a danger for vehicles that accidentally run off the road.

3.7.8 Examples

Perhaps the most innovative wind turbine model proposed for highway ROW was designed by a student from Arizona State University (see Figure 3.7.10). As already mentioned, this model intends to harvest energy generated by the traffic turbulence and convert it into electricity. It is estimated that, at an average speed of 70 mph, each turbine could generate 9,600 KWh per year (AutoblogGreen, 2007). However, similar to the traditional wind turbines, this model presents issues related to safety (e.g., ice throw, broken parts falling, etc.) and the environment (e.g., bird kill). Furthermore, some questions remain unanswered regarding whether traffic turbulence could be maintained and keep the turbines working, as well as the efficiency of the model (AutoblogGreen, 2007).

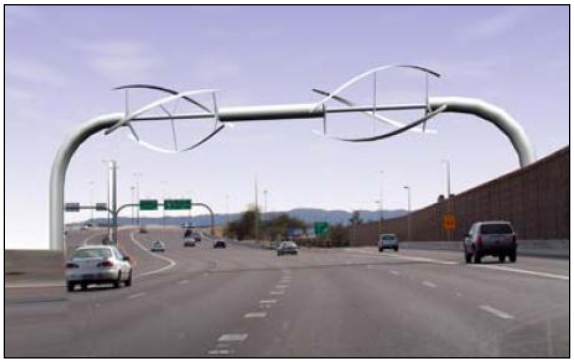


Figure 3.7.10: ASU Contest Design
Source: Abuelsamid (2007)

A different model of wind turbine, proposed by Mark Oberholzer, is known as the New Jersey barrier (see Figure 3.7.11). In this model, wind turbines are embedded into the New Jersey barrier that protect or separate road lanes. This new model for harvesting energy from vehicle turbulence is still being researched. However, Oberholzer stated that the barriers "are perfectly positioned to take advantage of the wind that passing cars generate" (Cavanaugh, 2007). Oberholzer acknowledged some technical issues concerning connecting the system to the grid. This issue can, however, be overcome if the power is used on site. An example would be to install and integrate the barrier along a subway or light-rail train system.

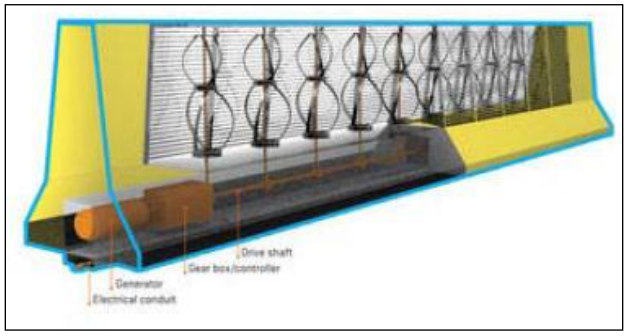


Figure 3.7.11: New Jersey Barrier
Source: Cavanaugh (2007)

Finally, TAK Studio envisioned and designed a wind turbine similar to the model developed by the ASU student (see Figure 3.7.12). The TAK studio aims to harness the energy generated by the traffic turbulence and the wind and convert it into electricity. However, in this case, the device would supply only the energy needed to illuminate the highways. A more realistic example can be found in Israel, where the Israel National Roads Company is conducting the feasibility studies (i.e., front-end planning) to install small wind turbines tied in lighting poles along the coastal road, taking advantage of sea winds; and in Twain, where small wind turbines are being incorporated with parking lots (Volpe Center, 2011).

A number of examples exist where wind turbines have been installed at rest areas to provide energy and promote renewable energy generation. In Texas, two 50 KWh wind turbines have been installed at two rest areas—on IH 40 close to Amarillo and close to Lubbock. Each turbine costs about $2 million and supplies part of the electricity used by the rest area. According to TxDOT, the wind turbines spark the curiosity of most visitors and, therefore, "promote" green energy awareness. A wind turbine project has also been explored at the Blandford rest area on the Massachusetts Turnpike (see Figure 3.7.13). A 400-foot-tall wind turbine with the potential to generate 1.5 MW has been considered to be installed in the middle of the 68-acre site (see Figure 3.7.13), reaching around 1,500ft of set-back from the highway. This device is expected to generate 3,000 MWh of electricity per year, enough to supply the energy need of nearly 400 households. The electricity will potentially be sold to Western Massachusetts Electric Company or another utility provider. The company responsible for installing the wind turbine leases the land and will pay the Massachusetts DOT a rent equivalent to 3.5% of the annual power sale with a minimum rent guaranteed at $15,000 per year over a 20-year lease period (Shoemaker, Jace 2010). However, the registered voters at Town of Blandford recently defeated a wind power zoning bylaw, what raised some concerns and questions about the future and viability of the project (Volpe Center,2011). In case the project moves forward, MassDOT envisions as business model to charge the developer a rent fee of 3.5% of the power sales, with a minimum of $15,000 a year. The Ohio DOT (ODOT) is installing a small 32KW wind turbine at a maintenance facility in Northwood, adjacent to highway ROW along I-68. The wind turbine is approximately 100 feet tall and is located 140 feet from the roadway (i.e.,

Figure 3.7.12: TAK Studio Design
Source: Voelcker (2010)

setback). The wind system proposed is intended to help to provide up to 65% of the electricity consumed by the facility (Volpe Center, 2011).

Figure 3.7.13: Location of proposed Blandford rest area wind turbine
Source: Volpe Center (2011)

Ultimately, a broader approach has been undertaken by Colorado DOT (CDOT), Ohio DOT, MassDOT, and Illinois DOT that have worked with local consulting companies and/or universities to identify opportunity zones and sites suitable for renewable energy and revenue generating projects on highway ROW, rest areas, and weigh stations. The identification has been made by overlaying ROW maps and geographic information system (GIS) data layers of potential renewable energy source (i.e., solar, wind, geothermal, and biomass resource maps) (Volpe Center, 2011).

3.7.9 Concluding Remarks

Wind turbines raise several concerns and relevant aspects that directly impact the feasibility of this VEA and, therefore, must be carefully addressed. These factors include:

a. importance of site location and characteristics (i.e., electricity generation is site-driven, such as area, plainness, alternative access road, clear zone, wind obstruction, existing zoning laws, aesthetics, and average wind speed);

b. area required/impacted by wind turbines and minimal distance required between two adjacent wind turbines—small wind turbines require less area and shorter distance;

c. maintenance study and access are crucial (i.e., intensive maintenance);

d. likely issues can arise when installing wind turbine close to communities (e.g., noise, shade, tourism, and property value);

e. potential conflicts with Texas's Highway Beautification Act and Wildflower program;

f. wind turbine height can be a limited by law enforcement (e.g., zoning law and FAA regulation) in some locations (e.g., neighborhood and airports). It is fundamental to consult FAA, DOD, and the Joint Program Office (JPO) in the very beginning of the project and prior moving forward with further studies and negotiations in order to avoid delays and unnecessary efforts and expenditures;

g. safety considerations play a decisive role on site and equipment selection (e.g., possible structural failure, hail and snow being thrown with power against vehicles, safety zone, oil being spilled onto the pavement, and wind turbine posing as distraction for drivers);

h. wind turbines can help to reduce carbon footprint and attain renewable energy goals. But the wind turbines can also pose some risks to the environment, such as bird and bat deaths, noise, shadows, visual impacts, oil leak, contamination from the detergent used to clean the wind turbines, and fires on the turbine rotor;

i. wind turbines typically have high initial costs but better cost per KWh produced compared to other renewable energy sources;

j. in remote areas, solar panels can be a solution to overcome or reduce cost of transmission lines;

k. in urban areas, the distance from transmission lines is an important factor for the feasibility of the project;

l. in remote areas, wind turbines can be a solution to overcome or reduce cost of transmission lines;

m. business model, permit (i.e., utility accommodation, airspace lease, special use permit, and easement), and legal considerations regarding REC, incentives, and patents;

n. contractual agreements, liabilities, and responsibilities (e.g., site security, maintenance, vacating the site and removing the equipment, termination conditions, and ownership of the REC). Importance of shared risk and guarantee of long-term commitment;

o. involvement of the State Department of Justice (DOJ), as well as legal counsels is always recommended to advise and review the written agreements with private parties, and minimize any potential risks and undesired liability;

p. legal considerations regarding RECs, incentives, and patents;

q. as renewable energy source, wind turbines are important to carbon footprint reduction, less dependence on fossil fuels, and sustainability;

r. importance of upper-management support and an in-house champion, who would be responsible for leading and conducting the entire implementation process;

s. need of effective public involvement and support. Importance of conducting an effective and efficient public outreach; and

t. environmental impact analysis and assessment, including hazardous material, water quality, historic resources, and threatened or endangered species, as well as the costs of mitigating and remediating the impacts. Compliance with NEPA and other environmental regulations.

3.8 SPECIAL ROAD (SOLAR ROADS / PIEZOELECTRIC ASPHALT)

Many research studies have been conducted to use the road pavement for generating electricity. Most of these applications are, however, in development and testing stage. Solar road, for example, is an application that uses solar panels – usually

12’x12’ - in lieu of asphalt or concrete pavement. In the case of piezoelectric asphalt, piezoelectric cells are embedded in the asphalt pavement. The piezoelectric cells convert the mechanical deformation of the pavement into electricity. Innowattech, an Israeli company, and Technion Israel Institute of Technology are working on a pilot project that will produce an estimated of 200KWh per 0.625 miles lane.

3.8.1 Technical Feasibility

As previously stated, both the solar road and piezoelectric asphalt application have not been proven to be technically feasible. However, pilot tests have been conducted to assess potential obstacles and requirements, as well as the actual efficiency of each technology.

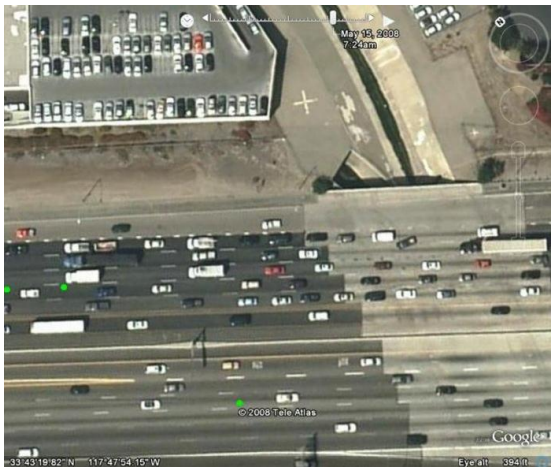


Figure 3.8.1 - Orange County, CA during work traffic
Source: Solar Roadways (2010)

In the case of the piezoelectric road application, the efficiency of the application depends on the traffic volume and vehicle weight (i.e., trucks and cars). An Associate Professor at Ryerson University in Toronto, Lloyd Alter, is skeptical of the efficiency of the application arguing that piezoelectric road “is converting the energy from gasoline, paid for by the driver and inefficiently converted into forward motion, into electricity by increasing drag”. Furthermore, concerns exist about the impact on pavement structure, durability, and performance. The piezoelectric cells require mechanical deformation to function and; therefore, the application is limited to flexible pavement (i.e., not rigid).

In the case of solar roads, a major question is whether the panels are capable to efficiently generate energy on roads with high level of traffic and congestion. An assessment made by Solar Roadways concluded that even on congested roads, the space

between vehicles is enough to generate a reasonable amount of energy in sunlight conditions (see Figure 3.8.1).

Concerns also exist about the strength and loading support of the panels (i.e., structural integrity), especially for moving heavy trucks. The developers, however, assert that the panels are designed to endure heavy loads and intense traffic. Another potential concern surrounds the placing of the panels on an irregular surface and keeping the joints between adjacent panels smooth and continuous. The solution to overcome this last problem on pilot test was to lay down the panels over a concrete bed. The cost of this solution, however, may turn the application economically unfeasible. Thus far, both pilot tests have not shown any results and as previously mentioned they are in an infancy stage. In the case of solar roads, for example, the developers are currently working on strength of the panel and glass, as well as on the development of the electrical system.

Furthermore, concern has been expressed about how to conduct pavement maintenance or rehabilitation activities, as well as how disruptive intervention will be to daily traffic. For piezoelectric roads, in particular, the question remains how to integrate and schedule pavement intervention with the piezoelectric cell maintenance? Finally, questions about surrounding ownership and liability persist with these applications.

3.8.4 Political/Public Concerns

In general, new inventions and technologies are often met with skepticism and concerns from users and investors and therefore need to be fully tested and proved to secure support. These applications may thus face some opposition and obstacles to implementation in the short term until results regarding efficiency, reliability, and cost-effectiveness have emerged and been published. A solar road pilot project is being funded by the U.S. DOT in Idaho. The piezoelectric asphalt application, on the other hand, has evoked questions and doubts in the scientific community.

The prime political concern, however, is how integrate all agencies and parties (e.g., Department of Energy, DOT, General Land Office, FHWA, and utility companies) likely involved within this VEA to work together with synergy and harmonically.

3.8.4 Legal Considerations

Since these applications are new and innovative, no legal or regulatory precedent pertaining to these technologies exist (e.g. FHWA and AASHTO). Also, pavement and road design standards are not necessarily applicable to ensure the quality and performance of these applications. Specifically concerns regarding ownership and liability of the pavement, maintenance and operation, as well as the performance and quality of the final product (i.e., solar pavement) have to be addressed. Also, although these technologies are considered "green" and renewable sources of energy, questions remain as to what incentives, credits, and REC markets apply do these applications legally qualify for. Finally, another legal issue initially involves the competitive bidding process that is required for most of public projects. Given only one vendor, contractors and other stakeholders may plead unfair competition and hinder the implementation of the application.

3.8.4 Financial/Economic Feasibility

Since both applications are still in the development stage costs and economic feasibility information are largely unavailable. Questions about the cost of installation, frequency and cost of maintenance, system efficiency, and durability still has to be answered to have a better understanding about the prospects of the application. However, similar to other renewable energy sources, these applications may also be qualified for federal and state incentives. In addition, the infrastructure needed to implement the solar road application – i.e., the conduits – can potentially be used to acquire additional revenue through leasing it to service providers such as, internet, cable TV, and telephone companies (Solar Roadways). Also, recharge stations for electric vehicles (EV) can be installed at the solar parking lots or along the solar roads, adding value to the asset.

Finally, developer argues that the cost of the solar panel pavement would need to be offset by the cost of power plants, grid infrastructure investment, and traditional pavement expenditures. The developer also estimates a 20 years of payback period for the solar road application A detailed study or analysis of the costs of the solar road application is, however, not available.

3.8.5 Environmental Considerations

Similar to Solar panels, solar roads are environmentally-friendly, do not produce emissions, and are non-polluting. Therefore, it does not contribute to noise, air, or effluent pollution as well as carbon footprint or disposal wastes. Moreover, photovoltaic panels – that also are used as pavement - do not need and use water for electricity generation. Solar panels furthermore contribute to reduce water consumption since solar energy offset the likely energy production from conventional energy sources, which require water, to satisfy the same demand (SECO, 2008). Water is a precious natural resource and has been the subject of many discussions among environmental and political groups. Researchers have argued that clean and drinkable water will be scarce in the future and, hence, for the worldwide preservation and conservation of water using an energy source that does not require water is beneficial.

Despite the environmental benefits of solar panels, some concerns have surged regarding the disposal of these panels at the end of their life (SECO, 2008). Photovoltaic technology uses heavy metals such as, cadmium, and improper equipment disposal could harm the environment. Some solar manufacturers have, however, developed or implemented recycling programs and reprocessing techniques, which can overcome disposal issues (SECO, 2008).

In the case of piezoelectric cells, a concrete or asphalt layer will still be needed, but the thickness will likely be lower. Finally, both applications facilitate the implementation of electric-vehicle recharging stations along the roadways and, thereby incentivizing the adoption and use of electric vehicles, which are environmental friendly.

3.8.6 Potential Social Impacts/Benefits

The frequency and level of technology maintenance could potentially impact traffic flow and congestion, consequently, impacting the users and nearby communities. A potential benefit, however, involves job creation as these applications would generate employment opportunities in equipment manufacturing. Furthermore, the construction of these roads (i.e., solar roads or piezoelectric roads) may be more labor intensive than traditional road projects, which are highly mechanized. Another indirect social benefit would stem from installing electric vehicle recharging stations along highways and at parking lots. These stations are becoming popular and available at retail stores and gas stations; thereby enhancing the practicability of using electric cars for long trips and facilitating the day-by-day operation of electric-vehicle owners. Electric vehicle recharging stations can therefore generating extra revenue. Furthermore, solar roads inherent capability of eliminating snow and ice accumulation on the pavement surface, hence, no more school and business will result in closures because of weather conditions (i.e., snow), benefiting students, business owners, and the community at large.

3.8.7 Safety Considerations

In the case of the solar road application, a major concern revolves around the skid resistance (i.e., adherence between tire and pavement), mainly in rain and snowy conditions. The solar road developers, however, argue that the solar panels are "rugged" enough to prevent skids, contain "LED lighting (to enable real-time communication with drivers)", contain "heating units (to prevent icing)", as well as wildlife detector sensors. The LED lighting could be used to instruct drivers to "slow down" (see Figure 3.8.2) or about a detour ahead yielding safer driving conditions especially at night. The heating units in the surface of the panel will also avoid snow and ice buildup, rendering safer winter driving conditions. The wildlife detectors will be integrated with the lighting system to warn drivers to "slow down". Therefore, the developers assert that all these devices will enhance the safety of the roadway. On the other hand, as mentioned before the irregular base may result in the level of adjacent panels being different at the joints, causing discomfort and risk to road users. Likewise, for piezoelectric application, possible excess pavement deformation or patch can be detrimental to the safety and comfort of the drivers.

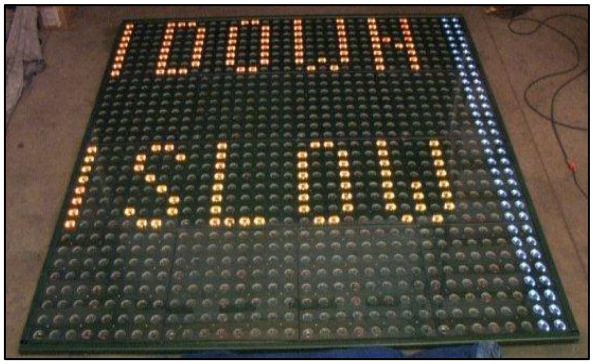


Figure 3.8.2 – Solar Road Module
Source: Solar Roadways (2010)

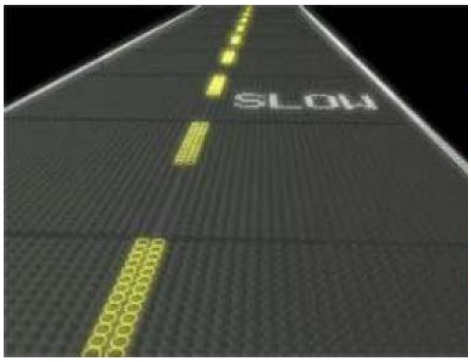


Figure 3.8.3 – Solar Road Simulation
Source: Solar Roadways (2010)

3.8.8 Examples

Two examples of these applications are currently being piloted. In the case of the solar road, the U.S. DOT has provided $100,000 for a pilot project in Idaho being conducted (see Figure 3.8.3) by Sagle – Idaho startup Solar Roadways. Sagle aims to build a prototype solar road to assess the potential cost-benefit and technical feasibility of the technology. For this pilot project, a 36x12 section of a parking embedded with 12'x12' solar panels – that cost $10,000 each - on its surface is being tested.

In terms of the piezoelectric pavement application (see Figure 3.8.4), Israel has been the pioneer in testing the system. As part of a pilot project, the Innowattech – an Israeli based company- inserted piezoelectric generators on 33 feet of a road in Haifa at 2 inches below the surface. A major challenge was to prove that the system would not affect the integrity and performance of the pavement. Monitoring has shown that no pavement degradation had occurred. Moreover, it has estimated that half a mile of a busy lane could produce enough energy for nearly 150 homes.

In the case of both applications, no results or reports have been published.

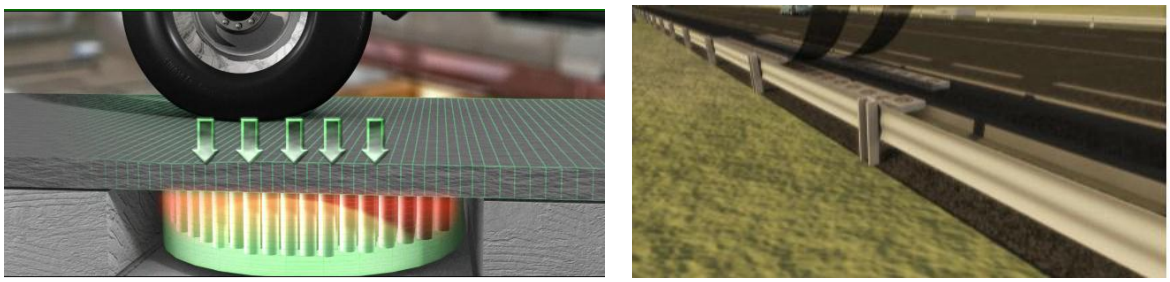


Figure 3.8.4 – Piezoelectric Cell Illustration
Source: Innowattech (2010)

3.8.9 Concluding Remarks

Because both of these applications involve new technology and still in testing stage, they have some peculiar characteristics that must be understood and addressed. Major considerations and comments regarding these VEAs are:

a. technologies are still in developing stage and being tested;
b. only one pilot project for each technology exists and no data/result has been published yet;
c. needs for a different approach regarding business organization and parties involved (i.e., DOT, Utility Company, DOE, Vendor, and Investor);
d. skepticism of some Pavement Engineers about the real efficiency and reliability of the piezoelectric pavement system;
e. concerns about ownership of the pavement and maintenance, as well as liability;
f. solar road can enhance road safety (e.g., LED lighting can transmit message for drivers, snow and icing prevention, wildlife detection, and pavement roughness and skid resistance), but can also raise some concern (e.g., light reflection); and
g. concerns about the pavement structure, deformation

3.9 GEOTHERMAL AND CARBON ENERGY

Geothermal energy is also a renewable energy source and it involves the use of the "earth's heat" to generate electricity and/or hot water. The "earth's heat" can be extracted in two manners. First, by drilling wells deep into the earth, electricity can be produced using heated water (i.e., hydrothermal heat). Second, in areas where the earth's surface has high temperatures, geothermal heat pumps (GHP) can be used to heat and cool buildings by exchanging heat between spaces (SECO). The heat pump system is the simplest way to exploit geothermal energy and is composed of pipes buried near the surface of the ground—with high surface temperature—and fluid (usually water) circulating between the pipes and the pump (see Figure 3.9.1). Similar to an air conditioner or furnace, the fluid exchanges heat between the ground and the building. This system is generally used when the outside temperature is uncomfortably cold or hot (Wendell et al.). Geothermal systems – similar to GHP – have been applied as a de-icing mechanism on highways since late 40's. In this system, "heat pipes" are embedded in the pavement, where snow or ice layers have been constantly critical. According to up-to-

date observations, it has been estimated that geothermal systems could keep the pavement free of snow and ice at temperature as low as -10°F (-23°C). Several DOTs have been adopted the geothermal system in very specific location, such as New Jersey, South Dakota, Wyoming, and Virginia, as well as countries such as, Japan, Switzerland, and Argentina (Volpe Center, 2011).

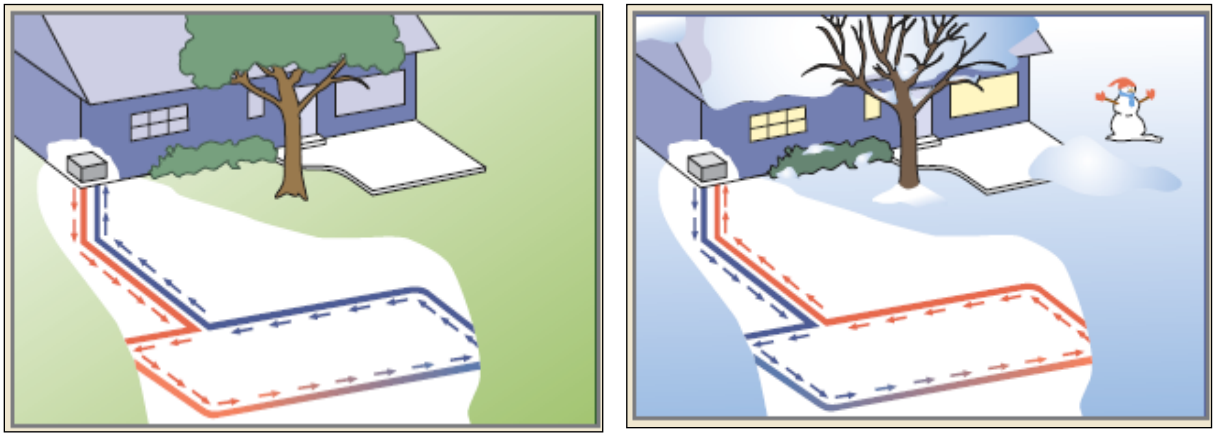


Figure 3.9.1: Heat Pump Operation
Source: Wendell et al. (2003)

3.9.1 Technical Feasibility

Geothermal energy is potentially an important natural resource that is constant and unaffected by changes in the earth's surface conditions that affect other renewable energy sources (SECO, 2008). The greatest advantages of geothermal energy are that it can be generated on a small scale and anywhere in Texas. The major challenges, however, are to determine where and how deep the geothermal resources are located and how to get to and exploit the resource (SECO, 2008). Basically, four different methods of exploiting geothermal energy can be used depending on the underground characteristics (see Table 3.9.1). In areas with low soil temperature, the heat pump can be applied as the geoexchange systems. The geothermal heat pumps (GHP) (see Figure 3.9.2) transfer heat between warm and cool areas and can be implemented at offices and rest areas. Geothermal heat pumps are typically integrated with HVAC systems, improving their

efficiency and, consequently, saving electricity. The U.S. Environmental Protection Agency (EPA) regards the GHP as the most energy-efficient, environmentally clean, and cost-effective method of temperature control (SECO, 2008). In areas with high soil temperature and enough energy for electric power generation, a geothermal power plant can be implemented. In a traditional geothermal power plant, a well is drilled to extract steam and water from a geothermal reservoir. The steam is separated from the water and conducted to turbines that generate energy. The steam is then condensed and either disposed of or reused (see Figure 3.9.3). Finally, areas with hot water available can use the hot water directly for several purposes. The State Energy Conservation Office (SECO, 2008) lists potential direct use as (a) generating electricity for industrial heating needs, (b) fish farming, (c) food processing, (d) pasteurizing milk, (e) spa and hot springs, (f) nurseries, and (g) residential and commercial heating. In Texas, extensive experience and knowledge exist about soil features and composition, because of the oil and gas exploration in the state. Detailed analyses of heat resources, reservoirs, and deep water availability can thus be readily accessed. In fact, the existing oil and gas wells can be used for generating thermal energy, thereby reducing the investment required (SECO, 2008).

Table 3.9.1: Classification of Geothermal Energy
Source: SECO (2008)

EXHIBIT 7-1 Temperature-Based Classification of Geothermal Energy

Resource Temperature	Best Applications For Geothermal Heat*
Surface Temperature (40°F to 80°F)	Geothermal HVAC systems for homes and buildings
Low Temperature (70°F to 165°F)	Direct Use: agriculture and greenhouses, aquaculture (fish farming), mineral water spas and bath facilities, district water heating, soil warming, fruit & vegetable drying, concrete curing, food processing
Moderate Temperature (165°F to 300°F)	Binary fluid generators for electrical production; Direct Use: absorption chillers, fabric dyeing, pulp and paper processing, lumber and cement drying, sugar evaporation
High Temperature (>300°F)	Electricity production, minerals recovery, hydrogen production, ethanol and biofuels production

*Uses of geothermal energy adapted from the Geothermal Education Office materials.

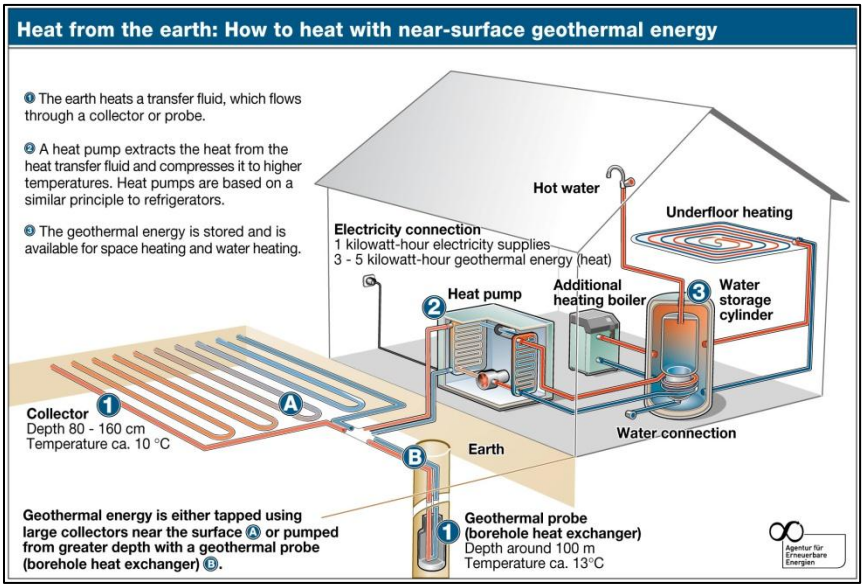


Figure 3.9.2: Generating Geothermal Energy
Source: ESM (2010)

SECO has worked with Southern Methodist University's Geothermal Laboratory and The University of Texas at the Permian Basin to analyze and determine the potential for geothermal energy generation in different regions of Texas. Figure 3.9.4 illustrates the available geothermal resources across the state. The orange color depicts where hydrothermal resources can be explored for space heating, fish farming, desalinization, and resort spas. Hydrothermal resources are defined as hot water and/or steam found in fractured or porous rock at moderate depth. The green color depicts geopressure resources that can be used for heating, enhanced oil recovery, and electricity generation. Geopressure resources are hot brine water saturated with methane recovered from large and deep aquifers under high pressure. Finally, the blue color depicts areas with hot dry rock that can be used for heating and electricity. Hot dry rock is a heated geological formation and, unlike hydrothermal resources, it does not contain water. In addition, the map also depicts five regions in Texas that have great potential for geothermal electrical power generation (SECO Website). It should be noted that only a few Texas aquifers have been analyzed and their thermal characteristics assessed (SECO, 2008).

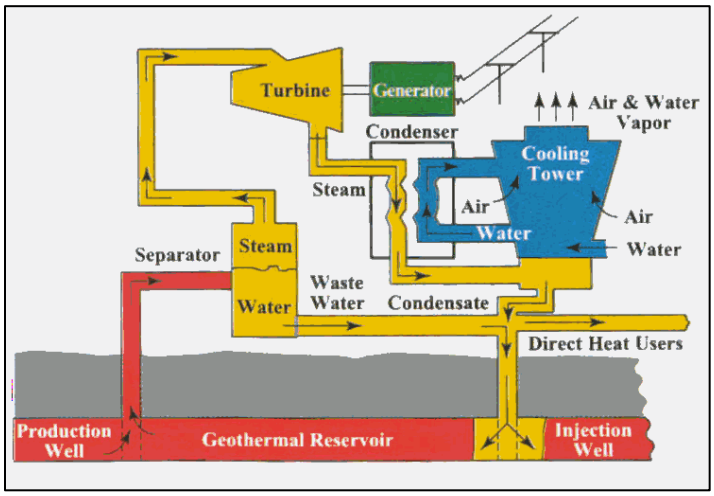


Figure 3.9.3: Geothermal Energy Process
Source: Planet Earth and Humanity (2010)

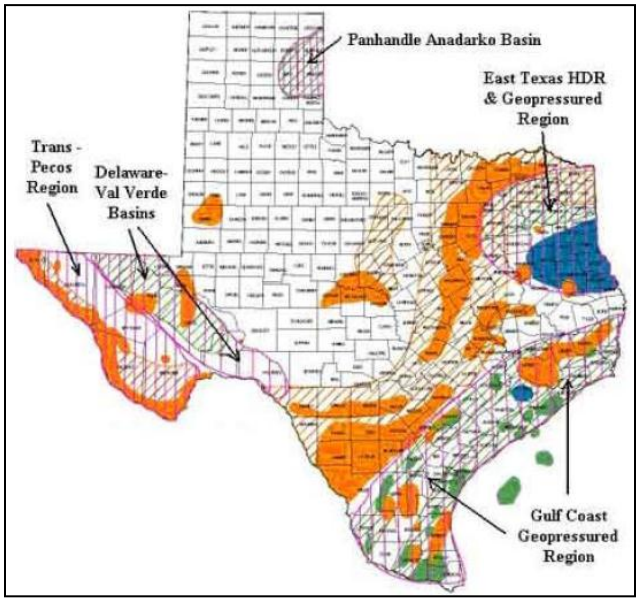


Figure 3.9.4: Texas Geothermal Map
Source: SECO (2008)

The major advantage of geothermal energy over solar and wind energy is that electricity generation does not depend on weather conditions, seasons, or time of day; therefore, battery backup systems are not required. Furthermore, geothermal power plants are reliable, going off-line only about 5% of the time. The plants can be located in major population centers or rural communities and scaled to meet demand. In serving major population centers, the existence or need for transmission lines has to be evaluated and considered as it often determines the technical and economic feasibility of geothermal projects.

3.9.2 Political/Public Concerns

Geothermal energy exploration has sparked the interest of Texas and Federal legislature. For example, the Executive Order 13514 issued by President Obama sets up "an integrate strategy toward sustainability in Federal Government and to make reduction of greenhouse gas emissions a priority of Federal agencies". Likewise, FHWA is endorsing and promoting the incorporation of climate change considerations into transportation decision-making process. A few permits have already been awarded by Texas government and GLO to explore this energy resource on public lands. On the other hand, concerns can be raised regarding impacts on communities and environment (e.g., use or contamination of water, noise, and steam provoked by power generation, and impacts on land value).

3.9.3 Legal Considerations

Because geothermal energy uses underground natural resources, some legal issues may exist regarding ownership and the exploiting of natural resources. As noted earlier in this review, TxDOT will have to take into consideration how such geothermal VEAs will impact safety, maintenance, operation, congestion and beautification of the highway system, and whether these were appropriate types of leases of highway asset property.. Further legal considerations, such as P3, liabilities, long-term commitment, shared risk, incentives, and REC, must be carefully assessed and addressed, as previously mentioned for other renewable energy sources (i.e., solar panels and wind turbines). In addition, Massachusetts DOT (MassDOT) points out the importance of verifying local zoning laws prior to moving forward with the project. MassDOT argues that most cities do not have zoning laws revised to address and regulate renewable projects. The lack of zoning law can defer or even impair the implementation of geothermal projects. Another issue is the proximity to public and military airports and likely interference or obstruction with air traffic, aircraft navigation/communication systems, and military radars. For any construction over 200ft, the form "74601-Notice of Proposed Construction or Alteration" must be filed with the Federal Aviation Administration (FAA) prior its outset. The FAA and the Department of Defense (DOD) will review the form and issue a permit. Typically, sites that are not within 3-5miles of an airport are not deemed as hazard to air traffic (Volpe Center, 2011). Environmental analysis is also a requirement for any renewable energy projects on public land. A project must be in compliance with NEPA – either FHWA or DOE process, if not both – to receive an environmental permit. Ultimately, if the project is located in highway ROW, FHWA has to review all documents (e.g., permits, drawings, analysis of impacts, and contractual agreements) from the project to issue a final permit, allowing the project moves forward. Furthermore, whenever the project concerns partnership with third parties, Oregon DOT (ODOT) recommends the involvement of the State Department of Justice (DOJ), as well as legal

counsels to advise and review the written agreements with private parties to minimize any potential risks and undesired liability.

3.9.4 Financial/Economic Feasibility

The geoexchange system (i.e., heat pump) can be expensive to install. However, it is estimated that the initial investment cost can be recovered in 2 to 10 years from energy savings associated with heating and cooling systems. Hence, heat pumps can be very cost-effective (SECO Website). Nonetheless, direct use of hot water is by far the cheapest way of exploring geothermal energy.

The cost of a geothermal power plant depends upon the energy generation of the proposed plant. Regardless of the installed capacity of the power plant, a major cost component is the drilling of the well to reach water hot enough for power generation. Sometimes, the wells are thousands of feet deep, thus significantly increasing the installation cost. On the other hand, the power resource can continuously operate at very low costs and with no carbon footprint (Lxrichter, 2010).

The U.S. Bureau of Land Management (BLM) is a pioneer in leasing federal land for geothermal energy development. From 2007 to 2010, the BLM generated more than $57 million in auctioning off leases for geothermal resources on federal lands in Idaho and nearby states (Lxricther, 2010). In Texas, most of the state has geothermal resources that can be accessed for electricity production. Economic feasibility, however, varies with the quality of the resource—i.e., its temperature, depth, and fluid characteristics—and the ease and rate with which the geofluids can be extracted and then reinjected (SECO, 2008). These factors depend on the site geology and have to be carefully analyzed prior to proceeding with the project. In general, the payback period for geothermal power projects is 10 to 30 years due to the high upfront investment.

Geothermal energy is also eligible for federal and state incentives. Furthermore, the economic feasibility of geothermal energy projects is usually influenced by the electricity price of conventional sources. In Texas, the price of electricity must continue

to be in excess of $0.08 per KWh for geothermal electricity production to be economically competitive. This number, however, varies from area to area given the quality of the resource and the need for transmission lines.

3.9.5 Environmental Considerations

The GHP does not impose significant negative environmental impacts; preserving it. Geothermal energy is also considered clean energy source—i.e., it is pollution free and a non-contributor to greenhouse gas (GHG) emissions—because it emits much less carbon dioxide than fossil fuels (see Figure 3.9.5). In addition, a geothermal power plant also has comparatively small surface footprint.

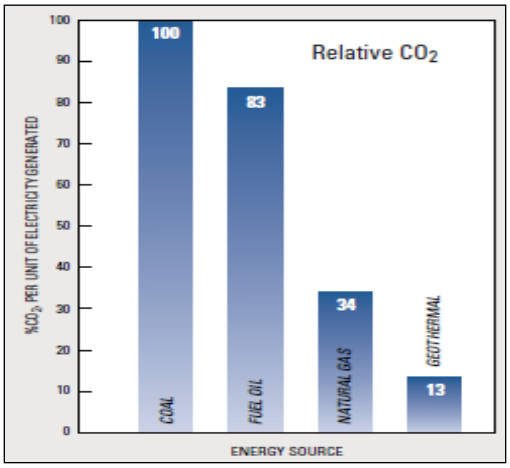


Figure 3.9.5: Relative CO2 Emission
Source: Wendell et al. (2003)

A major concern, however, involves the use of water. Geothermal energy production requires large volumes of water that often contain dissolved toxic substances that are reinjected into the earth. The availability, quality, and mainly the disposal of water raise major concerns. Similar issues pertain to the direct use of hot water. The use and disposal of water have to be studied and considered carefully to avoid waste or contamination of aquifers. Special treatments, techniques (e.g., closed loop systems) and interventions may be needed. Furthermore, the ability of the aquifers to endure long-term high-flow rates has to be analyzed early on in project developments.

Ultimately, some concerns may surge regarding impacts of noise and steam on nearby community and surrounding wildlife habitat. These impacts are typically from power generation application and their intensity depends on the size/capacity of the system, as well as the technology used.

3.9.6 Potential Social Impacts/Benefits

GHPs can reduce grid energy consumption and, thus save money. Although GHPs are not feasible in ROWs, rest areas and offices are potential places that can benefit from this application, specifically facilities in rural areas. Hot water aquifers—i.e., direct use—have a potential business, tourism, and economic exploration application. Examples of potential business opportunities are spa health facilities and therapy pools, industrial use, and agribusiness (e.g., fish farming, vegetable and flower growing). Therefore, the presence of hot ground water can promote economic and, consequently, social development in rural or semi-rural areas in addition to the electricity generation potential. Geothermal energy can provide electricity to remote areas at relatively low costs because it can be produced close to the end-user, thereby reducing the need for transmission lines. As previously mentioned, electricity is important to promoting social welfare, quality of life, and economic development.

3.9.7 Safety Considerations

Geothermal energy is in general a safe energy resource. However, if existing oil and gas wells are being used for geothermal energy production, precautions must be undertaken to prevent explosions or fire. Geothermal power plants and geysers are not recommended for implementation in highway ROW—i.e., close to the road—because, among other considerations, the water and steam may pose risks for the road users, especially steam that can resemble fog. On the other hand, implementing geothermal systems (i.e., GHP) to avoid icing roads or directly using hot water to de-ice the pavement can help to maintain the pavement skid resistance during cold weather (i.e., winter), thereby enhancing road safety.

3.9.8 Examples

The following pictures exemplify and illustrate some possible ways of harnessing geothermal energy. As mentioned, geothermal heat pumps (see Figure 3.9.7) are widely

used nationwide. The size and complexity of GHP systems depends on the use of HVAC systems and the amount of electricity that is intended to be saved. Figure 3.9.6 depicts a typical system used in homes and small buildings (e.g., school). Another typical geothermal energy application is power generation. Like GHP, the size of geothermal power plants varies with the capacity (i.e., maximum electricity generated). For office buildings and warehouses, a small generator (see Figure 3.9.7) may be enough to provide the entire electricity used in these facilities, whereas for larger demand power plants must be built to provide the electricity needed (see Figure 3.9.8). However, in the latter case considerable area and investment are required.

Geothermal heat pump installation (loop water pumps and piping).

Presently, many Texas homes, schools and other buildings are using geoexchange systems to take advantage of the cost savings in heating and cooling the inside of a building.

Figure 3.9.6: Heat Pump System
Source: SECO (2010)

Figure 3.9.7: Geothermal Power Generator
Source: PBPA (2009)

There is an increasing interest in geothermal development in the state of Idaho, as show in more than 80 applications for geothermal leases just in recent weeks.

Figure 3.9.8: Geothermal Power Plant in Idaho
Source: Lxrichter (2011)

3.9.9 Concluding Remarks

Geothermal energy has a diversified use and can potentially be explored in Texas. The main or most common characteristics and particularities of this VEA are:

a. there are different uses of geothermal energy (e.g., GHP, direct use, and electricity generation);

b. importance of site location and its characteristics (e.g., area, alternative access road, clear zone, existing zoning laws, and, mostly, underground resource);

c. GHP systems can be implemented almost everywhere in Texas and financially recovered in 2 to 10 years through electricity saving;

d. GHP does not require any private involvement or partnership;

e. direct use and electricity generation applications depend on underground geothermal characteristics (e.g., temperature and water availability). Their costs also vary according to the underground conditions (e.g., depth needed to reach certain temperature and geotechnical properties);

f. geothermal resources do not depend on weather conditions, season, or time of day;

g. electricity generation may impose some safety issues (e.g., steam), require considerable area, and impact on communities and wildlife habitat (e.g., noise, water, and steam). On the other hand, GHP embedded into the pavement and/or direct use of hot water can help to prevent snow and/or ice layer from be formed; thereby enhancing road safety in cold weather (i.e., winter);

h. business model adopted, permit (i.e., utility accommodation, airspace lease, special use permit, and easement), and legal considerations for incentives and REC. It may also entail concerns such as P3 and ownership of natural underground resources;

i. contractual agreements, liabilities, and responsibilities (e.g., site security, maintenance, vacating the site and removing the equipment, termination conditions, and ownership of the REC). Importance of shared risk and guarantee of long-term commitment;

j. involvement of the State Department of Justice (DOJ), as well as legal counsels is always recommended to advise and review the written agreements with private parties, and minimize any potential risks and undesired liability;

k. legal considerations, such as zoning laws and FAA permits;

l. potential conflicts with Texas's Highway Beautification Act and Wildflower program;

m. geothermal power plants typically have 10 to 30 years of payback period;

n. importance of upper-management support and an in-house champion, who would be responsible for leading and conducting the entire implementation process;

o. in remote areas, solar panels can be a solution to overcome or reduce cost of transmission lines;

p. as renewable energy source, geothermal energy can be an important step toward carbon footprint reduction, less dependence on fossil fuels, and sustainability;

q. need of effective public involvement and support. Importance of conducting an effective and efficient public outreach; and

r. environmental impact analysis and assessment, including hazardous material, water quality, historic resources, and threatened or endangered species, as well as the costs of mitigating and remediating the impacts. Compliance with NEPA and other environmental regulations.

3.10 CARBON SEQUESTRATION AND BIOMASS

3.10.A Carbon Sequestration

Carbon sequestration is the process of capturing and removing CO_2 and other forms of carbon from the atmosphere and then "storing" it in "reservoirs." A variety of techniques to sequester carbon exist, but the focus here is exclusively on vegetation management. The objective is to improve vegetation management through the implementation of a modified and sustainable maintenance approach. Furthermore, The Carbon Sequestration Pilot Program (CSPP), led by the FHWA's Office of Natural and Human Environment (ONHE) and the New Mexico DOT (NMDOT), reported that in addition to improved vegetation management, carbon sequestration allows for "(1) selling carbon credits on an appropriate GHG market or registry for revenue, (2) using carbon

credits to offset the DOT's emissions, or (3) using the credits toward meeting statewide objectives" (FHWA and Volpe, 2009).

The goals are to reduce mowing expenses and/or generate revenues from selling carbon credits in a specific market.

3.10.1.A Technical Feasibility

A major concern regarding the implementation of carbon sequestration programs is that the carbon sequestered has to be clearly demonstrated as "additional" compared to a realistic calculated baseline and emission reduction projection. This requires that a comprehensive analysis be conducted to identify the current baseline, the carbon sequestration rate, and, subsequently, the additional carbon sequestered. A Geographical Information System (GIS) can be an important tool to establish a baseline in a specific year (TTI, 2001). Furthermore, carbon sequestration programs require the involvement of two technical entities: a carbon aggregator and a carbon verifier. Carbon aggregators are brokers who represent small projects in the carbon market. Carbon aggregators collect carbon credits from small projects and efficiently trade them as large blocks for a fee. The carbon aggregator can be in-house. The NMDOT, for example, envisions the opportunity to become its own aggregator by partnering with other states (FHWA, 2009). Partnership can avoid the cost of hiring a third party and also help ensure that a substantial volume of carbon is sequestered to earn a good return in the market. The carbon aggregator has to work in harmony with a carbon verifier. The carbon verifier is responsible for ensuring the enrolled land complies with the established protocol to enter into the carbon market. The NMDOT points to the importance of understanding carbon verification, the requirements, and how to meet the requirements in terms of ecological and biological analyses, and the economic considerations. The available carbon verifiers with expertise in the ecoregions and regional native grasses are, however, a challenge (FHWA, 2009). Involving staff with knowledge of the process in order to better assess risks, rewards, and next steps in quantifying, verifying, and selling carbon credits is also

considered important. This is because some physical ROW characteristics (e.g., precipitation, soil, temperature, and standing crop) impact the potential carbon that can be sequestered (FHWA, 2009). The CSPP has focused on quantifying and evaluating the viability and efficiency of carbon sequestration using grasslands along highway ROW. Although the program is being conducted in New Mexico, the results are expected to be applicable nationwide.

In Texas, it is believed that a major impediment to an extensive and widely adopted carbon sequestration program is the long-term commitment of up to 30 years needed to qualify for the carbon credits. Thus, utility access to state highway ROW and future road expansion will prohibit TxDOT from committing portions of its ROW to carbon sequestration programs. Also, TxDOT has ceased to mow several areas of ROW—mostly on very remote areas—and has reduced mowing in all other areas as much as possible. Currently, TxDOT mows most areas only two times per year—i.e., in April and November—to save costs. Opportunities for securing "additional" credit through vegetation management as part of carbon sequestration program are thus regarded as limited. On the other hand, beautification programs, such as the Green Ribbon Project—a corridor aesthetic and landscape master plan—requires TxDOT to plant a certain number of bushes and trees per year along TxDOT ROW. TxDOT could potentially receive credits from these programs as bushes and trees absorb more carbon than grass and flowers.

3.10.2.A Political/Public Concerns

Global warming and GHG emissions are global concerns that have fostered intensive public and political discussion and involvement. In general, though, initiatives that enhance road aesthetics and combat global warming may be well supported by the public. Also, because carbon sequestration could potentially save mowing costs (at a minimum) and/or generate revenue (at a maximum), public support (in general) is anticipated.

In the case of carbon sequestration and carbon trading, the federal government has given special attention to these types of applications in U.S. congressional debates centered on preceding national climate change legislation. There is special emphasis on minimizing the cost of cap-and-trade systems and/or supporting the sale of carbon offsets to ensure a potential revenue stream for those who want to implement carbon sequestration as a land management strategy (FHWA 2010).

In Texas, some precautions have to be taken to prevent this VEA from competing with and/or affecting the ongoing roadside beautification and wildflower programs.

3.10.3.A Legal Considerations

Major concerns regarding the carbon sequestration program involve the lack of regulations and/or direction in terms of a DOT's ownership of the carbon credits generated by vegetation management practices on federal lands and how these carbon credits can be traded by a public agency.

While Texas statute allows public utility companies to locate their infrastructure in the ROW of state-owned highways, the provisions within Transportation Code and Texas Administrative Code set out duties and liabilities of the parties for such transactions. Utility providers may be concerned about being liable for any damage to vegetation planted along the ROW and may seek to have priority over a carbon sequestration program application. However, under TAC Rule 21.602 any leases of highway assets require that TxDOT under any written lease drawn up requires TxDOT approval of all construction plans, and permission for employees to enter the property for inspection, maintenance, or reconstruction purposes.

43 TAC Chapter 21 also sets out the rules for leasing of highway assets. Under the terms of the contract the lessee will be required to include terms including:

- a statement on the authorized use of the leased asset and the requirement that any change of use requires prior written approval of the director of the department,

- a requirement for department approval of all construction plans regarding the asset,
- permission for employees of the department to enter the property for inspection, maintenance, reconstruction of highway facilities as necessary, or to determine lease compliance,
- that any improvements will be maintained by lessee at their expense, and must be kept in good condition for safety and appearance and not interfere with highway use,
- a statement requiring forfeiture of the deposit, payment of litigation costs or other expenses due to nonperformance of the lease terms,
- a performance bond,
- adequate public liability insurance for the leased asset, conduct of lessee's business, and their indemnifications and obligations to the department, to be paid for by lessee and naming the department as an additional insured, and include other endorsements acceptable to the department for damages occurring to the highway facility, or for public or personal injury, loss of life, or property damage.
- The director can waive this requirement where the lease is with a county, city, state agency or federal government if they assume specific responsibility for such payments, that the lessee assumes all risk of losses resulting from the lease, and
- any other provisions deemed necessary or desirable by the director

As has been noted in previous sections of this thesis, any lease for such sequestration projects on or adjacent to the ROW (federal and state) will also have to comply with the provisions of CFR, TC and TAC and not compromise, mobility, safety, and the ability of the DOT to control its assets in the best interests of the general public, and will need to be charged at not less than fair market value.

3.10.4.A Financial/Economic Feasibility

TxDOT currently spends about $40 million per year in general mowing and $10 million for curbside vegetation. By reducing mowing frequency, maintenance expenditures, as well as GHG emissions emitted by maintenance equipment, can be reduced. TxDOT believes that it already reduced mowing activity to the maximum extent possible.

An economic analysis of a carbon sequestration program is quite complex. The FHWA has funded the development of a Carbon Sequestration Estimator Tool to estimate the potential revenue generated by carbon credits. In general, the costs of a carbon sequestration program include the expenses associated with planting and maintenance, the carbon aggregator, the carbon verifier, and internal personnel. The valuation of the benefits is even more complex. For example, there is no conclusive research on the efficiency of carbon sequestration, the establishment of a carbon baseline, and the real rate of carbon sequestered by grass. NMDOT is currently undertaking a study to establish a protocol for carbon credits for grasslands that—once approved by the carbon trading market—can be implemented nationally. On the other hand, the revenues generated are a function of carbon prices, management techniques, and ecological variability. Therefore, these revenues may vary substantially from state to state. At the same time, the carbon credit trading or offsetting markets are still developing and are not well established. As an example, the Chicago Climate Exchange (CCX) was launched in 2003 (FHWA 2009). Similar to the stock market, the price of carbon floats, making the future revenue predictions uncertain. Figure 3.10.1 illustrates the fluctuation in the carbon price in the CCX market from 2004 to 2009 (FHWA 2009).

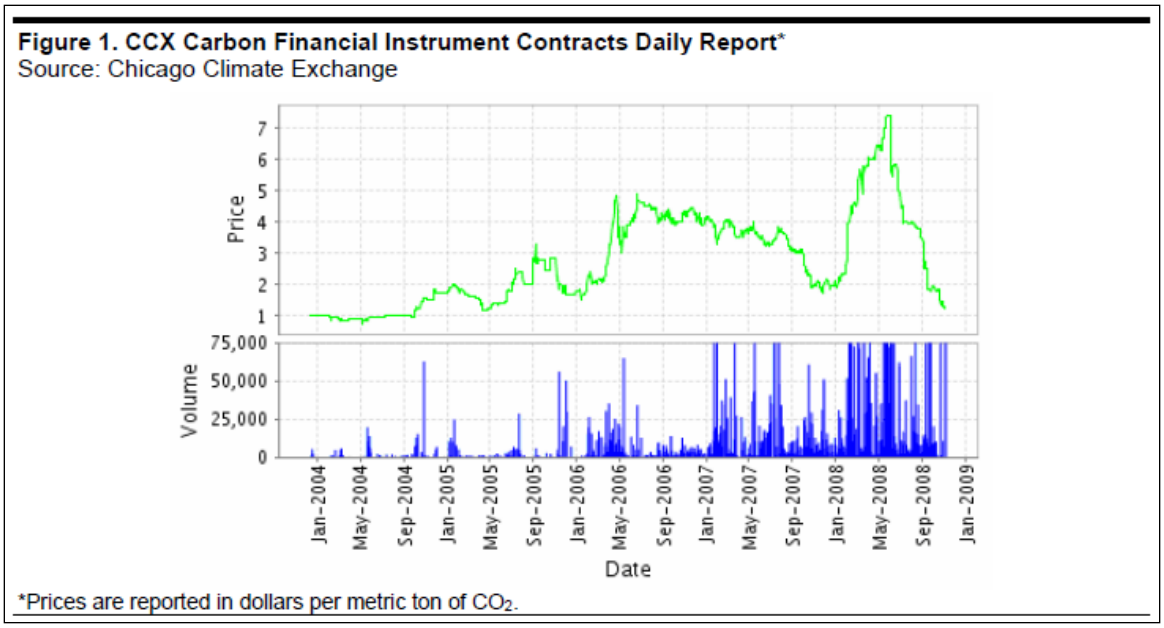


Figure 3.10.1: CCX Carbon Price Fluctuation
Source: FHWA (2009)

The amount of "additional" carbon sequestered can either be used by a DOT to offset its carbon emissions and to meet the state's objectives or can be sold as carbon credits on an appropriate "GHG market" or "registry revenue" that function as a national "cap and trade" system. In both cases, the carbon verifier typically charges a commission of 5 to 20% of the amount of carbon credits sold in the market. A considerable amount of carbon thus has to be sequestered to cover the total cost of the program and be attractive to the verifier. The Jornada Experimental Range project warns that for carbon sequestration to be economically feasible, the verification process has to conclude that storing the carbon costs less than the value of the carbon if sold in the market (FHWA, 2009). To reduce the implementation costs (e.g., labor, seeds, and watering) of the carbon sequestration program, the FHWA strongly recommends the use of native and self-sustaining vegetation (FHWA, 2010). Moreover, FHWA recommends the consideration of vegetation that also serves other purposes (e.g., safety protection and erosion prevention) to increase the economic feasibility of a carbon sequestration program.

3.10.5.A Environmental Considerations

The primary objective of carbon sequestration is to mitigate global warming by reducing the carbon in the atmosphere. Also, an effective vegetation management program can help enhance the habitat surrounding the road and create a natural barrier for animals, helping preserve species.

3.10.6.A Potential Social Impacts/Benefits

A carbon sequestration program can improve air quality by reducing the amount of CO_2 and GHG on the atmosphere. Therefore, a carbon sequestration program can help to prevent human respiratory diseases and enhance life quality. In addition, by saving mowing and maintenance costs, the DOT can divert and concentrate more focus and investments on highway system improvements (i.e., new projects and pavement maintenance), thereby potentially generating societal benefits such as job creation, less traffic congestion, and lower freight costs (i.e., lower food, material, and product prices).

3.10.7.A Safety Considerations

A good vegetation management strategy—crucial for a carbon sequestration program—enhances road safety and prevents roadside erosion. Vegetation along highway ROW defers erosion by reducing landslides, controlling invasive plant species, retaining stormwater, and holding snow (i.e., living snow fence). Appropriate vegetation can provide a natural protection barrier for coastal roads, along hills and valleys, and against animals, thereby reducing animal-vehicle collisions. On the other hand, some precaution must be considered and taken, because some vegetation can attract animals—to feed themselves or use as shelter—and reduce the visibility and sight range of drivers (e.g., trees and tall grasses), thereby increasing driver risk. In addition, woody vegetation (e.g., trees) can pose hazardous obstacles for drivers that run off the road. To overcome safety concerns, the Tennessee DOT recommends a clearance (i.e., safety zone) of at least 30 feet from the road edges to vegetation (i.e., trees and switchgrass).

3.10.8.A Examples

There is no formal carbon sequestration program in the U.S. besides the pilot programs and research studies conducted in states such as New Mexico and Utah. The Carbon Sequestration Pilot Program (CSPP), led by FHWA' Office of Natural and Human Environment (ONHE) and the New Mexico Department of Transportation (NWDOT), reported that in addition to improved vegetation management, carbon sequestration allows for: "(1) selling carbon credits on an appropriate GHG market or registry for revenue, (2) using carbon credits to offset the DOT's emissions, or (3) using the credits toward meeting statewide objectives" (FHWA and Volpe Center, 2009).

3.10.9.A Concluding Remarks

The main or most common characteristics and particularities of carbon sequestration as VEA are:

a. lack of a well-defined carbon market;
b. long-term commitment and future expansion assessments are required;
a. interference with utility companies and ROW access;
c. only the additional amount of carbon sequestered is considered as carbon credit;
d. requirement of an expert consultant/staff (i.e., carbon aggregator and carbon verifier) to attest, validate, and sell the carbon credit;
e. lack of an established protocol for grass, which is needed to quantify the carbon sequestered and enter in the carbon market; and
f. Texas has an enormous variability of soil and weather conditions that directly influence the capacity, feasibility, and cost of sequestering carbon.

3.10.B Biomass

Biomass, such as wood, waste, (hydrogen) gas, alcohol fuels, and plant matter, is typically used as a renewable energy source to generate electricity or produce heat. Although several sources of biomass exist, such as solid waste, urban waste, and construction residue, the most common sources are crops, including sugar cane, switchgrass, sorghum, oilseed crops, and grains (SECO, 2008). The Tennessee Department of Transportation (TDOT), for example, is conducting a pilot project with Genera Energy LLC—a Knoxville-based renewable energy company—using switchgrass planted on a few test plots along the highway ROW. "Switchgrass is one of the primary feedstock used to produce cellulosic ethanol" (Genera Energy, 2010). TDOT is exploring the potential to reduce cost of grass mowing, use the biomass for energy production, and combat roadside erosion. Concurrently, the Utah DOT (UDOT) and Utah State University (USU) are assessing the viability of planting oilseed crops on highway ROW to produce biofuel.

In the case of biomass production, the goals are to reduce mowing expenses and/or generate revenues from harvesting certain types of crops used for biofuel production.

3.10.1.B Technical Feasibility

In the case of biomass energy production, Texas "contains one of the most diverse and most accommodating growing environments in the United States, and boasts a plethora of potential biomass-based renewable energy sources" (SECO, 2008). For example, biomass sorghum, sugar cane, and switchgrass are important potential energy sources as lingo-cellulosic feedstock in Texas. The production of each specific crop will largely be determined by available land, rainfall, competition, producer interest, economic incentives, and equipment needed. Corn is also a potential feedstock for biofuel production in Texas, but it is not considered a "dedicated energy crop" as it is used for different processes besides energy production. TxDOT sows approximately 70 different

seed mixes along the highway ROW for erosion control and compliance with the wildflower program. These seed mixes vary by region, but none contain any major oil seed or are intended for biofuel production. Water availability is crucial for most agriculture activity. Although some drought-tolerant crops exist, it is generally believed that it would be very difficult to cultivate crops for biofuel production in areas with less than 14 to 16 inches of rainfall (Hank, 2011). Another important factor is the quality and characteristics of the soil. Different crops grow differently depending on the soil and weather conditions. Also, de-icing products (e.g., salt) and run-off water can affect and change the proprieties of the soil in the ROW, hindering the growth of crops. Regarding the latter, Hank (2011) reported that on the Utah pilot project, this issue was not encountered because of how the roads are designed. To facilitate drainage, pavements are designed to move water from the road and drain it to a specific point. This prevents contaminated water (i.e., containing oil and salt) from seeping into the adjacent soil. In Tennessee, a major challenge was the notoriously difficult switchgrass establishment—which takes up to 3 years, even when some chemical fertilizers were used. Throughout the four acres—divided into eight plots—used for the pilot project, 15–20% of the area had to be re-planted. The most common problems encountered were lack of moisture, high level of soil compaction, and defects on the seed drill. Moisture is a critical factor for the success of planting; it is recommended to use land with at least 16 inches of annual rain average and conduct planting during the rainy season. On the sites with competitive native vegetation, herbicides have to be used during the first year until establishment. In addition, humus may be applied during the second year.

The distance to the refinery is also an important factor in the feasibility of biomass production. For example, in the case of sugar cane and sweet sorghum (e.g., switchgrass), the sucrose for energy production must be extracted within 24 to 48 hours after harvesting. Therefore, planting has to be near the biorefinery. TDOT suggests 50 miles as the longest distance between the plot and the refinery. The distance will influence the technical and economic feasibility. In Texas, the areas along the Gulf Coast and in the northeast have the highest potential for biomass production because of existing refining capacity, strong producer networks, and available fertile land. On the other hand, the logistics for vegetable oil is less complicated because the oil is contained in the crop seeds. Cotton is the major oilseed crop in Texas, although other crops also have some potential. Table 3.10.1 provides information on oilseed crops, including their characteristics and potential.

Table 3.10.1: Oilseed Crops' Characteristics
Source: SECO (2008)

Crop	Major, Minor or Potential (World)	Cool or Warm Season	Perennial or Annual	Oil Percentage
Cotton	Major	Warm	Annual	17
Soybean	Major	Warm	Annual	18
Peanut	Minor	Warm	Annual	45
Canola	Major	Cool	Annual	40
Flax	Minor	Cool	Annual	35
Sunflower	Major	Warm	Annual	42
Safflower	Minor	Warm (and cool)	Annual	42
Sesame	Minor	Warm	Annual	50
Tung	Potential	Warm/ Subtropical	Perennial	35
Palm	Major	Warm/ Tropical	Perennial	35
Camelina	Potential	Cool	Annual	40
Brown Mustard	Potential	Cool	Annual	40
Castor	Potential	Warm	Annual	50
Chinese Tallow	Potential	Warm	Perennial	31
Jatropha	Potential	Warm/ Subtropical	Perennial	35

Source: Dr. David Baltensperger, Texas A&M University, Soil and Crop Sciences

Another issue of concern is the harvesting frequency and the harvesting procedure (i.e., manually or with machinery) (SECO, 2008). The ROW features (e.g., width and steepness) and the geographic characteristics (e.g., equipment and workforce

availability and weather) may impose some challenges. TxDOT's ROW varies from 30 to 700 feet wide and from flat to very steep. A GIS database that captures the geospatial characteristics of TxDOT's ROW would aid in the identification and determination of which ROW parcels are appropriate for biomass production.

3.10.2.B Political/Public Concerns

Global warming and GHG emissions are a global concern that can initiate intensive public and political discussion and involvement. For example, the Executive Order 13514 issued by President Obama sets up "an integrate strategy toward sustainability in Federal Government and to make reduction of greenhouse gas emissions a priority of Federal agencies". Likewise, FHWA is endorsing and promoting the incorporation of climate change considerations into transportation decision-making process. Furthermore, Federal government has specifically endorsed the development and use of domestically-produced biofuel for transportation as an alternative to combat the increasingly skyrocketing price of fossil fuel. In addition, the Energy Independence Security Act of 2007 - intended to reduce the national dependence on fossil-fuel - has launched as primary strategy the augmentation of biofuel use in the Nation's vehicle fleet. Concurrently, initiatives that enhance road aesthetics and support energy independence may be well supported by the public. Also, because biomass production could potentially save mowing costs (at a minimum) and/or generate revenue (at a maximum) public support (in general) is anticipated. In the case of the Tennessee pilot project, for example, a first positive reception existed, but then concerns and questions arose regarding the expenses and possible additional taxes. TDOT argues that, should this VEA reach a large scale of implementation, an intensive awareness initiative and feasibility demonstration will be necessary to justify the upfront investment and bring the support of political and public entities.

In Texas, some precautions have to be taken to prevent this VEA from competing with and/or affecting the ongoing roadside beautification and wildflower programs. Some crops do not create the same aesthetic effect as do the flowers of existing programs.

3.10.3.B Legal Considerations

In terms of biomass production, major concerns include possible legal considerations surrounding how the DOT can generate revenue from the harvested crops, how to establish P3s to develop a biomass program, and how to set up ROW leasing or easement contracts with farmers or private companies.

Texas legislation allows public utility companies to locate their infrastructure in the ROW of state-owned highways. Therefore, utility providers will be concerned about being liable for any damage to vegetation planted along the ROW and will seek to have priority over a carbon sequestration program or biofuel production application. In fact, TxDOT as the lessee of ROW may be held responsible and liable for any damage that may occur to utilities that have been accommodated in TxDOT ROW as a result of mowing, planting, and harvesting. Hence, liability concerns will have to be clearly addressed in leasing agreements to avoid future disputes. Therefore, whenever the project concerns partnership with third parties, Oregon DOT (ODOT) recommends the involvement of the State Department of Justice (DOJ), as well as legal counsels to advise and review the written agreements with private parties to minimize any potential risks and undesired liability.

Environmental analysis is also a requirement for any renewable energy projects or activity on public land. A project must be in compliance with NEPA – either FHWA or DOE process, if not both – to receive an environmental permit. Ultimately, FHWA has to review all documents (e.g., permits, drawings, analysis of impacts, and contractual agreements) from the project – if located in highway ROW - to issue a final permit, allowing the project moves forward.

3.10.4.B Financial/Economic Feasibility

In the case of biomass production, significant economic benefits have been reported in term of energy production—it is estimated that 30% of the liquid fuel demand in the U.S. could be supplied by biomass—and because the growing of crops can help rural development through job creation and enhanced business activities (SECO, 2008). Costs to consider in the economic analysis of biomass production include the expenses of agricultural activities such as fertilizing, soil stabilization, watering, seeds, harvesting, and removal of existing vegetation as needed to establish the crops. In regions with poor or dry soil, these factors will be critical in determining the viability of the program. According to the UDOT, by selecting the appropriate crop seed and using some agronomical techniques, the need for water, fertilize, humus, and insecticide could be reduced by 80% in comparison to the planting of grass or flowers in ROW. The main objective of a biomass program is to substitute the vegetation the DOT already plants and/or mows with a revenue-generating crop that can add commercial value to the existing activity. In addition, biomass production requires only two costly activities per year—i.e., planting and harvesting—whereas some vegetation management programs require mowing more than two times in a year. Also, it is important to bear in mind that each crop has a different production capacity and cost-effectiveness that varies according to site characteristics. The price of the biofuel also affects the economic feasibility of a program. On the other hand, the use of appropriate vegetation or crops can reduce and solve maintenance and pest control problems. These additional benefits enhance the economic feasibility of this application while benefiting the environment (e.g., more green, less pesticides, and less carbon emission from equipment). These variables and uncertainties, however, make the economic analysis complex and unique for each circumstance.

Regarding potential business models for biomass projects, various possibilities exist. The adoption of a specific business model will vary according to the DOT's goal and the interest of the investor. It is important to bear in mind that the attractiveness and

economic feasibility of the project may vary depending on the business model adopted. The main four business models generally used for biomass are:

- The DOT sows, cultivates, and harvests the biocrop feedstock and then pays a biorefinery to process and convert the feedstock into biofuel that the DOT will use on its own fleet. This model is being used by North Caroline DOT;
- The DOT sows, cultivates, and harvests the biocrop feedstock and then sells the feedstock to a private company (i.e., biofuel producer/vendor);
- The DOT issue a permit to nearby farmers – through leasing agreement (i.e., rent fee payment) – allowing the farmers to sow, cultivate, and harvest the biocrop feedstock, and then use the feedstock as they want to.
- The DOT is responsible for performing all tasks (i.e., farming and refining). Utah DOT has been using this model with the Utah State University (USU) in their pilot project.

3.10.5.B Environmental Considerations

Although biomass and biofuel production are not completely "clean energy" sources—GHG emissions are still emitted during energy production—they are producing considerably less carbon compared to fossil fuels. Two major environmental issues associated with biofuel are the need for water for planting in some Texas regions and for energy production itself. Some perennial vegetation, such as switchgrass, does not require watering once established and can endure extremely hot weather. In addition, some drought-tolerant crops that can be used for biofuel production do not require water (Wakil et al., 2007). The use of fertilizer raises some environmental concerns and costs and is typically avoided. On the other hand, using highway ROW for biomass production can help to avoid the expansion of farming into environmentally sensitive areas—a common challenge found with conventional biofuel production. Moreover, biofuel is non-toxic to humans and animals as well as biodegradable (i.e., disposal and waste are absorbed by the environment without being polluting). It emits lower levels of GHG

emissions compared to conventional fossil fuels, it is a renewable fuel and energy source, and it can be produced from diverse feedstock (Wakil et al., 2007).

3.10.6.B Potential Social Impacts/Benefits

The ethanol and biodiesel market has gained prominence worldwide due to increasing fossil fuel prices and pollution concerns. In Texas, the ethanol and biodiesel market is not as prominent partly because grain has mostly been produced for animal—mostly cattle—consumption. Concern has also been expressed that the plant of any crop for energy production can have a negative effect on food prices, and thus be detrimental to society. For example, ethanol production has been cited as removing corn from the food market, resulting in an increase in the price of corn and corn products. In addition, land competition and crop substitution have raised the price of commodities. Using DOT ROW for biomass production can thus reduce the need for using farm land for energy crop production, thereby alleviating pressure on food and other commodities' prices (SECO, 2008). It is also expected that forms of ethanol and biodiesel can be produced for less than petroleum-based fuels—if the price of crude oil per barrel remains at the current level. Finally, biorefineries have to be developed close to where the feedstocks are produced, thereby requiring infrastructure investments such as roads, warehouse, and storage. These investments could generate temporary and permanent jobs in rural areas, and help to support rural and agricultural activities.

3.10.7.B Safety Considerations

A good vegetation management strategy enhances road safety and prevents erosion. Vegetation along highway ROW defers erosion by reducing landslides, controlling invasive plant species, retaining stormwater, and holding snow (i.e., living snow fence). Appropriate vegetation can provide a natural protection barrier for coastal roads, along hills and valleys, and against animals, thereby reducing animal-vehicle collisions. In the UDOT pilot project, crops that do not attract animals were reportedly planted; nonetheless, studies are not being undertaken to correlate animal attraction to the

type of crop. On the other hand, the switchgrass planted in Tennessee would be a problem, because its high height could attract animals to use the switchgrass as "home" and for protection shields (Hank, 2011). In addition, tall grasses, such as switchgrass, can reduce the visibility and sight range of drivers, thereby increasing driver risk. Some concern has also been expressed by TxDOT that switchgrass can be invasive and cause erosion problems, therefore requiring frequent mowing. Tennessee DOT indeed acknowledges all these problems, but TDOT argues that the plot selection could solve these issues—for example, not planting on central ROW lands.

Woody vegetation (e.g., trees) can pose hazardous obstacles for drivers that run off the road. To overcome safety concerns, TDOT recommends a clearance (i.e., safety zone) of at least 30 feet from the road edges to vegetation (i.e., trees and switchgrass). Another potential concern is the impact of agricultural activities—such as plowing, tilling, harvesting, and mowing of agricultural machines—and/or vegetation roots on underground utilities (e.g., gas lines, oil lines, electricity, telephone, water, and fiber optics) that are also using the ROW. This simultaneous use of ROW for utilities and farming is a potentially dangerous situation that can not only cause a road accident but also interrupt service to customers (Minnesota DOT, 2006). In the case of the UDOT pilot project, the crops will be planted in areas where some vegetation already exists and mowing activities are performed. Moreover, all equipment used for planting and harvesting crops would be similar to the equipment used to mow. Therefore, biomass production is not believed to present any risk to utilities. However, it was recommended to coordinate with utility companies if utilities are buried underground. Safety is the primary concern of any DOT and, hence, the UDOT biofuel program has to be as safe as possible. Farmers and any person involved with the program are and will be trained on how to be safe on the roadside. Traffic control plan is also a requirement and have to be done prior to any activity takes place on the ROW. Also, because both the equipment and activities of the biomass program resemble the equipment for mowing and the mowing

process, all the safety concerns and precautions that are already used for mowing will apply.

3.10.8.B Examples

In the case of biomass production, several DOTs have been conducting research and supporting pilot projects. UDOT, for example, launched a research project in 2006 in conjunction with USU to assess the feasibility of planting drought-tolerant crops such as canola, safflower, dwarf sunflower, camelina, gumweed, mustard, and perennial flax (see Figure 3.10.2) along the ROW in a non-irrigated environment (see Figures 3.10.3 and 3.10.4) (Wakil et al., 2007).

Figure 3.10.2: Seed Crops Used in Utah Pilot Project
Source: Wakil et al., (2007)

This was the first project devoted to evaluating the feasibility of growing seed crops in highway ROW. The idea—as envisioned by the researchers—is to harvest enough seed to produce in-house biodiesel for the UDOT's fleet, including heavy diesel machineries and snow plows. In addition, the seed crops will render a more beautiful ROW and reduce the roadside maintenance costs (e.g., mowing and pest control). It is estimated that a 100-foot-wide ROW with a 66% dry land yield could potentially produce more than 500 gallons of biodiesel per mile of land, using agronomic methods and equipment (Wakil et al., 2007).

Figure 3.10.3: Utah Pilot Project Plot
Source: Wakil et al. (2007)

The USU researchers listed the following potential benefits and advantages of biofuel production in highway ROW: increased aesthetics of the roadside, reduced maintenance costs, advertising of and public education on renewable fuel, sustainability, and environmental issues, no effect on food supply, and all associated benefits of biofuel. The USU researchers are also assessing potential impacts such as safety, structural integrity of the road and shoulders, establishment and harvesting of the crops, economic viability, wildlife impacts, ecology/ environmental impacts, water quality, and grower concerns (Wakil et al., 2007). In summary, USU researchers asserts that the feasibility of biomass projects should be assessed according to the following criteria: crop type, erosion, structural integrity, habitat issues, sight clearness, risk management, ecological impacts, and water concerns (Volpe Center, 2011).

Figure 3.10.4: Mowing the Highway ROW for Utah Pilot Project
Source: Wakil et al. (2007)

Following the same line of UDOT, the North Caroline DOT (NCDOT) initiated in 2009 its biomass and biofuel project. Currently, the NCDOT's project is recognized as one of the largely successful biomass projects nationwide, mostly because of the state moist climate, fertile soil, and support from the State legislature. The project started with four 1-acre plots of canola or sunflower crops. These crops were selected by NCDOT, in conjunction with North Caroline State University, because their estimated greater potential of yield in ROW scenario. NCDOT has been working with seasonally rotated crops on the same plot, thereby being able to meet or exceed national standards for crop production (Volpe Center, 2011).

A different pilot project is being conducted by Genera Energy LCC—a for-profit limited liability company wholly owned by the University of Tennessee Research Foundation—in partnership with TDOT. The objective of the pilot project is to verify if

switchgrass—one of the primary feedstocks used to produce cellulosic ethanol and native to all American states—planted along the highway ROW can yield reduced maintenance costs due to less mowing activities and erosion on the roadside, as well as generate revenue from biomass for biofuel production (see Figure 3.10.4) (Burke, 2010). The switchgrass was chosen because it is "a native plant that can reach a height of 10 feet" (see Figures 9.5, 9.6, and 9.7) and can produce considerable tons for ethanol production per acre, thereby replacing corn as the primary feedstock for ethanol. TDOT stated that "we won't mow it for biofuel…it's going to be for erosion and hopefully save us some money on mowing." The erosion protection is attributed to the long and very distributive roots that can reach 8–9 feet into the soil. In addition, the root characteristics contribute to better water absorption by the soil—mainly for compact soil—which helps prevent or defer soil erosion as well.

In terms of cost, it is estimated that a pound of switchgrass costs about $20 to be planted and established. TDOT asserts that the ideal location will be where the current cost of mowing is lower because usually it is correlated to better access, less traffic disruption, less safety concerns, and effective support (i.e., infrastructure). Although TDOT seeks only cost savings as a benefit, the agency acknowledges and envisions carbon credits and biofuel production as potential revenue streams. Furthermore, locating plots near each other will also reduce cost of plating, mowing, and hauling the switchgrass. Another consideration involves the plot characteristics: because of the cost of planting and harvesting, the minimal plot area should be greater than 1 acre and at least 300 feet wide. No effort and thought have, however, been put into a potential business model. TDOT anticipates that some state law will likely preclude large application, mainly regarding the direct sale by the agency; therefore, farmers will be involved. Another legal issue is environmental permits to use federal land for farming and agricultural activities.

Colorado DOT (CDOT) and Ohio DOT have worked with local consulting companies and/or universities to identify opportunity zones and sites suitable for

renewable energy and revenue generating projects on highway ROW. The identification has been made by overlaying ROW maps and geographic information system (GIS) data layers of potential renewable energy source (i.e., solar, wind, biomass resource maps). Michigan DOT has identified 10,000 ROW acres suitable for planting and it plans to open to bid proposal soon (Volpe Center, 2011).

In Texas, TxDOT is exploring leasing highway ROW to farmers during the grass period, so additional grass can be harvested and gathered for feeding cattle and other animals during the dry season.

Figure 3.10.5: Switchgrass
Source: Marin (2008)

Figure 3.10.6: Bales of Switchgrass
Source: Energy Insight (2007)

Figure 3.10.7: Plot of Switchgrass
Source: ScienceDaily (2008)

3.10.9.B Concluding Remarks

In the case of biomass, the main or most common characteristics and particularities of this VEA are:

a. requirement of minimum 16 inches of rainfall and regional climate (e.g., humidity and temperature);

b. site's location and characteristics (e.g., width, access, area, and slope);

c. safety and logistic considerations (e.g., clear zone, animal attraction, distance from refineries, harvesting machineries, access, and staff training);

d. soil characteristics determine successful implementation (i.e., cost-effectiveness);

e. long-term commitment and future expansion assessment are required;

f. interference with utility companies and ROW access (i.e., risks);

g. importance of upper-management support and an in-house champion, who would be responsible for leading and conducting the entire implementation process;

h. business model, permit (i.e., utility accommodation, airspace lease, special use permit, and easement), and legal considerations regarding REC, incentives, and patents;

i. potential conflicts with Texas's Highway Beautification Act and Wildflower program;

j. contractual agreements, liabilities, and responsibilities (e.g., site security, maintenance, vacating the site and removing the equipment, termination conditions, and ownership of the REC). Importance of shared risk and guarantee of long-term commitment;

k. involvement of the State Department of Justice (DOJ), as well as legal counsels is always recommended to advise and review the written agreements with private parties, and minimize any potential risks and undesired liability;

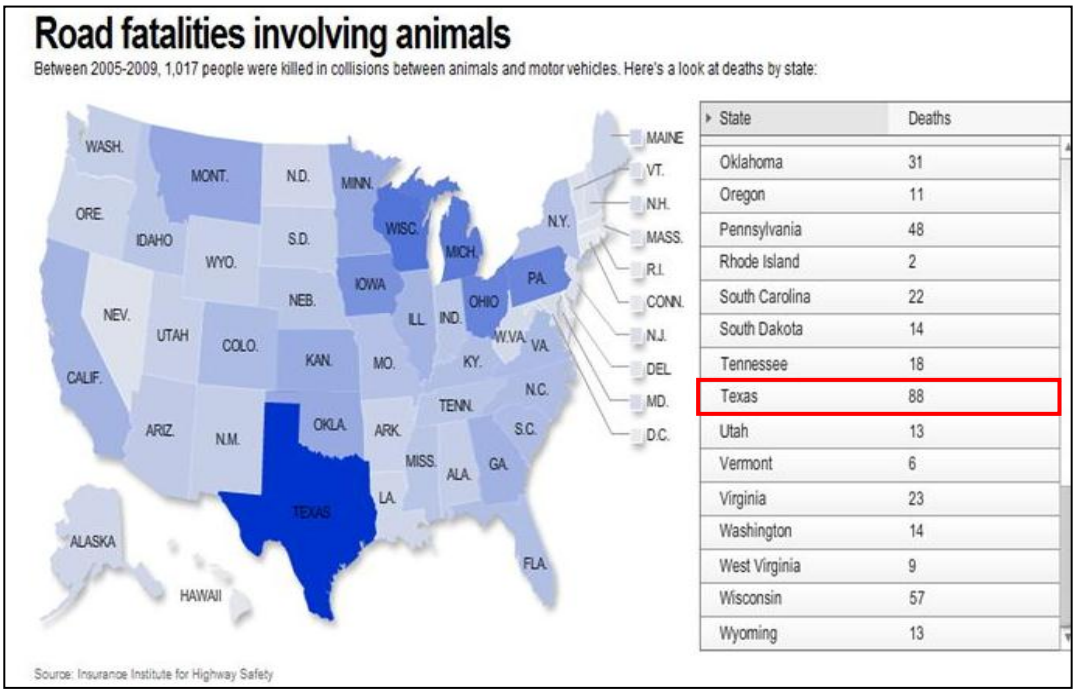
l. legal considerations regarding REC, incentives, and patents;

m. need of effective public involvement and support. Importance of conducting an effective and efficient public outreach; and

n. environmental impact analysis and assessment, including hazardous material, water quality, historic resources, and threatened or endangered species, as well as the costs of mitigating and remediating the impacts. Compliance with NEPA and other environmental regulations.

3.11 WILDLIFE CROSSING

Accidents involving animals are a concern worldwide. In October 2010, TxDOT issued a warning to drivers about deer during the fall season. TxDOT estimated that in 2009, more than 7,000 animal-related crashes occurred on the Texas highways, of which 25 entailed a fatality (TxDOT, 2010). Furthermore, Texas has been the state with the highest number of fatalities from animal-vehicle crashes since 1996 (Deer Crash Website). Figure 3.11.1 presents nationwide statistics.



State	Deaths
Oklahoma	31
Oregon	11
Pennsylvania	48
Rhode Island	2
South Carolina	22
South Dakota	14
Tennessee	18
Texas	88
Utah	13
Vermont	6
Virginia	23
Washington	14
West Virginia	9
Wisconsin	57
Wyoming	13

Figure 3.11.1: USA Statistics of Road Fatalities Involving Animals
Source: USAToday (2010)

Approximately 300,000 accidents involving cars and large animals occur annually in the U.S. Furthermore, if unreported collisions with animals are included, the number is likely to reach one to two million incidents. Nearly 26,000 animal-vehicle crashes cause human injury and 200 results in a human fatality (FHWA, 2008). These statistics do not consider the number of animals killed. A study conducted by FHWA "identified 21

federally listed threatened or endangered animal species in the U. S. for which road mortality was documented as a major threat to their survival" (FHWA, 2008). Most studies that researched wildlife collisions and the types of roadways also found that most of the wildlife-vehicle collisions have occurred in rural areas (FHWA, 2008).

Figure 3.11.2: Wildlife Fence
Source: Quinn (2008)

Figure 3.11.3: Wildlife Barrier
Source: Quinn (2008)

Figure 3.11.4: Wildlife Sign
Source: Quinn (2008)

Several measures exist to mitigate wildlife-vehicle collisions and preserve species, such as signs, fencing, barriers, vegetation removal, and animal detection systems (see Figures 10.2, 10.3, and 10.4). Nonetheless, "wildlife crossings have been the most successful at reducing both habitat fragmentation and wildlife-vehicle collisions caused by roads" (Clevenger, 2006). Therefore, strategically located wildlife crossings have the potential to not only reduce fatalities, but also preserve animal life and endangered species. Wildlife crossings are defined as structural passages under or over roadways that enable animals to safely move across roadways. Examples include structures (viaducts), valleys, ridgelines, and game trails. Wildlife crossings are regarded as essential to habitat conservation because they combat habitat fragmentation caused by roadways by allowing a connection or re-connection between habitats (Clevenger, 2006).

3.11.1 Technical Feasibility

The effectiveness and efficiency of wildlife crossing structures are largely a function of the location, type, and dimensions of the crossings and, hence, are site specific. The attributes of wildlife crossings thus have to be carefully studied and planned to accommodate the species targeted and the surrounding landscape (FHWA, 2008). Existing information about wildlife movement and occurrence in the project area (e.g., road-kill data, maintenance reports, and DOT, agency, university, and Non-governmental organization (NGO) studies) have to be critically reviewed before selecting the type and location of specific wildlife crossings (Quinn, 2008). Given a lack of information to inform a decision, a field survey should be conducted. Furthermore, some researchers have found that arched structures may reduce the effectiveness of the crossing, because the arc shape hinders the animal's visibility, preventing it from seeing the other side of the road before climbing up it to cross (MountainNature.com, 2005). In addition, the type of crossing (i.e., overpass and underpass) preferred by different animals varies. Research conducted in 1996 on the crossing structures in the Banff National Park determined that underpass structures were "very effective for elk, deer, and coyotes," while large carnivores (e.g., wolves, cougars, and black and grizzly bears) were "reluctant to use them." However, more recently it has been shown that animals can adapt and start to use underpass crossings (MountainNature.com, 2005).

The design of the wildlife crossing structure is arguably the most important consideration, because it not only influences the cost but it also determines the effectiveness of the crossing. Therefore, it is essential that the following basic elements be incorporated into the design. First, the appearance of the structure should be natural and, thus, fit into the surrounding area. The vegetation approaching the structure thus has to be similar to the adjacent habitat and the "floor" of the structure has to have the soil as if the structure was not there. This will instill more comfort and confidence in the animal to use it. Moreover, the wildlife crossing should be located on the animal's natural migration route, i.e., where they naturally approach the road or where they are

historically found. Location is one of the paramount factors in determining the success of the wildlife crossing. Second, discordant elements, such as bright metal signs and construction materials, should be avoided near the approach areas, because they reduce the effectiveness of the wildlife crossing. Also, fencing is critical to the success of the wildlife crossing, because forces and trains animals to use the structure. Third, it is important that the crossing structure provides a clear line of sight, i.e., the animal is able to see the other side of the road (Carnivore Safe Passage, 2007).

As mentioned before, the design of wildlife crossing structures is arguably the most important aspect and determinant of the success of the structure. However, the construction of the structure can impose some challenges and hinder the feasibility of this VEA, especially when a crossing is implemented over or under an existing road. A number of construction techniques and structural solutions must be considered and evaluated during the initial planning and design phases. Traffic control or detours may also be required. Some solutions such as large underpasses may be inconvenient and very expensive. On new highway projects, most obstacles can be easily overcome if assessed and incorporated early on in the planning phases of the new project.

3.11.2 Political/Public Concerns

The implementation of wildlife crossing structures has received substantial support from the U.S. Congress. The approval of a federal highway bill—i.e., the Transportation Equity Act (TEA-21)—guaranteed the availability of federal funds for wildlife crossing structures on existing roads, as well as new road projects (Hartmann, 2001). In addition, The Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) (Public Law 109-59) "directed the Secretary of Transportation to conduct a national wildlife-vehicle collision study" (FHWA, 2008). These bills provide evidence of political concern for the road users' safety and environmental preservation.

Concurrently, the Humane Society of the U.S. has pointed to the impacts imposed on wildlife by roads and reported and supported initiatives that aim to mitigate wildlife-vehicle collisions and reduce road kill. Wildlife preservation has been debated and discussed among governments and organizations worldwide. All new road projects are required to have an environmental impact study and mitigation strategy for fauna and flora. Therefore, measures for engaging the public, communities, and various organizations, as well as for sharing a DOT's efforts and attitudes toward the environment and wildlife preservation, can be fundamental to reduce public controversy and outcry against projects (see Figure 3.11.5) (Quinn, 2008). Several ways exist to share information, including brochures, e-mails, mail, billboards, and signs (see Figure 3.11.6).

Figure 3.11.5: Public Outcry
Source: Quinn (2008)

Figure 3.11.6: Educational Billboard and Program
Source: Quinn (2008)

3.11.3 Legal Considerations

Environmental protection and traffic safety have been intensively discussed by lawmakers and governments. Several regulations and entities have been created and established nationwide and statewide to determine the impacts of infrastructure projects on the environment and road users. In the case of highway projects, the following regulations and entities pertain to the implementation of wildlife crossings: NEPA, the Ecological Society of America (ESA), and SAFETEA-LU at the national level, and the Texas Commission on Environmental Act (TXEA) at the state level. An example of how the courts can interpret the laws and regulations occurred in 2003, when the Arizona Court of Appeals ruled in favor of a motorist that collided with a road-killed elk on Interstate 40 (Ecostudies Institute, 2005). The court awarded $3.1 million to the plaintiff. Although other courts have ruled differently on the liability of states for animal-vehicle crashes, the decision of the Arizona Court of Appeals has initiated different perspectives for state DOTs regarding the need for and importance of wildlife crossings.

3.11.4 Financial/Economic Feasibility

The cost of a wildlife crossing structure is determined by the type of crossing (i.e., underpasses or overpasses) and if it will be built on an existing road or as part of a new highway project. In general, the overall cost of overpass structures is higher than underpasses. For example, an overpass that is being proposed on Montana Highway 83 (two-lane road) is estimated to cost between $1.5 and $2.4 million (FHWA, 2008). However, the benefits generated by wildlife crossings seem to outweigh the construction and maintenance cost of the structure. It is estimated that the cost of including a wildlife crossing in a road project increases the total cost of the project by only 7–8% (Bank et al., 2002).

Regarding potential funding sources to support the construction of wildlife crossings, many federal funding sources included in SAFETEA-LU presents a potential

source for wildlife crossings. Table 3.11.1 summarizes the potential funding sources that have been included in SAFETEA-LU for wildlife crossings.

Table 3.11.1: SAFETEA-LU Funding Sources
Source: FHWA (2008)

Funding Source	**Amount (2005-2009)**	**Notes**
Highway Safety Improvement Program (HSIP)	$5.1 bill.	This program has $90 million set aside each year for high-risk rural roads (wildlife-vehicle-collisions (WVC) are commonly a rural challenge). To be eligible for these funds, WVC mitigation projects need to be part of a state's Strategic Highway Safety Plan.
Bridge	$21.6 bill.	Bridge projects can provide an opportunity, with limited wildlife exclusion fencing and a limited extension to the length of a bridge, to funnel wildlife under the bridge, removing the hazard from the roadway.
Interstate Maintenance, Surface Transportation, National Highway Programs.	$25.2 bill. $32.5 bill. $30.5 bill.	Incorporate WVC mitigations within reconstruction and maintenance projects that are funded by these programs
Planning, Environment, and Realty (HEP) Programs	Numerous sources	Other federal transportation resources for WVC mitigation can be found in U.S. DOT agencies and programs. A list of programs funding environmental activities is on its website at http://www.fhwa.dot.gov/hep/index.htm (accessed 6 June 2008).
Public Lands Highways Discretionary Program	In 2006, 77 projects designated to receive $95.2 mill.	This program is authorized to fund projects on an annual basis in 11 western states that contain at least 3% of the total public land in the United States. See website at http://www.fhwa.dot.gov/discretionary/ (accessed 6 June 2008).
Surface Transportation Environment and Planning Cooperative Research Program (STEP)	$67.5 mill.	STEP is the sole source of funds for all FHWA research on planning and environmental issues. One environmental emphasis area called Natural Environment includes wildlife habitat. The FHWA will provide ongoing opportunities for funding collaborative research. See website at http://www.fhwa.dot.gov/hep/step/step.htm (accessed 6 June 2008).

Table 3.11.1m, cont.

Funding Source	Amount (2005-2009)	Notes
Technology Deployment Program	$4.1 mill.	Administered by FHWA, this program includes the Innovative Bridge Research and Deployment Program, which is intended to promote, demonstrate, evaluate, and document innovative designs, materials, and construction methods of bridges and other highway structures.
Transportation Enhancement Program (TEP)	Part of the Surface Transporta-tion Program	TEP funds transportation-related projects designed to strengthen the cultural, aesthetic, and environmental aspects of the U.S. intermodal transportation system, offering communities additional non-traditional transportation choices. See website at http://www.fhwa.dot.gov/environment/te/ (accessed 6 June 2008).
Federal Lands Highway Program (FLHP)	$893 mill.	The primary purpose is to provide funding for a coordinated program of public roads to serve the transportation needs of federal lands that are not a state or local government responsibility. This program contains five categories: Indian Reservation Roads, Park Roads and Parkways, Forest Highways, Public Lands Highways, and Refuge Roads. The FLHP roads serve recreational travel and tourism, protect and enhance natural resources, provide sustained economic development in rural areas, and provide needed transportation access for Native Americans. See website at http://www.fhwa.dot.gov/flh/flhprog.htm (accessed 6 June 2008).
Coordinated Federal Lands Highway Technology Implementa-tion Program (CTIP)	Numerous Sources	This is a cooperative technology deployment and sharing program between the FHWA Federal Lands Highway office and federal land management agencies. It provides a forum for identifying, studying, documenting, and transferring new technology to the transportation community. Many new innovative technologies, such as measures allowing fish passage through culverts, have been funded through the CTIP program. CTIP funds are normally used for technology projects related to transportation networks on federal public lands. Research projects are not eligible under this program. See website at http://www.fhwa.dot.gov/flh/ctip.htm (accessed 6 June 2008).
Federal Transit Administration	$45.3 bill.	This has a grant program for funding for transit-related planning and other projects. See web site at http://www. fta. dot.gov/grants_financing.html (accessed 6 June 2008).

Table 3.11.1m, cont.

Funding Source	Amount (2005-2009)	Notes
State and Community Highway Safety Program	Variable	Administered by National Highway Traffic Safety Administration, this program provides grants for the states, federally recognized Indian tribes, the District of Columbia, Puerto Rico, American Samoa, Guam, Northern Marianas, and the Virgin Islands. See website at http://www. federalgrantswire.com/state_and_community_highway_safety.html (accessed 6 June 2008).

In addition to the listed federal funding sources in Table 3.10.1, other federal programs can also grant funding for wildlife crossings, such as the U.S. Fish and Wildlife Service (FWS), Natural Resource Assistance Grant Programs, and Cooperative Endangered Species Conservation Fund. Furthermore, wildlife-vehicle collision mitigation programs can be eligible for funding support from private foundations, such as the National Fish and Wildlife Foundation and National Park Foundation, as well as corporate philanthropies, such as the National Directory of Corporate Giving and Fundsnet Services Online. Finally, Arizona local tax measures were approved to fund wildlife crossing structures (FHWA—Chapter 7).

The Western Transportation Institute conducted research to assess wildlife-vehicle collision cost in terms of the following parameters: property damage (e.g., vehicle repair cost), human injuries, human fatalities, towing, accident attendance and investigation, the monetary value of the animal involved, and disposal cost of the animal carcass (FHWA, 2008). Table 3.10.2 summarizes the estimated cost of colliding with the three most common animals involved in accidents (i.e., deer, elk, and moose).

Table 3.11.2: Estimated Cost of Wildlife-Vehicle Crash
Source: FHWA (2008)

Description	Deer	Elk	Moose
Vehicle repair costs per collision	$1,840	$3,000	$4,000
Human injuries per collision	$2,702	$5,403	$10,807
Human fatalities per collision	$1,671	$6,683	$13,366
Towing, accident attendance and investigation	$125	$375	$500
Monetary value animal per collision	$2,000	$3,000	$2,000
Carcass removal and disposal per collision	$50	$100	$100
Total	$8,388	$18,561	$30,773

From Table 3.11.2, it can be seen that collisions involving deer alone—which is the majority of the collisions at approximately one million per year in the U.S.—cost $8.39 billion annually to users, insurance companies, and the government (FHWA, 2008). In addition, the Insurance Institute for Highway Safety reported that more than 1.5 million deer-car crashes occurred in the U.S. in 2009, resulting in $1.1 billion in estimated vehicle damage alone (TxDOT, 2010).

Bridget Donaldson at the Virginia Transportation Research Council examined two underpasses in Virginia from June 1, 2004, to May 31, 2005, to assess their cost-effectiveness. Donaldson concluded that the least expensive underpass—i.e., $250,000 in construction costs—would re-pay its investment cost with the prevention of only three deer-vehicle collisions per year, whereas the more expensive underpass—$590,000 of construction costs—would require the prevention of nine deer-vehicle collisions per year to re-pay its investment cost (Donaldson 2005). In this cost-effectiveness analysis, only the costs to property damage were included. The true cost of each collision is much higher if insurance cost, "cost associated with human injury or death, cost of lost productivity, the economic value of the animal, and the cost of cleaning up the accident and removing the animal carcass" are considered (Ecostudies Institute, 2005).

Several mitigation methods for wildlife vehicle collisions have been pointed out in a 2008 sponsored by FHWA study (2008). Table 3.10.3 summarizes the mitigation methods analyzed and evaluated in the study. From Table 3.10.3 it is evident that

crossing structures (i.e., underpasses and overpasses) have the highest net benefit minus cost balance in preventing animal-vehicle collisions.

Table 3.11.3: Cost-benefit of Mitigation Measure
Source: FHWA (2008)

Mitigation measure	Cost ($/km/yr)	% DVC Reduction	Benefit ($/km/yr)	Balance ($/km/yr)
Standard warning signs	$18	0%	$0	-$18
Enhanced wildlife warning signs	$249	?	?	?
Seasonal wildlife warning signs	$27	26%	$10,904	$10,878
Animal detection systems (ADS)	$31,300	82%	$34,391	$3,091
ADS linked to on-board computer	?*	82%	$34,391	?
On-board animal detectors	$2,225*	?	?	?
Vegetation removal	$500	38%	$15,937	$15,437
Deer reflectors and mirrors	$495	0%	$0	-$495
Deer whistles	$23.5*	0%	$0	?
Carcass removal	$250*	?	?	?
Population culling	$2,508	50%	$20,970	$18,462
Relocation	$10,260	50%	$20,970	$10,710
Anti-fertility treatment	$61,702	50%	$20,970	-$40,732
Fence (including dig barrier)	$3,760	87%	$36,488	$32,728
Boulders in right of way	$2,461	?	?	?
Long bridges	$781,250	100%	$41,940	-$739,310
Long tunnels or long bridges	$1,500,000	100%	$41,940	-$1,458,060
Fence with gap and warning signs	$3,772	0%	$0	-$3,772
Fence with gap and crosswalk	$5,585	40%	$16,776	$11,191
Fence with gap and ADS	$9,930	82%	$34,391	$24,461
Fence with underpasses	$5,860	87%	$36,488	$30,628
Fence with overpasses	$26,485	87%	$36,488	$10,003
Fence with under- and overpasses	$7,510	87%	$36,488	$28,978

Assumes 1 km with 5 DVCs per year.
* Costs not in dollars/km/year, but in a different unit; see text.
? = Unknown or uncertain.

3.11.5 Environmental Considerations

Highways and roads have the "most widespread and detrimental impacts" (Spellerberg, 1998) and are threatening endangered species and animal habitats as follows: first, roads reduce the quality and amount of habitat. Second, roads increase animal mortality due to animal-vehicle collisions (i.e., road kill). Third, roads divide habitat in two sides, preventing animals on one side to access resources on the other side and vice-versa. Finally, roads segregate wildlife populations into smaller groups, making the groups more vulnerable. In summary, habitat fragmentation can entail extinction or

extirpation of particular species. Therefore, constructing wildlife crossings can be fundamental in minimizing the impacts of roads on the environment. Wildlife crossings can thus integrate habitats, reduce animal mortality, and help to save endangered species.

3.11.6 Potential Social Impacts/Benefits

The major and crucial social benefits of wildlife crossing structures encompass the fact that they reduce human fatalities and car accidents, thereby helping to preserve human life and assets as well as governmental and personal expenditures. Spending less money on road maintenance (e.g., removing animal carcass, investigating and reporting accidents, etc.) the government can direct the money to other priorities and, hence, benefit society. Finally, the construction of the crossing structure itself entails in job creation, contributing to social development.

3.11.7 Safety Considerations

According to the 2008 FHWA study, wildlife-vehicle collisions "are less severe than other crashes" and in general almost all animal-vehicle collisions "resulted in no human injury (95.4%)" (FHWA, 2008). Nonetheless, it still results in a number of human fatalities. Figure 3.11.7 illustrates the severity distribution of vehicle collisions with animals. In addition, several studies have demonstrated that a well-designed wildlife crossing can effectively enhance the roadway safety and diminish the number of animal-vehicle accidents. The solely safety concern that may arise whenever a wildlife crossing project is planned involves the construction of crossing structures on existing roads. As previously discussed on the technical feasibility section, some precautions have to be made to ensure safety, such as detours, traffic controls, and a constructability study.

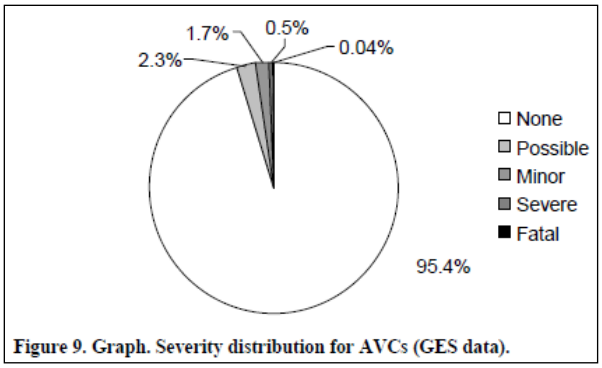


Figure 3.11.7: Severity Distribution of Animal-Vehicle Collision
Source: FHWA (2008)

3.11.8 Examples

Wildlife overpasses are very common in Europe. In North America, however, there are only six examples of these structures, of which two are located in the Banff National Park in Alberta, Canada. On the other hand, tunnels (i.e., underpasses) have more widely been implemented.

The Banff National Park and Trans-Canada Highway (in Alberta, Canada) have perhaps the "most recognizable wildlife crossings in the world" (Clevenger, 2006). There are 22 underpasses and two overpasses[7] (see Figures 10.8 and 10.9) in the Banff National Park that have been monitored and studied for more than 25 years. One of the findings of these studies is that ten species of large mammals have used the 24 crossings more than 84,000 times. Furthermore, wildlife crossings with fencing reduced the number of large ungulates' mortality by more than 80% in animal-vehicle collisions. Because of the documented benefits of the current wildlife crossings and in an effort to increase driver safety, Parks Canada is planning to build 17 new crossing structures across the Trans-Canada Highway (Clevenger, 2007).

[7] The two overpasses were constructed in 1997 at a cost of approximately $1.851 million (MountainNature.com).

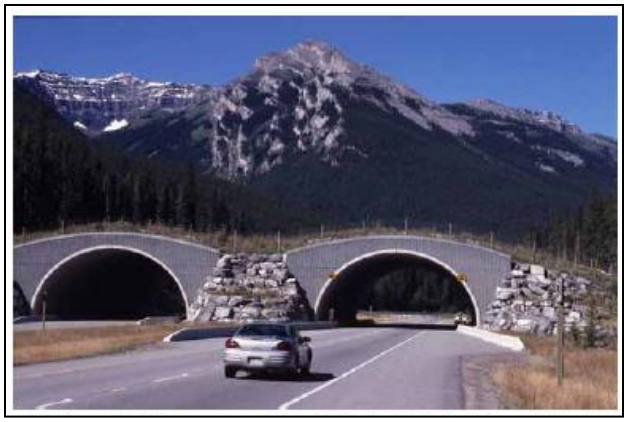


Figure 3.11.8: Wildlife Overpass in Banff National Park
Source: FHWA (2008)

Figure 3.11.9: Underpass Crossing
Source: Quinn (2008)

Interstate 75 (Collier and Lee Counties, Florida) has 24 highway underpasses (see Figure 3.11.10 and 10.11) and 12 bridges that were modified for wildlife crossings along 40 miles. These crossing structures are "specifically designed to target and protect the endangered Florida panther" (Scott, 2007). The Florida Fish and Wildlife Conservation Commission reported that no panther has been killed in areas with wildlife crossings and fencing; therefore, the state intends to build many more crossing structures.

Figure 3.11.10: Southern Florida Underpass for Wildlife
Source: FHWA (2008)

Figure 3.11.11: Underpass Crossing
Source: Quinn (2008)

Finally, the Hoge Veluwe National Park in the Netherlands has three wildlife overpasses (called ecoducts) across Highway A50. It is estimated that in one year almost 5,000 deer and wild bears used at least one of the crossing structure (Danby, 2004). Figure 3.11.12 presents computer-generated illustrations of an overpass crossing.

Figure 3.11.12: Overpass Crossing Illustration
Source: Quinn (2008)

3.11.9 Concluding Remarks

Wildlife crossings have gained attention and consideration on several highway projects. Despite the benefits for safety and environment, some points must be considered when assessing the feasibility and importance of this VEA. These points include:

a. location and design of wildlife crossing structure are crucial and determine the effectiveness of the project;
b. studies about wildlife migration routes must be undertaken to determine the most effective location;
c. Federal funding programs and accounts exist and can be used to finance wildlife crossing projects;
d. underpass and overpass structures are the most cost-effective solutions to mitigate and reduce vehicle-animal accidents;

e. construction of wildlife crossings on existing roads can entail and require some safety considerations; and

f. possible liability exists for DOTs for animal-vehicle collisions.

CHAPTER 4: VEA METHODOLOGICAL FRAMEWORK

This Chapter explains the methodological framework that was developed to guide TxDOT in identifying and selecting the most appropriate VEA – given a specific objective and TxDOT's land holding – for implementation. The Chapter concludes with some remarks and general recommendations regarding the methodological framework and decision making process are presented.

4.1 METHODOLOGICAL FRAMEWORK

This section of Chapter 4 explains the methodological framework (see Figure 4.1) that was developed to provide TxDOT with step-by-step guidance throughout the decision making process of evaluating and selecting the most suitable VEA – given the agency's land asset and objective – for implementation, as well as identifying and involving key stakeholders. The methodological framework is rooted in the information and findings collected during the research project. Each of the steps (see Figure 4.1) is sequentially discussed in this section. An explanation of the function and, consequently, importance of each step is provided. Important information pertaining either to the decision step or methodological framework is also introduced where appropriate. Finally, an example – i.e., hypothetical 30 acres of vacant land owned by TxDOT in a residential neighborhood in central Austin – is used to illustrate how to use the methodological framework. The example depicts each step of the methodological framework by simulating the identification and assessment process of potential VEAs – given a specific scenario – and key stakeholders.

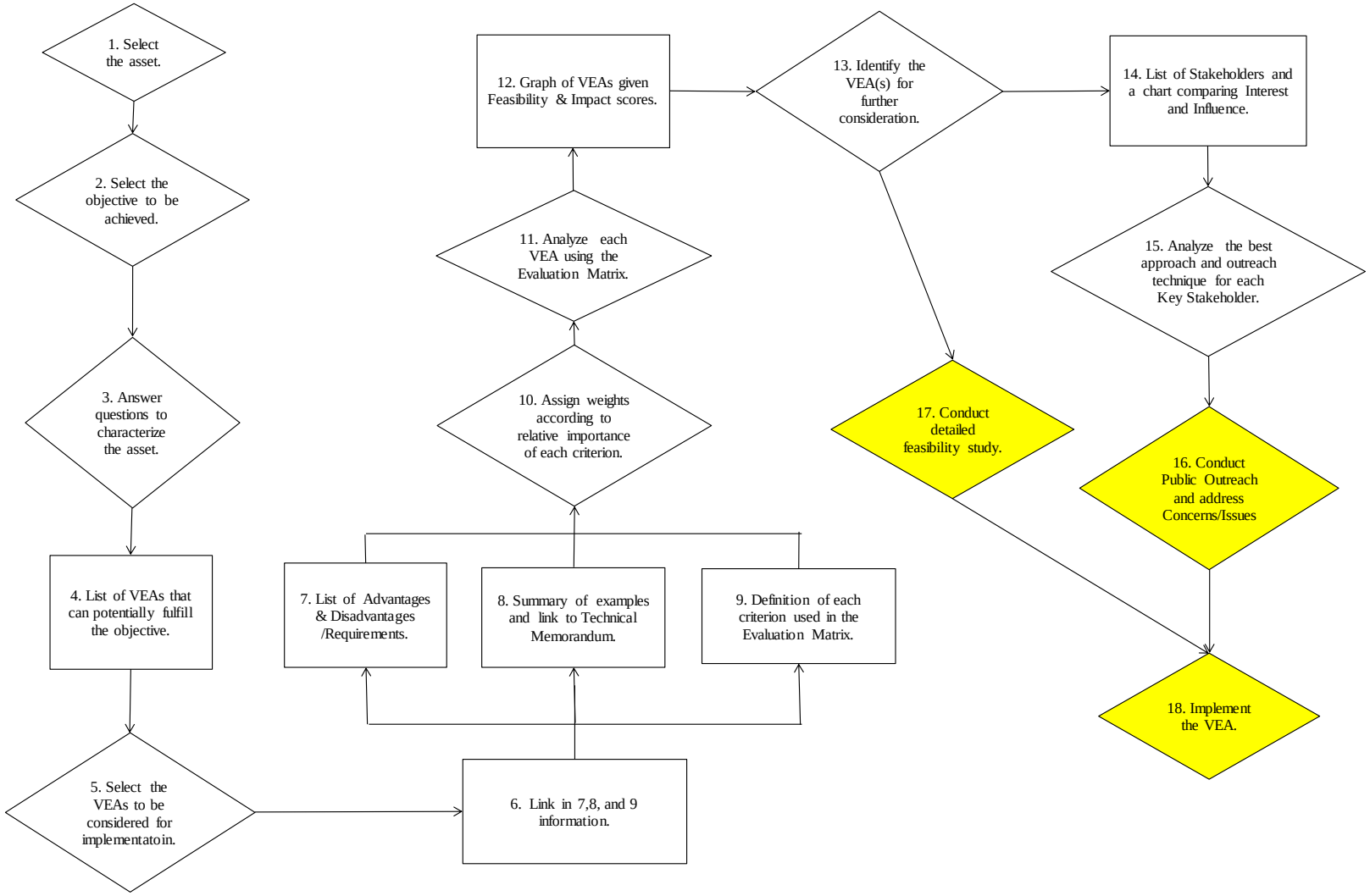


Figure 4.1: Value Extraction Application Methodological Framework

Select Type of Asset (Step 1) and Specify Objective (Step 2)

The first step in the methodological framework is selecting the type of asset on which the the VEA will be implemented and the objective to be achieved. The reason is that not all eleven VEAs are appropriate for all types of TxDOT assets – which comprise vacant lands, right-of-way (ROW), office and facility buildings, and rest areas (see Figure 4.2). At the same time, not all eleven VEAs can potentially meet TxDOT's three objectives – i.e., save costs, increase revenue streams, and enhance societal goals (see Figure 4.3). Therefore, by specifying the type of asset and intended objective TxDOT can start to filter and reduce the number of potential VEAs considered. Figure 4.4 to Figure 4.7 illustrate all the potential VEAs initially considered given the type of asset and intended objective. For the example, a vacant land is the type of asset (see Figure 4.2) and increase revenue streams is selected as the objective (see Figure 4.3). It is worth to noting that although some VEAs can potentially help TxDOT achieve more than one objective simultaneously, this framework requires the selection of one primary objective.

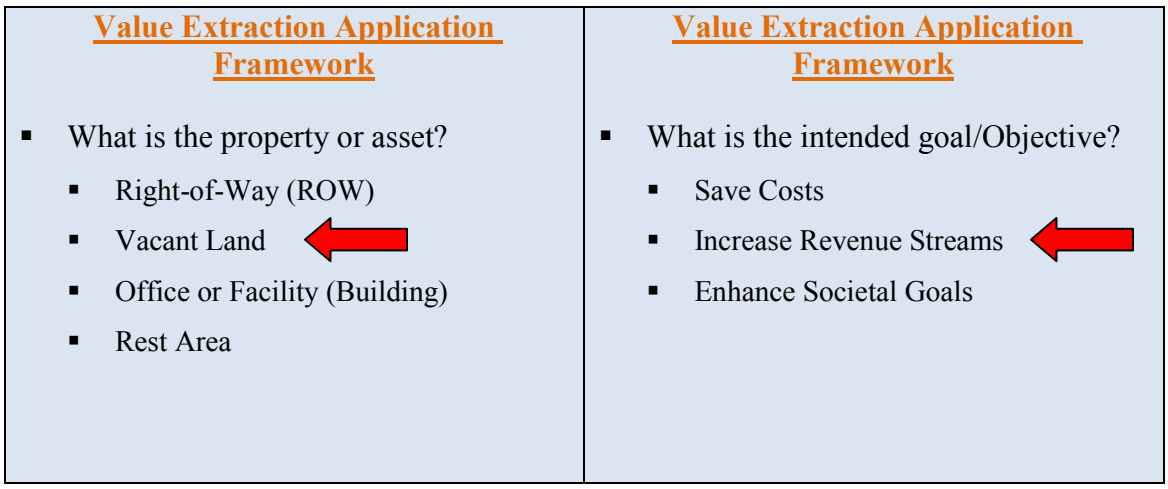


Figure 4.2: Selection of the Asset Type

Figure 4.3: Selection of the Objective

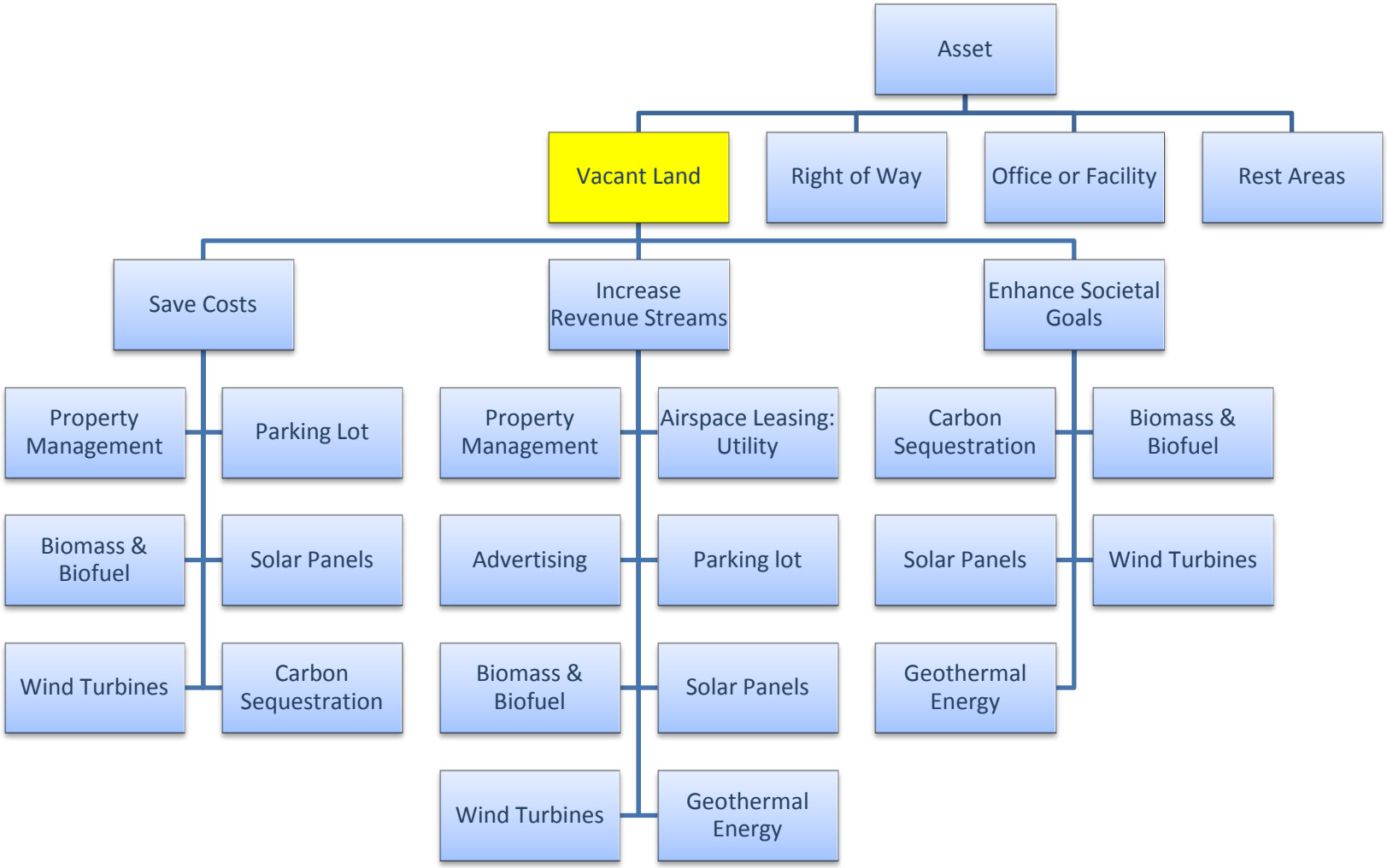


Figure 4.4: List of potential VEAs for vacant land

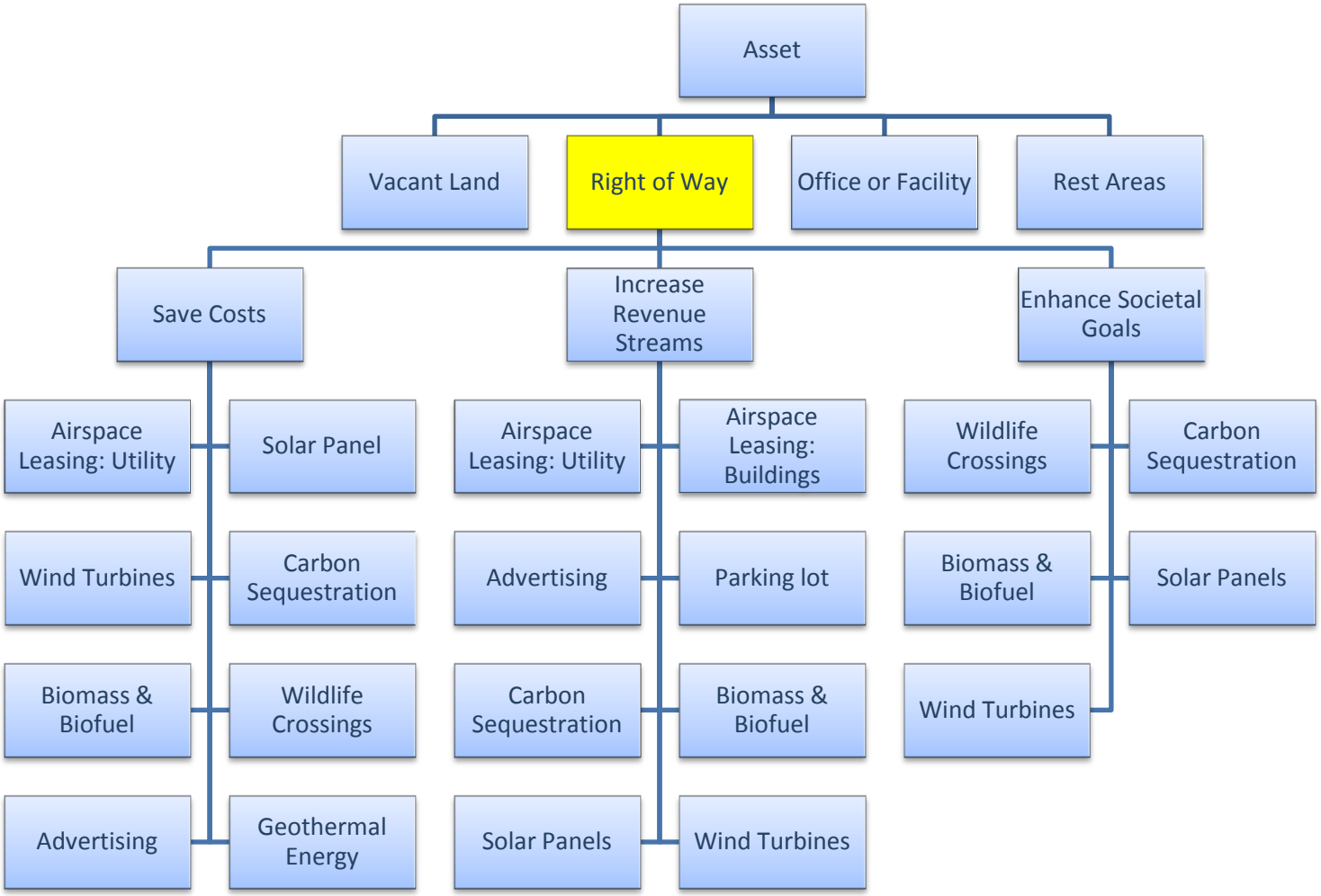


Figure 4.5: List of potential VEAs for ROW

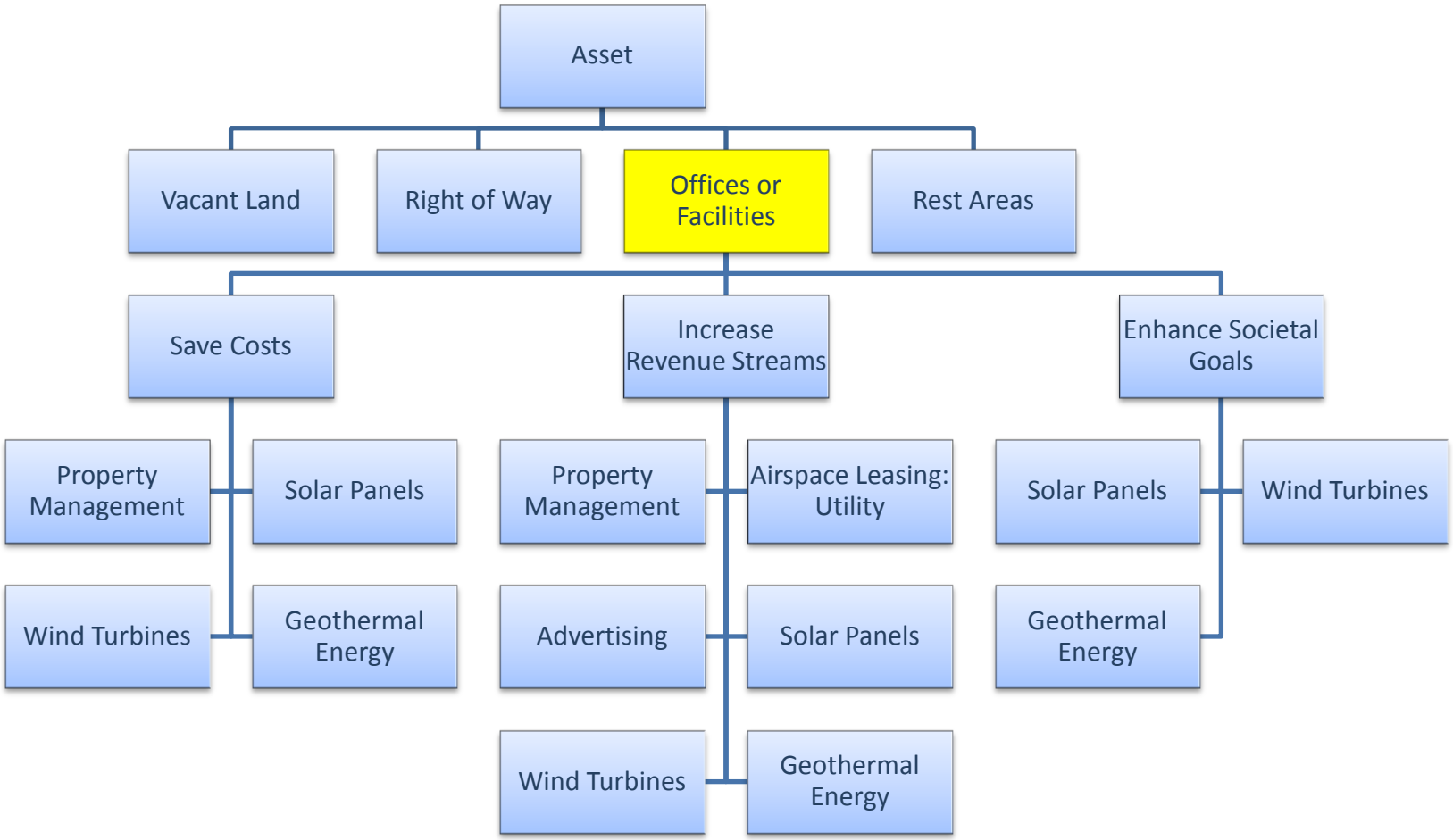


Figure 4.6: List of potential VEAs for offices and facilities

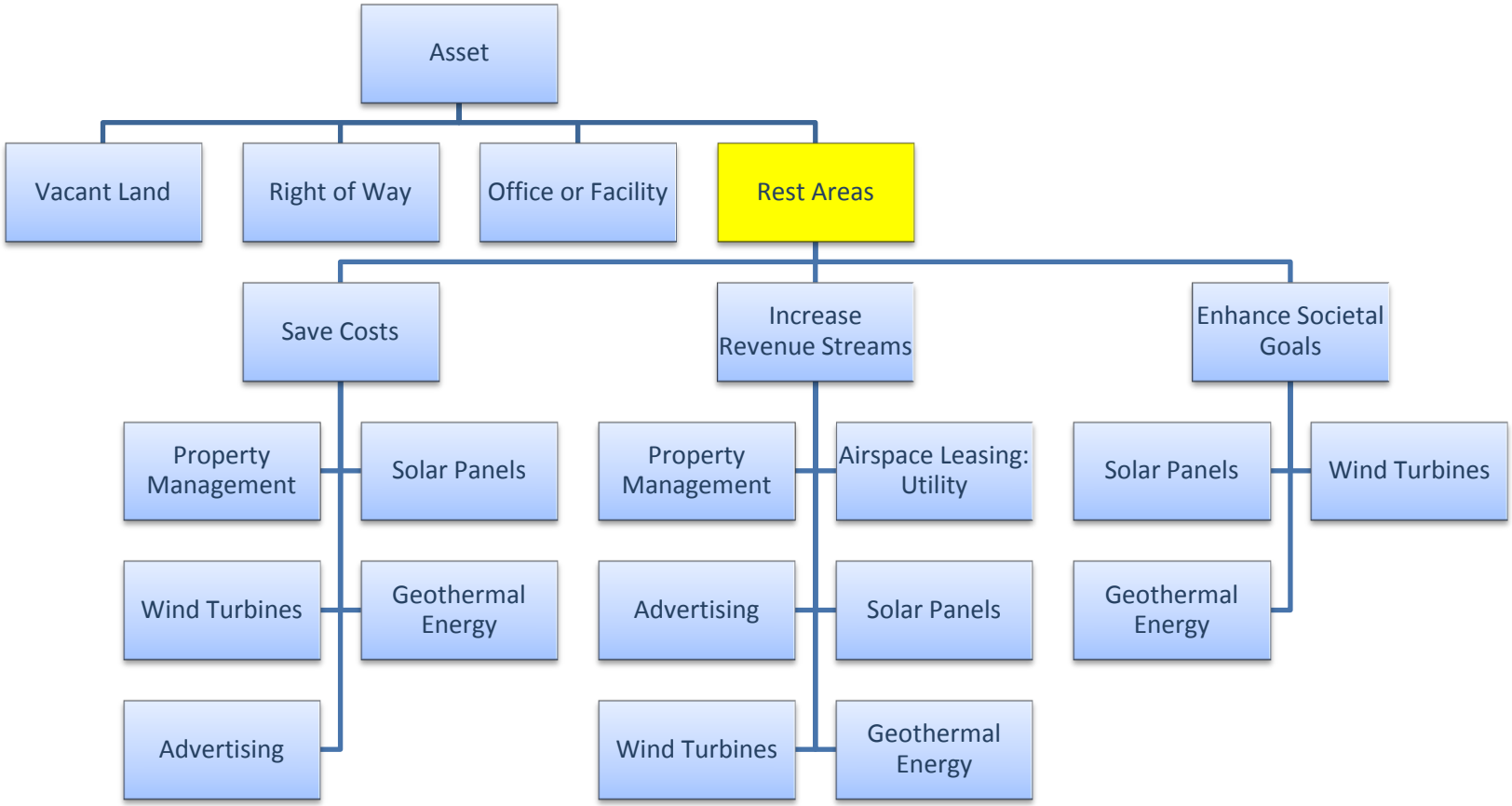


Figure 4.7: List of potential VEAs for Rest Areas

Answer Questions to characterize The Asset (Step 3)

In addition to the type of asset it is also important to consider the features, proprieties, and characteristics of the asset as it influences and determines the feasibility of specific VEAs. Therefore, the next step in the methodological framework is to characterize the asset considered. To do so, questions are provided to characterize the different type of assets (see Figure 4.8 and Appendix I). The questions address aspects that can prevent/impede the implementation the VEA and/or can preclude a VEA from achieving the stated objective. The questions relate to location of the asset (e.g., urban center), surrounding environment (e.g., distance to transmission lines and wetlands), climate and weather of the area (e.g., rainfall, and solar and wind energy potential), current use, timeframe to use property, and size of the property. These questions are intended to be as a second filter of the potential VEAs, thereby reducing the number of alternatives further. Appendix II explains how the questions affect and filter potential VEAs. Figure 4.8 shows questions for vacant land and the answers for the hypothetical example that is provided. Similar questions for the other three types of assets (i.e., ROW, office & facilities, and rest areas) can be found in Appendix I.

Value Extraction Application Framework

- What are the characteristics of the vacant land?

1	Is the property in a prime real estate location?	~~Yes~~		No
2	Is the property in an urban center or commercial area or near a community center?	Yes		~~No~~
3	Is the property adjacent to or near a residential or commercial area?	~~Yes~~		No
4	Does the property have good easy access (or can access be secured)?	~~Yes~~		No
5	When will the property be developed (i.e., in how many years)?	< 5 yrs	5 yrs > < 20 yrs	~~> = 20 yrs~~
6	Is the property exposed to high traffic volumes?	Yes		~~No~~
7	How large (acres) is the property?	< 5 Acres		~~>= 5 Acres~~
8	Is the property on a flat terrain (or on a terrain with slope less than 20%)?	~~Yes~~		No
9	Does the property have good sun exposure (i.e., no sunlight obstruction)?	~~Yes~~		No
10	How far (miles) is the nearest a transmission line or electricity user/customer to the property?	~~< 1 mile~~		> = 1 mile
11	Is the property in a Competitive Renewable Energy Zone?	Yes		~~No~~
12	Is the property free of any wind obstructions (e.g., buildings, mountains, and hills)?	~~Yes~~		No
13	Is the property being mowed?	~~Yes~~		No
14	Can mowing of the property be halted?	Yes		~~No~~
15	What is the predominant vegetation on the property?	~~Grass~~	None	Tree
16	What is the average rainfall at the property?	< 15 in		~~> = 15 in~~
17	How far (miles) is the nearest biorefinery to the property?	= < 50 miles		~~> 50 miles~~

Figure 4.8: Questions to Characterize Vacant Land (Example)

Select from the list of VEAs that can potentially fulfill the objective the ones to be considered in the analyzed (Step 5 & 6)

As previously mentioned, according to the decision maker/user's responses on the previous step, some preliminary potential VEAs may become unfeasible to be implemented or unable to fulfill the primary TxDOT's objective, therefore being disregarded from the proceeding decision analysis process (see Figure 4.9). Moreover, if for any reason the decision maker/user does not want to consider certain potential VEAs, which were not eliminated by the answers of the questionnaire, he or she will be able to select additional VEAs to be dismissed from the decision analysis. In the example used herein, the decision maker/user decided to not select geothermal energy to proceed within the decision analysis, thereby remaining only 3 of 4 potential VEAs (see Figure 4.9). A thorough explanation about how the asset characteristics affect (i.e., answer for the questions) potential VEAs is found in Appendix II.

Value Extraction Application Framework

- Increase Revenue Stream (Vacant Land)
  - Potential VEAs:
    - **Property Management (e.g., sell, lease, or swap land)**
    - **Leasing: Utility (e.g., telecommunication antenna)**
    - Advertising
    - Parking lot
    - Biomass & Biofuel
    - **Solar Panels**
    - Wind Turbine
    - **Geothermal Energy**

Figure 4.9: Selected VEAs for Further Analysis (Example)

Review the Provided Information to Gain Information/Insight about Potential Benefits, Impacts, Obstacles and Challenges Associated with Each VEA (Step 7 and 8)

Prior to assessing each potential VEA, the user has to gain an understanding of the benefits, requirements, and impacts of the VEAs, as well as implementation challenges. To facilitate this understanding, a summary of advantages and disadvantages/requirements is provided (see Appendix III) for each VEA. In addition, a link to best practice examples uncovered during the background review is provided (see Appendix I and Appendix V). The user is also able to access technical information about each VEA - presented as Chapter 3 in this thesis. Figure 4.10 provides the advantages and disadvantages/requirements of one potential VEA considered– i.e., Airspace Leasing: Utilities – as the example. Figure 4.11 provides a best practice example for another potential VEA – i.e., Solar Panels.

Value Extraction Application Framework

Airspace Leasing (Utilities)

Go to Examples

Advantages	Disadvantages / Requirements
▪ Enhanced and available telecommunication signals can contribute to social and educational development, as well as help promote economic development and create jobs. ▪ Can enhance safety in remote area (e.g., tornado warming, communication of animal carcass, existing obstacle, pavement conditions, and severe weather conditions). ▪ Several potential ways to implement this VEA. ▪ Can be even easier to implement if considered in new highway projects. ▪ Can provide the State access to technology infrastructure. ▪ Can y ield a better telecommunication network , helping TxDOT and other public agencies to improve their information management systems and, consequently, enhance their services, implement an efficient maintenance program, and make better decision (i.e., wisely spend public money). ▪ TxDOT already has some airspace agreements for utilities that generate revenue, but not a formalized program. A formal program could bring more contracts and revenue for the agency and State. ▪ Some application can be implemented with a short-term agreement (5 years) ▪ Can facilitate the implementation or expansion of TxDOT's Advanced Rural Transportation System (ARTS) , Dynamic Message Signs, 511 travel information, and Highway Advisory Radio.	▪ Requires license and permits such as environmental ▪ Need to comply with FHWA and ASSTHO guidelines and requirements, as well as NEPA. Some policies may be out of date and not address new technologies. ▪ Importance of contractual agreement (i.e., liabilities and responsibilities) and legal consul during the process. ▪ Only applicable to private utilities ▪ Some utilities can entail safety and environmental concerns (e.g., explosion, contamination, leak, and crash) ▪ May cause traffic disruption and hazardous situation during construction and maintenance. Importance of good planning and assessment, as well as access to the site. ▪ FHWA requires environmental evaluation and compliance with NEPA ▪ Requires a formalized, clear, and public (open) process (i.e., fair market price, equal right to all interested parties, auction and bid, specifications, and guidelines) ▪ Requires a construction and maintenance plan (i.e., access, minimize impacts on traffic, safety, and execution method) ▪ Some application requires special considerations such as, buried depth, concrete coat, and reinforcement. ▪ Private companies will need to have free or partial access to ROW or public properties. ▪ May compete with private sector (e.g. tower companies).

Figure 4.10: Advantages & Disadvantages/Requirements (Example)

Go to Back to Adv./Disadv.

Value Extraction Application Framework

Example: Solar Panels

Go to Technical Memorandum

Oregon DOT (ODOT) is the pioneer in implementing solar panels in highway ROW. In December 2008, ODOT concluded the installation of the first solar arrays project at the interchange of IH-5 (see figure 5.8). The arrays can produce up to 117 KWh annually, i.e., 1/3 of the energy needed on the site. Basically, the solar arrays feed the grid with the electricity produced during the day whereas at night the grid supplies the electricity for interchange lighting.

Currently, SMUD Sacramento (California) is exploring a 594 solar panels project. Also, Caltrans is analyzing the feasibility of installing solar charge stations for electrical vehicles along highways, as well as the installation of solar panels for light poles.

In 2010 the Ohio DOT, in conjunction with the University of Toledo, installed a 100KW solar array – composed by 966 rigid solar panels and 198 flexible solar panels – in the ROW off IH-280 and Greenbelt Parkway in Toledo, OH. The solar array provide the entire electricity demanded at the Veteran's Glass City Skyway Bridge, which has a 196-foot lighted pylon containing 384 light emitting diode fixtures

A number of solar projects can be found in European and Oceania transportation ROW. Germany, for example, has invested € 11 million in a solar panel project on top of a tunnel on highway A3 that has a 2.8 MW capacity. It is expected that the investment cost will be recovery in 16 years from cost savings. The 16,000 solar modules occupy 2.7 km and will provide electricity to nearly 600 houses. In Australia and some European countries, solar panels have a "dual use". Besides energy generation, the panels also act as sound barriers.

Figure 4.11: Solar Panel Application (Example)

Understand the Seven Criteria and Assign their Weights (Step 9 & 10)

The second step preceding the assessment of each potential VEA is assigning weights to the seven criteria in accordance with their respective significance in influencing the outcome. Also, a link to the definition of each criterion – as noted in Chapter 2 – is provided (see Figure 4.12). As explained in Chapter 2, the user can resort to different methods to weigh the criteria, but ultimately the weights need to be

normalized in terms of the feasibility and impact criteria categories. In the example used, a scale of 1 to 10 was adopted (seen the yellow column in the left table in Figure 4.13). The grey column in Figure 4.13 represents the calculated normalized weights. Finally, the right table in Figure 4.13 contains the scoring scale and the meaning that are attached to the difference score values. A complete and detailed explanation of the importance and methods for weighting the criteria, as well as the scoring scale can be found in Chapter 2.

Value Extraction Application Framework

Go Back

CRITERION	DESCRIPTION
Technical Feasibility	Technical Feasibility consists of requirements needed to facilitate and ensure a successful implementation of a VEA. For example, site characteristics are fundamental and determinant for several VEAs such as, solar panels (e.g., proximity to transmission lines, plainness, and minimum of 5 acres of available land) and biomass (e.g., minimum of 15 inches rainfall, soil characteristics, distance to biorefineries, and minimum of 1 acre of available land). Technical feasibility also concerns engineering and construction standards and requirements. For example, to construct a building over a highway the distance between columns (i.e., free span), minimal clearance, construction methods, and access to the jobsite can impose challenges and difficulties, thereby precluding or preventing the project execution.

Figure 4.12: Definition of Technical Feasibility Criterion

Value Extraction Application Framework

Criteria Weight & Score Scale

	Weight Scale		
Feasibility	Technical	0.23	5
	Legal	0.45	10
	Economical	0.32	7
Impact	Political/Public	0.21	6
	Environmental	0.24	7
	Safety	0.34	10
	Social	0.21	6

Score Scale		
Negative Impact	-2	Major Concerns
	-1.5	
Somewhat Negative	-1	Minor Concerns
	-0.5	
Neutral	0	Neutral
	0.5	
Somewhat Positive	1	Minor Benefits
	1.5	
Positive Impact	2	Major Benefits

Weight Scale:
10 = Very Important
1 = Insignificant or Indifferent

Figure 4.13: Assigning Criteria Weights (Example)

Analyze each VEA using the Evaluation Matrix (Step 11)

In next step, each potential VEA is assessed using the evaluation matrix developed in this research project and discussed in Chapter 2. At this point, the user must have a clear understanding of each potential VEA, its benefits, challenges, and impacts. If not, additional information should be gathered regarding the specifics of the VEA.

As presented in Chapter 2 and illustrated in Figure 4.14, the evaluation matrix comprises a set of statements pertaining to potential impacts – positive or negative -, benefits, concerns, and requirements in terms of the seven criteria aforementioned (see Figure 4.13). The user has to assign a score – from -2 to 2 – to each criterion when assessing each statement (see Figure 4.14). The total score for the feasibility and impact categories is calculated by summing the contribution of each criterion included in the category. The contribution of each criterion is calculated by multiplying the respective normalized weight of the criterion with the average score assigned to each statement (see

Figure 4.14). A detailed explanation of the partial and total score calculations can be found in Chapter 2 while Appendix IV presents the statements and respective criteria of the evaluation matrix for each VEA.

Value Extraction Application Framework

Property Management

		FEASIBILITY			IMPACT					
		Technical	Legal	Economical	Political/ Public	Environmental	Safety	Social		
1	Trained in-house staff in ROW and Real Estate management	1		-0.5						
2	In-house staff member to champion the evaluation and implementation of a property management application	2		-0.5						
3	Ease of integrating property management application in TxDOT's organazational and decision-making structure	-0.5								
4	Availability of resources to update databases and/or GIS inventory of assets	1			1					
5	In-house resource to systematically review and assess current asset and future asset needs	0.5			1.5					
6	Willingness to invest in resources such as, information system, website, and GIS system	1		-0.5	-0.5					
7	Access to TxDOT's property inventory to characterize property assets (e.g., size, location, value, maintenance cost, and overall condition)	2								
8	Ability to communicate, involve, and share information with general public and stakeholders about the value extraction application project (i.e., transparency and equal access to information)	1			1.5					
9	Current value (i.e., market/Real Estate price) of the property	-0.5	1	2	1					
10	Current maintenance expenses on the property asset and potential savings if disposing of the property			2						
11	Formal procedures/guidelines available to conduct/implement TxDOT property management program	0.5	2		0.5					
12	Anticipated impacts on nearby community of "new" property use (i.e., new owner or lessee), including potential to mitigate anticipated impacts				-0.5	-1	0.5	1.5		
13	Anticipated environmental impacts and mitigation measurements of "new" property use		0.5	-0.5		1.5		0.5		
14	Permit or license required for "new" property use		1.5	-0.5						
15	Financial resources of and warranties (i.e., bond approval and surety) provided by the developer interested in buying/leasing/swapping property		2	2						
16	Anticipated direct and indirect jobs created and economic development impacts resulting from "new" use of property			2	2			2		
17	Anticipated benefits to TxDOT (e.g., financial, technical, and safety) of disposing of "obsolete" assets	2		2	2		0.5	1		
18	Potential concerns anticipated by General Land Office (GLO) or another public agency (e.g., FHWA, DOE, and DOD)		-0.5		-1					
19	Potential conflict with zoning law, city's master plan, and transportation's plan		0.5		-0.5			-0.5		
20	Anticipated political and public opposition to transaction (e.g., controversy and potential impacts triggered by the "new" use)				0.5					
21	Legal constraints/issues that can jeopardize the transaction		2							
22	Available legal consultants/resources to implement TxDOT property management program		0.5	-0.5						
23	Available legal consultants/resources to advise and review transactions and contractual agreements		1.5	-0.5						
24	Resources required to train or acquire in-house legal resources/counsel			-0.5	-0.5					
25	TxDOT's exposure in terms of liability and risks		0.5	-0.5	-0.5				Feasibility Score	Impact Score
26	Investment required by TxDOT to implement the Value Extraction Application			-0.5	0.5					
	TOTAL CONTRIBUTION OF EACH CRITERION	0.21	0.48	0.11	0.10	0.06	0.17	0.19	**0.79**	**0.52**

Figure 4.14: Evaluation Matrix for Property Management (Example)

Analyze VEA(s) Given Feasibility and Impact Scores and Identify VEA(s) for Further Consideration (Step 12 & 13)

The outcome of Step 11 is a chart displaying the feasibility and impact scores of each VEA assessed (see Figure 4.15). The feasibility score is presented as the X-axis coordinate and the impact score is presented as the Y-axis coordinate. In the example, it is evident that the property management VEA is the most feasible and has the higher impact score given the specific circumstances. However, a VEA may have a relatively higher feasibility but lower impact score compared to the other VEA(s). In this case, the user will have to decide whether to move forward in considering one or more VEA(s). It is also important to bear in mind that the outcome reflects the inputs entered by the user and will vary given changes to criteria weights and/or assigned scores. Furthermore, as stated in chapter 2, a positive score does not necessarily imply no concerns or challenges surrounding the implementation of the VEA. The evaluation matrix though provides TxDOT with a resource and a mechanism to assess potential VEAs and to discard obvious VEAs that are unfeasible

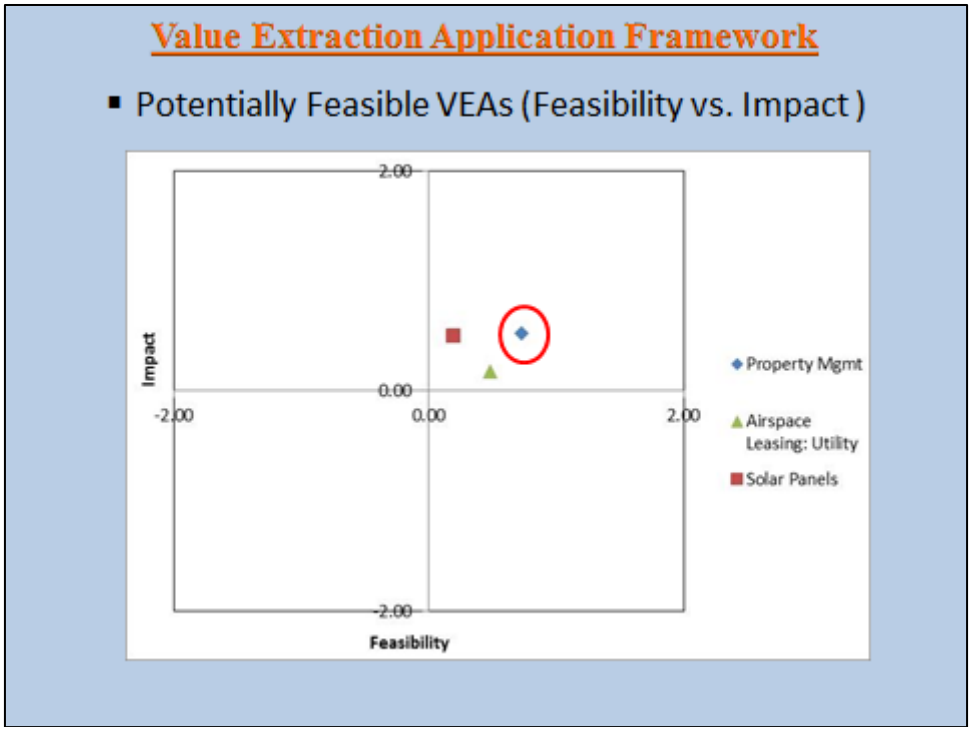


Figure 4.15: Example of outcome from evaluation matrix

List Stakeholder and Assess Interest and Influence (Step 14)

Once TxDOT has identified a VEA for implementation, the next stop is stakeholders outreach. However, a general outreach approach or attempting to reach out to a large and diversified group of stakeholders with various levels of interest and influence can be ineffective and costly. On the other hand, failing to reach out to specific stakeholders can jeopardize the VEA implementation.

Similar to the technique used to evaluate and compare potential, the user has to assess the level of interest and influence of the identified stakeholders. In summary, influence is the ability of a stakeholder to impede or expedite the implementation of an application, while interest represents the importance of the application to the stakeholder. This evaluation allows for the identification of key stakeholders and focused public outreach. The importance of stakeholder analysis and the concept of influence and interest are discussed in Chapter 5.

To assist TxDOT in identifying key stakeholders, a list of potential stakeholders is provided for each VEA (see Appendix VI). Figure 4.16 illustrates the identified stakeholders for the property management. The user has to evaluate each stakeholder on a scale of 0 to 5 (see Figure 4.16) in terms of its influence and interest. Similar to the evaluation matrix, a chart is provided to facilitate the visualization and identification of key stakeholders (see Figure 4.16). Chapter 5 explains each of the quadrants in the chart in detail.

Value Extraction Application Framework

- List of Stakeholders: Property Management

Stakeholder	Influence	Interest
Local government		
Zoning/Planning department	3	3
Mayor/Council	4	3
State government & Legislators	5	4
Nearby landowners	2	5
Nearby Businesses	3	5
General public	2.5	2.5
Potential buyers, Developers, or Investors	1	5
TXDOT Employees	5	2
Transit agency	3	4
Transportation Agencies (FHWA and AASHTO)	5	4
Environmental Agencies	4	5
General Land Office (GLO)	3.5	4

Score Scale:
5 = Very Important
0 = Insignificant or Indifferent

Figure 4.16: Stakeholder Analysis (Example)

Analyze the Best Approach and Outreach Technique for each Key Stakeholder (Step 15)

Once the key stakeholders have been identified the next step is to determine the best approach and outreach technique to engage the identified key stakeholders. Several

techniques exist to conduct stakeholder outreach, but these vary substantially in terms of cost and effectiveness. Hence, it is fundamental to determine the best approach to reach out to different key stakeholders. Chapter 5 lists and discusses available outreach techniques.

Conduct Detailed Feasibility Study and Public Outreach (Step 16, 17, and 18)

After identifying the VEA for implementation, identifying key stakeholders, and determining the outreach approaches, TxDOT also has to conduct three tasks to ensure successful implementation. First, TxDOT has to conduct the public outreach and address any concerns or issues that may arise. TxDOT also has to conduct a detailed feasibility study for the selected VEA, including an economic and financial analysis, technical analysis, and resources analysis. Ultimately, when the VEA is implemented legal and contractual agreements will be required, as well as design plans, construction schedules, mitigation measures, and financial agreements.

4.2 CONCLUDING REMARKS AND GENERAL RECOMMENDATIONS

The methodological framework presented in this chapter was developed to assist and guide TxDOT in identifying the most appropriate VEA(s) for implementation and key stakeholders that should be engaged. The methodological framework comprises a series of steps/questions intended to filter potential VEAs given the property asset and the agency's objective. Multi-attribute criteria decision analysis is used to evaluate and compare different potential VEAs. The methodological framework also helps TxDOT to recognize and understand barriers, challenges, benefits, impacts, and implications associated with each VEA. Nonetheless, some issues that may affect the implementation may not be covered in this framework. Also, additional information about current technologies, local vendors, funding strategies, and project specifics may be valuable prior to or during the evaluation process. Finally, it is important that TxDOT documents and maintains lessons learned, as well as update the questions and potential VEAs. Lessons learned can continue to improve the methodological framework and increase the

likelihood of successful VEA implementation. Moreover, the methodological framework was developed based on actual information (i.e., economic, technological, and political) collected on existing projects – some of which were pilot projects. New VEAs may emerge and technologies may become more cost-effective and/or efficient, thereby altering the requirements and/or reducing barriers.

In evaluating the potential VEAs, it is recommended that the TxDOT user consults with agency staff from the Environment, Traffic Operations, Planning, Public Relations, Maintenance, and ROW Division, as well as the Office of General Council. This will assist the user in evaluating each criterion in the evaluation matrix. Also, the methodological framework may not yield one "right" VEA. Indeed, the ultimate decision on whether to pursue which VEA still pertains solely to the TxDOT user.

CHAPTER 5: STAKEHOLDER ANALYSIS

This Chapter introduces and discusses the stakeholder[8] analysis framework that was developed to assist TxDOT in identifying, reaching out, and involving key stakeholders[9] when considering VEA implementation.

5.1 STAKEHOLDER ANALYSIS FRAMEWORK

Stakeholder outreach is an important component of most transportation projects. However, a general outreach approach or attempting to reach a very large and diversified group of stakeholders with various levels of influence and interest can be ineffective and costly. Too often public outreach efforts are conducted with very few attendees or without achieving the set objectives. On the other hand, failing to reach out to specific key stakeholders can jeopardize the VEA implementation. Therefore, meaningful stakeholder outreach will require a targeted approach to ensure that these outreach efforts are conducted in an efficient and cost-effective manner. To do so, a stakeholder analysis framework that comprises a process to identify potential stakeholders, sort stakeholders according to interest and influence, identify key stakeholders, and select and conduct the most appropriate outreach technique was developed (see Figure 5.1).

This Chapter explains each step of the stakeholder analysis framework (see Figure 5.1.) in detail.

[8] Stakeholders are persons, groups, or institutions with interests in a project or policy or who may be directly or indirectly affected by the process or the outcome. (World Health Organization, ND)

[9] Key Stakeholders are those who can significantly influence, or are important to the success of the project." (World Health Organization, ND)

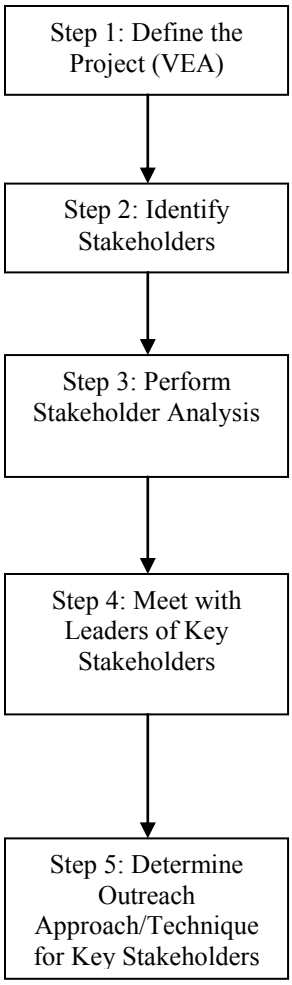


Figure 5.1: Stakeholder Analysis Flowchart

Step 1: Define the Project (VEA)

Before any stakeholder analysis is conducted, the goals and objectives of the VEA must be defined so that they can be effectively communicated to the. Furthermore, outlining the potential advantages and disadvantages of the VEA helps in determining who the stakeholders may be.

Step 2: Identify Stakeholders

Based on the characteristics of the VEA, its location, and the likely impacts, potential stakeholders can be identified. This includes both internal (different departments within the organization) and external stakeholders (all interested and influential parties outside of the organization). Indeed, potential stakeholders include those that could be impacted, those that could influence the implementation of the VEA, those that need to be involved, and those whose capacity needs to be enhanced to enable them to be involved. Potential stakeholders thus could include individuals that represent the energy sector (e.g., solar and utility developers), public agencies (e.g., MPOs, counties, and cities), the railroads, parks and wildlife, special interest groups (e.g., land developers, private rest area owners), and the general public.

A "base" list of stakeholders that would generally be associated with each VEA can be found in Appendix VI. Nonetheless, there are a number of ways that can be used to identify stakeholders. Although it is not always possible to think of every interested party, the following are potential questions/approaches that may assist in identifying as many stakeholders as possible.

Questions to Ask

The following are questions that can be asked to assist in identifying stakeholders.

- Who might be affected?
- Who has jurisdiction over influencing the project?
- Who can delay the project? Who can stop it?
- Who might oppose the project?
- Who might be involved in the project?
- Of those stakeholders identified, who might they influence to be interested in the project?
- Who may support the project?

Interest Type

Isolating particular interests can also help make the process of identifying stakeholders more manageable, as each stakeholder likely has a primary reason for their concern with theVEA.

- Economic – those who may obtain an economic gain or suffer an economic loss, or even those who might be concerned with which other stakeholders may see a gain or loss;
- Application – those who may use or operate the VEA, or those who may suffer a loss/reduction in the use of another resource;
- Regulatory – government agencies responsible for regulations or other civic-related items that the VEA may need to meet or falls under;
- Proximity – those nearby who the VEA could impact, including landowners and businesses, which could involve groups at great distance depending on the impact (visual, environmental, traffic, etc.); and
- Political – those who may feel compelled to be involved due to their values, elected status, or desire to be involved in certain spheres of influence.
- Location - municipality, county, and other local jurisdictions, rural or urban communities, states, corridors, and regional coalitions (including Mexico).

Identity

Stakeholders can also be grouped in terms of the sector they represent.

- Public – external governmental and publicly-owned entities that may have authority over the VEA, can be influenced by the public to take interest in the VEA, or have resources to contribute;
- Internal – other departments within TxDOT that may have issues with the VEA or resources to contribute;
- Private – businesses and residential organizations that may be impacted;

- Interest Groups – coalitions, advocacy groups, and other organizations that have a core interest that may be in line or in conflict with the VEA (e.g., environmental, wildlife, and trade); and
- Individuals – homeowners, landowners, and community leaders that may be impacted.

Step 3: Perform Stakeholder Analysis

Two dimensions are used to evaluate stakeholders and to determine their potential level of impact on implementation of the VEA: interest and influence. Interest is defined as the importance of the VEA in terms of stakeholder's values, operations, and/or goals. Influence is defined as the stakeholder's ability to alter the VEA, whether that means championing, changing the scope, delaying, or completely stopping the implementation of the VEA. Thus, stakeholder analysis aims to assess the interest and importance of the identified stakeholders in an effort to identify key stakeholders that may influence the acceptance and ultimate success of implementing different VEAs.

As discussed in Chapter 4, the stakeholder analysis is performed by assigning interest and influence scores – on a scale of 0 to 5 – to identified stakeholders. Each stakeholder is then ranked according to their interest and influence to determine the appropriate level of engagement for that stakeholder, and to understand how they might become involved in implementing the VEA. In addition, a chart (see Figure 5.2) is plotted with a stakeholder's influence score represented as the X-axis coordinate and the interest score presented as the Y-axis coordinate. Figure 5.2 also shows the meaning of each quadrant of the chart.

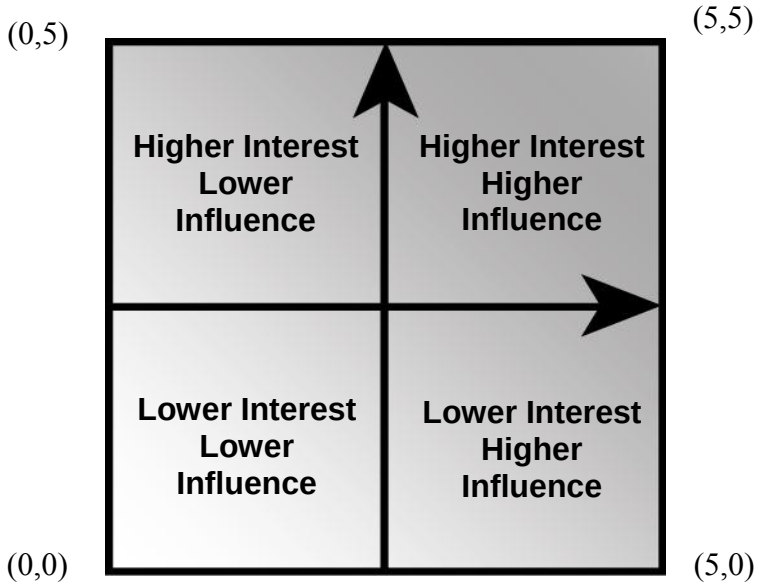


Figure 5.2: Stakeholder Interest vs. Influence Diagram

Interest

Interest relates the likelihood that the stakeholder wants to be involved and engaged. It can also be perceived as the likelihood of conflict arising if the stakeholder is omitted. There are three general categories of interest:

1. Interest from Direct Impact or Ideological Beliefs;
2. Interest from Indirect Impact; and
3. No Interest.

Interest derived from direct impact or ideological beliefs is regarded as the highest form of interest. Indirect impact typically generates a moderate amount of interest, but can include stakeholder whose interest were sparked by other highly interested stakeholders that may not have much influence over the implementation of the VEA. Lastly, no interest potentially requires that these stakeholders may need to be notified of the VEA, but their level of involvement will ultimately be determined by their level of influence. Interest should; however, be monitored, as a stakeholder's interest may change given the point in the process, recent developments, or influence from other stakeholders.

Influence

Influence refers to the stakeholder's ability to impact the implementation of the VEA. Like interest, influence can be categorized as:

1. The ability to stop or accelerate the implementation of a VEA;
2. The ability to delay or champion the implementation of a VEA;
3. The ability to disrupt or bring together key relationships; and
4. No influence.

The ability to stop or accelerate the implementation of a VEA is the highest level of influence as these stakeholders are essentially decision-makers. Some may have a low level of interest, but should be involved as they can be influenced by other stakeholders to become more involved. The ability to delay or champion the implementation of a VEA means the stakeholder does not necessarily have direct influence over the project, but the stakeholder can complicate or persuade others to support the implementation of a VEA. Lastly, a stakeholder may be able to influence relationships in a negative or positive manner, such as bringing together multiple stakeholders to approve or disapprove the implementation of a VEA. Influence can be weighted by the likelihood of being exercised given the level of interest and where the agency is in the process, but the potential exercising influence should always be monitored.

Step 4: Meet with Leaders of Key Stakeholders

Once key stakeholders have been identified (i.e., stakeholders with high levels of interest, high levels of influence, and both), meetings with these stakeholders should be conducted.

Introduce Project to the Stakeholder

An initial stakeholder meeting allows the stakeholder to be introduced to the project directly. At this meeting, purpose and goals can be directly communicated and the initial reaction can be ascertained.

Identify Potential Conflicts

Perhaps the most important reason for an initial meeting is that it can allow for any potential conflicts to be identified early on, allowing for ample time to prepare and even make changes to the project. Furthermore, this information can help determine the level and type of outreach that will need to follow for that stakeholder.

Identify Omitted Stakeholders

Meeting with key stakeholders can help the agency identify any omitted stakeholders with high levels of interest or influence or both. There are a host of reasons for why someone may feel that he/she should be consulted, including stakeholders that may have been thought of as being too far away from the implementation site to have interest and/or influence. Key stakeholders can help to identify omitted stakeholders and avoid surprises later on in the VEA implementation process. The same stakeholder analysis should be applied to newly identified stakeholders as well.

Step 5: Determine Outreach Approach/Technique

Based on the level of interest and influence of each stakeholder, and the insight gathered from initial meetings, an outreach plan should be developed for each quadrant of the stakeholders (see Figure 5.2). In general, those with high levels of interest and influence will require a substantial engagement. They also want to know how their input will be used in the implementation of the VEA. If stakeholders with high interest levels are left out, these stakeholders may seek assistance from stakeholders with less interest, but high levels of influence to disrupt the implementation of the VEA. Stakeholders with high levels of influence should receive regular updates and information on the implementation process. These stakeholders should also be provided with an avenue to raise concerns.

Furthermore, the type of stakeholder also determines the type of outreach to be performed. Government representatives may require constant updates and information, while key stakeholders will require not only information, but also avenues for.

5.2 CONCLUDING REMARKS

Stakeholder outreach is essential to ensure a successful VEA implementation. However, a general outreach approach or attempting to reach a very large and diversified group of stakeholders with various levels of influence and interest can be ineffective and costly. On the other hand, failing to reach out to specific key stakeholders can jeopardize the VEA implementation. Therefore, a stakeholder analysis framework that comprises a process to identify potential stakeholders, sort stakeholders according to interest and influence, identify key stakeholders, and select and conduct the most appropriate outreach technique was developed to assist TxDOT to reach out to stakeholders in a cost-effectively manner.

In general, potential stakeholders include those that could be impacted, those that could influence the implementation of the VEA, those that need to be involved, and those whose capacity needs to be enhanced to enable them to be involved. Although it may seem difficult to identify all potential stakeholders for a VEA project, different approaches exist to ease the process (e.g., ask questions, isolate particular/potential interests, and sort in terms of the social/economic/market). Also, stakeholders can be differentiated in terms of interest and influence. For example, key stakeholders are those who have high interest and high influence on a VEA implementation.

Finally, TxDOT must initiate the stakeholder outreach efforts by defining the goals and objectives and outlining potential advantages and disadvantages of the VEA implementation. These steps can facilitate an effective communication with stakeholders and help in determining who the stakeholders may be. Subsequently, TxDOT should conduct meetings with key stakeholders to convey important information and address major concerns and issues. Ultimately, an outreach plan should be developed based on the level of interest and influence of each stakeholder, and the insight gathered from initial meetings. It is fundamental that key stakeholders receive regular updates and information on the implementation process and be provided with an avenue to raise concerns.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

This research was primarily intended to identify potential VEA – and their respective barriers, challenges, requirements, benefits, and impacts – that could help TxDOT save costs, increase revenue streams, or enhance societal goals. This research also aimed to provide TxDOT with insight and guidance in determining when, where, and under what circumstances to pursue the implementation of which VEA(s), as well as structured guidance on identifying and involving key stakeholders in the implementation of feasible VEA(s).

This Chapter provides conclusions regarding the tasks undertaken to achieve the research objectives and recommendations for enhancing the decision making process and increasing the likelihood of success when pursing the implementation of VEAs. The Chapter concludes with some remarks regarding the contribution of this research and some final remarks as to the focus of the research effort.

6.1 CONCLUSIONS

This section presents a review and the conclusions of the research findings and outcomes – i.e., VEA methodological framework and stakeholder analysis framework developed. The ensuing remarks pertain to the research objective to identify potential VEA(s) and their respective barriers, requirements, challenges, benefits, and impacts.

- Based on an extensive literature review, a list of potential VEAs was developed. These potential VEAs were subsequently grouped into 11 categories.
- Despite the large number of references consulted, most of the published literature comprised short articles, commercial presentations, and pilot project fact sheets/summaries. Previous research reports were limited to addressing specific aspects of some potential VEAs (e.g., wildlife crossings, airspace leasing for buildings, and carbon sequestration). Most VEAs; however, lacked of in-depth research, scientific data, and conclusive results.

- Some VEAs are currently being piloted. Other VEAs are well-established practices (e.g., property management, advertising, and airspace leasing for parking lots), but limited quantitative information (e.g., to measure efficiency or cost effectiveness) is available in the literature. Nonetheless, some lessons learned and insights could be obtained from interviews.
- All information gathered was compiled and synthetized, yielding a comprehensive and detailed technical review (see Chapter 3) that discusses each VEA in terms of seven defined criteria.
- The evaluation matrix developed comprises and highlights important aspects associated with each VEA (i.e., barriers, challenges, requirements, benefits, and impacts) that must be considered or addressed by TxDOT during the assessment, decision making, and implementation processes of each VEA.
- Two potential VEAs – i.e., solar roads and piezoelectric pavements (the special road category) – were discarded from further consideration, as these technologies are largely experimental. Also, no detailed technical or economic information were available for these VEAs.
- On the other hand, the use of highway and transportation infrastructure, properties, and ROW to implement renewable energy sources has increasingly gained attention and has been piloted in the U.S. and overseas. Several pilot projects have thus resulted in initial findings and information about challenges, requirements, and benefits that can be acquired. Conclusive results and in-depth research are; however, still needed.

The following points pertain to the research objective to provide TxDOT with comprehensive insight and guidance in determining when, where, and under what circumstances to pursue the implementation of which VEA(s).

- A methodological framework, which include an evaluation matrix, was developed to guide and assist TxDOT in identifying and implementing the most promising VEA, given TxDOT's asset and objective.

- The methodological framework comprises sequential steps that gradually filter the universe of potential VEAs through set of questions. The first questions address the conditional factors – i.e., type of asset, primary objective, and major characteristics of the property - that would prevent the implementation of specific VEAs or impede the agency from achieving its objective. These initial steps are not subject to the judgment or assessment of the user.
- The evaluation matrix, which is the main component of the methodological framework, is used to compare potential VEAs. The evaluation matrix; however, do not determine the VEA to be implemented. The final decision exclusively pertains to TxDOT. The evaluation matrix only assists the user in identifying potentially feasible VEA(s).
- The evaluation matrix - although a straightforward mechanism for assessment - does incorporate subjectivity in the weighting and criterion score assignment. Changes in these parameters may affect and alter the final outcome – i.e., feasibility and impact of potential VEAs.
- The methodological framework, identified VEAs, and evaluation matrix reflects current available technologies, current economic conditions (e.g., oil and gas price, solar panels costs, etc.), and existing Federal and State legislation, as well as TxDOT policies and regulations. Changes to these features and variables can influence and modify some considerations and requirements – thereby affecting the feasibility of the identified VEAs. Also, new technologies may emerge, creating not only new opportunities but potentially new VEAs. Hence, the methodological framework and evaluation matrix will require periodic updates. Also, documentation of the lessons learned and major issues could inform the implementation of specific VEA(s)

The following conclusions specifically relate to the eleven VEAs identified during the literature review.

- The feasibility of any VEA is site specific and depends on different factors, which must be carefully and individually considered and analyzed. Similarly, economic results and financial outcomes cannot be generalized. Economic/financial analysis must be conducted for each VEA to reflect actual conditions and to account for the correct variables and values.
- Leadership (i.e., a champion) is essential to pursue the implementation of a VEA. Thus, TxDOT should identify an in-house staff member to champion the evaluation and implementation of VEA(s) (i.e., methodological framework steps).
- Public outreach and involvement is fundamental to avoid potential opposition and obstruction to the implementation of feasible VEAs.
- Safety is always a major concern for any project along highway ROW. However, special design features (e.g., guard rails and clear zone) and/or appropriate site selection can eliminate or mitigate potential safety concerns.
- Environmental protection and awareness have increasingly gained attention and is an important component and determinant for any public project. Specific demands for transportation projects to be more sustainable and environmental-friendly are made at the Federal level. Furthermore, the NEPA process, which "consists of an evaluation of the environmental effects of a federal undertaking including its alternatives" (U.S. Environmental Protection Agency, 2011), is typically mandatory and may impact the implementation of some VEAs.
- Legislation and regulatory agencies govern what can be done by public agencies and with public properties. Hence, the legal aspects must be considered early on in the process when identifying, evaluating, and implementing feasible VEAs. Chapter 3 provides insights regarding the laws, regulations, and policies that may affect, dictate, or influence the implementation of VEA(s).
- Written agreements are a key step in the implementation of VEA(s) and protects the DOT from unnecessary risks and liabilities. Thus, legal counsel must

participate when implementing all VEA(s), but specifically when a private entity is involved (e.g., public-private-partnership and airspace leasing).

- Various business models – i.e., how TxDOT approaches and relates to private entities – exist. Yet some business models can be very complex and demand intensive administrative and legal resources, selecting the most appropriate business model is not only important to achieve the agency's objective but also to maximize the benefits when implementing the VEA.
- Permits and licenses are typically needed.
- Despite the general remarks listed above, each VEA has particularities that have to be considered, analyzed, and managed individually.

6.2 RECOMMENDATIONS

This section provides TxDOT with recommendations that can help ensure a strong and robust VEA program, as well as enhance the application of the methodological framework (i.e., identification, evaluation, and implementation of specific VEA(s)). The recommendations are based on the information gathered during the literature review – i.e mostly from identified best practices and interviews conducted.

- TxDOT should consider pursuing an integrated, systematic, and formal property management program – e.g., including investment in a GIS and/or other information management system. A formal property management program can facilitate the identification of opportunities for VEA implementation, as well as the actual implementation of feasible VEAs.
- In evaluating different potential VEA, TxDOT should involve employees with diversified background and expertise (e.g., maintenance, traffic, safety, public relations, legal, and construction personnel) to evaluate and anticipate potential challenges and concerns. In addition, TxDOT should assign one person – preferably an in-house staff member - to champion and lead the process. This person leader should be empowered to make decisions.

- Due to a lack of scientific publications and implemented VEAs, TxDOT should document lessons learned, monitor results (e.g., time, cost, revenue, resources, and issues) and conduct a post-evaluation of implemented VEAs (e.g., benefits and impacts) to enhance the decision-making process and methodological framework.
- TxDOT should collect further information regarding technology, specifications, and requirements pertaining to new VEAs before assessing them with the evaluation matrix.
- Even if the evaluation matrix and methodological framework indicate the VEA is potentially economically feasible (i.e., a positive score for the economic criterion), TxDOT should conduct a detailed economic and financial analysis, incorporating site specific data/information, values, and quantities to determine the actual financial benefits, payback period, and costs involved.
- Since most of the VEAs involve a private party, TxDOT should carefully evaluate and decide who to partner with. Special attention should be given to the financial resources of, and sureties and warranties provided by the private entity or project developer. TxDOT should also retain legal counsel to assist and review any written agreement and/or contractual document, looking mainly at liabilities, risks, responsibilities, and the intended use of TxDOT's asset by the private party (if applicable).

6.3 RESEARCH CONTRIBUTION

This research has contributed to an increased understanding of the different VEAs that can help TxDOT and other DOTs to save costs, increase revenue streams, or enhance societal goals. This research also provided TxDOT and other DOTs with a framework to systematically review and identify potentially viable VEA(s) given an agency's property asset and intended objective. Initially, criteria that influence and drive the pursuit and selection of a VEA for implementation were identified and defined. Subsequently, the

factors that can affect the decision criteria and necessary conditions for implementing each VEA were also identified, as well as general stakeholders that may be interested or may influence the implementation of each VEA. A systematic and comprehensive methodological framework, which incorporates the findings and information acquired in this research effort, were developed to assist TxDOT in the process of identifying and selecting the most appropriate VEA(s); hopefully facilitating inter-departmental communication, coordination, and decision-making. Finally, this research yielded a detailed and extensive compilation of published documents (e.g., reports and articles) regarding various potential VEA(s), which is in itself a unique contribution.

APPENDIX I: METHODOLOGICAL FRAMEWORK INPUTS & OUTPUTS

Step 1: Select the asset.

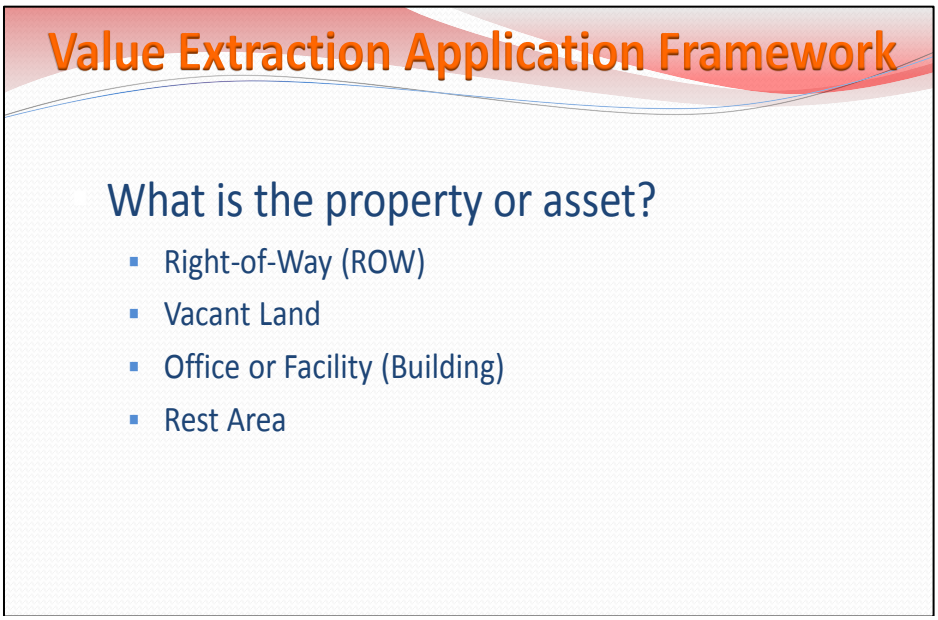


Figure II.6: Selection of type the asset

Step 2: Select the objective to be achieved.

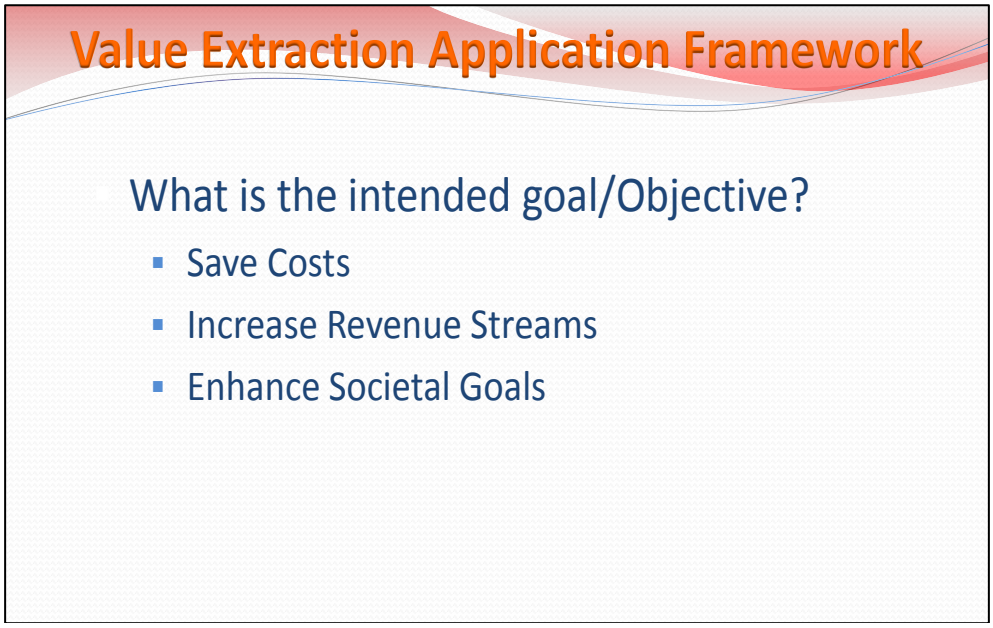


Figure II.7: Selection of intended goal/objective

Step 3: List of questions to characterize the asset.

Value Extraction Application Framework

What are the characteristics of the vacant land?

1	Is the property in a prime real estate location?	Yes		No
2	Is the property in an urban center or commercial area or near a community center?	Yes		No
3	Is the property adjacent to or near a residential or commercial area?	Yes		No
4	Does the property have good easy access (or can access be secured)?	Yes		No
5	When will the property be developed (i.e., in how many years)?	< 5 yrs	5 yrs > < 20 yrs	> = 20 yrs
6	Is the property exposed to high traffic volumes?	Yes		No
7	How large (acres) is the property?	< 5 Acres		>= 5 Acres
8	Is the property on a flat terrain (or on a terrain with slope less than 20%)?	Yes		No
9	Does the property have good sun exposure (i.e., no sunlight obstruction)?	Yes		No
10	How far (miles) is the nearest a transmission line or electricity user/customer to the property?	< 1 mile		> = 1 mile
11	Is the property in a Competitive Renewable Energy Zone?	Yes		No
12	Is the property free of any wind obstructions (e.g., buildings, mountains, and hills)?	Yes		No
13	Is the property being mowed?	Yes		No
14	Can mowing of the property be halted?	Yes		No
15	What is the predominant vegetation on the property?	Grass	None	Tree
16	What is the average rainfall at the property?	< 15 in		> = 15 in
17	How far (miles) is the nearest biorefinery to the property?	= < 50 miles		> 50 miles

Figure II.8: Questionnaire to characterize the vacant land

Value Extraction Application Framework

What are the characteristics of the ROW?

1	How much ROW area (acres) besides the safety zone is available?	< 5 Acres		>= 5 Acres
2	What is the ROW width (feet) after excluding the safety zone?	< 10 ft		> = 10 ft
3	Is the ROW in a prime real estate location?	Yes		No
4	Is the ROW in an urban center or commercial area or near a community center?	Yes		No
5	When will the ROW be used (i.e., in how many years)?	< 5 yrs	5 yrs > < 20 yrs	> = 20 yrs
6	Does the site have good easy access (or can access be secured)?	Yes		No
7	Is the ROW exposed to high traffic volume?	Yes		No
8	Is the ROW on the Federal network?	Yes		No
9	Is the site on a flat terrain (or an terrain with a slope less than 20%)?	Yes		No
10	Is the site impacted by flooding, wetlands, or protected streams?	Yes		No
11	Has documented endangered or threatened flora or fauna been identified on or adjacent to the site?	Yes		No
12	Is the site on a designated state or federal scenic corridor or in a protected viewshed?	Yes		No
13	Have any cultural or historic artifacts been identified on or adjacent to the site?	Yes		No
14	Is this a site with a high occurrence of animal-vehicle-crash accidents?	Yes		No
15	Does the site have good sun exposure (i.e., no sunlight obstruction)?	Yes		No
16	How far (miles) is the nearest transmission lines or potential electricity user/customers to the site?	< 1 mile		> = 1 mile
17	Is the site adjacent to or near a residential or commercial area?	Yes		No
18	Is there any utility infrastructure on the site (including buried utilities)?	Yes		No
19	Is the ROW in a Competitive Renewable Energy Zone?	Yes		No
20	Is the site free of any wind obstructions (e.g., buildings, mountains, and hills)?	Yes		No
21	Is the ROW being mowed?	Yes		No
22	Can mowing of the ROW be halted?	Yes		No
23	What is the predominant vegetation on the site?	Grass	None	Tree
24	What is the average rainfall at the site?	< 15 in		> = 15 in
25	How far (miles) is the closest biorefinery?	= < 50 miles		> 50 miles
26	Does it snow/ice at this location?	Yes		No

Figure II.9: Questionnaire to characterize the ROW

Value Extraction Application Framework

What are the characteristics of the office or facility?

1	Is the building in a prime real estate location?	Yes	No
2	Is the building in an urban center or residential or commercial area?	Yes	No
3	Is it an old building with high maintenance cost?	Yes	No
4	Is the building's electricity consumption relatively high?	Yes	No
5	Is the building's HVAC energy consumption relatively high?	Yes	No
6	Does the building have good sun exposure (i.e., no sunlight obstruction)?	Yes	No
7	Is the building in a Competitive Renewable Energy Zone?	Yes	No
8	Is the building at a site that is free from wind obstruction (e.g., other buildings, mountains, and hills)?	Yes	No
9	Is the building critical and essential to TxDOT's future operations (i.e., cannot be replaced)?	Yes	No
10	Is the building fully occupied and utilized?	Yes	No
11	Does the building site have any antenna tower or is there available area to install an antenna/radio tower at the site?	Yes	No
12	For how long does TxDOT plan to occupy and/or own the property?	< 20 yrs	> = 20 yrs

Figure II.10 Questionnaire to characterize the office or facility

Value Extraction Application Framework

What are the characteristics of the rest area?

1	Is the rest area on a Federal network?	Yes	No
2	How far (miles) is the rest area from the nearest transmission lines?	< 1 mile	> = 1 mile
3	How far (miles) is the rest area from the nearest business or community area?	= < 30 miles	> 30 miles
4	Is the rest area's electricity consumption relatively high?	Yes	No
5	Is the rest area's HVAC energy consumption relatively high	Yes	No
6	Does the rest area have good sun exposure (i.e., no sunlight obstruction)?	Yes	No
7	Is the rest area located in a Competitive Renewable Energy Zone?	Yes	No
8	Is the rest area at a site that is free from wind obstruction (e.g., buildings, mountains, and hills)?	Yes	No
9	How large (acres) is the rest area site that is vacant (i.e., excluding the area used for buildings, parking, etc.)?	< 5 Acres	>= 5 Acres

Figure II.11 Questionnaire to characterize the rest area

Step 5: List of VEAs that can potentially fulfill the objective.

Figure II.12: Potential VEAs (Vacant Land & Save Costs)

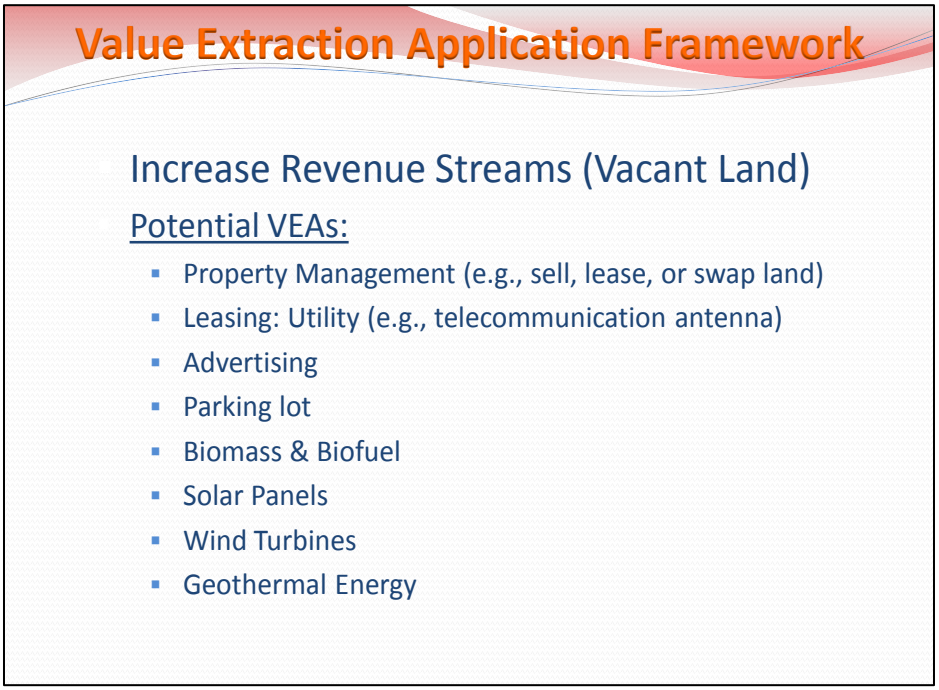


Figure II.13: Potential VEAs (Vacant Land & Increase Revenue Streams)

Value Extraction Application Framework

Enhance Societal Goals (Vacant Land)

Potential VEAs:

- Carbon Sequestration
- Biomass & Biofuel
- Solar Panels
- Wind Turbines
- Geothermal Energy

Figure II.14: Potential VEAs (Vacant Land & Enhance Societal Goals)

Value Extraction Application Framework

Save Costs (ROW)

Potential VEAs:

- Leasing Utility (e.g., telecommunication antenna and fiber optics)
- Biomass & Biofuel
- Solar Panels
- Wind Turbines
- Advertising (e.g., Adopt-a-Highway)
- Wildlife Crossings
- Carbon Sequestration
- Geothermal Energy

Figure II.15: Potential VEAs (ROW & Save Costs)

Value Extraction Application Framework

Increase Revenue Streams (ROW)

Potential VEAs:

- Leasing: Utility (e.g., telecommunication antenna, pipelines, and fiber optics)
- Airspace Leasing: Buildings
- Advertising
- Parking lot
- Carbon Sequestration
- Biomass & Biofuel
- Solar Panels
- Wind Turbines

Figure II.16: Potential VEAs (ROW & Increase Revenue Streams)

Value Extraction Application Framework

Enhance Societal Goals (ROW)

Potential VEAs:

- Wildlife Crossings
- Carbon Sequestration
- Biomass & Biofuel
- Solar Panels
- Wind Turbines

Figure II.17: Potential VEAs (ROW & Enhance Societal Goals)

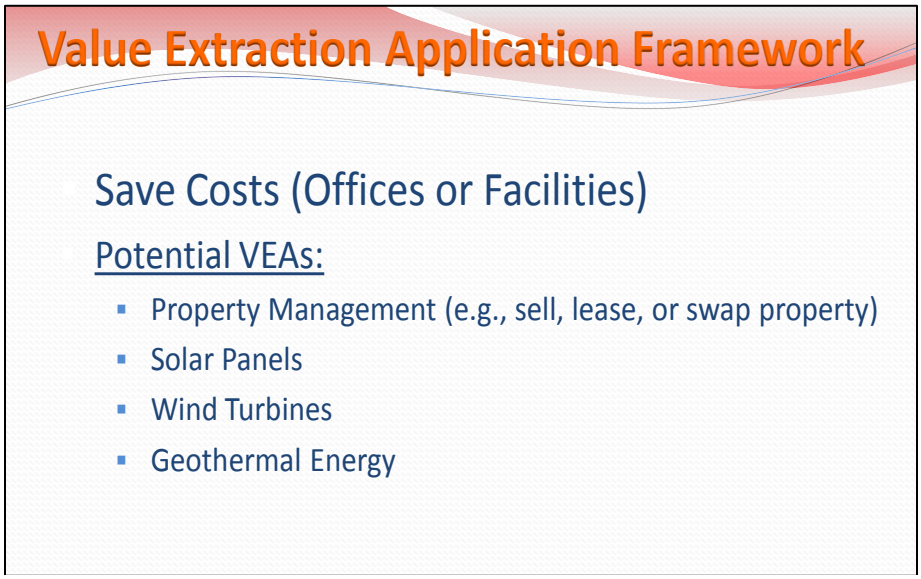


Figure II.18: Potential VEAs (Offices or Facilities & Save Costs)

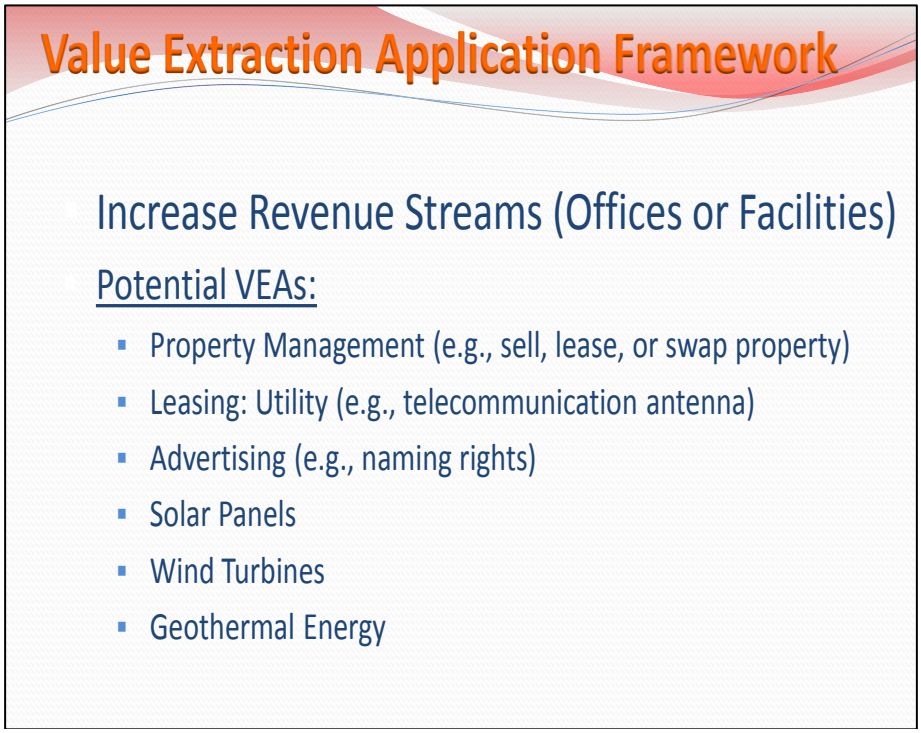


Figure II.19: Potential VEAs (Offices or Facilities & Increase Revenue Streams)

Figure II.20: Potential VEAs (Offices or Facilities & Enhance Societal Goals)

Figure II.21: Potential VEAs (Rest Area & Save Costs)

Value Extraction Application Framework

Increase Revenue Streams (Rest Area)

Potential VEAs:

- Property Management (e.g., privatization and commercialization)
- Leasing: Utility (e.g., telecommunication antenna)
- Advertising
- Solar Panels
- Wind Turbines
- Geothermal Energy

Figure II.22: Potential VEAs (Rest Area & Increase Revenue Streams)

Value Extraction Application Framework

Enhance Societal Goals(Rest Area)

Potential VEAs:

- Solar Panels
- Wind Turbines
- Geothermal Energy

Figure II.23: Potential VEAs (Rest Area & Enhance Societal Goals)

Step 8: List of Advantages & Disadvantages/requirements

Value Extraction Application Framework

Property Management

Go to Examples

Advantages

- Provide full control and awareness of the agency's inventory, needs, and opportunities.
- Does not present any substantial technical challenge.
- Simple communication Frameworks such as emails, Craig's list and TxDOT website can be used to disseminate information and reach out likely interested parties.
- Can promote economic development and create jobs
- Increases tax payment by private sector (State and Federal Taxes)
- Can help TxDOT to build more efficient and updated facilities (e.g., barter transaction)
- Can enhance TxDOT decision making process
- Can enable TxDOT to have better understanding of its needs and make better and wiser investments and expenditures (i.e., budget allocation).
- State law enables TxDOT to lease any real property held or controlled by the agency that is not needed for highway purpose.
- TxDOT can resort to GSC and/or GLO for specialized skills on asset planning, management, and disposition.
- Can enhance internal and cross-departmental communication.

Disadvantages / Requirements

- Requires investment on in-house staff with knowledge of best practices in efficient, least-cost space utilization and functional adjacencies, real estate market interaction for acquisition/disposition pricing, financial feasibility determinations, transaction structuring (where values and complexities warrant), strategic plan preparation that is proactive and anticipatory of future needs, and financial optimization.
- Requires a systematic and comprehensive property evaluation process (i.e., annually) .
- Investment in a efficient information system (e.g., website, database, and GIS) and asset management capable of rendering real-time information to facilitate the decision making process
- Potential impacts of the new use on nearby neighborhood, community, business, and traffic
- Potential conflict with highway system future needs.
- Potential political and public opposition
- Requires a formalized, clear, and public (open) process (i.e., fair market price, equal opportunity to interested parties, auction, and bid). Ensure total transparency.
- May require some licenses and permits
- Intensive contractual and legal work to clearly state responsibilities, liabilities, rights, duties, and other agreements (e.g., period, price, new use)

Figure II.24: Adv. and Disadv./Req. of Property Management

Value Extraction Application Framework

Property Management (Rest Area)

Go to Examples

Advantages

- Can avoid closure of or even increase the number of rest areas.
- Can provide cleaner and safer rest areas (i.e., hygiene and security)
- Can enhance the service on rest areas (e.g., ATM, gas station, and food).
- Rest Areas are essential for road safety and trip quality .
- Can enhance road safety (i.e., reduction of accident due "drowsing" drivers).
- Is a simple value extraction application and does not demand any complex technical solution and/or high investment by TxDOT
- Attractive and useful rest areas encourage travelers to use a safe location off the roadway to take a break and return more alert to the highway.
- Can promote economic development and create jobs (i.e., when it does not compete with nearby business).
- Well served and interactive rest areas and welcome centers can potentially enhance the tourism market, create jobs and, therefore, help to develop rural regions (i.e., through the improvement of the quality of road trips).
- Increases Federal and State tax incomes (i.e., from private businesses and commercial activities).

Disadvantages / Requirements

- Potential political and public opposition (i.e., can be controversial).
- Potential impacts on nearby neighborhood, community, and business (i.e., economical impacts and unfair competition)
- Federal and States laws and regulations that precludes or prohibits private and commercial rest areas
- Require investment on staff to manage, control, and oversee private rest area design, construction, and operation (i.e., compliance with standards, specifications, and requirements)
- Interference with current social projects, such as " blind vendor support"
- Need to assess best location according to traffic, access, environment, and construction requirements
- Need an intensive traffic flow to be financial attractive to private sector. Hence, it will not solve the problems in very remote areas
- Requires a formalized, clear, and public (open) process (i.e., fair market price, equal right to all interested parties, auction, and bid)
- May require licenses and permits, mainly environmental.
- Intensive contractual and legal work to clearly state responsibilities, liabilities, rights, duties, and other agreements (e.g., period, price, new use)

Figure II.25: Adv. and Disadv./Req. of Property Management (Rest Area)

Value Extraction Application Framework

Airspace Leasing (Building)

Go to Examples

Advantages

- Easy to be implemented if considered in new highway projects.
- Some projects can be attractive to business and for the public. For example, rest areas over freeways can provide entertainment for travelers, mainly kids.
- Some projects can represent city landmark and touristic sight.
- Can help reduce urban center footprint, once the structure (i.e., building) is constructed over an existing construction (i.e., road).
- Provides opportunities for financial investments and business expansion.
- Can promote economic development and create jobs.
- Increases State tax incomes.
- Has long period of revenue.
- Can integrate communities and neighborhoods divided by the highway.

Disadvantages / Requirements

- Is a complex agreement that involves legal, planning, environmental, design, construction, maintenance, safety, security, and insurance considerations to be successful implemented.
- Requires intensive and burdensome contractual and legal work to clearly state responsibilities, liabilities, rights, duties, and other agreements (e.g., period, price, new use).
- Requires involvement of all internal departments and disciplines (e.g., design, traffic, ROW, maintenance, and planning).
- Requires specialized staff to conduct the evaluation and authorization process. If no expert is available in-house, outsourcing may be needed. Mainly for safety and security assessment.
- Possible impacts on neighborhood and environment (e.g., traffic, public health, privacy, shade, noise, heat island, and visual pollution).
- Potential political and public opposition.
- Involves very robust structure and technical challenges (e.g., site constraints).
- AASHTO and FHWA have strict design requirements for structure over highway that must be complied with (drainage, vibration, clearance, fire resistance, maintenance, and access).
- Need of a very long-term commitment to pay off. High planning, design, and construction cost. Economically feasible only in very dense urban centers (i.e., at prime location).
- Safety requirements (e.g., lighting, exhaustion, ventilation, access, fire protection, emergency access, surveillance, and tunnel signs).
- Construction requirements (e.g., structural, access, utilities, methods) , plans (e.g., safety, traffic, access, and impact mitigation), and disturbances (e.g., noise, dust, and traffic congestion) .
- Requires a formalized procedure (i.e., impact evaluation, contractual agreements, and liabilities).
- Cannot be used to store or manufacture flammable, explosive, or hazardous substances..
- Requires several licenses and permits (e.g., NEPA).

Figure II.26: Adv. and Disadv./Req. of Airspace Leasing (Building)

Value Extraction Application Framework

Airspace Leasing (Parking lot)

Go to Examples

Advantages

- Many urban areas have inadequate parking space .
- Can promote economic and business development and, hence, create jobs.
- Increase tax payment by private sector
- Can use short-term agreement (2-5 years).
- Can enhance safety and welfare (i.e., less congestion and accidents)
- Is an easy and simple VEA, not requiring high investment and efforts.
- Can be even easier to implement if considered in new highway projects.
- Can be a better solution than curb side parking (i.e., less traffic interference and more safety conditions).
- Can attract general public support.

Disadvantages / Requirements

- FHWA and ASSTHO guidelines and requirements
- Safety requirements (e.g., fence, curb, pedestrian access, and surveillance)
- Requires some investment and study on information system (e.g., parking meter, surveillance, and security)
- Require a well-done contractual agreement with a entity insured and with financial capacity to avoid possible TxDOT liabilities over third parties' properties (i.e., vehicles) and lawsuits.
- Requires easy and free access to be viable.
- Some environmentalists and transit providers see "parking unavailability" as a way to manage and reduce single vehicle occupant use and traffic congestion.
- Can negatively impact on the neighborhood (i.e., business expansion and increase traffic can entail noise and congestion).
- Some precautions have to be taken to avoid soil and water contamination from car oil, as well as to drain rain water to the public rainwater system.
- All security and safety measures must be approved by TxDOT engineering, operation, and safety personnel.

Figure II.27: Adv. and Disadv./Req. of Airspace Leasing (Parking Lot)

Value Extraction Application Framework

Go to Examples

Airspace Leasing (Utilities)

Advantages

- Enhanced and available telecommunication signals can contribute to social and educational development, as well as help promote economic development and create jobs.
- Can enhance safety in remote area (e.g., tornado warming, communication of animal carcass, existing obstacle, pavement conditions, and severe weather conditions).
- Several potential ways to implement this VEA.
- Can be even easier to implement if considered in new highway projects.
- Can provide the State access to technology infrastructure.
- Can yield a better telecommunication network, helping TxDOT and other public agencies to improve their information management systems and, consequently, enhance their services, implement an efficient maintenance program, and make better decision (i.e., wisely spend public money).
- TxDOT already has some airspace agreements for utilities that generate revenue, but not a formalized program. A formal program could bring more contracts and revenue for the agency and State.
- Some application can be implemented with a short-term agreement (5 years)
- Can facilitate the implementation or expansion of TxDOT's Advanced Rural Transportation System (ARTS), Dynamic Message Signs, 511 travel information, and Highway Advisory Radio.

Disadvantages / Requirements

- Requires license and permits such as environmental
- Need to comply with FHWA and ASSTHO guidelines and requirements, as well as NEPA. Some policies may be out of date and not address new technologies.
- Importance of contractual agreement (i.e., liabilities and responsibilities) and legal consul during the process.
- Only applicable to private utilities
- Some utilities can entail safety and environmental concerns (e.g., explosion, contamination, leak, and crash)
- May cause traffic disruption and hazardous situation during construction and maintenance . Importance of good planning and assessment, as well as access to the site.
- FHWA requires environmental evaluation and compliance with NEPA
- Requires a formalized, clear, and public (open) process (i.e., fair market price, equal right to all interested parties, auction and bid, specifications, and guidelines)
- Requires a construction and maintenance plan (i.e., access, minimize impacts on traffic, safety, and execution method)
- Some application requires special considerations such as, buried depth, concrete coat, and reinforcement.
- Private companies will need to have free or partial access to ROW or public properties.
- May compete with private sector (e.g. tower companies).

Figure II.28: Adv. and Disadv./Req. of Airspace Leasing (Utilities)

Value Extraction Application Framework

Go to Examples

Advertising

Advantages

- Is significantly simple application and provides several means to be implemented.
- Has a diversified portfolio of applications.
- Can be used to educate, warn, and guide drivers toward safer behavior (e.g., " drink-and-drive", "no texting", and "buckle-up").
- Can be used to conduct public outreach , disseminate information, integrate communities, engage public participation, and share ideas.
- Can help to promote businesses , tourism activities, and, hence, economic development (mainly in rural areas).
- New technologies provide good potential and alternative to implement this VEA (e.g., website, internet, electronic screens, and TVs).
- Does not cause any environmental threat or impact.
- Programs, such as Adopt-a-Highway, can make roadside litter-free, helping to preserve fauna and flora, to avoid soil and water contamination, prevent insect proliferation and, consequently, diseases, and generate local employment.
- Programs, such as Adopt-a-Watt, Adopt-a-Highway, and Naming Rights, can foster and facilitate the implementation of other value extraction applications.

Disadvantages / Requirements

- Some sort of advertising are illegal and others are regulated and/or restricted by FHWA.
- Potential political and public opposition
- Some advertising (i.e., message and content) can be controversial and lead to misinterpretation.
- Demand some precaution with controversial advertisings.
- Different regulations and laws that dictate and control the use of advertising in public assets and highway ROW.
- May require some license or permit.
- May cause visual impacts (aesthetic) .
- May impact on and/or be in conflict with Texas Highway Beautification Act (HBA) and State Rural Roads Act (RRA).
- High administration cost (e.g., intensive contractual and paper work).
- Requires several "small" contracts to offset the administrative costs.
- May entail safety concerns (e.g., driver distraction and obstacle).
- Requires a formalized, clear, and public (open) process (i.e., fair market price, equal right to all interested parties, auction and bid, specifications, and guidelines).

Figure II.29: Adv. and Disadv./Req. of Advertising

Value Extraction Application Framework

Solar Panel (ROW and Vacant Land)

Go to Examples

Advantages

- Has no moving part, does not require water, does no make noise, and does not produce any waste or GHG emission.
- Solar energy is a key component of the U.S. national strategy for reducing carbon footprint and promoting renewable energy.
- Texas has a great solar energy potential.
- Renewable energy has gained momentum due to "an increase in environmental awareness, skyrocket oil and gas price, and national security concerns". Also, can protect the agency against oil price volatility.
- Texas energy production has not followed the State energy demand (i.e., consumption).
- Can help to reduce the dependence on fossil fuels and foreign energy.
- Using a value-based procurement (local vendors, maintenance expert, and workers) can promote economic development and create jobs.
- The technology is still evolving and becoming cheaper and more efficient
- Can be installed close to the end-user and with any scale (i.e., size), therefore not requiring long transmission lines and reducing heat loss – mainly in remote areas.
- Is a environmentally-friendly energy source and can generate electricity without disturbing the surrounding environment or community.
- Can enhance TxDOT image and bring political and public support.
- Is easy to implement if considered in highway new projects.
- Has low maintenance frequency and cost. Further, vendors provide 25-year warranty.
- Existing incentives granted by state and federal governments and REC credits.
- Can help TxDOT meet carbon emission and renewable energy consumption goals.
- The panels can be recycled.
- Solar energy is a safe source of electricity (i.e., does not pose any risk of explosion, fire, disasters, structural failure, or accidents).
- Can promote awareness and educate general public on green energy, importance of carbon reduction, and renewable energy.

Disadvantages / Requirements

- Feasibility and efficiency is very local-driven.
- Require a high up-front investment, what entails a long payback and commitment period.
- Requires a formalized procedure (i.e., impact evaluation, contractual agreements, and liabilities).
- Involves a public-private-partnership, therefore an intensive and burdensome contractual and legal work.
- Can use several, but complex, business models that vary according to the shared risks, liabilities, electricity buyer, and renewable energy credits.
- Has some patent issues.
- May cause some impacts on nearby communities (i.e., property value).
- Works only during the day (i.e., sunlight); otherwise need batteries or other electricity source.
- Relies upon the weather conditions, requiring batteries or other electricity source for more reliability
- Requires a clean, easy, independent, and safe access (i.e., aside the main road).
- Must comply with FHWA and ASSTHO regulations regarding the use of ROW.
- May need some security precaution against theft and vandalism
- Require considerations and a plan on the solar panel disposal, once the panels are composed by heavy metals, such as cadmium. Need a recycle program.
- May raise some safety concerns (e.g., roadside obstruction and driver's distraction), but site or guardrail can resolve these issues.
- Zoning law can preclude or impede the implementation.
- Has a low energy density production (i.e., requires somewhat area)
- Is still driven by incentives.
- May impact on Texas Highway Beautification Act.

Figure II.30: Adv. and Disadv./Req. of Solar Panel (ROW/Vacant Land)

Value Extraction Application Framework

Solar Panel (Building and Rest Area)

Go to Examples

Advantages

- Has no moving part, does not require water, does no make noise, and does not produce any waste or GHG emission.
- Solar energy is a key component of the U.S. national strategy for reducing carbon footprint and promoting renewable energy.
- Texas has a great solar energy potential.
- Renewable energy has gained momentum due to "an increase in environmental awareness, skyrocket oil and gas price, and national security concerns". Also, can protect the agency against oil price volatility.
- Texas energy production has not followed the State energy demand (i.e., consumption).
- Can help to reduce the dependence on fossil fuels and foreign energy.
- Using a value-based procurement (local vendors, maintenance expert, and workers) can promote economic development and create jobs.
- The technology is still evolving and becoming cheaper and more efficient
- Can be installed close to the end-user and with any scale (i.e., size), therefore not requiring long transmission lines and reducing heat loss – mainly in remote areas.
- Is a environmentally-friendly energy source and can generate electricity without disturbing the surrounding environment or community.
- Can enhance TxDOT image and bring political and public support.
- Is easy to implement if considered in new buildings.
- Has low maintenance frequency and cost. Further, vendors provide 25-year warranty.
- Existing incentives granted by state and federal governments and REC credits.
- Can help TxDOT meet carbon emission and renewable energy consumption goals.
- The panels can be recycled.
- Solar energy is a safe source of electricity (i.e., does not pose any risk of explosion, fire, disasters, structural failure, or accidents).
- May not Involves a public-private-partnership.
- Can promote awareness and educate general public on green energy, importance of carbon reduction, and renewable energy.

Disadvantages / Requirements

- Feasibility and efficiency is very local-driven.
- Require a high up-front investment, what entails a long payback and commitment period.
- May Involves a public-private-partnership, therefore an intensive and burdensome contractual and legal work.
- Requires a formalized procedure (i.e., impact evaluation, contractual agreements, and liabilities).
- Can use several, but complex, business models that vary according to the shared risks , liabilities, electricity buyer, and renewable energy credits.
- May cause some impacts on nearby communities (i.e., property value).
- Works only during the day (i.e., sunlight); otherwise need batteries or other electricity source.
- Relies upon the weather conditions, requiring batteries or other electricity source for more reliability
- May need some security precaution against theft and vandalism
- Require considerations and a plan on the solar panel disposal, once the panels are composed by heavy metals, such as cadmium. Need a recycle program.
- Zoning law can preclude or impede the implementation.
- Has a low energy density production (i.e., requires somewhat area)
- May require some update and/or revamp on the existing electrical installation and systems.
- Is still driven by incentives.

Figure II.31: Adv. and Disadv./Req. of Solar Panel (Building/Rest Area)

Value Extraction Application Framework

Wind Turbine (ROW and Vacant Land)

Go to Examples

Advantages

- Some regions of Texas (i.e., CREZ) has a great wind energy potential
- New technologies (i.e., small wind turbines) can help to overcome space issues, reduce up-front investment, and others barriers.
- Has high electricity production per area
- Does not require water and does not produce any waste or GHG emission.
- Can generate energy any time of the day.
- Wind turbine is a key component of the U.S. national strategy for reducing carbon footprint and promoting renewable energy.
- Renewable energy has gained momentum due to "an increase in environmental awareness, skyrocket oil and gas price, and national security concerns". Also, can protect the agency against oil price volatility.
- Texas energy production has not followed the State energy demand (i.e., consumption).
- Can help to reduce the dependence on fossil fuels and foreign energy.
- Using a value-based procurement (local vendors, maintenance expert, and workers) can promote economic development and create jobs.
- The technology is still evolving and becoming cheaper and more efficient
- Can be installed close to the end-user and with any scale (i.e., size), therefore not requiring long transmission lines and reducing heat loss – mainly in remote areas.
- Is a environmentally-friendly energy source
- Can enhance TxDOT image and bring political and public support.
- Is easy to implement if considered in highway new projects.
- Existing incentives granted by state and federal governments and REC credits.
- Can help TxDOT meet carbon emission and renewable energy consumption goals.
- Can promote awareness and educate general public on green energy, importance of carbon reduction, and renewable energy.
- Is more cost-efficient than other renewable energy source (i.e., $ per KWh generated) and is still evolving.
- Involves intense work-force, contributing thus for employment.

Disadvantages / Requirements

- Feasibility and efficiency (i.e., energy production) is very local-driven.
- Can highly impacts on nearby communities and environment (e.g., property value, noise, bird kill, shade, oil leaks, visual aesthetics, tourism, public safety, and quality of life, visual intrusion, and flickering of light)
- Has somewhat intensive maintenance
- Need of construction and maintenance plan (i.e., transport, minimal distance between turbines, installation, access and maintenance procedures). Can potentially impact on traffic and road structure.
- Require a high up-front investment, what entails a long payback and commitment period.
- Requires a formalized procedure (i.e., impact evaluation, contractual agreements, and liabilities).
- Involves a public-private-partnership, therefore an intensive and burdensome contractual and legal work.
- Can use several, but complex, business models that vary according to the shared risks , liabilities, electricity buyer, and renewable energy credits.
- Has some patent issues.
- May cause some impacts on nearby communities (i.e., property value).
- Relies somewhat upon the weather conditions , requiring batteries or other electricity source for more reliability
- May impact on Texas Highway Beautification Act.
- Requires a clean, easy, independent, and safe access (i.e., aside the main road).
- Must comply with FHWA and ASSTHO regulations regarding the use of ROW.
- May raise some safety concerns (e.g., roadside obstruction, blade failure, oil spill on the road, turbine catching on fire, and driver's distraction), but site can resolve these issues.
- Zoning law can preclude or impede the implementation (e.g., height limit).
- The wind turbine/system must comply with local electrical code requirements, the National Electrical Code (NEC), and Fire Protection Association.
- May require some licenses and permits (e.g., FAA permit)
- Can interfere on telecommunication, radio, internet, TV, and radar signals
- Is still driven by incentives.

Figure II.32: Adv. and Disadv./Req. of Wind Turbine (ROW/Vacant Land)

Value Extraction Application Framework

Go to Examples

Wind Turbine (Building and Rest Area)

Advantages

- Some regions of Texas (i.e., CREZ) has a great wind energy potential
- New technologies (i.e., small wind turbines) can help to overcome space issues, reduce up-front investment, and others barriers.
- Has high electricity production per area
- Does not require water and does not produce any waste or GHG emission.
- Can generate energy any time of the day.
- Wind turbine is a key component of the U.S. national strategy for reducing carbon footprint and promoting renewable energy.
- Renewable energy has gained momentum due to "an increase in environmental awareness, skyrocket oil and gas price, and national security concerns". Also, can protect the agency against oil price volatility.
- Texas energy production has not followed the State energy demand (i.e., consumption).
- Can help to reduce the dependence on fossil fuels and foreign energy.
- Using a value-based procurement (local vendors, maintenance expert, and workers) can promote economic development and create jobs.
- The technology is still evolving and becoming cheaper and more efficient
- Can be installed close to the end-user and with any scale (i.e., size), therefore not requiring long transmission lines and reducing heat loss – mainly in remote areas.
- Is a environmentally-friendly energy source
- Can enhance TxDOT image and bring political and public support.
- Is easy to implement if considered in new buildings.
- Existing incentives granted by state and federal governments and REC credits.
- Can help TxDOT meet carbon emission and renewable energy consumption goals.
- Can promote awareness and educate general public on green energy, importance of carbon reduction, and renewable energy.
- Is more cost-efficient than other renewable energy source (i.e., $ per KWh generated) and is still evolving.
- Involves intense work-force, contributing thus for employment.

Disadvantages / Requirements

- Feasibility and efficiency (i.e., energy production) is very local-driven.
- Can highly impacts on nearby communities and environment (e.g., property value, noise, bird kill, shade, oil leaks, visual aesthetics, tourism, public safety, and quality of life, visual intrusion, and flickering of light)
- Has somewhat intensive maintenance
- Need of construction and maintenance plan (i.e., transport, minimal distance between turbines, installation, access and maintenance procedures).
- Require a high up-front investment, what entails a long payback and commitment period.
- Requires a formalized procedure (i.e., impact evaluation, contractual agreements, and liabilities).
- May involves a public-private-partnership, therefore an intensive and burdensome contractual and legal work.
- Can use several, but complex, business models that vary according to the shared risks, liabilities, electricity buyer, and renewable energy credits.
- May cause some impacts on nearby communities (i.e., property value).
- Relies somewhat upon the weather conditions , requiring batteries or other electricity source for more reliability
- May raise some safety concerns (e.g., blade failure, oil spill, and turbine catching on fire).
- Zoning law can preclude or impede the implementation (e.g., height limit).
- The wind turbine/system must comply with local electrical code requirements, the National Electrical Code (NEC), and Fire Protection Association.
- May require some licenses and permits (e.g., FAA permit)
- Can interfere on telecommunication, radio, internet, TV, and radar signals
- Is still driven by incentives.

Figure II.33: Adv. and Disadv./Req. of Wind Turbine (Building/Facility)

Value Extraction Application Framework

Go to Examples

Geothermal Energy

Advantages

- Does not depend on weather conditions , day-time, or season. Therefore, does not require back-up battery.
- Geothermal power plants are reliable and can be implemented anywhere (i.e., urban center and remote areas) in any scale.
- Can be implemented in small scale and almost everywhere in Texas.
- Can be installed close to the end-user and with any scale (i.e., size), therefore not requiring long transmission lines and reducing heat loss– mainly in remote areas.
- Is a environmentally-friendly energy source
- Geothermal Heat Pump can be used anywhere in Texas and have short payback period
- Geothermal Heat Pump is regarded as the most energy-efficient, environmentally clean, and cost-effective method of temperature control.
- Is a key component of the U.S. national strategy for reducing carbon footprint and promoting renewable energy.
- Renewable energy has gained momentum due to "an increase in environmental awareness, skyrocket oil and gas price, and national security concerns". Also, can protect the agency against oil price volatility.
- Texas energy production has not followed the State energy demand (i.e., consumption).
- Can help to reduce the dependence on fossil fuels and foreign energy.
- Can enhance TxDOT image and bring political and public support.
- Is easy to implement if considered in highway new projects.
- Existing incentives granted by state and federal governments and REC credits.
- Can help TxDOT meet carbon emission and renewable energy consumption goals.
- Can promote awareness and educate general public on green energy, importance of carbon reduction, and renewable energy.
- May not Involves a public-private-partnership.
- Geothermal power plant has comparatively small surface footprint.
- Can be used as de-icing mechanisms for pavement, therefore enhancing safety, reducing costs, and avoiding contamination of roadside soil by chemical and salty substances

Disadvantages / Requirements

- Type of application and feasibility are highly dependent on the underground characteristics and quality of the resource (i.e., temperature, depth, fluid characteristics , ease and rate the fluid can be extracted and reinjected). Its cost can significantly increase if the useful resource is located deep (i.e., high drilling cost).
- Geothermal power plant has a medium to long payback period
- Geothermal power plant requires a formalized procedure (i.e., impact evaluation, contractual agreements, liabilities, licenses, and permits)
- May involve a public-private-partnership, therefore an intensive and burdensome contractual and legal work.
- Can use several, but complex, business models that vary according to the shared risks , liabilities, electricity buyer, and renewable energy credits.
- May have some patent issues.
- May cause some impacts on nearby communities and/or wildlife habitat (i.e., property value, noise, steam).
- May raise some safety concerns (e.g., steam).
- Zoning law can preclude or impede the implementation (e.g., height limit).
- May require some licenses and permits (e.g., NEPA permit)
- May involve a high up-front investment , depending the size and complex of the system.
- May rise issues regarding ownership and use of natural and underground resources. May require involvement of NEPA and environmental agencies.
- Its major issue is perhaps the use of water. Geothermal energy production requires large volume of water that often contains dissolved toxic substances.
- May raise some environmental concerns (i.e., water consumption and aquifer contamination).
- May require some precaution to avoid explosion and/or fire when drilling wells.

Figure II.34: Adv. and Disadv./Req. of Geothermal Energy

Value Extraction Application Framework

Carbon Sequestration

Go to Examples

Advantages

- Can help to reduce carbon footprint and combat global warming
- Can help to enhance TxDOT image
- Vegetation on ROW can be beneficial to road preservation (i.e., erosion prevention and reduction)
- Can help enhance the habitat surrounding the road and create a natural barrier for animals, helping preserve species.
- Can improve air quality by reducing the amount of CO2 and GHG on the atmosphere. Therefore, can help to prevent human respiratory diseases and enhance life quality.
- Can help TxDOT to divert and concentrate more focus and investments on highway system improvements (i.e., new projects and pavement maintenance), thereby potentially generating societal benefits such as: job creation, less traffic congestion, and lower freight costs (i.e., lower food, material, and product prices).
- Can enhance road safety and prevent roadside erosion (e.g., help preserve the pavement)
- Can provide a natural protection barrier for coastal roads, along hills and valleys, and against animals, thereby reducing animal-vehicle collisions and accidents.
- The federal government has given special attention to these types of applications in U.S. congressional debates centered preceding national climate change legislation. Therefore, it can bring political and public support.
- Some State beautification programs, such as the Green Ribbon Project – a corridor aesthetic and landscape master plan – requires TxDOT to plant a certain number of bushes and trees per year along TxDOT ROW. TxDOT could potentially receive credits from these programs . Also, bushes and trees absorb more carbon than grass and flowers (i.e., more efficient).

Disadvantages / Requirements

- Has to be clearly demonstrated as additional amount of carbon is being sequestrated to be counted and considered as carbon credit.
- The potential carbon that can be sequestrated varies with the site characteristics (i.e., soil, vegetation, and weather). Further, Texas has an enormous variability of soil and weather conditions that directly influences the capacity, feasibility, and cost of sequestrating carbon
- Requires involvement of very specialized staff (i.e., carbon aggregator and carbon verifier).
- Requires a long-term commitment (i.e., around 30 years) to qualify for carbon sequestration program.
- May impact on Texas Highway beautification program (i.e., wildflower program).
- May impose some safety concerns (e.g., some vegetation can attract animals, be a roadside obstruction, and reduce visibility and sight range).
- Carbon credit does not have a solid and well-established market yet. Carbon price floats, making economic analysis uncertain, complex, and difficult.
- There is no conclusive research on the efficiency of carbon sequestration, the establishment of a carbon baseline, and the real rate of carbon sequestrated by grass. Also, lacks of established protocol for grass vegetation.
- May rise some concerns from utility providers about liability on any damage on the vegetation planted along the ROW. Utility providers will seek and lobby to have priority over a carbon sequestration program application (long-term commitment)
- Lacks of regulations and/or direction in terms of the DOT's ownership on carbon credits generated by vegetation management practices on federal lands and how these carbon credits can be traded by a public agency.

Figure II.35: Adv. and Disadv./Req. of Carbon Sequestration

Value Extraction Application Framework

Go to Examples

Biomass and Biofuel

Advantages

- Texas contains one of the most diverse and most accommodating growing environments in the United States, and boasts a plethora of potential biomass-based renewable energy sources.
- The areas along the Gulf Coast and Northeast have the highest potential for biomass production because of existing refining capacity, strong producer networks, and available fertile land.
- Can promote economic development and create jobs
- The equipment used is similar to mowing equipment.
- Activities undertaken are very similar to mowing activities.
- Can produce biofuel without competing with food market.
- Can reduce and solve roadside maintenance and pest control problems.
- Requires low up-front investment
- Vegetation on ROW can be beneficial to road preservation (i.e., erosion prevention and reduction). Also, a good vegetation management strategy enhances road safety and prevents erosion. Vegetation along highway ROW defers erosion by reducing landslides, controlling evasive plant species, retaining stormwater, and holding snow (i.e., living snow fence).
- Same precautions and traffic control used to mowing activities can be adopted to plant and harvest crops.
- Biofuel combustion emits considerable less carbon than fossil fuel.
- The ethanol and biodiesel market has gained prominence worldwide due to increasing fossil fuel prices and pollution concerns.
- Can help to avoid the expansion of farming into environmentally sensitive areas; a commonly challenge found with conventional biofuel production
- Biofuel is non-toxic to humans and animals as well as biodegradable (i.e., disposal and waste are absorbed by the environment without being polluting).
- Using DOT ROW for biomass production can thus reduce the need for using farm land for energy crop production; thereby alleviating pressure on food and other commodities' price.

Disadvantages / Requirements

- Its feasibility and productivity (cost-effectiveness) depends on soil and weather conditions. Further, the production of each specific crop will largely be determined by available land, rainfall, competition, producer interest, economic incentives, and equipment needed.
- Water availability is crucial for most agriculture activity . It is generally believed that it would be very difficult to cultivate crops for biofuel production in areas with less than 14 to 16 inches of rainfall
- Logistic considerations (e.g., planting, harvesting, transporting, biorefinery, and access)
- Requires a formalized procedure (i.e., impact evaluation, contractual agreements, and liabilities). Also, questions about how to establish the business models and explore agricultural activities on public lands.
- May rise some concerns from utility providers about liability on any damage on the vegetation planted along the ROW. Utility providers will seek and lobby to have priority over a biomass production application (long-term commitment).
- May require intensive coordination with utility providers and agricultural activities – such as, plowing, tilling, harvesting, and mowing. Vegetation roots may impact on underground utilities (e.g., gas lines, oil lines, electricity, telephone, water, and fiber optics) that are also using the ROW. Contractual and legal issues with responsibilities and liabilities
- The use of de-icing products (e.g., salt) and run-off water can affect and change the proprieties of the soil in the ROW, hindering the growth of crops.
- Some crops and vegetation (e.g., switchgrass) has notorious difficult for establishment . Some takes up to 3years, even when some chemical fertilizers were used.
- Investment in a GIS database that captures the geospatial characteristics of TxDOT's ROW would aid in the identification and determination of which ROW parcels are appropriate for biomass production.
- May compete with and/or affects the ongoing roadside beautification and wildflower programs. Some crops do not promote the same aesthetical effect the flowers that integrate these programs have.
- Involves several variables and uncertainties, making the economic analysis complex and unique for each circumstance.
- In Texas, the ethanol and biodiesel market is not as prominent partly because grain has mostly been produced for animal – mostly cattle – consumption.
- May impose some safety concerns (e.g., some vegetation can attract animals, be a roadside obstruction, and reduce visibility and sight range).
- Licenses and permits required to exploit public land for agricultural activities.
- Has to comply with FHWA and ASSTHO regulations.

Figure II.36: Adv. and Disadv./Req. of Biomass & Biofuel

Value Extraction Application Framework

Wildlife Crossing

Go to Examples

Advantages

- Texas has been the state with the highest number of fatalities from animal-vehicle crashes since 1996
- FHWA "identified 21 federally listed threatened or endangered animal species in the U. S. for which road mortality was documented as a major threat to their survival. Wildlife crossing can help reduce and mitigate this problem. It can thus integrate habitats, reduce animal mortality, and help to save endangered species.
- Has been the most successful way to reduce both habitat fragmentation and wildlife-vehicle collisions caused by roads
- The construction of wildlife crossing can create jobs, usually in remote communities maximizing social benefit.
- A well designed wildlife crossing can effectively enhance the roadway safety and diminish the number of animal-vehicle accidents.
- Can reduce expenditures on road maintenance (e.g., removing animal carcass and investigating and reporting accidents). Thus, the government can direct larger portion of the budget to other priorities and, hence, benefiting the society.
- Can prevent potential lawsuit against TxDOT and liability over accidents and fatalities.
- Can reduce human fatalities, accidents, and consequently car insurance costs.
- Several federal funding programs exist to finance wildlife crossing projects
- Can be easily implemented and with lower cost if considered in new highway projects
- Can bring political and public support and enhance TxDOT image
- The implementation of wildlife crossing structures has received substantial support from the U.S. congress.. The approval of a federal highway bill – i.e., the Transportation Equity Act (TEA-21), guaranteed the availability of federal funds for wildlife crossing structures on existing roads, as well as new road projects.
- All new road projects are required to have an environmental impact study and mitigation strategy for fauna and flora.
- DOT's efforts and attitudes toward the environment and wildlife preservation can be fundamental to reduce public controversy and outcry against projects.
- Several federal funding sources can be used to support and afford the construction of wildlife crossings. Further federal programs can also grant funding for wildlife crossings such as, U.S. Fish and Wildlife Service (FWS), Natural Resource Assistance Grant Programs, and Cooperative Endangered Species Conservation Fund.
- Can be eligible for funding support from private foundations
- Has the highest net benefit minus cost balance in preventing animal-vehicle collisions.

Disadvantages / Requirements

- The effectiveness and efficiency of wildlife crossing structures are largely a function of the location, type, and dimensions of the crossings and, hence, are site-specific. The attributes of wildlife crossings thus have to be carefully studied and planned to accommodate the species targeted and the surrounding landscape.
- Requires extensive study and data regarding migration routes to identify the best location of the crossing (i.e., hot spot)
- Require wildlife crossing experts in the design team.
- May impose some construction challenges to be implemented in existing roads (e.g., supply chain, execution methods, and safety concerns).
- Traffic control and detours may also be required.
- Some engineering and technical solution may be inconvenient and expensive.

Figure II.37: Adv. and Disadv./Req. of Wildlife Crossing

Step 9: Summary of examples

Value Extraction Application Framework

Examples: Property Management

Go to Technical Memorandum

The California Department of Transportation (Caltrans) is the best example of how to implement a robust, efficient, and successful property management program. Caltrans' property management program revolves around a well-developed and comprehensive website that contains detailed information regarding auction procedures, leasing guidelines, and property announcements. Currently, Caltrans has about 12 managers and 48 employees in 12 districts involved in property management, whom are not dedicated 100% to the program. In summary, the property management program is divided into three value extraction functions: Airspace & ROW leasing, property management, and excess land sales. The airspace leasing component generated about $25 million in FY2009 with the leasing of airspace beneath viaducts for parking lots, leasing airspace over freeways, and leasing right-of-ways for telecommunication antennas. The property management division has secured about $12 millions in revenue per year, mostly from the leasing of property in two significant corridors owned by Caltrans. Finally, the excess land component is responsible for lands or properties that are not needed or will not be used within 20 years and secured nearly $11.5 million in revenue that came from selling 290 parcels.

Figure II.38: Examples of Property Management

Value Extraction Application Framework

Examples: Property Management (Rest Area)

Go to Technical Memorandum

The Interstate Oasis program was launched in 2006 by the FHWA to overcome the problem of a lack of rest areas and the barriers to rest area privatization, as well as to reduce the financial and administrative costs of the State DOTs. Interstate Oasis program is a public-private-partnership defined by FHWA as an off-freeway facility that aims to supplement the public rest area. To qualify as an Interstate Oasis, the facility has to comply with a list of requirements and specifications, including a standardized design, offering of products and services to the public, 24-hour access to restrooms, and parking for autos and heavy trucks. Furthermore, a specific and unique logo has to be adopted to identify the units that are part of the program.

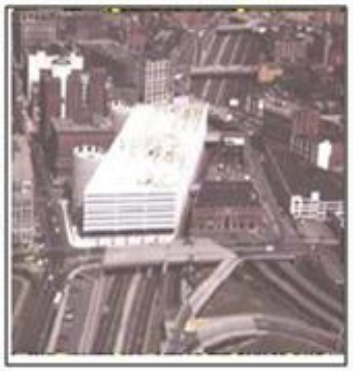
Another important example of how to extract value from rest areas is presented by the Oases complex in Illinois. The complex comprises seven private and commercialized rest areas that are located on the I-294/94, I-90, and I-88 tollways and offers several services, such as gas station, car wash, food court, shopping, and ATM.

Figure II.39: Examples of Property Mngm (Rest Area)

Value Extraction Application Framework

Examples: Airspace Leasing (Building)

Go to Technical Memorandum



In Boston, the airspace over the Massachusetts Turnpike holds at least three formalized airspace leasing agreements for buildings, which have been topic of research, inclusively. The first is the Copley Place, a 3.5 million square-feet complex constructed in 1986 that comprises hotel, retail store, office, parking and housing. The second in Columbus Center, a complex of buildings that occupies 7 acres divided into 4 parcels of air rights and totalizes 1.4 million square-feet of construction. The Columbus Center consists of hotel, restaurant, retail store, health club, residential building, and parking. The last is The One Kenmore that occupies 1 parcel of airspace and is still in development. When concluded, The One Kenmore will have 1.2 million square-feet of construction, including office, health club, grocery store, community center, and parking. The economic feasibility of all three projects was ensured by an airspace premium funding granted by the City of Boston. This fund was needed because the land value in Boston in the outset of the projects was not yet high to spark and encourage private investment. In terms of benefits, the City of Boston could reconnect the neighbors that have been divided by the highway corridor, generate new tax revenue, and create permanent jobs with the economic development.

Figure II.40: Examples of Airspace Leasing (Building)

Value Extraction Application Framework

Examples: Airspace Leasing (Parking lot)

Go to Technical Memorandum

Parking Lot under a Viaduct in California
Source: Caltrans Monthly Newsletter

The California Department of Transportation (Caltrans) has extensively used airspace leasing for parking lots as a value extraction application. Caltrans has entered into both long-term and short-term leasing agreement for parking. In general, the private sector has approached Caltrans to lease available spaces. Some parking lot structures are, however, leased to parking companies via a competitive bid for two or three years. To announce the bidding process, Caltrans resorts to Frameworks such as, Craigslist and email. In addition, park-and-ride lots usually somewhat distant from downtown areas are typically leased to independent car sellers or for community events on, for example, weekends. These park-and-ride leases, usually, involve community centers that are responsible for providing security and cleaning the area. The community centers, typically, pay a lower rate for leasing the park-and-ride lot. Caltrans currently has around 400 parking lot leasing agreements that generate a reasonable level of income.

In Texas, some examples of parking lots beneath TxDOT highways can also be encountered. However, TxDOT comments that the agreement typically involves other public agency (e.g., city, court house, and DPS) and does not include any financial payment or benefit.

Figure II.41: Examples of Airspace Leasing (Parking Lot)

Value Extraction Application Framework

Examples: Airspace Leasing (Utilities)

Go to Technical Memorandum

In 1999, "The Florida DOT reached a 30-year lease agreement with Lodestar Towers, Inc., allowing Lodestar Towers, Inc. to lease access to the Department's limited access rights-of-way in return for compensation formulated as a percentage of the gross revenues received from renting antenna space to commercial wireless service providers". The public private lease agreement was developed in compliance with the Department's Telecommunications Policy, whose goal is "to consolidate wireless tower use to the Department's limited access rights-of-way by providing equal access and opportunity to all wireless service providers. This strategy encourages wireless service providers to collocate on towers located on the Department's limited access rights-of-way instead of developing numerous new tower sites in local communities. The resulting reduction of the number of towers and the location of needed towers as far from residential areas as possible facilitates the intent of the lease to support the wireless service providers while minimizing wireless tower proliferation". "To date, Lodestar Towers, Inc. has constructed 26 towers on the Department's rights-of-way. Another 22 proposed towers are under siting and design review by the Department" (Florida ITS, 2001).

Wireless monopole with an electrical vault and fencing. To

The California Department of Transportation (Caltrans) received $7.3 million in revenue in FY 2008 from its airspace leasing program, of which $1.3 million came from 52 cell towers (Caltrans, 2009). Caltrans's Leasing Program Administration personnel regard the cost-effectiveness of cell towers to be a major benefit. Cell towers do not require extensive maintenance on the sites and generate reasonable revenues (Caltrans, 2009). Caltrans's Airspace program for telecommunications is administrated by an agent and five-person team that are responsible for managing the relationship with renters, seeking business opportunities, and implementing the procedures needed for leasing (Caltrans, 2009). Most of the airspace leasing agreements involve telecommunication providers, which encompass 20 different companies. Most of the telecommunication leasing agreements are located in urban areas (about 90%) and all of them are in accordance with the Caltrans's master license agreement that grants a 5 year license for a specific site, with the option to renew the license five times for 5 years each.

In Texas, TxDOT estimates to receive between $2 million to $4 million from an informal and inactive program. TxDOT also believes that formalizing this program could bring more management efficiency and incomes to the state.

Figure II.42: Examples of Airspace Leasing (Utilities)

Value Extraction Application Framework

Examples: Advertising

Go to Technical Memorandum

In Washington, Rest areas are equipped with brochure dispensers that are rented to vendors and companies. The vendor can rent dispenser space at a rest area or at several rest areas (i.e., packages). The rent price varies depending on the number of rest areas in the rent package and/or the size of the panel.

Another interesting application of this value extraction option is found in Toronto, Canada, where the vegetation along the highway that links the international airport to downtown is used to advertise companies.

Figure II.43: Examples of Advertising

Value Extraction Application Framework

Examples: Advertising

Go to Technical Memorandum

Blue signs (or Logo signs) are definitely the most common advertising type encountered throughout the U.S. highway system and is used mainly to inform travelers about services along the road.

Naming Right is also a very popular advertising program used by the private sector and that has been adopt by the public sector in certain circumstances, such as train station, airports, toll booth, rest areas, highway corridors. Here, a private company pays a Naming Right fee in exchanging of having its company name and/or logo associated with the property (e.g., rest areas, toll plaza, bridge, and highway).

In general, there are two nationwide programs concerning sponsorship for littering removal and roadside maintenance: The Adopt A Highway Maintenance Corporation (AHMC) and the Adopt A Highway - Litter Removal Service of America (AAH-LRSA). AHMC and AAH-LRSA provide the opportunity to brand a private company name and logo while supporting the community your customers live and work in. Companies that make a commitment to finance litter pick up along a stretch of highway, receive a sign that identifies them as a community minded, environmentally conscious business.

Another sort of sponsorship that can be used by TxDOT to fund some following VEA projects (i.e., renewable energy project) is called Adopt-A-Watt. Like Adopt-a-Highway, in an Adopt-a–Watt agreement companies can sponsor or fund clean energy and alternative fuel projects in exchanging of having their name advertised and acknowledged. Also, a sign template – that complies with FHWA Acknowledgment Sign Standards - is provided (see Figure 5.15). The two most popular programs are Sponsor-able Photo-Voltaic Light (SPVL) and Sponsor-able Photo-Voltaic Display (SPVD). In the case of solar lights, the sponsorship fees start at $2.000 per year, while for solar arrays the sponsorship fees start at $11.000 with a 3 year minimum commitment in both cases.

Figure II.44: Examples of Advertising

Value Extraction Application Framework

Examples: Solar Panel (ROW and Vacant Land)

Go to Technical Memorandum

Oregon DOT (ODOT) is the pioneer in implementing solar panels in highway ROW. In December 2008, ODOT concluded the installation of the first solar arrays project at the interchange of IH-5 (see figure 5.8). The arrays can produce up to 117 KWh annually, i.e., 1/3 of the energy needed on the site. Basically, the solar arrays feed the grid with the electricity produced during the day whereas at night the grid supplies the electricity for interchange lighting.

Currently, SMUD Sacramento (California) is exploring a 594 solar panels project. Also, Caltrans is analyzing the feasibility of installing solar charge stations for electrical vehicles along highways, as well as the installation of solar panels for light poles.

In 2010 the Ohio DOT, in conjunction with the University of Toledo, installed a 100KW solar array – composed by 966 rigid solar panels and 198 flexible solar panels – in the ROW off IH-280 and Greenbelt Parkway in Toledo, OH. The solar array provide the entire electricity demanded at the Veteran's Glass City Skyway Bridge, which has a 196-foot lighted pylon containing 384 light emitting diode fixtures

A number of solar projects can be found in European and Oceania transportation ROW. Germany, for example, has invested € 11 million in a solar panel project on top of a tunnel on highway A3 that has a 2.8 MW capacity. It is expected that the investment cost will be recovery in 16 years from cost savings. The 16,000 solar modules occupy 2.7 km and will provide electricity to nearly 600 houses . In Australia and some European countries, solar panels have a "dual use". Besides energy generation, the panels also act as sound barriers.

Figure II.45: Examples of Solar Panel (ROW/Vacant Land)

Value Extraction Application Framework

Examples: Solar Panel (Building and Rest Area)

Go to Technical Memorandum

Wyoming DOT has 19 rest areas that use solar power to provide an estimated half of the rest areas' energy needs. To bring more attention and curiosity about renewable energy and GHG emission reduction, Wyoming DOT installed solar "flowers" at a rest area on Interstate 70 near Parachute in August 2011. In this case, the solar panels have also an aesthetical function and educational purpose.

In Texas, solar panels will be installed at two new rest areas along I-20.

Figure II.46: Examples of Solar Panel (Building/Rest Area)

Value Extraction Application Framework

Examples: Wind Turbine (ROW and Vacant Land)

Go to Technical Memorandum

Although wind turbines along highway ROW are becoming increasingly common in Europe (e.g., Denmark, Germany, and the Netherlands), in the U.S. the value extraction application have not received great attention from the DOTs. One of the few examples can be found in the MassDOT (former Massachusetts Turnpike Authority), where a 400-foot-tall wind turbine with the potential to generate 1.5 MW has been considered to be installed in the middle of the 68-acre site, reaching around 1,500ft of set-back from the highway. This device is expected to generate 3,000 MWh of electricity per year, enough to supply the energy need of nearly 400 households. The land holding is adjacent to the Blandford service area.

The Ohio DOT (ODOT) is installing a small 32KW wind turbine at a maintenance facility in Northwood, adjacent to highway ROW along I-68. The wind turbine is approximately 100 feet tall and is located 140 feet from the roadway (i.e., setback). The wind system proposed is intended to help to provide up to 65% of the electricity consumed by the facility

TAK Studio envisioned light poles connected with wind turbines that would harvest the traffic turbulence and convert into electricity to supply the energy needed to illuminate the highways. The Israel National Roads Company is conducting the feasibility studies (i.e., front-end planning) to install small wind turbines tied in lighting poles along the coastal road, taking advantage of sea winds; and in Twain, where small wind turbines are being incorporated with parking lots.

The Colorado DOT (CDOT), Ohio DOT, MassDOT, and Illinois DOT that have worked with local consulting companies and/or universities to identify opportunity zones and sites suitable for renewable energy and revenue generating projects on highway ROW, rest areas, and weigh stations. The identification has been made by overlaying ROW maps and geographic information system (GIS) data layers of potential renewable energy source (i.e., solar, wind, geothermal, and biomass resource maps)

Figure II.47: Examples of Wind Turbine (ROW/Vacant Land)

Value Extraction Application Framework

Examples: Wind Turbine (Building and Rest Area)

Go to Technical Memorandum

A number of examples exist where wind turbines have been installed at rest areas and buildings to provide energy and promote renewable energy generation. A wind turbine project is also currently being explored at the Blandford rest area on the Massachusetts Turnpike. A 400-foot-tall wind turbine with the potential to generate 1.5 MW is being considered. This device is expected to generate 3,000 MWh of electricity per year, enough to supply the energy need of nearly 400 households.

The Ohio DOT (ODOT) is installing a small 32KW wind turbine at a maintenance facility in Northwood, adjacent to highway ROW along I-68. The wind turbine is approximately 100 feet tall and is located 140 feet from the roadway (i.e., setback). The wind system proposed is intended to help to provide up to 65% of the electricity consumed by the facility

The Israel National Roads Company is conducting the feasibility studies (i.e., front-end planning) to install small wind turbines tied in lighting poles along the coastal road, taking advantage of sea winds; and in Twain, where small wind turbines are being incorporated with parking lots

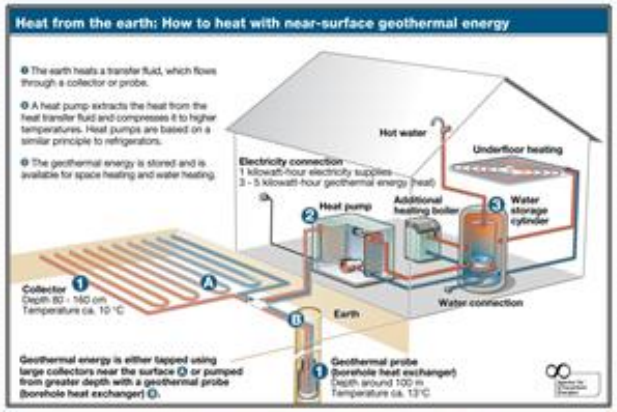
In Texas, two 50 KWh wind turbines have been installed at two rest areas – on I-40 close to Amarillo and close to Lubbock.

Figure II.48: Examples of Wind Turbine (Building/Rest Area)

Value Extraction Application Framework

Examples: Geothermal Energy

Go to Technical Memorandum



Geothermal heat pump is widely and commonly used in offices and residences to reduce energy consumption from HVAC systems. The size and complexity of GHP systems depends on the use of HVAC system and how much electricity is intended to be saved.

Geothermal systems – similar to GHP – have been applied as a de-icing mechanism on highways since late 40's. In this system, "heat pipes" are embedded in the pavement, where snow or ice layers have been constantly critical. According to up-to-date observations, it has been estimated that geothermal systems could keep the pavement free of snow and ice at temperature as low as -10°F (-23°C). Several DOTs have been adopted the geothermal system in very specific location, such as New Jersey, South Dakota, Wyoming, and Virginia, as well as countries such as, Japan, Switzerland, and Argentina

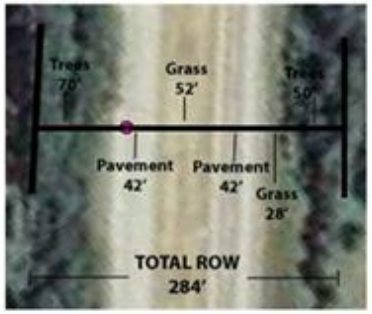
Ultimately, a broader approach has been undertaken by Colorado DOT (CDOT), Ohio DOT, MassDOT, and Illinois DOT that have worked with local consulting companies and/or universities to identify opportunity zones and sites suitable for renewable energy and revenue generating projects on highway ROW, rest areas, and weigh stations. The identification has been made by overlaying ROW maps and geographic information system (GIS) data layers of potential renewable energy source (i.e., solar, wind, geothermal, and biomass resource maps)

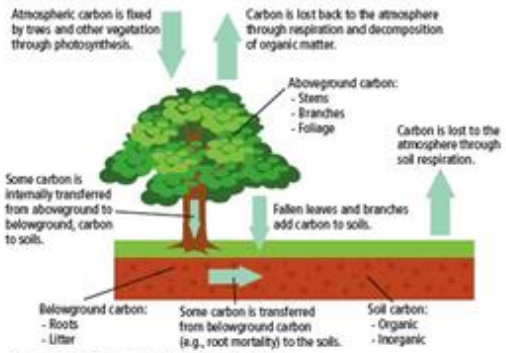
Figure II.49: Examples of Geothermal Energy

Value Extraction Application Framework

Examples: Carbon Sequestration

Go to Technical Memorandum





Source: U.S. Environmental Protection Agency

Carbon sequestration is the process of capturing and removing CO_2 and other forms of carbon from the atmosphere and, then, "storing" it in "reservoirs". A variety of techniques to sequester carbon exist, but the focus here is exclusively on vegetation management.

There is no formal carbon sequestration program in the U.S. besides the pilot programs and research studies conducted in states such as, New Mexico and Utah.

The Carbon Sequestration Pilot Program (CSPP), led by FHWA' Office of Natural and Human Environment (ONHE) and the New Mexico Department of Transportation (NWDOT), reported that in addition to improved vegetation management, carbon sequestration allows for: "(1) selling carbon credits on an appropriate GHG market or registry for revenue, (2) using carbon credits to offset the DOT's emissions, or (3) using the credits toward meeting statewide objectives."

Figure II.50: Examples of Carbon Sequestration

Value Extraction Application Framework

Examples: Biomass and Biofuel

Go to Technical Memorandum

The Utah DOT launched a research project in 2006 in conjunction with Utah State University (USU) to assess the feasibility of planting drought-tolerant crops such as canola, safflower, and dwarf sunflower along the ROW in a non-irrigated environment. The idea - as envisioned by the researchers - is to harvest enough seed to produce in-house biodiesel for the UDOT's fleet, including heavy diesel machineries and snow plows. As a result of the research, USU and UDOT could identify minimum requirements to initiate a biomass program.

The North Caroline DOT (NCDOT) initiated in 2009 its biomass and biofuel project. Currently, the NCDOT's project is recognized as one of the largely successful biomass projects nationwide, mostly because of the state moist climate, fertile soil, and support from the State legislature. The project started with four 1-acre plots of canola or sunflower crops. These crops were selected by NCDOT, in conjunction with North Caroline State University, because their estimated greater potential of yield in ROW scenario. NCDOT has been working with seasonally rotated crops on the same plot, thereby being able to meet or exceed national standards for crop production. In 2010, NCDOT extracted 3,000 lb of canola seed, which yielded 100 gallons of virgin oil. The virgin oil produced 150 gallons of B100, which was cut with conventional diesel to generate approximately 600 gallons of B20. The NCDOT used the B20 to fuel its dump trucks, tractors, and other equipment.

Another pilot project is being conducted by Genera Energy LCC – a for-profit limited liability company wholly owned by the University of Tennessee Research Foundation – in partnership with Tennessee DOT. The objective of the pilot project is to verify if switchgrass – one of the primary feedstock used to produce cellulosic ethanol and native for all American states – planted along the highway ROW can yield reduced maintenance costs due to less mowing activities and erosion on the roadside, as well as generate revenue from biomass for biofuel production.

Figure II.51: Examples of Biomass & Biofuel

Value Extraction Application Framework

Examples: Wildlife Crossing

Go to Technical Memorandum

Wildlife overpasses are very common in Europe. In North America, however, where there are only six examples of these structures of which two are located in the Banff National Park in Alberta, Canada.

The Banff National Park and Trans-Canada Highway (in Alberta, Canada) have perhaps the "most recognizable wildlife crossings in the world" with 22 underpasses and two overpasses.

The highway IH-75 (Florida) has 24 highway underpasses and 12 bridges that were modified for wildlife crossings along 40 miles. These crossing structures are "specifically designed to target and protect the endangered Florida panther".

The Hoge Veluwe National Park – in the Netherlands - has three wildlife overpasses (called Ecoducts) across highway A50. It is estimated that in one year almost 5,000 deer and wild bears used at least one of the crossing structure.

Several DOTs and Research Center have conducted studies regarding how to identify best location for wildlife crossing and design the structure effectively, including a Wildlife Decision Guide Framework .

Figure II.52: Examples of Wildlife Crossing

Step 10: Definition of each criterion used in the evaluation matrix.

Value Extraction Application Framework

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CRITERION	DESCRIPTION
Technical Feasibility	Technical Feasibility consists of requirements needed to facilitate and ensure a successful implementation of a VEA. For example, site characteristics are fundamental and determinant for several VEAs such as, solar panels (e.g., proximity to transmission lines, plainness, and minimum of 5 acres of available land) and biomass (e.g., minimum of 15 inches rainfall, soil characteristics, distance to biorefineries, and minimum of 1 acre of available land). Technical feasibility also concerns engineering and construction standards and requirements. For example, to construct a building over a highway the distance between columns (i.e., free span), minimal clearance, construction methods, and access to the jobsite can impose challenges and difficulties, thereby precluding or preventing the project execution.

Figure II.53: Definition of Technical Feasibility

Value Extraction Application Framework

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CRITERION	DESCRIPTION
Legal Considerations	Legal Considerations comprise, among others, Federal and State legislation, the FHWA policies and regulations, the National Environmental Policy Act (NEPA) and other environmental regulations, the Federal Aviation Association (FAA) regulations, and the AASHTO policies, which can directly or indirectly affect and/or drive the implementation of a potential VEA. Legal Considerations also concern studies and analysis that must be conducted, as well as permits and licenses that must be obtained. Finally, Legal Considerations include written agreements, liabilities, business models, and responsibilities. For example, Federal and State regulations govern the types of activities that can and cannot occur on ROW held by DOTs, or purchased by the DOTs. 23 Code of Federal Regulations (CFR) Chapter 1, for the most part, is the main source of regulation regarding the activities and opportunities that DOTs are granted vis-à-vis the federal system of interstate highways. Moreover, Federal law currently prohibits DOTs from privatizing and commercializing rest areas along the interstate highways. In Texas, Texas Transportation Code and Texas Administrative Code govern the activities and opportunities surrounding TxDOT's ROW and real estate. Furthermore, Transportation Code Sub-chapter C of Chapter 202 governs leases, easements, and agreements that concern highway property. Section 202.052 allows the department to lease a highway asset, part of the ROW, or airspace above or underground a highway, if the department determines that the interest to be leased will not be needed for a highway purpose during the term of the lease. Also in Texas, "TxDOT regulates the display of off-premise outdoor advertising signs along highways regulated by the Highway Beautification Act (HBA) and all other highways and roads located outside of the corporate limits of cities, towns and villages in Texas under the State Rural Roads Act (RRA)". In some cases, the lack of zoning law can defer or even impair the implementation of projects such as, solar, wind, and geothermal. As said, environmental analysis is also a requirement for any project on public land. A project must be in compliance with NEPA – either FHWA or DOE process, if not both – to receive an environmental permit. Finally, for any construction over 200ft, the form "74601-Notice of Proposed Construction or Alteration" must be filed with the Federal Aviation Administration (FAA) prior its outset. The FAA and the Department of Defense (DOD) will review the form and issue a permit.

Figure II.54: Definition of Legal Considerations

Value Extraction Application Framework

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CRITERION	DESCRIPTION
Financial / Economic Feasibility	The implementation of any VEA requires somewhat an upfront investment by TxDOT or private investors. The Financial/Economic Feasibility addresses the order of magnitude of the upfront investment and its consequential payback period, as well as indirect economic benefits that the implementation of a VEA can bring to TxDOT and society. For example, wildlife crossing projects will typically cost $1 to $3 million to TxDOT and will be paid off through cost savings from removing animal carcass and vehicle wrecks caused by animal-vehicle-crash incidents (AVC). Wildlife crossing can also economically benefit the society by preventing human fatalities from AVC (i.e., value of human life), reducing vehicle insurance costs, and creating temporary jobs (i.e., construction jobs). Another example is property management, which can generate revenue to TxDOT (e.g., selling or leasing land lots or properties) and/or saving costs (e.g., swap transaction with construction of a new facility). Furthermore, property management can also help to economically develop areas (i.e., creation of business opportunities and jobs on urban areas) and raise taxes payments for the state (i.e., payment of land taxes by private owners).

Figure II.55: Definition of Financial/Economic Feasibility

Value Extraction Application Framework

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CRITERION	DESCRIPTION
Political/Public Concerns	Political and Public Concerns refer to how the VEA will likely be seen and accepted by the general public and politicians. In other words, Political and Public Concerns look at whether the VEA is controversial, potential impacts on nearby communities and businesses, likelihood of sparking public outcry and opposition, and impacts on TxDOT image. For example, selling or leasing vacant land to new business development can negatively impact on neighbors (e.g., increase traffic congestion and decrease property value) and existing businesses (e.g., concurrence), therefore causing public dissatisfaction. Some VEA can, on the other hand, enhance TxDOT image and bring support from nearby communities, as well as local politicians. These positive results mostly occur when the VEA involves public goodwill and/or social benefits without entailing increase of tax payment. For example, wildlife crossing can integrate habitats, protect endangered species, enhance road safety, create jobs, and, even, reduce car insurance costs. Another example is parking lot that can alleviate traffic congestion, stimulate business development, and raise some funds for the department.

Figure II.56: Definition of Political/Public Concerns

Value Extraction Application Framework

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CRITERION	DESCRIPTION
Environmental Considerations	Highway projects is well-known from and continuously criticized because the environmental impacts provoked by them such as, habitat fragmentation, deforestation, noise and dust during and after construction, vehicular emissions (i.e., GHG), and threats on endangered species (i.e., animal-vehicle-crash). Environmental Considerations take into account the contribution a VEA can have to enhance and preserve the environment or, otherwise, harm and threaten the natural habitat. Wind turbine, for example, is a renewable and non-pollutant energy source. Wind turbine can thus contribute to reduce GHG emission from power generation and help to combat the global warming. On the other hand, wind turbine can be detrimental to nearby communities – because of noise and shade – and danger for birds and bats.

Figure II.57: Definition of Environmental Considerations

Value Extraction Application Framework

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CRITERION	DESCRIPTION
Safety Considerations	TxDOT's primary mission is to provide safe vehicle transportation routes with adequate capacity. Safety Considerations are thus crucial criterion and concern any potential impact that implementing a VEA can provoke on the safety of road users and general public. Basically, safety considerations look at clear zones, obstacles and obstruction created, accesses needed, risks imposed during implementation or maintenance of the VEA project, and likelihood of provoking accidents. Rest areas, for example, are essential to road safety. Privatizing and/or offering better service at rest areas can stimulate drivers to stop by, avoid rest areas' closure, and, even, increase the availability of rest stops. Consequently, road accidents caused by "drowsy driving" - a serious problem that leads to thousands of automobile crashes each year – can be reduced and, consequently, the road safety enhanced. Another good example is wildlife crossing. Several studies have demonstrated that a well-designed wildlife crossing can effectively enhance the roadway safety and diminish the occurrence of animal-vehicle accidents. On the other hand, safety concerns may arise whenever a wildlife crossing project is planned to be built on existing roads. Safety is also a major concern when using advertising in highway ROW. FHWA and AAA Foundation for Traffic Safety argue that advertising can distract drivers, thereby causing accidents. Furthermore, signs and billboards must be located outside the safety zone to protect drivers that run off the road.

Figure II.58: Definition of Safety Considerations

Value Extraction Application Framework

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CRITERION	DESCRIPTION
Potential Social Impacts / Benefits	Essentially, Social Impacts and/or Benefits concern how a VEA can impact on business opportunities, economic development, job creation, and general welfare. For example, facilitating the implementation of telecommunication tower in rural areas can enhance internet and cell-phone signals. Nowadays, these infrastructures are essential for economic development. Moreover, internet plays important role on education and professional development. On the other hand, privatizing rest areas may entail unfair competition with local business in small communities, hence negatively impacting on the social welfare. On the other hand, well served and interactive rest areas and welcome centers can potentially enhance the tourism market and create jobs, therefore helping to develop rural areas. Another example is renewable energy projects (i.e., solar, wind, geothermal, and biomass energy). Because of the scalability (i.e., capability of being implemented with different sizes and capacities), renewable energy project can be decentralized and deployed close to end-users. Not only can these proprieties reduce the cost of transmission lines, but they can be fundamental to enable electricity supply in remote and rural areas, thereby promoting economic development, jobs, and welfare. However, depending on location of the project, renewable systems can impact on nearby communities (e.g., noise, shade, and property value reduction).

Figure II.59: Definition of Potential Social Impacts/Benefits

Step 11: Assign weights according to relative importance of each criterion.

Value Extraction Application Framework

Criteria Weight & Score Scale

	Weight Scale		
Feasibility	Technical	0.23	5
	Legal	0.45	10
	Economical	0.32	7
Impact	Political/Public	0.21	6
	Environmental	0.24	7
	Safety	0.34	10
	Social	0.21	6

Score Scale		
Negative Impact	-2	Major Concerns
	-1.5	
Somewhat Negative	-1	Minor Concerns
	-0.5	
Neutral	0	Neutral
	0.5	
Somewhat Positive	1	Minor Benefits
	1.5	
Positive Impact	2	Major Benefits

Weight Scale:
10 = Very Important
1 = Insignificant or Indifferent

Figure II.60: Input of Criteria Weight and Display of Score Scale

Step 12: Analyze each VEA using the evaluation matrix.

Table II.1: Property Management Evaluation Matrix

#	Statement	Feasibility				Impact			
		Technical	**Legal**	**Economic**		**Political/ Public**	**Environmental**	**Safety**	**Social**
1	Trained in-house staff in ROW and Real Estate management.								
2	In-house staff member to champion the evaluation and implementation of a property management application.								
3	Ease of integrating property management application in TxDOT's organizational and decision-making structure.								
4	Availability of resources to update databases and/or GIS inventory								
5	In-house resource to systematically review and assess current asset and future asset needs.								
6	Willingness to invest in resources such as, information system, website, and GIS system.								
7	Access to TxDOT's property inventory to determine characteristics/features of property assets (e.g., size, location, value, maintenance cost, and overall condition).								
8	Ability to communicate, involve, and share information with general public and stakeholders about the Value Extraction Application project (i.e., transparency and equal access to information).								
9	Current value (i.e., market/Real Estate value) of the property.								
10	Current maintenance expenses on the property asset and potential savings if disposing of the property.								
11	Formal procedures/guidelines available to conduct/implement TxDOT property management								

#	Statement	Feasibility			Impact			
		Technical	**Legal**	**Economic**	**Political/ Public**	**Environmental**	**Safety**	**Social**
	program.			■		■	■	■
12	Anticipated impacts on nearby community of "new" property use (i.e., new owner or lessee), including potential to mitigate anticipated impacts.	■	■	■				
13	Anticipated environmental impacts and mitigation measurements of "new" property use.	■			■		■	
14	Permit or license required for "new" property use.	■			■	■	■	■
15	Financial resources of and warranties (i.e., bond approval and surety) provided by the developer interested in buying/leasing/swapping property.	■			■	■	■	■
16	Anticipated direct and indirect jobs created and economic development impacts resulting from "new" use of property.	■	■			■	■	
17	Anticipated benefits to TxDOT (e.g., financial, technical, and safety) of disposing of "obsolete" assets.		■			■		
18	Potential concerns anticipated by General Land Office (GLO) or another public agency (e.g., FHWA, DOE, and DOD).	■		■		■	■	■
19	Potential conflict with zoning law, city's master plan, and transportation's plan.	■		■		■	■	
20	Anticipated political and public opposition to transaction (e.g., controversy and potential impacts triggered by the "new" use).	■	■	■		■	■	■
21	Legal constraints/issues that can jeopardize the transaction.	■		■	■	■	■	■
22	Available legal consultants/resources to implement TxDOT property management program.	■			■	■	■	■
23	Available legal consultants/resources to advise and review transactions and contractual agreements.	■			■	■	■	■
24	Resources required to train or acquire in-house legal resources/counsel.	■	■			■	■	■
25	TxDOT's exposure in terms of liability and risks.	■				■	■	■

#	Statement	Feasibility				Impact			
		Technical	**Legal**	**Economic**		**Political/ Public**	**Environmental**	**Safety**	**Social**
26	Investment required by TxDOT to implement the Value Extraction Application.								
Total contribution of the criterion									

Table II.2: Property Management (Rest Area) Evaluation Matrix

#	Statement	Feasibility				Impact			
		Technical	**Legal**	**Economic**		**Political/ Public**	**Environmental**	**Safety**	**Social**
1	Trained in-house staff in ROW and Real Estate management.								
2	In-house staff member to champion the evaluation and implementation of the Value Extraction Application.								
3	If retrofitting rest areas, available in-house staff to specify and oversee design and construction (retrofit) of rest area.								
4	Available data on number of vehicles passing by (and visiting) the rest area.								
5	If considering privatization or a private partnership investor/developer(s) interested in managing/operating rest area.								
6	Access to TxDOT rest area inventory to determine characteristics/features (e.g., size, location, value, maintenance cost, and overall condition) of rest area.								
7	Ability to communicate, involve, and share information with general public and stakeholders about the Value Extraction Application project (i.e., transparency and equal access to information).								
8	Current value (i.e., market/Real Estate value) of the property.(i.e., rest area).								

#	Statement	Feasibility			Impact			
		Technical	**Legal**	**Economic**	**Political/ Public**	**Environmental**	**Safety**	**Social**
9	Current maintenance expenses on the rest area and potential savings from implementing the Value Extraction Application.							
10	Formal procedures/guidelines available to TxDOT to implement public-private partnership agreements and or privatize rest areas.							
11	Anticipated impacts of privatizing the rest area on nearby community (i.e., economic and social impacts), including potential to mitigate anticipated impacts.							
12	Anticipated environmental impacts and mitigation measures.							
13	Permit(s) or license(s) required.							
14	Financial resources of and warranties (i.e., bond approval and surety) provided by the developer interested in leasing or partnering with TxDOT.							
15	Anticipated direct and indirect jobs created and economic development impacts.							
16	Anticipated benefits to the region or state (e.g., increase local or state taxes).							
17	Anticipated benefits to TxDOT (e.g., financial, technical, and safety).							
18	Potential concerns anticipated by General Land Office (GLO) or another public agency (e.g., FHWA, DOE, and DOD).							
19	Potential conflict with zoning law, city's master plan, and transportation's plan.							
20	Anticipated political and public opposition to project (e.g., controversy and potential impacts triggered by rest area privatization).							
21	Potential risks and implications associated with considered business model (e.g., private-public-partnership, lease, easement, and sale).							

#	Statement	Feasibility				Impact			
		Technical	**Legal**	**Economic**		**Political/ Public**	**Environmental**	**Safety**	**Social**
22	Legal constraints and barriers that can impede/preclude the project (e.g., rest area privatization).								
23	Resources required to train and acquire in-house legal resources/counsel.								
24	Available legal consultants/resources to advise and review transactions and contractual agreements.								
25	TxDOT's exposure in terms of liability and risks.								
26	Compliance with Interstate Oasis Program, FHWA, AASTHO, and other's agency requirements and policies.								
27	Investment required by TxDOT to implement the Value Extraction Application.								
Total contribution of the criterion									

Table II.3: Airspace Leasing (Building) Evaluation Matrix

#	Statement	Feasibility				Impact			
		Technical	**Legal**	**Economic**		**Political/ Public**	**Environmental**	**Safety**	**Social**
1	Trained in-house or consultant staff to analyze the project, specifications, and potential impacts, and challenges.								
2	Staff to specify and oversee design and construction of the project.								
3	In-house staff member to champion the evaluation and implementation of the Value Extraction Application.								
4	Available in-house or consultant safety and security experts to conduct safety assessment, advise the design, and provide insight in the drafting of the concept and leasing agreement.								
5	Project characteristics (e.g., footprint) and								

#	Statement	Feasibility			Impact			
		Technical	**Legal**	**Economic**	**Political/ Public**	**Environmental**	**Safety**	**Social**
	potential impacts on traffic, utilities, community, and environment (e.g., congestion, aesthetics, privacy, shade, and property value) that could impact project/application feasibility.		■	■				
6	Site characteristics (i.e., location, logistics, access, environment, and infrastructure) that could impact project/application feasibility.		■		■			
7	Ability to communicate, involve, and share information with general public and stakeholders about the Value Extraction Application project (i.e., transparency and equal access to information).		■	■		■	■	■
8	Current value (i.e., market/Real Estate value) of the property.in the area.					■	■	■
9	Formal procedures/guidelines available to conduct/implement an airspace leasing program (i.e., agreement, design, construction, and maintenance).		■			■	■	■
10	The project is designed and implemented as a component/together with a new highway project (i.e., already included in the highway design).		■		■	■	■	■
11	Anticipated impacts of the project (i.e., "new owner or lessee") on nearby community (e.g., traffic congestion, shade, privacy, noise, and property values, including potential to mitigate anticipated impacts.	■	■	■				
12	Anticipated environmental impacts and mitigation measure for "new" property use/project.	■			■		■	
13	Construction plan includes measures to avoid/reduce traffic congestion, dust, noise, unsafe situations, accidents, and other negative community impacts.		■		■			
14	Traffic control plan during construction and anticipated safety training required.		■		■	■		■

#	Statement	Feasibility			Impact			
		Technical	**Legal**	**Economic**	**Political/ Public**	**Environmental**	**Safety**	**Social**
15	Building and tunnel comply with all safety requirements (e.g., lighting, exhaustion, ventilation, drainage, access, and fire protection).							
16	Compliance with FHWA, AASTHO, and other agency requirements.							
17	Anticipated future highway system needs (i.e., traffic volume, lanes, and clearances) that could require future road expansion.							
18	Permit or license required to execute/construct project.							
19	Financial resources of and warranties (i.e., bond approval and surety) provided by the project developer.							
20	Anticipated direct and indirect jobs created and economic development impacts resulting from the project.							
21	Anticipated benefits to the region or state (e.g., increase local or state taxes).							
22	Anticipated benefits to TxDOT (e.g., financial, technical, and safety).							
23	Potential concerns anticipated by General Land Office (GLO) or another public agency (e.g., FHWA, DOE, and DOD).							
24	Potential conflict with zoning law, city's master plan, and transportation's plan.							
25	Anticipated political and public opposition to transaction (e.g., controversy and potential impacts triggered by the "new" project).							
26	Potential risks and implications associated with considered business model (e.g., private-public-partnership, lease, easement, and sale).							
27	Legal constraints/concerns that can impede or prevent the transaction/project.							

#	Statement	Feasibility				Impact			
		Technical	**Legal**	**Economic**		**Political/ Public**	**Environmental**	**Safety**	**Social**
28	Available legal consultants/resources to implement TxDOT's airspace leasing program.								
29	Available legal consultants/resources to advise and review transactions and contractual agreements.								
30	Resources required to train or acquire in-house legal resources/counsel.								
31	TxDOT's exposure in terms of liability and risks.								
32	Investment required by TxDOT to implement the Value Extraction Application.								
Total contribution of the criterion									

Table II.4: Airspace Leasing (Parking lot) Evaluation Matrix

#	Statement	Feasibility				Impact			
		Technical	**Legal**	**Economic**		**Political/ Public**	**Environmental**	**Safety**	**Social**
1	Trained in-house or consultant staff to analyze the project, specifications, and potential impacts, and challenges.								
2	In-house staff member to champion the evaluation and implementation of the Value Extraction Application.								
3	Available in-house or consultant safety and security experts to conduct safety assessment, advise the design, and provide insight in the drafting of the concept and leasing agreement.								
4	Current demand/need for additional parking space in the area.								
5	Project characteristics and potential impacts on traffic, utilities, community, and environment (e.g., drainage and runoff) that could impact project/application feasibility.								
6	Site characteristics (i.e., location, clearances, visibility, access, and infrastructure) that could								

#	Statement	Feasibility			Impact			
		Technical	**Legal**	**Economic**	**Political/ Public**	**Environmental**	**Safety**	**Social**
	impact project/application feasibility.		■		■			■
7	Ability to communicate, involve, and share information with general public and stakeholders about the Value Extraction Application project (i.e., transparency and equal access to information).		■	■		■	■	■
8	Current value (i.e., market/Real Estate value) of the property.					■	■	■
9	Formal procedures/guidelines available to conduct/implement an airspace leasing program (i.e., agreement, design, construction, and maintenance).			■		■	■	■
10	The parking lot is designed and implemented as a component/together with a new highway project (i.e., already included in the highway design).		■		■	■	■	■
11	Anticipated traffic impacts of the new parking lot.	■	■	■				
12	Anticipated environmental impacts and mitigation measure for parking lot project.	■			■		■	
13	Construction plan includes measures to avoid/reduce traffic congestion, dust, noise, unsafe situations, accidents, and other negative community impacts.		■		■			
14	Required investments in technologies and systems (e.g., parking meters and surveillance systems).		■		■	■	■	■
15	Compliance with FHWA, AASTHO, and other agency requirements.				■	■		■
16	Parking lot design complies with safety requirements (e.g., curbs, fences, lighting, access, fire protection, pedestrian access, and surveillance).		■		■	■		■
17	Permit or license required to execute/construct project.	■			■	■	■	■
18	Financial resources of and warranties (i.e., bond	■			■	■	■	■

#	Statement	Feasibility				Impact			
		Technical	**Legal**	**Economic**		**Political/ Public**	**Environmental**	**Safety**	**Social**
	approval and surety) provided by the project developer.								
19	Anticipated direct and indirect jobs created and economic development impacts resulting from the project.								
20	Anticipated benefits to the region or state (e.g., increase local or state taxes).								
21	Anticipated benefits to TxDOT (e.g., financial, technical, and safety).								
22	Potential concerns anticipated by General Land Office (GLO) or another public agency (e.g., FHWA, DOE, and DOD).								
23	Potential conflict with zoning law, city's master plan, and transportation's plan.								
24	Anticipated political and public opposition to transaction (e.g., controversy and potential impacts triggered by the "new" project).								
25	Potential risks and implications associated with considered business model (e.g., private-public-partnership, lease, easement, and sale).								
26	Legal constraints/concerns that can impede or prevent the transaction/project.								
27	Available legal consultants/resources to implement TxDOT's airspace leasing program.								
28	Available legal consultants/resources to advise and review transactions and contractual agreements.								
29	Resources required to train or acquire in-house legal resources/counsel.								
30	TxDOT's exposure in terms of liability and risks.								
31	Investment required by TxDOT to implement the Value Extraction Application.								
Total contribution of the criterion									

Table II.5: Airspace Leasing (Utility) Evaluation Matrix

#	Statement	Feasibility			Impact			
		Technical	**Legal**	**Economic**	**Political/ Public**	**Environmental**	**Safety**	**Social**
1	Trained in-house or consultant staff to analyze the project, specifications, and potential impacts, and challenges.		■		■	■	■	■
2	In-house staff member to champion the evaluation and implementation of the Value Extraction Application.		■		■	■	■	■
3	Available in-house or consultant safety and security experts to conduct safety assessment, advise the design, and provide insight in the drafting of the concept and leasing agreement.		■		■	■		■
4	Interested parties (i.e., potential developers) have been identified or have approached TxDOT.		■		■	■	■	■
5	Utility is considered private (i.e., will require airspace leasing agreement).	■		■		■	■	■
6	Project characteristics and potential impacts on traffic, utilities, community, and environment (e.g., water or soil contamination, explosive, and safety concerns) that could impact project/application feasibility.		■					
7	Site characteristics (i.e., location, clearances, visibility, access, and infrastructure) that could impact project/application feasibility.		■		■			■
8	Anticipated future highway system needs (i.e., traffic volume, lanes, and clearances) that could require future road expansion.				■	■	■	
9	Current TxDOT demand/need for utility (e.g., electricity required to power Dynamic Message Signs and/or need for telecommunication signal (e.g., cell phone and internet, or for transmission of data).		■			■		
10	Potential for competing with private sector (e.g., existing private tower near TxDOT property	■		■		■	■	■

#	Statement	Feasibility			Impact			
		Technical	**Legal**	**Economic**	**Political/ Public**	**Environmental**	**Safety**	**Social**
	considered for airspace leasing).	■		■		■	■	■
11	The utility is designed and implemented as a component together with a new highway project (i.e., already included in the highway design).		■		■	■	■	■
12	Ability to appropriately divulgate, involve, and communicate the project to general public and stakeholders (i.e., transparency and equal opportunity).		■	■		■	■	■
13	Current value (i.e., market/Real Estate value) of the property					■	■	■
14	Formal procedures/guidelines available to conduct/implement an airspace leasing program (i.e., agreement, design, construction, and maintenance).			■		■	■	■
15	Potential impacts on road maintenance plan and operations (e.g., utilities crossing the road, antenna installation, and utility maintenance).		■		■	■		■
16	Anticipated environmental impacts and mitigation measures..	■			■		■	
17	Potential risk of accidents/unsafe situations (e.g., explosion precaution, electrical discharge/shock, leak detection, valves, clear zone, and accidents).							■
18	Construction plan includes measures to avoid/reduce traffic congestion, noise, unsafe situations, accidents, and other negative community impacts.		■		■			
19	Required investments in technologies and systems.		■		■	■	■	■
20	Compliance with FHWA, AASTHO, and other agency requirements.				■	■		■
21	Permit or license required to execute/construct project.	■			■	■	■	■
22	Federal Aviation Administration (FAA) and Department of Defense (DOD) approved and	■			■	■	■	■

#	Statement	Feasibility			Impact			
		Technical	**Legal**	**Economic**	**Political/ Public**	**Environmental**	**Safety**	**Social**
	granted permit for the project (i.e., if the project is located within 3-5 miles from a public or military airport, or has tower higher than 200ft).	■			■	■	■	■
23	Financial resources of and warranties (i.e., bond approval and surety) provided the project developer.	■			■	■	■	■
24	Anticipated direct and indirect jobs created and economic development impacts resulting from the project.	■	■			■	■	
25	Anticipated benefits to the region or state (e.g., increase local or state taxes).	■	■			■	■	
26	Anticipated benefits to TxDOT (e.g., financial, technical, and safety).		■		■	■		■
27	Potential concerns anticipated by General Land Office (GLO) or another public agency (e.g., FHWA, DOE, and DOD).	■	■			■	■	■
28	Potential conflict with zoning law, city's master plan, and transportation's plan.	■	■			■	■	
29	Anticipated political and public opposition to transaction (e.g., controversy and potential impacts triggered by the "new" project).	■	■	■		■	■	■
30	Potential risks and implications associated with considered business model (e.g., private-public-partnership, lease, easement, and sale).	■				■	■	■
31	Legal constraints/concerns that can impede or prevent the transaction/project.	■		■	■	■	■	■
32	Available legal consultants/resources to implement TxDOT's airspace leasing program.	■			■	■	■	■
33	Available legal consultants/resources to advise and review transactions and contractual agreements	■		■	■	■	■	■
34	Resources required to train or acquire in-house legal resources/counsel	■	■			■	■	■
35	TxDOT's exposure in terms of liability and risks	■				■	■	■

#	Statement	Feasibility				Impact			
		Technical	**Legal**	**Economic**		**Political/ Public**	**Environmental**	**Safety**	**Social**
	(e.g., utility relocation).								
36	Investment required by TxDOT to implement the Value Extraction Application								
Total contribution of the criterion									

Table II.6: Advertising Evaluation Matrix

#	Statement	Feasibility				Impact			
		Technical	**Legal**	**Economic**		**Political/ Public**	**Environmental**	**Safety**	**Social**
1	Trained in-house or consultant staff to analyze the project, specifications, and potential impacts, and challenges.								
2	In-house staff member to champion the evaluation and implementation of the Value Extraction Application.								
3	Interested parties have been identified or have approached TxDOT.								
4	Available data/information on traffic exposure (i.e., visibility).								
5	Identified and selected advertising mode (e.g., brochures, outdoor advertising, blue signs, live vegetation, or naming rights).								
6	Project characteristics and potential impacts on traffic, road maintenance, utilities, nearby communities, and the environment.								
7	Site characteristics (i.e., location, clearances, visibility, access, and infrastructure) that could impact project/application feasibility.								
8	Anticipated future highway system needs (i.e., traffic volume, lanes, and clearances) that could require future road expansion.								
9	Ability to communicate, involve, and share information with general public and stakeholders								

#	Statement	Feasibility			Impact			
		Technical	**Legal**	**Economic**	**Political/ Public**	**Environmental**	**Safety**	**Social**
	about the Value Extraction Application project (i.e., transparency and equal access to information).		■	■		■	■	■
10	Current value (i.e., market/Real Estate value) of the property.					■	■	■
11	Formal procedures/guidelines available to conduct/implement advertising program (e.g., staff, specifications, and agreements).			■		■	■	■
12	Anticipated environmental impacts and mitigation measures..	■			■		■	
13	Potential risk of accidents/unsafe situations (e.g., crash, clear zones, and driver distraction).				■	■		■
14	Potential educational benefits associated with advertising content (i.e., message and images).	■		■		■		
15	Required investments in technologies and systems (e.g., electricity, internet, and fiber optics).		■		■	■	■	■
16	Compliance with FHWA, AASTHO, TxDOT State Rural Act, and other agencies' requirements				■	■		■
17	Permit or license required to execute/construct project.	■			■	■	■	■
18	Compliance with Texas Highway Beautification Act (HBA).	■		■		■	■	■
19	Anticipated direct and indirect jobs created and economic development impacts resulting from the project.	■	■			■	■	
20	Anticipated benefits to the region or state (e.g., increase local or state taxes).	■	■			■	■	
21	Anticipated benefits to TxDOT (e.g., financial, technical, and safety).		■		■	■		■
22	Potential concerns anticipated by General Land Office (GLO) or another public agency (e.g., FHWA, DOE, and DOD).	■		■		■	■	■
23	Potential conflict with zoning law, city's master	■		■		■	■	

#	Statement	Feasibility				Impact			
		Technical	**Legal**	**Economic**		**Political/ Public**	**Environmental**	**Safety**	**Social**
	plan, and transportation's plan.								
24	Anticipated political and public opposition to transaction (e.g., controversy and potential impacts triggered by the "new" project).								
25	Potential risks and implications associated with considered business model (e.g., private-public-partnership, lease, easement, and sale).								
26	Legal constraints/concerns that can impede or prevent the transaction/project								
27	Available legal consultants/resources to implement TxDOT's advertising program.								
28	Available legal consultants/resources to advise and review transactions and contractual agreements.								
29	Resources required to train or acquire in-house legal resources/counsel.								
30	TxDOT's exposure in terms of liability and risks.								
31	Investment required by TxDOT to implement the Value Extraction Application.								
Total contribution of the criterion									

Table II.7: Solar Panels (ROW and Vacant Land) Evaluation Matrix

#	Statement	Feasibility				Impact			
		Technical	**Legal**	**Economic**		**Political/ Public**	**Environmental**	**Safety**	**Social**
1	Trained in-house or consultant staff to analyze the project, specifications, and potential impacts, and challenges.								
2	In-house staff member to champion the evaluation and implementation of the Value Extraction Application.								
3	Available in-house or consultant safety and security experts to conduct safety assessment, advise the design, and provide insight in the								

#	Statement	Feasibility			Impact			
		Technical	**Legal**	**Economic**	**Political/ Public**	**Environmental**	**Safety**	**Social**
	drafting of the concept and leasing agreement.		■		■	■		■
4	Interested parties (i.e., potential developers) have been identified or have approached TxDOT.		■		■	■	■	■
5	Project/application will assist TxDOT in meeting renewable energy consumption and carbon emissions goals.	■					■	■
6	Project characteristics and potential impacts on traffic (e.g., driver distraction), community (e.g., property values), and the environment.		■	■				
7	Site characteristics (i.e., location, solar potential, clearances, access, and infrastructure)		■		■			■
8	Anticipated future highway system needs (i.e., traffic volume, lanes, and clearances) that could require future road expansion.				■	■	■	
9	The solar project is designed and implemented as a component together with a new highway project (i.e., already included in the highway design)..		■		■	■	■	■
10	Ability to communicate, involve, and share information with general public and stakeholders about the Value Extraction Application project (i.e., transparency and equal access to information).		■	■		■	■	■
11	Access to vendors/solar specialists (e.g., for installation and maintenance).		■			■	■	
12	Current TxDOT demand/need for electricity at the project site (e.g., lighting pole and signs).		■		■	■	■	■
13	Ability/cost to connect to the grid (e.g., distance from transmission lines).		■		■	■	■	■
14	Need for backup system for solar project (i.e., battery or on-grid electricity source) to supply TxDOT's electricity needs.		■		■		■	
15	Available infrastructure (e.g., fiber optic or wireless signal) at site to support and facilitate		■			■	■	■

#	Statement	Feasibility			Impact			
		Technical	**Legal**	**Economic**	**Political/ Public**	**Environmental**	**Safety**	**Social**
	monitoring and management of the project/output.		■			■	■	■
16	Current value (i.e., market/Real Estate value) of the property.					■	■	■
17	Formal procedures/guidelines available to conduct/implement solar energy project (i.e., agreement, design, construction, and maintenance).			■		■	■	■
18	Potential impacts of the solar project on road maintenance and operations (e.g., impact of solar panel maintenance).		■		■	■		■
19	Anticipated environmental impacts and mitigation measures.	■			■		■	
20	Potential risk of accidents/unsafe situations (e.g., accidents, driver distraction, clear zones, guard rails, and adequate access to site).				■	■		■
21	Compliance with Texas Highway Beautification Act (HBA).	■		■		■	■	■
22	Construction plan includes measures to avoid/reduce traffic congestion, noise, unsafe situations, accidents, and other negative community impacts.		■		■			
23	Required investments in technologies and systems.		■		■	■	■	■
24	Compliance with FHWA, AASTHO, National Electrical Code, Fire Protection Association, and other agency requirements.				■	■		■
25	Permit or license required to execute/construct project.	■			■	■	■	■
26	Federal Aviation Administration (FAA) has approved and granted permit for the solar project (i.e., if the project is located within 3-5 miles from a public or military airport).	■			■	■	■	■
27	Net metering applies.	■	■		■	■	■	■
28	Federal and State incentives, as well as Renewable	■	■			■	■	■

#	Statement	Feasibility			Impact			
		Technical	**Legal**	**Economic**	**Political/ Public**	**Environmental**	**Safety**	**Social**
	Energy Credits (REC) are available.	■	■			■	■	■
29	Potential concerns about "free access" to TxDOT's property (i.e., facility, land, or ROW) by third party.	■		■		■		■
30	Financial resources of and warranties (i.e., bond approval and surety) provided by the project developer.	■			■	■	■	■
31	Potential for adopting a value-based procurement strategy (e.g., include considerations beyond project cost, such as social benefits and environmental impacts).	■	■				■	
32	Anticipated direct and indirect jobs created and economic development impacts resulting from the project.	■	■			■	■	
33	Anticipated benefits to the region or state (e.g., increase local or state taxes).	■	■			■	■	
34	Anticipated benefits to TxDOT (e.g., financial, technical, and safety).		■		■	■		■
35	Potential concerns anticipated by General Land Office (GLO) or another public agency (e.g., FHWA, DOE, and DOD).	■	■			■	■	■
36	Potential conflict with zoning law, city's master plan, and transportation's plan.	■		■		■	■	
37	Anticipated political and public opposition to transaction/project (e.g., controversy and potential impacts triggered by the "new" project)	■	■	■		■	■	■
38	Potential risks and implications associated with considered business model (e.g., private-public-partnership, lease, easement, and sale), as well as incentives and REC ownership.	■				■	■	■
39	Legal constraints/concerns that can impede or prevent the transaction/project.	■		■	■	■	■	■
40	Patents and associated costs that could impact	■			■	■	■	■

#	Statement	Feasibility			Impact			
		Technical	**Legal**	**Economic**	**Political/ Public**	**Environmental**	**Safety**	**Social**
	project/application feasibility.							
41	Available legal consultants/resources to implement TxDOT's solar program.							
42	Available legal consultants/resources to advise and review transactions and contractual agreements.							
43	Resources required to train or acquire in-house legal resources/counsel.							
44	TxDOT's exposure in terms of liability and risks (e.g., solar array relocation or damage).							
45	Investment required by TxDOT to implement the Value Extraction Application.							
Total contribution of the criterion								

Table II.8: Solar Panels (office & facility) Evaluation Matrix

#	Statement	Feasibility			Impact			
		Technical	**Legal**	**Economic**	**Political/ Public**	**Environmental**	**Safety**	**Social**
1	Trained in-house or consultant staff to analyze the project, specifications, and potential impacts, and challenges.							
2	In-house staff member to champion the evaluation and implementation of the Value Extraction Application.							
3	Available in-house or consultant safety and security experts to conduct safety assessment, advise the design, and provide insight in the drafting of the concept and leasing agreement							
4	Interested parties (i.e., potential developers) have been identified or approached TxDOT.							
5	Project/application will assist TxDOT in meeting renewable energy consumption and carbon emissions goals.							
6	Site/building characteristics (i.e., location, solar							

#	Statement	Feasibility			Impact			
		Technical	**Legal**	**Economic**	**Political/ Public**	**Environmental**	**Safety**	**Social**
	potential, access, and infrastructure) that could impact project/application feasibility.							
7	Building/facility's electrical system has been/can be retrofitted to use solar energy.							
8	The roof area/external area is large enough to generate sufficient energy to meet the building/facility's energy demand.							
9	The solar project is financially feasible.							
10	The solar project is designed and implemented as a component of building/facility (i.e., included in the building/facility design).							
11	Ability to communicate, involve, and share information with general public and stakeholders about the Value Extraction Application project (i.e., transparency and equal access to information).							
12	Access to vendors/ solar panel specialists (e.g., for installation and maintenance).							
13	Current TxDOT demand/need for electricity at the site (e.g., building/facility electricity usage).							
14	Ability/cost to connect to the grid (e.g., distance from transmission lines).							
15	Need for backup system for solar project (i.e., battery or on-grid electricity source) to supply TxDOT's electricity needs.							
16	Formal procedures/guidelines available to conduct/implement solar energy project (i.e., agreement, design, construction, and maintenance).							
17	Anticipated environmental impacts and mitigation measures.							
18	Potential risk of accidents/unsafe situations.							
19	Required investments in technologies and systems.							

#	Statement	Feasibility			Impact			
		Technical	**Legal**	**Economic**	**Political/ Public**	**Environmental**	**Safety**	**Social**
20	Compliance with FHWA, AASTHO, National Electrical Code, Fire Protection Association, and other agency requirements.							
21	Permit or license required to execute/construct project.							
22	Federal Aviation Administration (FAA) has approved and granted permit for the solar project (i.e., if the project is located within 3-5 miles from a public or military airport).							
23	Net metering applies.							
24	Federal and State incentives, as well as Renewable Energy Credits (REC) are available.							
25	Potential concerns about "free access" to TxDOT's property (i.e., facility or building) by third party.							
26	Financial resources of and warranties (i.e., bond approval and surety) provided by the project developer.							
27	Potential for adopting a value-based procurement strategy (e.g., include considerations beyond project cost, such as social benefits and environmental impacts).							
28	Anticipated benefits to TxDOT (e.g., financial, technical, and social).							
29	Potential concerns anticipated by General Land Office (GLO) or another public agency (e.g., FHWA, DOE, and DOD).							
30	Anticipated political and public opposition to solar project (e.g., controversy and potential impacts triggered by the "new" project).							
31	Potential risks and implications associated with considered business model (e.g., private-public-partnership, lease, easement, and sale), as well as incentives and REC ownership.							

#	Statement	Feasibility				Impact			
		Technical	**Legal**	**Economic**		**Political/ Public**	**Environmental**	**Safety**	**Social**
32	Legal constraints/concerns that can impede or prevent the transaction/project.								
33	Available legal consultants/resources to implement TxDOT solar program.								
34	Available legal consultants/resources to advise and review transactions and contractual agreements.								
35	Resources required to train or acquire in-house legal resources/counsel.								
36	TxDOT's exposure in terms of liability and risks (e.g., solar array relocation or damage).								
37	Investment required by TxDOT to implement the Value Extraction Application.								
Total Contribution of the criterion									

Table II.9: Wind Turbine Evaluation Matrix

#	Statement	Feasibility				Impact			
		Technical	**Legal**	**Economic**		**Political/ Public**	**Environmental**	**Safety**	**Social**
1	Trained in-house or consultant staff to analyze the project, specifications, and potential impacts, and challenges.								
2	In-house staff member to champion the evaluation and implementation of the Value Extraction Application.								
3	Available in-house or consultant safety and security experts to conduct safety assessment, advise the design, and provide insight in the drafting of the concept and leasing agreement.								
4	Interested parties (i.e., potential developers) have been identified or have approached TxDOT.								
5	Project/application will assist TxDOT in meeting renewable energy consumption and carbon emissions goals.								

#	Statement	Feasibility			Impact			
		Technical	**Legal**	**Economic**	**Political/ Public**	**Environmental**	**Safety**	**Social**
6	Project characteristics and potential impacts on traffic (e.g., driver distraction) and nearby community (e.g., property value, noise, shade, and tourism).		■	■				
7	Site characteristics (i.e., location, wind potential, clearances, access, and infrastructure)		■		■			■
8	Anticipated future highway system needs (i.e., traffic volume, lanes, and clearances) that could require future road expansion.				■	■	■	
9	The wind project is designed and implemented as a component together with a new highway project (i.e., already included in the highway design).		■		■	■	■	■
10	Ability to communicate, involve, and share information with general public and stakeholders about the Value Extraction Application project (i.e., transparency and equal access to information).		■	■		■	■	■
11	Access to vendors/ wind turbine specialists (e.g., for installation and maintenance).		■			■	■	
12	Current TxDOT demand/need for electricity at the project site (e.g., lighting pole and signs).	■	■		■	■	■	■
13	Ability/cost to connect to the grid (e.g., distance from transmission lines).		■		■	■	■	■
14	Need for backup system for wind project (i.e., battery or on-grid electricity source) to supply TxDOT's electricity needs.		■				■	
15	Available infrastructure (e.g., fiber optic or wireless signal) at site to support and facilitate monitoring and management of the wind energy project/output.		■		■	■	■	■
16	Current value (i.e., market/Real Estate value) of the property.					■	■	■
17	Formal procedures/guidelines available to			■		■	■	■

#	Statement	Feasibility			Impact			
		Technical	**Legal**	**Economic**	**Political/ Public**	**Environmental**	**Safety**	**Social**
	conduct/implement wind energy project (i.e., agreement, design, construction, and maintenance).			■		■	■	■
18	Potential impacts of the wind project on road maintenance and operations (e.g., impact of wind turbine installation and maintenance)		■		■	■		■
19	Anticipated environmental impacts and mitigation measures.	■			■		■	
20	Potential risk of accidents/unsafe situations (e.g., accidents, blade failure, fire, blade flickering, oil leaks, snow throw, driver distraction, clear zone, guard rails, and adequate access to site).	■	■	■			■	■
21	Compliance with Texas Highway Beautification Act (HBA).	■		■		■	■	■
22	Construction plan includes measures to avoid/reduce traffic congestion, noise, unsafe situations, accidents, and other negative community impacts.		■		■			
23	Required investments in technologies and systems.		■		■	■	■	■
24	Compliance with FHWA, AASTHO, National Electrical Code, Fire Protection Association, and other agency requirements.						■	
25	Permit or license required to execute/construct project.	■			■	■	■	■
26	Potential interference with nearby telecommunication, radar, and/or wireless signals.	■		■		■		
27	Federal Aviation Administration (FAA) and Department of Defense (DOD) approved and granted permit for the project (i.e., if the project is located within 3-5 miles from a public or military airport, or the wind turbine is higher than 200ft).	■			■	■	■	■
28	Net metering applies.	■	■		■	■	■	■
29	Federal and State incentives, as well as Renewable	■	■			■	■	■

#	Statement	Feasibility			Impact			
		Technical	**Legal**	**Economic**	**Political/ Public**	**Environmental**	**Safety**	**Social**
	Energy Credits (REC) are available.	■	■			■	■	■
30	Potential concerns about "free access" to TxDOT's property (i.e., land or ROW) by third party.	■		■		■		■
31	Financial resources of and warranties (i.e., bond approval and surety) provided by the project developer.	■			■	■	■	■
32	Potential for adopting a value-based procurement strategy (e.g., include considerations beyond project cost, such as social benefits and environmental impacts).	■	■				■	
33	Anticipated direct and indirect jobs created and economic development impacts resulting from the project.	■	■			■	■	
34	Anticipated benefits to the region or state (e.g., increase local or state taxes).	■	■			■	■	
35	Anticipated benefits to TxDOT (e.g., financial, technical, and safety).		■		■	■		■
36	Potential concerns anticipated by General Land Office (GLO) or another public agency (e.g., FHWA, DOE, and DOD).	■		■		■	■	■
37	Potential conflict with zoning law, city's master plan, and transportation's plan.	■		■		■	■	
38	Anticipated political and public opposition to wind energy project (e.g., controversy and potential impacts triggered by the "new" project).	■	■	■		■	■	■
39	Potential risks and implications associated with considered business model (e.g., private-public-partnership, lease, easement, and sale), as well as incentives and REC ownership.	■				■	■	■
40	Legal constraints/concerns that can impede or prevent the transaction/project.	■		■	■	■	■	■
41	Patents and associated costs that could impact project/application feasibility.	■			■	■	■	■

#	Statement	Feasibility				Impact			
		Technical	**Legal**	**Economic**		**Political/ Public**	**Environmental**	**Safety**	**Social**
42	Available legal consultants/resources to implement TxDOT wind program.								
43	Available legal consultants/resources to advise and review transactions and contractual agreements.								
44	Resources required to train or acquire in-house legal resources/counsel.								
45	TxDOT's exposure in terms of liability and risks (e.g., wind turbine relocation or damage).								
46	Investment required by TxDOT to implement the Value Extraction Application.								
Total contribution of the criterion									

Table II.10: Wind Turbine (Office & Facility) Evaluation Matrix

#	Statement	Feasibility				Impact			
		Technical	**Legal**	**Economic**		**Political/ Public**	**Environmental**	**Safety**	**Social**
1	Trained in-house or consultant staff to analyze the project, specifications, and potential impacts, and challenges.								
2	In-house staff member to champion the evaluation and implementation of the Value Extraction Application								
3	Available in-house or consultant safety and security experts to conduct safety assessment, advise the design, and provide insight in the drafting of the concept and leasing agreement.								
4	Interested parties (i.e., potential developers) have been identified or approached TxDOT.								
5	Project/application will assist TxDOT in meeting renewable energy consumption and carbon emissions goals.								
6	Project characteristics and potential impacts on traffic (e.g., driver distraction) and nearby								

#	Statement	Feasibility			Impact			
		Technical	**Legal**	**Economic**	**Political/ Public**	**Environmental**	**Safety**	**Social**
	community (e.g., property value, noise, shade, and tourism) that could impact project/application feasibility.							
7	Site/building characteristics for implementation of the wind system project (i.e., location, wind potential, access, and infrastructure) that could impact project/application feasibility.							
8	Building/facility's electrical system has been/can be retrofitted to use wind system.							
9	The roof area/external area is large enough to generate sufficient energy to meet the building/facility's energy demand.							
10	The wind project is financially feasible.							
11	The wind project is designed and implemented as a component of building/facility (i.e., included in the building/facility design).							
12	Ability to communicate, involve, and share information with general public and stakeholders about the Value Extraction Application project (i.e., transparency and equal access to information).							
13	Access to vendors/ wind turbine specialists (e.g., for installation and maintenance).							
14	Current TxDOT demand/need for electricity at the site (e.g., building/facility electricity usage).							
15	Ability/cost to connect to the grid (e.g., distance from transmission lines).							
16	Need for backup system for wind project (i.e., battery or on-grid electricity source) to supply TxDOT's electricity needs.							
17	Formal procedures/guidelines available to conduct/implement wind energy project (i.e., agreement, design, construction, and							

#	Statement	Feasibility			Impact			
		Technical	**Legal**	**Economic**	**Political/ Public**	**Environmental**	**Safety**	**Social**
	maintenance).			■		■	■	■
18	Anticipated environmental impacts and mitigation measures.	■			■		■	
19	Potential risk of accidents/unsafe situations (e.g., accident, electrical shock, blade failure, fire, blade flickering, oil leak, and snow throw).				■	■		■
20	Required investments in technologies and systems.		■		■	■	■	■
21	Compliance with FHWA, AASTHO, National Electrical Code, Fire Protection Association, and other agency requirements.				■	■		■
22	Permit or license required to execute/construct project.	■			■	■	■	■
23	Potential interference with nearby telecommunication, radar, and/or wireless signal.	■		■		■		
24	Federal Aviation Administration (FAA) and Department of Defense (DOD) approved and granted permit for the project (i.e., if the project is located within 3-5 miles from a public or military airport, or the wind turbine is higher than 200ft).	■			■	■	■	■
25	Net metering applies.	■	■		■	■	■	■
26	Federal and State incentives, as well as Renewable Energy Credits (REC) are available.	■	■			■	■	■
27	Potential concerns about "free access" to TxDOT's property (i.e., office and facility) by third party.	■		■		■		■
28	Financial resources of and warranties (i.e., bond approval and surety) provided by the project developer.	■			■	■	■	■
29	Potential for adopting a value-based procurement strategy (e.g., include considerations beyond project cost, such as social benefits and environmental impacts).	■	■				■	
30	Anticipated benefits to TxDOT (e.g., financial, technical, and social).		■			■	■	

#	Statement	Feasibility				Impact			
		Technical	**Legal**	**Economic**		**Political/ Public**	**Environmental**	**Safety**	**Social**
31	Potential concerns anticipated by General Land Office (GLO) or another public agency (e.g., FHWA, DOE, and DOD).								
32	Anticipated political and public opposition to transaction (e.g., controversy and potential impacts triggered by the "new" project).								
33	Potential risks and implications associated with considered business model (e.g., private-public-partnership, lease, easement, and sale), as well as incentives and REC ownership.								
34	Legal constraints/concerns that can impede or prevent the transaction/project.								
35	Available legal consultants/resources to implement TxDOT wind program.								
36	Available legal consultants/resources to advise and review transactions and contractual agreements.								
37	Resources required to train or acquire in-house legal resources/counsel.								
38	TxDOT's exposure in terms of liability and risks (e.g., wind turbine relocation or damage).								
39	Investment required by TxDOT to implement the Value Extraction Application.								
Total contribution of the criterion									

Table II.11: Geothermal Energy Evaluation Matrix

#	Statement	Feasibility				Impact			
		Technical	**Legal**	**Economic**		**Political/ Public**	**Environmental**	**Safety**	**Social**
1	Trained in-house or consultant staff to analyze the project, specifications, and potential impacts, and challenges.								
2	In-house staff member to champion the evaluation and implementation of the Value Extraction								

#	Statement	Feasibility			Impact			
		Technical	**Legal**	**Economic**	**Political/ Public**	**Environmental**	**Safety**	**Social**
	Application.		■		■	■	■	■
3	Available in-house or consultant safety and security experts to conduct safety assessment, advise the design, and provide insight in the drafting of the concept and leasing agreement		■		■	■		■
4	Interested parties (i.e., potential developers) have been identified or have approached TxDOT.		■		■	■	■	■
5	Project/application will assist TxDOT in meeting renewable energy consumption and carbon emissions goals.	■					■	■
6	Project characteristics and potential impacts on traffic (e.g., driver distraction) and nearby community (e.g., property value, noise, steam, water disposal, and aquifer).		■	■				
7	Site characteristics (i.e., location, clearances, visibility, access, and infrastructure) that could impact project/application feasibility.		■		■			■
8	Quality of the underground resource (i.e., temperature, depth, water, ease to drill) is coherent with the intended application (i.e., direct use of hot water, geothermal heat pump, pavement de-icing, and electricity generation).		■		■	■	■	■
9	The roof and/or external area is large enough to install the geothermal energy system (i.e., power plant and/or geothermal heat pump) demanded in the building/facility or to generate sufficient energy to the building/facility's energy demand.		■		■	■	■	■
10	The geothermal project is financially feasible.	■	■		■	■	■	
11	Anticipated future highway system needs (i.e., traffic volume, lanes, and clearances) that could require future road expansion.				■	■	■	
12	The geothermal energy is designed and implemented as a component together with a new		■		■	■	■	■

#	Statement	Feasibility			Impact			
		Technical	**Legal**	**Economic**	**Political/ Public**	**Environmental**	**Safety**	**Social**
	highway or building project (i.e., already included in the highway or building design).		■		■	■	■	■
13	Building/facility's electrical and/or HVAC systems have been/can be retrofitted to use geothermal energy (i.e., power plant and/or geothermal heat pump).		■	■	■	■	■	■
14	Ability to communicate, involve, and share information about the project/application with general public and stakeholders (i.e., transparency and equal opportunity).		■	■		■	■	■
15	Access to vendors/ geothermal energy specialists (e.g., for installation and maintenance).		■			■	■	
16	Current TxDOT demand/need for electricity at the project site (e.g., lighting pole and signs).	■	■		■	■	■	■
17	Ability/cost to connect to the grid (e.g., distance from transmission lines).		■		■	■	■	■
18	Available infrastructure (e.g., fiber optic or wireless signal) at site to support and facilitate monitoring and management of the project/output.		■		■	■	■	■
19	Current value (i.e., market/Real Estate value) of the property.					■	■	■
20	Formal procedures/guidelines available to conduct/implement geothermal energy project (i.e., agreement, design, construction, and maintenance).			■		■	■	■
21	Potential impacts of the geothermal project on road maintenance and operations (e.g., impact of geothermal system installation and maintenance).		■		■	■		■
22	Anticipated environmental impacts and mitigation measures.	■			■		■	
23	Potential risk of accidents/unsafe situations (e.g., steam, water, icing, snow, roadside erosion, explosion, fire, pavement failure, clear zones, and				■	■		■

#	Statement	Feasibility			Impact			
		Technical	**Legal**	**Economic**	**Political/ Public**	**Environmental**	**Safety**	**Social**
	guard rails).				■	■		■
24	Compliance with Texas Highway Beautification Act (HBA).	■		■		■	■	■
25	Construction plan includes measures to avoid/reduce traffic congestion, noise, unsafe situations, accidents, and other negative community impacts.		■		■			
26	Required investments in technologies and systems.		■		■	■	■	■
27	Compliance with FHWA, AASTHO, National Electrical Code, Fire Protection Association, and other agency requirements.				■	■		■
28	Permit or license required to execute/construct project, including use of underground resources.	■			■	■	■	■
29	Federal Aviation Administration (FAA) has approved and granted permit for the project (i.e., if the project is located within 3-5 miles from a public or military airport).	■			■	■	■	■
30	Net metering applies.	■	■		■	■	■	■
31	Federal and State incentives, as well as Renewable Energy Credits (REC) are available.	■	■			■	■	■
32	Potential concerns about “free access” to TxDOT’s property (i.e., facility, land, or ROW) by third party.	■		■		■		■
33	Financial resources of and warranties (i.e., bond approval and surety) provided by the project developer.	■			■	■	■	■
34	Potential for adopting a value-based procurement strategy (e.g., include considerations beyond project cost, such as social benefits and environmental impacts).	■	■				■	
35	Anticipated direct and indirect jobs created and economic development impacts resulting from the project.	■	■			■	■	

#	Statement	Feasibility				Impact			
		Technical	**Legal**	**Economic**		**Political/ Public**	**Environmental**	**Safety**	**Social**
36	Anticipated benefits to the region or state (e.g., increase local or state taxes).								
37	Anticipated benefits to TxDOT (e.g., financial, technical, and safety).								
38	Potential concerns anticipated by General Land Office (GLO) or another public agency (e.g., FHWA, DOE, and DOD).								
39	Potential conflict with zoning law, city's master plan, and transportation's plan.								
40	Anticipated political and public opposition to transaction (e.g., controversy and potential impacts triggered by the "new" project).								
41	Potential risks and implications associated with considered business model (e.g., private-public-partnership, lease, easement, and sale), as well as incentives and REC ownership.								
42	Legal constraints/concerns that can impede or prevent the transaction/project, including ownership over underground resources.								
43	Patents and associated costs that could impact project/application feasibility.								
44	Available legal consultants/resources to implement TxDOT's geothermal energy program.								
45	Available legal consultants/resources to advise and review transactions and contractual agreements.								
46	Resources required to train or acquire in-house legal resources/counsel.								
47	TxDOT's exposure in terms of liability and risks (e.g., geothermal system relocation or damage).								
48	Investment required by TxDOT to implement the Value Extraction Application.								
Total contribution of the criterion									

Table II.12: Carbon Sequestration Evaluation Matrix

#	Statement	Feasibility			Impact			
		Technical	**Legal**	**Economic**	**Political/ Public**	**Environmental**	**Safety**	**Social**
1	Trained in-house or consultant staff to analyze the project, and potential impacts, and challenges.		■		■	■	■	■
2	In-house staff member to champion the evaluation and implementation of the Value Extraction Application.		■		■	■	■	■
3	Available in-house or consultant safety and security experts to conduct safety assessment, advise the design, and provide insight in the drafting of the concept and leasing agreement		■		■	■		■
4	Available in-house or consultant carbon sequestration experts (i.e., carbon verifier and carbon aggregator) to participate in the implementation.		■		■	■	■	■
5	Project/application will assist TxDOT in meeting carbon emission goals.	■					■	■
6	Project characteristics and potential impacts on traffic, utilities, community, and environment (e.g., drainage).		■	■				
7	Site characteristics (i.e., location, soil quality, average rainfall, visibility, access, and infrastructure) that could impact project/application feasibility.		■		■			■
8	Anticipated future highway system needs (i.e., traffic volume, lanes, and clearances) that could require future road expansion.				■	■	■	
9	The carbon sequestration program is designed and implemented as a component together with a new highway project (i.e., already included in the highway design).		■		■	■	■	■
10	Anticipated potential of sequestrating carbon from the existing/native vegetation.		■		■		■	■
11	Current carbon sequestration baseline at the site		■		■	■	■	■

#	Statement	Feasibility			Impact			
		Technical	**Legal**	**Economic**	**Political/ Public**	**Environmental**	**Safety**	**Social**
	has been established.							
12	Amount of "additional carbon" that is expected to potentially be sequestrated with the carbon sequestration program.							
13	Available carbon sequestration protocol for the vegetation envisioned to be used.							
14	Carbon market (i.e., formal or informal) to trade or sell carbon credits and current carbon price (i.e., flotation) have been identified.							
15	Ability to communicate, involve, and share information about the project/application with general public and stakeholders (i.e., transparency).							
16	Formal procedures/guidelines available to conduct/implement TxDOT's carbon sequestration program (i.e., agreement, trade, and vegetation).							
17	Potential impacts of the carbon sequestration project on road maintenance and operations.							
18	Anticipated environmental impacts and mitigation measures.							
19	Potential risk of accidents/unsafe situations (e.g., safety zone, animal attraction, roadside erosion, runoff water, and guard rails).							
20	Compliance with Texas Highway Beautification Act (HBA).							
21	Current State programs (HBA, Wildflower, and Green Ribbon projects) and existing obligations to plant along the highways (i.e., that could be used to receive carbon credits).							
22	Compliance with FHWA, AASTHO, and other agency requirements.							
23	Federal and State incentives, as well as Renewable Energy Credits (REC) are available.							

#	Statement	Feasibility			Impact			
		Technical	**Legal**	**Economic**	**Political/ Public**	**Environmental**	**Safety**	**Social**
24	Anticipated direct and indirect jobs created and economic development impacts resulting from the project.	■	■			■	■	
25	Anticipated benefits to the region or state (e.g., increase local or state taxes).		■			■	■	
26	Anticipated benefits to TxDOT (e.g., financial, technical, and safety).	■	■		■	■		■
27	Potential concerns anticipated by the General Land Office (GLO) or another public agency (e.g., FHWA, DOE, DOD, and utility company).	■		■		■	■	■
28	Potential conflict with zoning law, city's master plan, and transportation's plan	■		■		■	■	
29	Anticipated political and public opposition to carbon sequestration project (e.g., controversy and potential impacts triggered by the "new" project).	■	■	■		■	■	■
30	Potential risks and implications associated with considered business model (e.g., private-public-partnership, lease, easement, and sale), as well as incentives and REC ownership.	■				■	■	■
31	Legal constraints/concerns that can impede or prevent the transaction/project, including participation in carbon market and ownership over carbon credits.	■		■	■	■	■	■
32	Available legal consultants/resources to implement TxDOT carbon sequestration program.	■			■	■	■	■
33	Available legal consultants/resources to advise and review transactions and contractual agreements.	■			■	■	■	■
34	Resources required to train or acquire in-house legal resources/counsel.	■	■			■	■	■
35	TxDOT's exposure in terms of liability and risks (e.g., damage on vegetation).	■				■	■	■
36	Investment required by TxDOT to implement the Value Extraction Application.	■	■			■	■	■

#	Statement	Feasibility				Impact			
		Technical	**Legal**	**Economic**		**Political/ Public**	**Environmental**	**Safety**	**Social**
Total contribution of the criterion									

Table II.13: Biomass & Biofuel Evaluation Matrix

#	Statement	Feasibility				Impact			
		Technical	**Legal**	**Economic**		**Political/ Public**	**Environmental**	**Safety**	**Social**
1	Trained in-house or consultant staff to analyze the project, specifications, and potential impacts, and challenges.								
2	In-house staff member to champion the evaluation and implementation of the Value Extraction Application.								
3	Available in-house or consultant safety and security experts to conduct safety assessment, advise the design, and provide insight in the drafting of the concept and leasing agreement								
4	Interested parties (i.e., farmers or private companies) have been identified or approached TxDOT.								
5	Available in-house or consultant biomass & biofuel specialists (e.g., agronomist).								
6	Project/application will assist TxDOT in meeting renewable energy and carbon emission goals.								
7	Project characteristics and potential impacts on traffic, utilities, community, and environment (e.g., drainage and property value).								
8	Site characteristics (i.e., location, soil quality and compaction, average rainfall, ease to mow, logistics, clearances, visibility, access, and infrastructure) that could impact project/application feasibility.								
9	Anticipated future highway system needs (i.e., traffic volume, lanes, and clearances) that could								

#	Statement	Feasibility			Impact			
		Technical	**Legal**	**Economic**	**Political/ Public**	**Environmental**	**Safety**	**Social**
	require future road expansion.				■	■	■	
10	The biomass & biofuel program is designed and implemented as a component together with a new highway project (i.e., already included in the highway design).		■			■	■	■
11	Needs for fertilize, herbicide, and/or irrigation.		■			■	■	
12	Potential yield and biofuel production capacity of the crop/vegetation.		■		■	■	■	■
13	Available biomass & biofuel market to trade or process biomass (e.g., biorefinery).		■		■	■	■	■
14	Ability to communicate, involve, and share information with general public and stakeholders about the Value Extraction Application project (i.e., transparency and equal access to information).		■	■		■	■	■
15	Current value (i.e., market/Real Estate value) of the property.					■	■	■
16	Formal procedures/guidelines available to conduct/implement TxDOT's biomass & biofuel program (i.e., agreement, trade, biofuel refine, and farming procedures).			■		■	■	■
17	Potential impacts of biomass & biofuel program on road maintenance and operations (e.g., impacts of planting, harvesting, and transporting biomass).		■		■	■		■
18	Anticipated environmental impacts and mitigation measures.	■			■		■	
19	Potential risk of accidents/unsafe situations (e.g., safety zone, machinery access, animal attraction, roadside erosion, runoff water, and guard rails).				■	■		■
20	Compliance with Texas Highway Beautification Act (HBA) and Wildflower program.	■		■		■	■	■
21	Current State programs (HBA, Wildflower, and Green Ribbon projects) and existing obligations to	■				■	■	■

#	Statement	Feasibility			Impact			
		Technical	**Legal**	**Economic**	**Political/ Public**	**Environmental**	**Safety**	**Social**
	plant along the highways (i.e., that could be used to extract biomass & biofuel).	■				■	■	■
22	Existing training requirements (i.e., safety) and traffic control plan to staff and third parties involved in planting and harvesting.		■		■	■		■
23	Compliance with FHWA, AASTHO, and other agency requirements.				■	■		■
24	Permit or license required to execute/construct project (e.g., agricultural activities on public land).	■			■	■	■	■
25	Federal and State incentives, as well as Renewable Energy Credits (REC) are available.	■	■			■	■	■
26	Potential concerns about "free access" to TxDOT's property (i.e., land and ROW) by third party.	■		■		■		■
27	Anticipated direct and indirect jobs created and economic development impacts resulting from the project.	■	■			■	■	
28	Anticipated benefits to the region or state (e.g., increase local or state taxes).	■	■			■	■	
29	Anticipated benefits to TxDOT (e.g., financial, technical, and safety).		■		■	■		■
30	Potential concerns anticipated by the General Land Office (GLO) or another public agency (e.g., FHWA, DOE, DOD, and utility company).	■		■		■	■	■
31	Potential conflict with zoning law, city's master plan, and transportation's plan.	■		■		■	■	
32	Anticipated political and public opposition to biomass & biofuel project (e.g., controversy and potential impacts triggered by the "new" project).	■	■	■		■	■	■
33	Potential risks and implications associated with considered business model (e.g., private-public-partnership, lease, easement, and sale), as well as incentives and REC ownership.	■				■	■	■

#	Statement	Feasibility				Impact			
		Technical	**Legal**	**Economic**		**Political/ Public**	**Environmental**	**Safety**	**Social**
34	Legal constraints/concerns that can impede or prevent the transaction/project, including ownership over biomass harvested.								
35	Patents and associated costs that could impact project/application feasibility.								
36	Available legal consultants/resources to implement TxDOT biomass & biofuel program.								
37	Available legal consultants/resources to advise and review transactions and contractual agreements.								
38	Resources required to train or acquire in-house legal resources/counsel.								
39	TxDOT's exposure in terms of liability and risks (e.g., damage on plantation).								
40	Investment required by TxDOT to implement the Value Extraction Application.								
Total contribution of the criterion									

Table II.14: Wildlife Crossing Evaluation Matrix

#	Statement	Feasibility				Impact			
		Technical	**Legal**	**Economic**		**Political/ Public**	**Environmental**	**Safety**	**Social**
1	Trained in-house or consultant staff to analyze the project, specifications, and potential impacts, and challenges.								
2	In-house staff member to champion the evaluation and implementation of the Value Extraction Application.								
3	Available in-house or consultant safety and security experts to conduct safety assessment, advise the design, and provide insight in the drafting of the concept and leasing agreement.								
4	Available in-house staff to specify and oversee								

#	Statement	Feasibility			Impact			
		Technical	**Legal**	**Economic**	**Political/ Public**	**Environmental**	**Safety**	**Social**
	design and construction of the project.		■		■	■	■	■
5	Available in-house or consultant wildlife crossing experts to conduct and advise design concept.		■		■	■	■	■
6	Target species (e.g., deer, reptiles, and small mammals) have been identified.		■	■	■	■	■	■
7	Available data/information on animal migratory routes and movement (i.e., hot spot location).		■	■	■	■	■	■
8	Project characteristics and potential impacts on traffic and community (e.g., habitat integration and wildlife preservation).		■	■				
9	Site characteristics (i.e., location, clearances, visibility, and infrastructure) that could impact project/application feasibility.		■		■			■
10	Anticipated future highway system needs (i.e., traffic volume, lanes, and clearances) that could require future road expansion.				■	■	■	
11	Frequency of occurrence of fatal accidents resulted from vehicle-animal-crash at the site and potential reduction with the wildlife crossing project.	■				■		■
12	The wildlife crossing project is designed and implemented as a component together with a new highway project (i.e., already included in the highway design).		■		■	■	■	■
13	Available infrastructure (e.g., fiber optic and wireless signal) at the site to support and facilitate monitoring and management of effectiveness and use of the wildlife crossing project.		■		■	■	■	■
14	Ability to communicate, involve, and share information with general public and stakeholders about the Value Extraction Application project (i.e., transparency and equal access to information).		■	■		■	■	■

#	Statement	Feasibility			Impact			
		Technical	**Legal**	**Economic**	**Political/ Public**	**Environmental**	**Safety**	**Social**
15	Formal procedures/guidelines available to conduct/implement TxDOT's wildlife crossing program (i.e., agreement, design, construction, and maintenance).			■		■	■	■
16	Potential impacts of the wildlife crossing project on road maintenance and operations.		■		■	■		■
17	Anticipated environmental impacts and mitigation measures.	■			■		■	
18	Potential risk of accidents/unsafe situations (e.g., clear zone, clear sight, lighting, signs, traffic control, access, fence, and guard rail, as well as during construction) and mitigation measurements.				■	■		■
19	Existing training requirements (i.e., safety) and traffic control plan to staff and third parties involved in the construction of the wildlife crossing.		■		■	■		■
20	Compliance with FHWA, AASTHO, and other agency requirements.				■	■		■
21	Permit or license required to execute/construct project.	■			■	■	■	■
22	Federal and State funds and/or incentives for wildlife crossing projects are available.	■	■			■	■	■
23	Anticipated sponsors for wildlife crossing projects (e.g., ONGs and insurance companies).	■	■			■	■	■
24	Anticipated car insurance cost reduction.	■	■			■	■	■
25	Anticipated direct and indirect jobs created and economic development impacts resulting from the project.	■	■			■	■	
26	Anticipated benefits to TxDOT (e.g., financial, technical, and safety).		■			■		■
27	Potential concerns anticipated by the General Land Office (GLO) or another public agency (e.g., FHWA, DOE, DOD, and utility company).	■		■		■	■	■

#	Statement	Feasibility				Impact			
		Technical	**Legal**	**Economic**		**Political/ Public**	**Environmental**	**Safety**	**Social**
28	Potential conflict with zoning law, city's master plan, and transportation's plan.								
29	Anticipated political and public opposition to wildlife crossing project (e.g., controversy and potential impacts triggered by the "new" project).								
30	Potential risks and implications associated with considered business model (e.g., private-public-partnership, lease, easement, and sale), including incentives, sponsorship, and donation.								
31	Legal constraints/concerns that can impede or prevent the transaction/project.								
32	Available legal consultants/resources to implement TxDOT's wildlife crossing program.								
33	Available legal consultants/resources to advise and review transactions and contractual agreements.								
34	Resources required to train or acquire in-house legal resources/counsel.								
35	TxDOT's exposure in terms of liability and risks (i.e., during construction and after completion).								
36	Investment required by TxDOT to implement the Value Extraction Application.								
Total contribution of the criterion									

Step 14: Graph of VEAs according to their feasibility and impact scores.

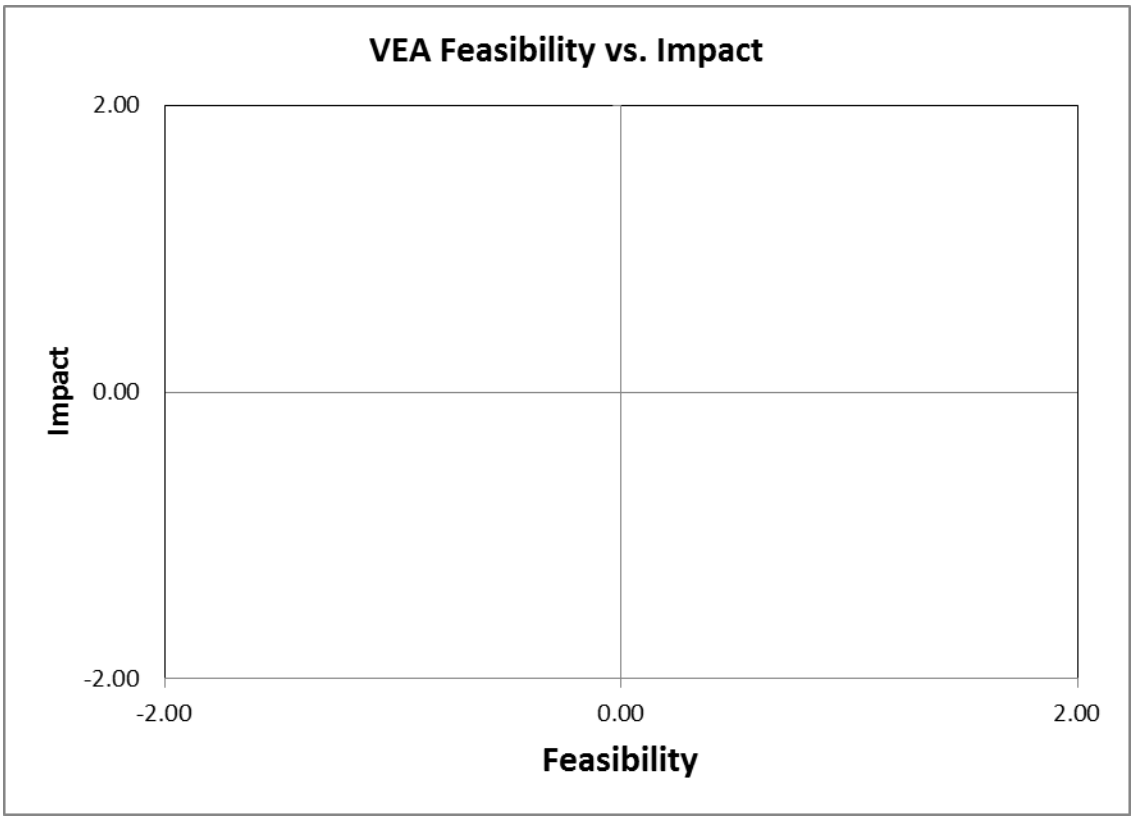

Figure II.61: Example of Feasibility vs. Impact Chart

Step 16: List of stakeholders and a chart comparing them (interest vs. influence).

Value Extraction Application Framework

List of Stakeholders: Property Management

Stakeholder	Influence	Interest
Local government		
Zoning/Planning department	0	0
Mayor/Council	0	0
State government & Legislators	0	0
Nearby landowners	0	0
Nearby Businesses	0	0
General public	0	0
Potential buyers, Developers, or Investors	0	0
TXDOT Employees	0	0
Transit agency	0	0
Transportation Agencies (FHWA and AASHTO)	0	0
Environmental Agencies	0	0
General Land Office (GLO)	0	0

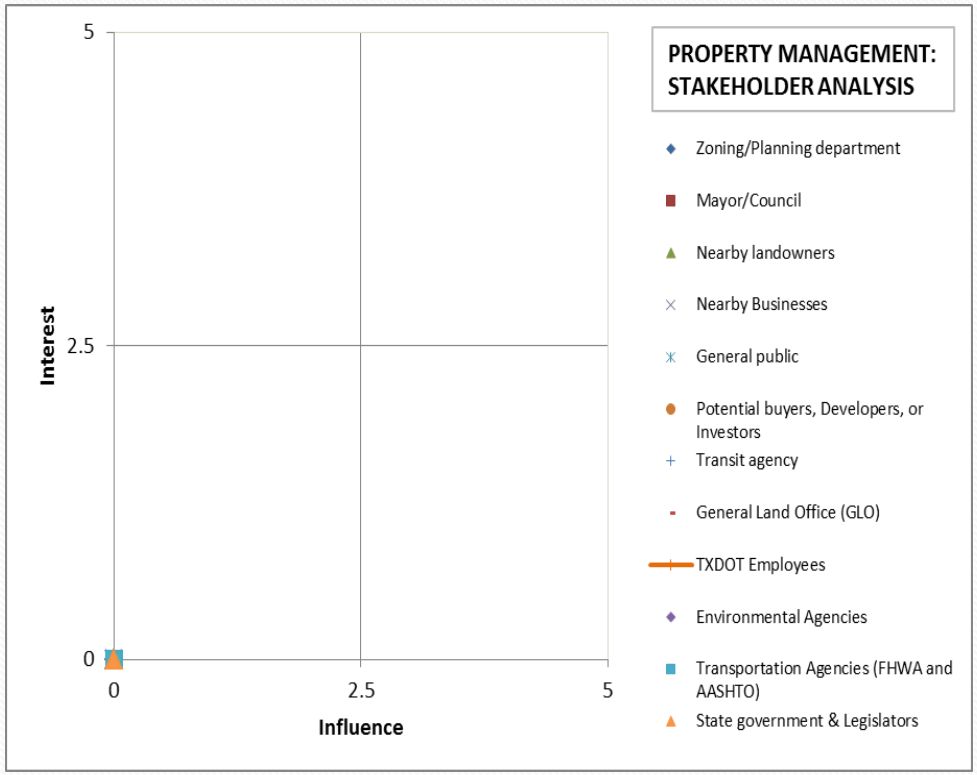

Figure II.62: List of Stakeholders of Airspace Leasing (Property Management)

Value Extraction Application Framework

List of Stakeholders: Rest Areas

Stakeholder	Influence	Interest
Local government		
Zoning/Planning department	0	0
Mayor/Council	0	0
State government & Legislators	0	0
Nearby landowners	0	0
Nearby Businesses	0	0
General public	0	0
Potential Developers or Investors	0	0
TXDOT Employees	0	0
Transportation Agencies (FHWA and AASHTO)	0	0
Utility providers	0	0
Environmental Agencies	0	0
Community Representatives	0	0
General Land Office (GLO)	0	0

Figure II.63: List of Stakeholders of Airspace Leasing for Rest Areas

Value Extraction Application Framework

List of Stakeholders: Airspace Leasing - Buildings

Stakeholder	Influence	Interest
Local government		
Zoning/Planning department	0	0
Mayor/Council	0	0
Nearby landowners	0	0
Nearby Businesses	0	0
Nearby Residents	0	0
General public	0	0
Potential Developers	0	0
TXDOT Employees	0	0
Transit agency	0	0
Utility providers	0	0
Environmental Agencies	0	0
Community Representatives	0	0
Transportation Agencies (FHWA and AASHTO)	0	0

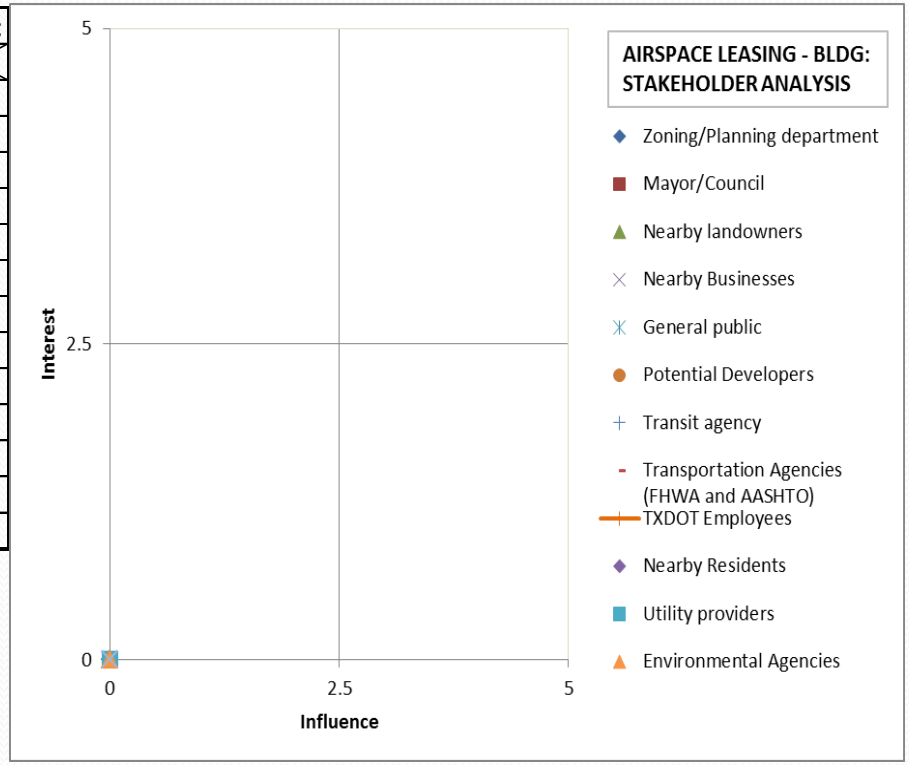

Figure II.64: List of Stakeholders of Airspace Leasing for Buildings

Value Extraction Application Framework

List of Stakeholders: Airspace Leasing – Parking Lot

Stakeholder	Influence	Interest
Local government		
Zoning/Planning department	0	0
Mayor/Council	0	0
Public Works/Transportation department	0	0
Nearby landowners	0	0
Nearby Businesses	0	0
Nearby Residents	0	0
General public	0	0
Police and Fire Departments	0	0
TXDOT Employees	0	0
Transit agency	0	0
Environmental Agencies	0	0
Community Representatives	0	0
Transportation Agencies (FHWA and AASHTO)	0	0
Department of Public Safety	0	0

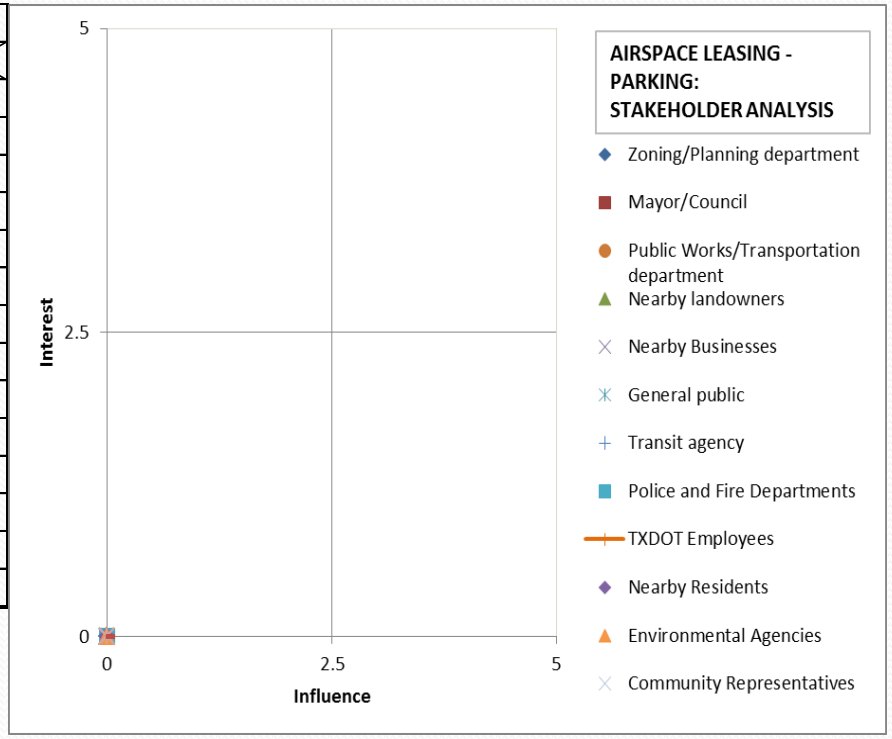

Figure II.65: List of Stakeholders of Airspace Leasing (Parking Lot)

Value Extraction Application Framework

List of Stakeholders: Airspace Leasing – Utilities & Telecommunication

Stakeholder	Influence	Interest
Local government		
Zoning/Planning department	0	0
Mayor/Council	0	0
Utility providers	0	0
Telecommunication Companies	0	0
Tower Leasing Companies	0	0
Oil & Gas Companies	0	0
General public	0	0
Nearby Residents	0	0
Nearby landowners	0	0
TXDOT Employees	0	0
Transit agency	0	0
Federal Aviation Administration (FAA)	0	0
Environmental Agencies	0	0
Community Representatives	0	0
State representatives for district	0	0
Transportation Agencies (FHWA and AASHTO)	0	0

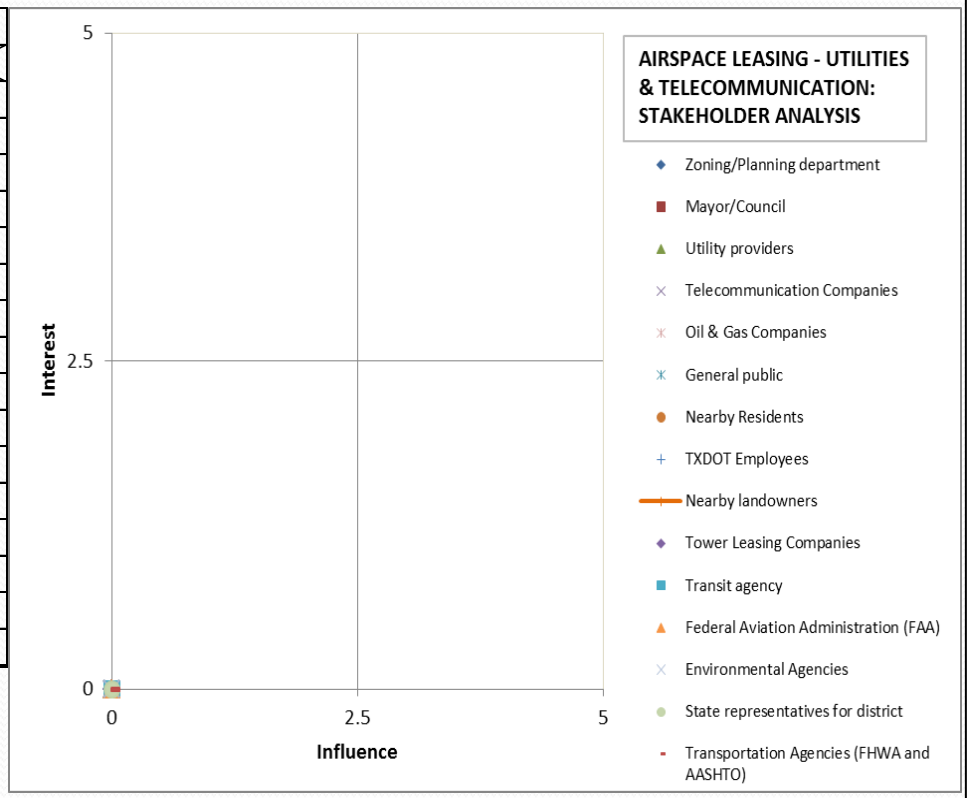

Figure II.66: List of Stakeholders of Airspace Leasing for Utilities

Value Extraction Application Framework

List of Stakeholders: Advertising

Stakeholder	Influence	Interest
State government & Legislators	0	0
Local Zoning/Planning department	0	0
Advertising and Marketing Companies	0	0
Nearby landowners	0	0
Nearby Businesses	0	0
Nearby Residents	0	0
General public	0	0
TXDOT Employees	0	0
Transit agency	0	0
Environmental Agencies	0	0
Transportation Agencies (FHWA and AASHTO)	0	0

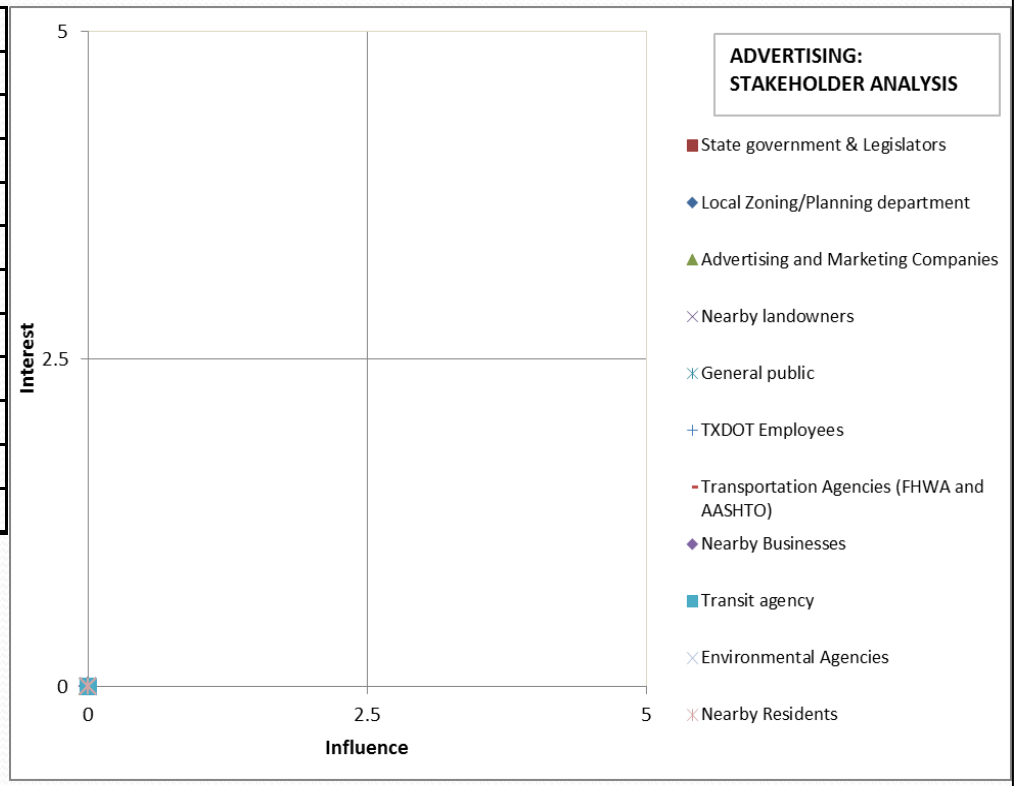

Figure II.67: List of Stakeholders of Advertising

Value Extraction Application Framework

List of Stakeholders: Solar Panels

Stakeholder	Influence	Interest
Local government		
Public Works/City/DOT	0	0
Mayor/Council	0	0
Zoning/Planning department	0	0
State government & Legislators	0	0
Nearby landowners	0	0
Community Representatives	0	0
General public	0	0
Developers or Investors	0	0
TXDOT Employees	0	0
Transit agency	0	0
General Land Office (GLO)	0	0
Utility providers	0	0
Department of Energy (DOE)	0	0
Transportation Agencies (FHWA and AASHTO)	0	0
Federal Aviation Administration (FAA)	0	0
Environmental Agencies	0	0
Solar Panel Vendors	0	0
Telecommunication Companies	0	0
Department of Defense (DOD)	0	0

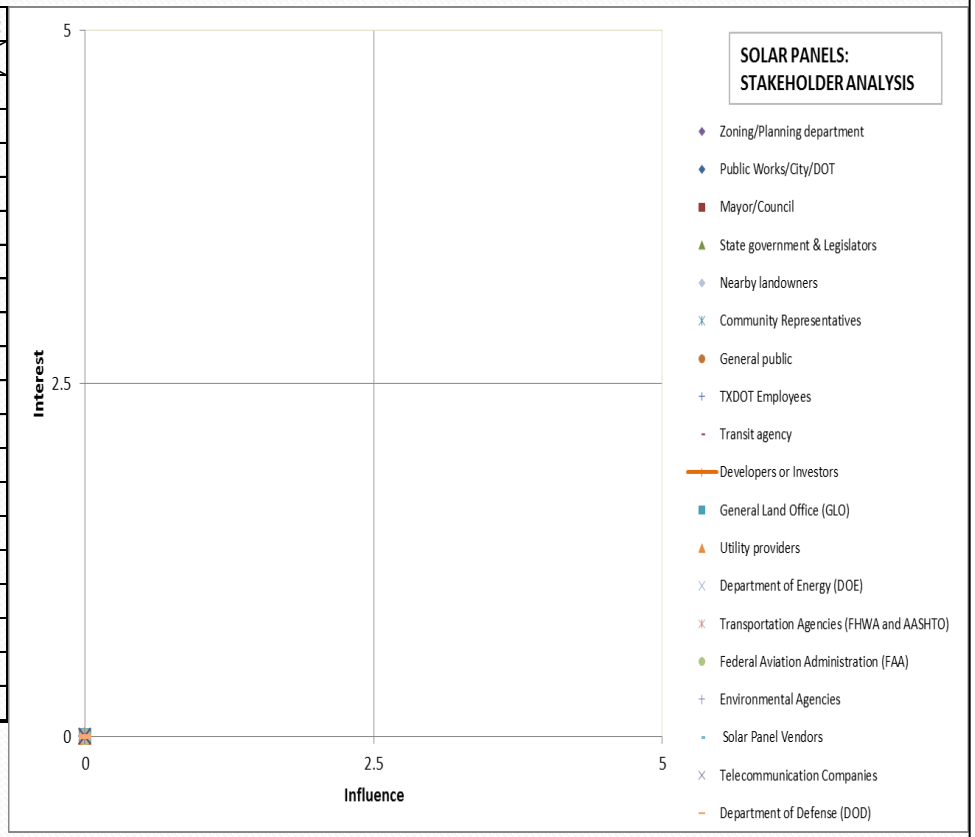

Figure II.68: List of Stakeholders of Solar Panels

Value Extraction Application Framework

List of Stakeholders: Wind Turbines

Stakeholder	Influence	Interest
Local government		
Public Works/City/DOT	0	0
Mayor/Council	0	0
Zoning/Planning department	0	0
State government & Legislators	0	0
Nearby landowners	0	0
Community Representatives	0	0
General public	0	0
Developers or Investors	0	0
TXDOT Employees	0	0
Transit agency	0	0
General Land Office (GLO)	0	0
Utility providers	0	0
Department of Energy (DOE)	0	0
Transportation Agencies (FHWA and AASHTO)	0	0
Federal Aviation Administration (FAA)	0	0
Environmental Agencies	0	0
Wind Turbine Vendors	0	0
Telecommunication Companies	0	0
Department of Defense (DOD)	0	0

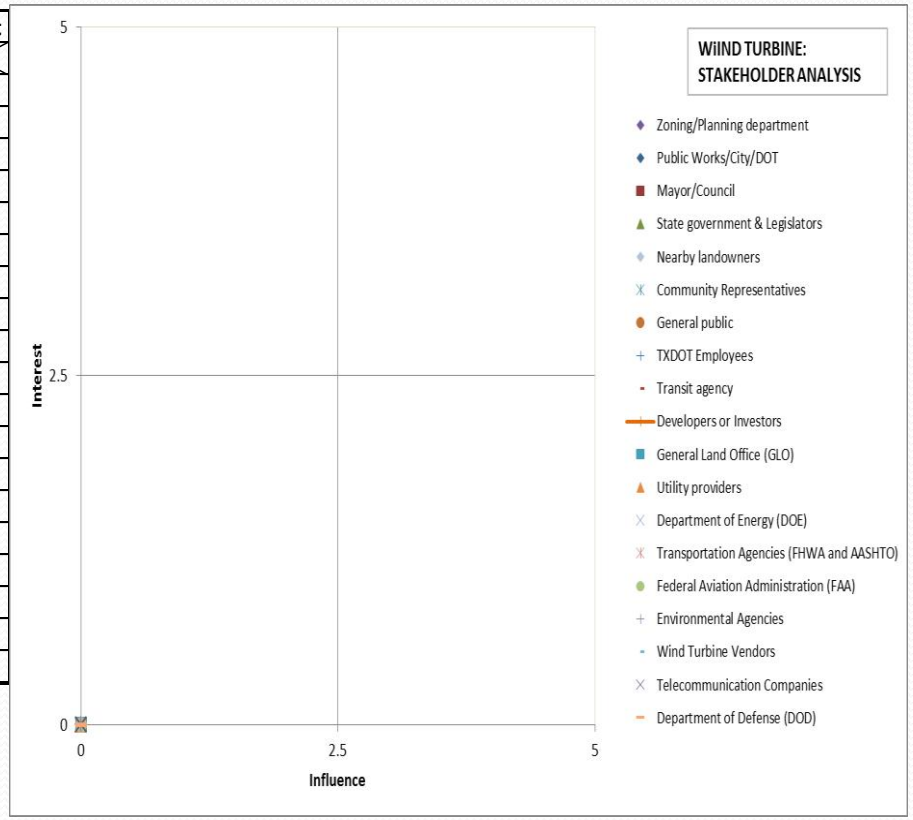

Figure II.69: List of Stakeholders of Wind Turbine

Value Extraction Application Framework

List of Stakeholders: Geothermal Energy

Stakeholder	Influence	Interest
Local government		
Public Works/City/DOT	0	0
Mayor/Council	0	0
Zoning/Planning department	0	0
State government & Legislators	0	0
Nearby landowners	0	0
Community Representatives	0	0
General public	0	0
Developers or Investors	0	0
TXDOT Employees	0	0
Transit agency	0	0
General Land Office (GLO)	0	0
Utility providers	0	0
Department of Energy (DOE)	0	0
Transportation Agencies (FHWA and AASHTO)	0	0
Federal Aviation Administration (FAA)	0	0
Environmental Agencies	0	0
Geothermal System Vendors	0	0
Department of Defense (DOD)	0	0

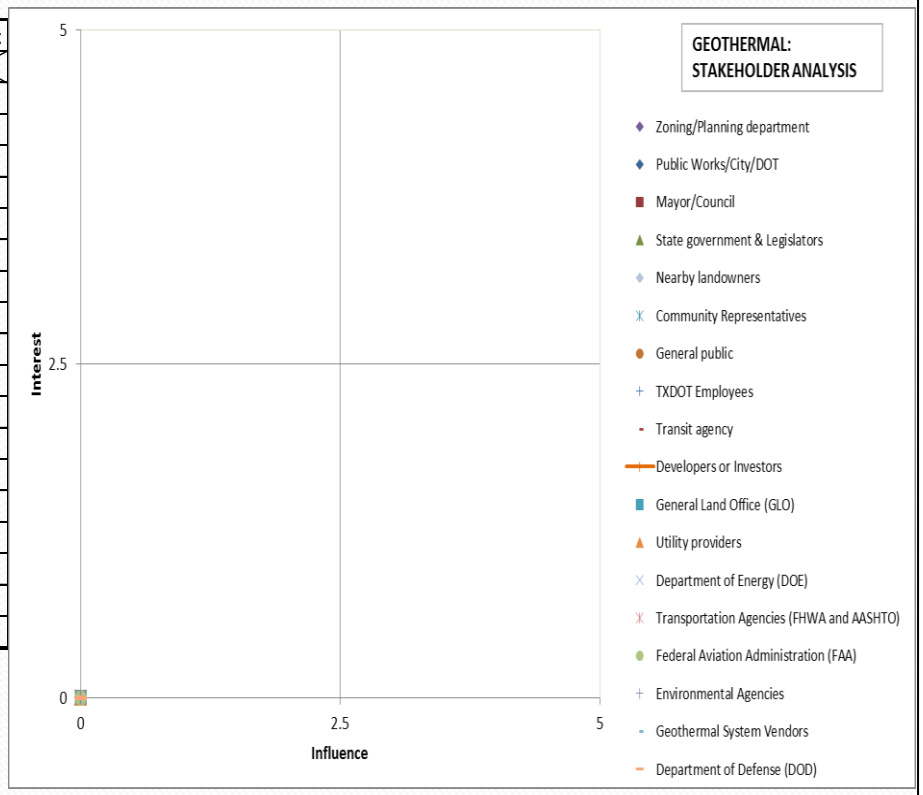

Figure II.70: List of Stakeholders of Geothermal Energy

Value Extraction Application Framework

List of Stakeholders: Carbon Sequestration

Stakeholder	Influence	Interest
Local government		
Public Works/City/DOT	0	0
Zoning/Planning department	0	0
State government & Legislators	0	0
Nearby landowners	0	0
General public	0	0
Developers or Investors	0	0
TXDOT Employees	0	0
General Land Office (GLO)	0	0
Utility providers	0	0
Department of Energy (DOE)	0	0
Transportation Agencies (FHWA and AASHTO)	0	0
Environmental Agencies	0	0
Carbon Sequestration Experts	0	0
Carbon Market Personnel	0	0

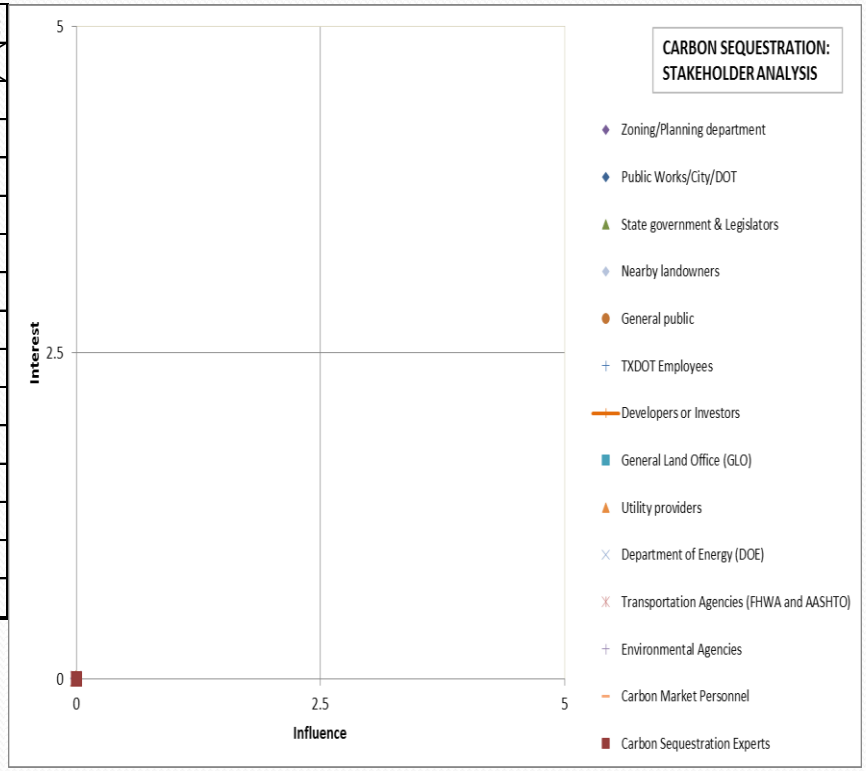

Figure II.71: List of Stakeholders of Carbon Sequestration

Value Extraction Application Framework

List of Stakeholders: Biomass & Biofuel

Stakeholder	Influence	Interest
Local government		
Public Works/City/DOT	0	0
Mayor/Council	0	0
Zoning/Planning department	0	0
State government & Legislators	0	0
Nearby landowners or Farmers	0	0
Community Representatives	0	0
General public	0	0
Developers or Investors	0	0
TXDOT Employees	0	0
Transit agency	0	0
General Land Office (GLO)	0	0
Utility providers	0	0
Department of Energy (DOE)	0	0
Transportation Agencies (FHWA and AASHTO)	0	0
Environmental Agencies	0	0
Biofuel Suppliers (i.e., Gas Stations)	0	0
Biofuel Companies (i.e., Biorefineries)	0	0

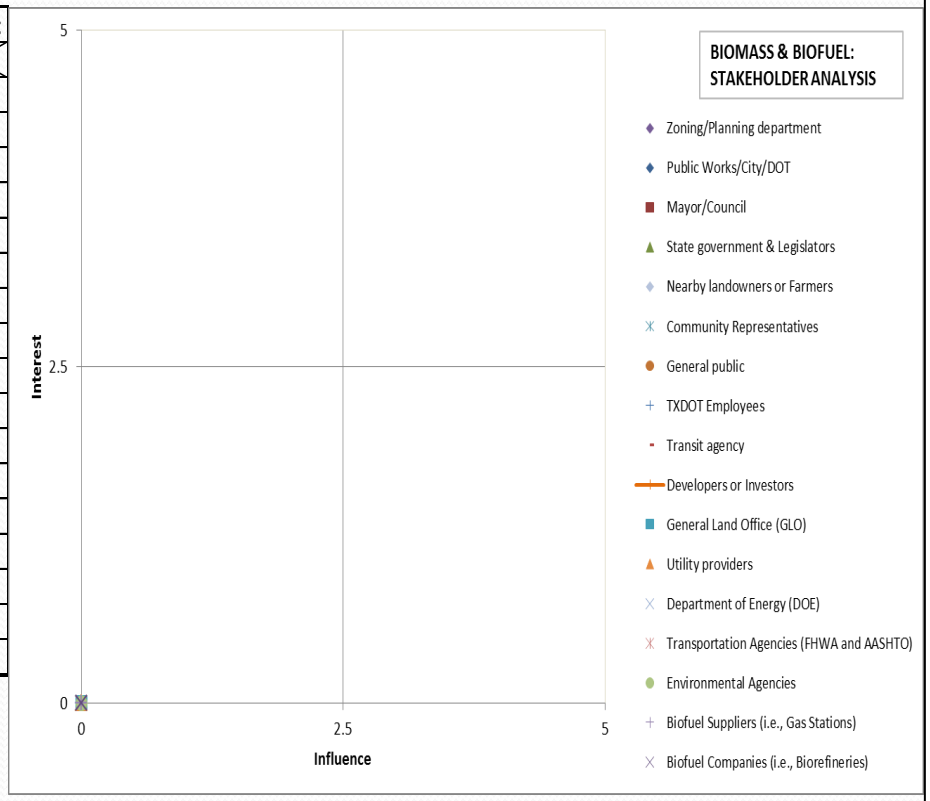

Figure II.72: List of Stakeholders of Biomass & Biofuel

Value Extraction Application Framework

List of Stakeholders: Wildlife Crossing

Stakeholder	Influence	Interest
Local government		
Public Works/City/DOT	0	0
Mayor/Council	0	0
Zoning/Planning department	0	0
State government & Legislators	0	0
Nearby landowners	0	0
Community Representatives	0	0
General public	0	0
Developers or Investors	0	0
TXDOT Employees	0	0
Transit agency	0	0
General Land Office (GLO)	0	0
Insurance Companies	0	0
Transportation Agencies (FHWA and AASHTO)	0	0
Environmental Agencies	0	0
Department of Defense (DOD)	0	0

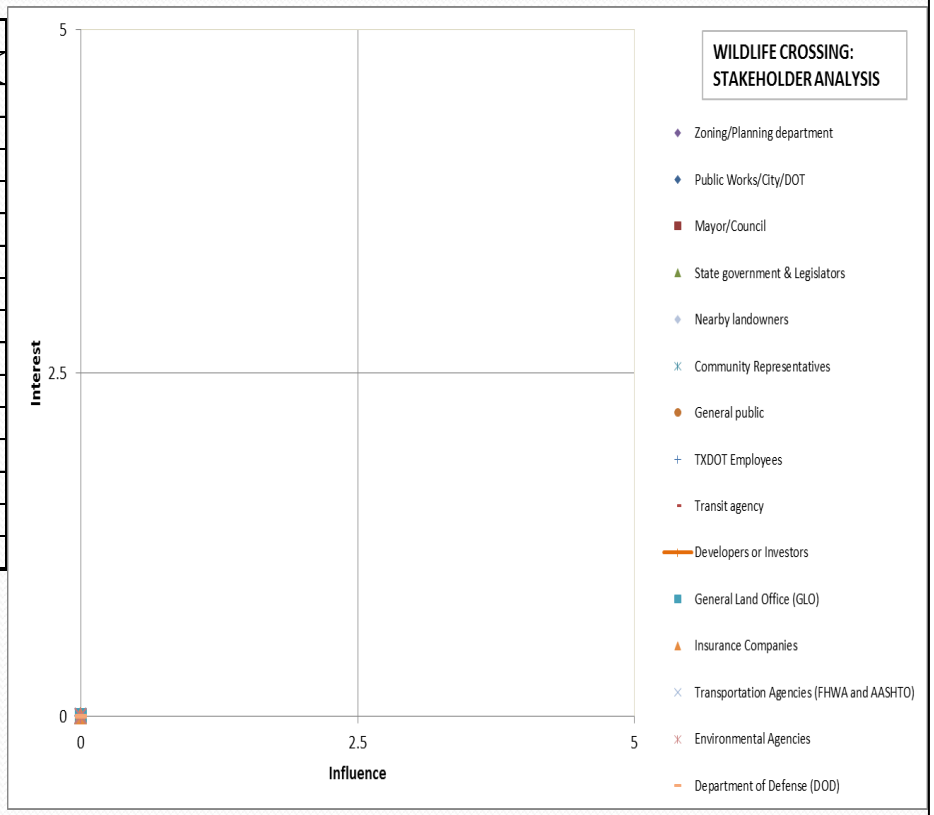

Figure II.73: List of Stakeholders of Wildlife Crossing

APPENDIX II: CHARACTERISTICS OF THE ASSET AND IMPLICATIONS ON VEA

Vacant Land

1. Is the property in a prime real estate location?

   Answer: NO

Objective	Unfeasible Value Extraction Application
Increase Revenue Stream	Property Management

2. Is the property in an urban center or commercial area or near a community center?

   Answer: NO

Objective	Unfeasible Value Extraction Application
Increase Revenue Stream	Parking Lot

3. Is the property adjacent to or near a residential or commercial area?

   Answer: YES

Objective	Unfeasible Value Extraction Application
Save Cost	Wind Turbine
Increase Revenue Stream	Wind Turbine
Enhance Environment	Wind Turbine

4. Does the property have good easy access (or can access be secured)?

   Answer: NO

Objective	Unfeasible Value Extraction Application
Increase Revenue Stream	Parking Lot

5. When will the property be developed (i.e., in how many years)?

Answer: < 5 years

Objective	Unfeasible Value Extraction Application
Save Cost	Solar Panels, Wind Turbine, Biomass & Biofuel, and Carbon Sequestration
Increase Revenue Stream	Solar Panels, Wind Turbine, Leasing - Utility, Geothermal Energy, Parking Lot, and Biomass & Biofuel
Enhance Environment	Solar Panels, Wind Turbine, Geothermal Energy, and Biomass & Biofuel

Answer: 5 years < > 20 years

Objective	Unfeasible Value Extraction Application
Save Cost	Solar Panels and Wind Turbine
Increase Revenue Stream	Solar Panels, Wind Turbine, and Geothermal Energy

6. Is the property exposed to high traffic volumes?

Answer: NO

Objective	Unfeasible Value Extraction Application
Save Cost	Advertising
Increase Revenue Stream	Advertising
Enhance Environment	Solar Panels, Wind Turbine, Geothermal Energy, and Biomass & Biofuel

7. How large (acres) is the property?

   Answer: < 5acres

Objective	Unfeasible Value Extraction Application
Increase Revenue Stream	Solar Panels, Biomass & Biofuel, and Wind Turbine

8. Is the property on a flat terrain (or on a terrain with slope less than 20%)?

   Answer: NO

Objective	Unfeasible Value Extraction Application
Save Cost	Wind Turbine and Biomass & Biofuel
Increase Revenue Stream	Wind Turbine, Parking Lot, and Biomass & Biofuel
Enhance Environment	Wind Turbine, and Biomass & Biofuel

9. Does the property have good sun exposure (i.e., no sunlight obstruction)?

   Answer: NO

Objective	Unfeasible Value Extraction Application
Save Cost	Solar Panels
Increase Revenue Stream	Solar Panels

10. How far (miles) is the nearest a transmission line or electricity user/customer to the property?

    Answer: > 1 miles

Objective	Unfeasible Value Extraction Application
Increase Revenue Stream	Solar Panels, Wind Turbine, and Geothermal Energy

11. Is the property in a Competitive Renewable Energy Zone?

Answer: NO

Objective	Unfeasible Value Extraction Application
Save Cost	Wind Turbine
Increase Revenue Stream	Wind Turbine

12. Is the property free of any wind obstructions (e.g., buildings, mountains, and hills)?

Answer: NO

Objective	Unfeasible Value Extraction Application
Save Cost	Wind Turbine
Increase Revenue Stream	Wind Turbine
Enhance Environment	Wind Turbine

13. Is the property being mowed?

Answer: NO

Objective	Unfeasible Value Extraction Application
Save Cost	Biomass & Biofuel and Carbon Sequestration
Increase Revenue Stream	Carbon Sequestration

14. Can mowing of the property be halted?

Answer: NO

Objective	Unfeasible Value Extraction Application
Save Cost	Carbon Sequestration
Increase Revenue Stream	Carbon Sequestration
Enhance Environment	Carbon Sequestration

15. What is the predominant vegetation on the property?

Answer: TREE

Objective	Unfeasible Value Extraction Application
Save Cost	Solar Panels, Wind Turbine, Biomass & Biofuel, and parking lot
Increase Revenue Stream	Solar Panels, Wind Turbine, Parking Lot, Geothermal Energy, Biomass & Biofuel, Carbon Sequestration, and Advertising
Enhance Environment	Solar Panels, Wind Turbine, Geothermal, and Biomass & Biofuel

Answer: NONE

Objective	Unfeasible Value Extraction Application
Save Cost	Carbon Sequestration and Biomass & Biofuel
Increase Revenue Stream	Carbon Sequestration

16. What is the average rainfall at the property?

Answer: < 15 INCHES

Objective	Unfeasible Value Extraction Application
Save Cost	Biomass & Biofuel
Increase Revenue Stream	Biomass & Biofuel
Enhance Environment	Biomass & Biofuel

17. How far (miles) is the nearest biorefinery to the property?

Answer: > 50 MILES

Objective	Unfeasible Value Extraction Application
Save Cost	Biomass & Biofuel
Increase Revenue Stream	Biomass & Biofuel
Enhance Environment	Biomass & Biofuel

Right of way (ROW)

1. How much ROW area (acres) besides the safety zone is available?

Answer: < 5acres

Objective	Unfeasible Value Extraction Application
Increase Revenue Stream	Solar Panels, Biomass & Biofuel, and Wind Turbine

2. What is the ROW width (feet) after excluding the safety zone?

Answer: < 10ft

Objective	Unfeasible Value Extraction Application
Save Cost	Solar Panels, Wind Turbine, Wildlife Crossing, and Biomass & Biofuel
Increase Revenue Stream	Solar Panels, Wind Turbine, and Biomass & Biofuel
Enhance Environment	Solar Panels, Wind Turbine, Wildlife Crossing, and Biomass & Biofuel

3. Is the ROW in a prime real estate location?

Answer: NO

Objective	Unfeasible Value Extraction Application
Increase Revenue Stream	Airspace leasing- Buildings

4. Is the ROW in an urban center or commercial area or near a community center?

Answer: NO

Objective	Unfeasible Value Extraction Application
Increase Revenue Stream	Parking Lot

5. When will the ROW be used (i.e., in how many years)?

Answer: < 5 years

Objective	Unfeasible Value Extraction Application
Save Cost	Solar Panels, Wind Turbine, Leasing - Utilities, Wildlife Crossing, Geothermal Energy, and Biomass & Biofuel
Increase Revenue Stream	Solar Panels, Wind Turbine, Leasing - Utility, Parking Lot, Carbon Sequestration, and Biomass & Biofuel
Enhance Environment	Wildlife Crossing, Carbon Sequestration, and Biomass & Biofuel

Answer: 5 years < > 20 years

Objective	Unfeasible Value Extraction Application
Save Cost	Solar Panels and Wind Turbine
Increase Revenue Stream	Solar Panels, Wind Turbine, and Carbon Sequestration
Enhance Environment	Wildlife Crossing

6. Does the site have good easy access (or can access be secured)?

Answer: NO

Objective	Unfeasible Value Extraction Application
Save Cost	Solar Panels, Wind Turbine, Biomass & Biofuel, and Leasing - Utilities
Increase Revenue Stream	Solar Panels, Wind Turbine, Leasing - Utility, Parking Lot, Biomass & Biofuel, and Airspace Leasing - Buildings
Enhance Environment	Solar Panels, Wind Turbine, and Biomass & Biofuel

7. Is the ROW exposed to high traffic volume?

Answer: NO

Objective	Unfeasible Value Extraction Application
Save Cost	Advertising
Increase Revenue Stream	Advertising
Enhance Environment	Solar Panels, Wind Turbine, and Biomass & Biofuel

8. Is the ROW on the Federal network?

Answer: YES

Objective	Unfeasible Value Extraction Application
Save Cost	Advertising
Increase Revenue Stream	Advertising

9. Is the site on a flat terrain (or a terrain with a slope less than 20%)?

Answer: NO

Objective	Unfeasible Value Extraction Application
Save Cost	Wind Turbine and Biomass & Biofuel
Increase Revenue Stream	Wind Turbine, Parking Lot, and Biomass & Biofuel
Enhance Environment	Wind Turbine, and Biomass & Biofuel

10. Is the site impacted by flooding, wetlands, or protected streams?

Answer: YES

Objective	Unfeasible Value Extraction Application
Save Cost	Solar Panels, Wind Turbine, and Leasing - Utilities
Increase Revenue Stream	Solar Panels, Wind Turbine, Leasing - Utility, Parking Lot, Airspace Leasing - Buildings, and Advertising
Enhance Environment	Solar Panels and Wind Turbine

11. Has documented endangered or threatened flora or fauna been identified on or adjacent to the site?

    Answer: YES

Objective	Unfeasible Value Extraction Application
Save Cost	Solar Panels, Wind Turbine, Biomass & Biofuel, and Leasing - Utilities
Increase Revenue Stream	Solar Panels, Wind Turbine, Leasing - Utility, Parking Lot, Biomass & Biofuel, and Airspace Leasing - Buildings
Enhance Environment	Solar Panels, Wind Turbine, and Biomass & Biofuel

12. Is the site on a designated state or federal scenic corridor or in a protected viewshed?

    Answer: YES

Objective	Unfeasible Value Extraction Application
Save Cost	Solar Panels, Wind Turbine, and advertising
Increase Revenue Stream	Solar Panels, Wind Turbine, Airspace Leasing - Buildings, and Advertising
Enhance Environment	Solar Panels and Wind Turbine

13. Have any cultural or historic artifacts been identified on or adjacent to the site?

Answer: YES

Objective	Unfeasible Value Extraction Application
Save Cost	Solar Panels, Wind Turbine, Leasing - Utilities, and Biomass & Biofuel
Increase Revenue Stream	Solar Panels, Wind Turbine, Leasing - Utility, Parking Lot, Biomass & Biofuel, and Airspace Leasing – Buildings
Enhance Environment	Solar Panels, Wind Turbine, and Biomass & Biofuel

14. Is this a site with a high occurrence of animal-vehicle-crash accidents?

Answer: NO

Objective	Unfeasible Value Extraction Application
Save Cost	Wildlife Crossing
Enhance Environment	Wildlife Crossing

15. Does the site have good sun exposure (i.e., no sunlight obstruction)?

Answer: NO

Objective	Unfeasible Value Extraction Application
Save Cost	Solar Panels
Increase Revenue Stream	Solar Panels

16. How far (miles) is the nearest transmission lines or potential electricity user/customers to the site?

Answer: > 1 miles

Objective	Unfeasible Value Extraction Application
Increase Revenue Stream	Solar Panels and Wind Turbine

17. Is the site adjacent to or near a residential or commercial area?

Answer: YES

Objective	Unfeasible Value Extraction Application
Save Cost	Wind Turbine
Increase Revenue Stream	Wind Turbine
Enhance Environment	Wind Turbine

18. Is there any utility infrastructure on the site (including buried utilities)?

Answer: YES

Objective	Unfeasible Value Extraction Application
Save Cost	Solar Panels, Wind Turbine, and Carbon Sequestration
Increase Revenue Stream	Solar Panels, Wind Turbine, Parking Lot, Biomass & Biofuel, and Carbon Sequestration
Enhance Environment	Solar Panels and Wind Turbine

19. Is the ROW in a Competitive Renewable Energy Zone?

Answer: NO

Objective	Unfeasible Value Extraction Application
Save Cost	Wind Turbine
Increase Revenue Stream	Wind Turbine

20. Is the site free of any wind obstructions (e.g., buildings, mountains, and hills)?

Answer: NO

Objective	Unfeasible Value Extraction Application
Save Cost	Wind Turbine
Increase Revenue Stream	Wind Turbine
Enhance Environment	Wind Turbine

21. Is the ROW being mowed?

Answer: NO

Objective	Unfeasible Value Extraction Application
Save Cost	Biomass & Biofuel and Carbon Sequestration
Increase Revenue Stream	Carbon Sequestration

22. Can mowing of the ROW be halted?

Answer: NO

Objective	Unfeasible Value Extraction Application
Save Cost	Carbon Sequestration
Increase Revenue Stream	Carbon Sequestration
Enhance Environment	Carbon Sequestration

23. What is the predominant vegetation on the site?

Answer: TREE

Objective	Unfeasible Value Extraction Application
Save Cost	Solar Panels, Wind Turbine, Biomass & Biofuel, and Advertising
Increase Revenue Stream	Solar Panels, Wind Turbine, Parking Lot, Biomass & Biofuel, Advertising, Airspace Leasing – Buildings, and Carbon Sequestration
Enhance Environment	Solar Panels, Wind Turbine, and Biomass & Biofuel

Answer: NONE

Objective	Unfeasible Value Extraction Application
Save Cost	Carbon Sequestration and Biomass & Biofuel
Increase Revenue Stream	Carbon Sequestration

24. What is the average rainfall at the site?

Answer: < 15 INCHES

Objective	Unfeasible Value Extraction Application
Save Cost	Biomass & Biofuel
Increase Revenue Stream	Biomass & Biofuel
Enhance Environment	Biomass & Biofuel

25. How far (miles) is the closest biorefinery?

Answer: > 50 MILES

Objective	Unfeasible Value Extraction Application
Save Cost	Biomass & Biofuel
Increase Revenue Stream	Biomass & Biofuel
Enhance Environment	Biomass & Biofuel

26. Does it snow/ice at this location?

Answer: NO

Objective	Unfeasible Value Extraction Application
Save Cost	Geothermal Energy

Offices and Facilities

1. Is the building in a prime real estate location?

Answer: NO

Objective	Unfeasible Value Extraction Application
Increase Revenue Stream	Property Management

2. Is the building in an urban center or residential or commercial area?

Answer: YES

Objective	Unfeasible Value Extraction Application
Increase Revenue Stream	Wind Turbine

3. Is it an old building with high maintenance cost?

Answer: NO

Objective	Unfeasible Value Extraction Application
Save Cost	Property Management

4. Is the building's electricity consumption relatively high?

   Answer: NO

Objective	Unfeasible Value Extraction Application
Save Cost	Solar Panels, Wind Turbine, and Geothermal Energy

5. Is the building's HVAC energy consumption relatively high?

   Answer: NO

Objective	Unfeasible Value Extraction Application
Save Cost	Geothermal Energy

6. Does the building have good sun exposure (i.e., no sunlight obstruction)?

   Answer: NO

Objective	Unfeasible Value Extraction Application
Save Cost	Solar Panels
Increase Revenue Stream	Solar Panels

7. Is the building in a Competitive Renewable Energy Zone?

   Answer: NO

Objective	Unfeasible Value Extraction Application
Save Cost	Wind Turbine
Increase Revenue Stream	Wind Turbine

8. Is the building at a site that is free from wind obstruction (e.g., other buildings, mountains, and hills)?

   Answer: NO

Objective	Unfeasible Value Extraction Application
Save Cost	Wind Turbine
Increase Revenue Stream	Wind Turbine
Enhance Environment	Wind Turbine

9. Is the building critical and essential to TxDOT's future operations (i.e., cannot be replaced)?

   Answer: YES

Objective	Unfeasible Value Extraction Application
Increase Revenue Stream	Property Management

10. Is the building fully occupied and utilized?

    Answer: YES

Objective	Unfeasible Value Extraction Application
Save Cost	Property Management (IF QUESTION 3 is NO)

11. Does the building site have any antenna tower or is there available area to install an antenna/radio tower at the site?

    Answer: NO

Objective	Unfeasible Value Extraction Application
Increase Revenue Stream	Leasing - Utility

12. For how long does TxDOT plan to occupy and/or own the property?

Answer: < 20 years

Objective	Unfeasible Value Extraction Application
Save Cost	Solar Panels and Wind Turbine
Increase Revenue Stream	Solar Panels, Wind Turbine, and Geothermal Energy

Rest Areas

1. Is the rest area on a Federal network?

Answer: YES

Objective	Unfeasible Value Extraction Application
Save Cost	Property Management
Increase Revenue Stream	Property Management

2. How far (miles) is the rest area from the nearest transmission lines?

Answer: > 1 miles

Objective	Unfeasible Value Extraction Application
Increase Revenue Stream	Solar Panels, Wind Turbine, Geothermal Energy

3. How far (miles) is the rest area from the nearest business or community area?

Answer: < 30 miles

Objective	Unfeasible Value Extraction Application
Save Cost	Property Management
Increase Revenue Stream	Property Management

4. Is the rest area's electricity consumption relatively high?

   Answer: NO

Objective	Unfeasible Value Extraction Application
Save Cost	Solar Panels, Wind Turbine, and Geothermal Energy

5. Is the rest area's HVAC energy consumption relatively high?

   Answer: NO

Objective	Unfeasible Value Extraction Application
Save Cost	Geothermal Energy

6. Does the rest area have good sun exposure (i.e., no sunlight obstruction)?

   Answer: NO

Objective	Unfeasible Value Extraction Application
Save Cost	Solar Panels
Increase Revenue Stream	Solar Panels

7. Is the rest area located in a Competitive Renewable Energy Zone?

   Answer: NO

Objective	Unfeasible Value Extraction Application
Save Cost	Wind Turbine
Increase Revenue Stream	Wind Turbine

8. Is the rest area at a site that is free from wind obstruction (e.g., buildings, mountains, and hills)?

   Answer: NO

Objective	Unfeasible Value Extraction Application
Save Cost	Wind Turbine
Increase Revenue Stream	Wind Turbine

9. How large (acres) is the rest area site that is vacant (i.e., excluding the area used for buildings, parking, etc.)?

   Answer: < 5acres

Objective	Unfeasible Value Extraction Application
Increase Revenue Stream	Solar Panels and Wind Turbine

APPENDIX III: SUMMARY OF ADV. AND DISADV./REQ. OF VEA

Property Management

Advantages

- Provide full control and awareness of the agency's inventory, needs, and opportunities.
- Does not present any substantial technical challenge.
- Simple communication tools such as emails, Craig's list and TxDOT website can be used to disseminate information and reach out likely interested parties.
- Can promote economic development and create jobs
- Increases tax payment by private sector (State and Federal Taxes)
- Can help TxDOT to build more efficient and updated facilities (e.g., barter transaction)
- Can enhance TxDOT decision making process
- Can enable TxDOT to have better understanding of its needs and make better and wiser investments and expenditures (i.e., budget allocation).
- State law enables TxDOT to lease any real property held or controlled by the agency that is not needed for highway purpose.
- TxDOT can resort to GSC and/or GLO for specialized skills on asset planning, management, and disposition.
- Can enhance internal and cross-departmental communication.

Disadvantages / Requirements

- Requires investment on in-house staff with knowledge of best practices in efficient, least-cost space utilization and functional adjacencies, real estate market interaction for acquisition/disposition pricing, financial feasibility determinations, transaction structuring (where values and complexities warrant), strategic plan preparation that is proactive and anticipatory of future needs, and financial optimization.

- Requires a systematic and comprehensive property evaluation process (i.e., annually).
- Investment in an efficient information system (e.g., website, database, and GIS) and asset management capable of rendering real-time information to facilitate the decision making process
- Potential impacts of the new use on nearby neighborhood, community, business, and traffic
- Potential conflict with highway system future needs.
- Potential political and public opposition
- Requires a formalized, clear, and public (open) process (i.e., fair market price, equal opportunity to interested parties, auction, and bid). Ensure total transparency.
- May require some licenses and permits
- Intensive contractual and legal work to clearly state responsibilities, liabilities, rights, duties, and other agreements (e.g., period, price, new use)

Property Management (Rest Area)

Advantages

- Can avoid closure of or even increase the number of rest areas.
- Can provide cleaner and safer rest areas (i.e., hygiene and security)
- Can enhance the service on rest areas (e.g., ATM, gas station, and food).
- Rest Areas are essential for road safety and trip quality.
- Can enhance road safety (i.e., reduction of accident due "drowsing" drivers).
- Is a simple value extraction application and does not demand any complex technical solution and/or high investment by TxDOT
- Attractive and useful rest areas encourage travelers to use a safe location off the roadway to take a break and return more alert to the highway.
- Can promote economic development and create jobs (i.e., when it does not compete with nearby business).

- Well served and interactive rest areas and welcome centers can potentially enhance the tourism market, create jobs and, therefore, help to develop rural regions (i.e., through the improvement of the quality of road trips).
- Increases Federal and State tax incomes (i.e., from private businesses and commercial activities).

Disadvantages / Requirements

- Potential political and public opposition (i.e., can be controversial).
- Potential impacts on nearby neighborhood, community, and business (i.e., Economic impacts and unfair competition)
- Federal and States laws and regulations that precludes or prohibits private and commercial rest areas
- Require investment on staff to manage, control, and oversee private rest area design, construction, and operation (i.e., compliance with standards, specifications, and requirements)
- Interference with current social projects, such as " blind vendor support"
- Need to assess best location according to traffic, access, environment, and construction requirements
- Need an intensive traffic flow to be financial attractive to private sector. Hence, it will not solve the problems in very remote areas
- Requires a formalized, clear, and public (open) process (i.e., fair market price, equal right to all interested parties, auction, and bid)
- May require licenses and permits, mainly environmental.
- Intensive contractual and legal work to clearly state responsibilities, liabilities, rights, duties, and other agreements (e.g., period, price, new use)

Airspace Leasing (Building)

Advantages

- Easy to be implemented if considered in new highway projects.

- Some projects can be attractive to business and for the public. For example, rest areas over freeways can provide entertainment for travelers, mainly kids.
- Some projects can represent city landmark and touristic sight.
- Can help reduce urban center footprint, once the structure (i.e., building) is constructed over an existing construction (i.e., road).
- Provides opportunities for financial investments and business expansion.
- Can promote economic development and create jobs.
- Increases State tax incomes.
- Has long period of revenue.
- Can integrate communities and neighborhoods divided by the highway.

Disadvantages / Requirements

- Is a complex agreement that involves legal, planning, environmental, design, construction, maintenance, safety, security, and insurance considerations to be successful implemented.
- Requires intensive and burdensome contractual and legal work to clearly state responsibilities, liabilities, rights, duties, and other agreements (e.g., period, price, new use).
- Requires involvement of all internal departments and disciplines (e.g., design, traffic, ROW, maintenance, and planning).
- Requires specialized staff to conduct the evaluation and authorization process. If no expert is available in-house, outsourcing may be needed. Mainly for safety and security assessment.
- Possible impacts on neighborhood and environment (e.g., traffic, public health, privacy, shade, noise, heat island, and visual pollution).
- Potential political and public opposition.
- Involves very robust structure and technical challenges (e.g., site constraints).
- AASHTO and FHWA have strict design requirements for structure over highway that must be complied with (drainage, vibration, clearance, fire resistance, maintenance, and access).

- Need of a very long-term commitment to pay off. High planning, design, and construction cost. Economically feasible only in very dense urban centers (i.e., at prime location).
- Safety requirements (e.g., lighting, exhaustion, ventilation, access, fire protection, emergency access, surveillance, and tunnel signs).
- Construction requirements (e.g., structural, access, utilities, methods), plans (e.g., safety, traffic, access, and impact mitigation), and disturbances (e.g., noise, dust, and traffic congestion).
- Requires a formalized procedure (i.e., impact evaluation, contractual agreements, and liabilities).
- Cannot be used to store or manufacture flammable, explosive, or hazardous substances.
- Requires several licenses and permits (e.g., NEPA).

Airspace Leasing (Parking lot)

Advantages

- Many urban areas have inadequate parking space.
- Can promote economic and business development and, hence, create jobs.
- Increase tax payment by private sector
- Can use short-term agreement (2-5 years).
- Can enhance safety and welfare (i.e., less congestion and accidents)
- Is an easy and simple VEA, not requiring high investment and efforts.
- Can be even easier to implement if considered in new highway projects.
- Can be a better solution than curb side parking (i.e., less traffic interference and more safety conditions).
- Can attract general public support.

Disadvantages / Requirements

- FHWA and ASSTHO guidelines and requirements
- Safety requirements (e.g., fence, curb, pedestrian access, and surveillance)

- Requires some investment and study on information system (e.g., parking meter, surveillance, and security)
- Require a well-done contractual agreement with an entity insured and with financial capacity to avoid possible TxDOT liabilities over third parties' properties (i.e., vehicles) and lawsuits.
- Requires easy and free access to be viable.
- Some environmentalists and transit providers see "parking unavailability" as a way to manage and reduce single vehicle occupant use and traffic congestion.
- Can negatively impact on the neighborhood (i.e., business expansion and increase traffic can entail noise and congestion).
- Some precautions have to be taken to avoid soil and water contamination from car oil, as well as to drain rain water to the public rainwater system.
- All security and safety measures must be approved by TxDOT engineering, operation, and safety personnel.

Airspace Leasing (Utilities)

Advantages

- Enhanced and available telecommunication signals can contribute to social and educational development, as well as help promote economic development and create jobs.
- Can enhance safety in remote area (e.g., tornado warming, communication of animal carcass, existing obstacle, pavement conditions, and severe weather conditions).
- Several potential ways to implement this VEA.
- Can be even easier to implement if considered in new highway projects.
- Can provide the State access to technology infrastructure.
- Can yield a better telecommunication network , helping TxDOT and other public agencies to improve their information management systems and, consequently,

enhance their services, implement an efficient maintenance program, and make better decision (i.e., wisely spend public money).

- TxDOT already has some airspace agreements for utilities that generate revenue, but not a formalized program. A formal program could bring more contracts and revenue for the agency and State.
- Some application can be implemented with a short-term agreement (5 years)
- Can facilitate the implementation or expansion of TxDOT's Advanced Rural Transportation System (ARTS), Dynamic Message Signs, 511 travel information, and Highway Advisory Radio.

Disadvantages / Requirements

- Requires license and permits such as environmental
- Need to comply with FHWA and ASSTHO guidelines and requirements, as well as NEPA. Some policies may be out of date and not address new technologies.
- Importance of contractual agreement (i.e., liabilities and responsibilities) and legal consul during the process.
- Only applicable to private utilities
- Some utilities can entail safety and environmental concerns (e.g., explosion, contamination, leak, and crash)
- May cause traffic disruption and hazardous situation during construction and maintenance. Importance of good planning and assessment, as well as access to the site.
- FHWA requires environmental evaluation and compliance with NEPA
- Requires a formalized, clear, and public (open) process (i.e., fair market price, equal right to all interested parties, auction and bid, specifications, and guidelines)
- Requires a construction and maintenance plan (i.e., access, minimize impacts on traffic, safety, and execution method)
- Some application requires special considerations such as, buried depth, concrete coat, and reinforcement.

- Private companies will need to have free or partial access to ROW or public properties.
- May compete with private sector (e.g. tower companies).

Advertising

Advantages

- Is significantly simple application and provides several means to be implemented.
- Has a diversified portfolio of applications.
- Can be used to educate, warn, and guide drivers toward safer behavior (e.g., "drink-and-drive", "no texting", and "buckle-up").
- Can be used to conduct public outreach, disseminate information, integrate communities, engage public participation, and share ideas.
- Can help to promote businesses, tourism activities, and, hence, economic development (mainly in rural areas).
- New technologies provide good potential and alternative to implement this VEA (e.g., website, internet, electronic screens, and TVs).
- Does not cause any environmental threat or impact.
- Programs, such as Adopt-a-Highway, can make roadside litter-free, helping to preserve fauna and flora, to avoid soil and water contamination, prevent insect proliferation and, consequently, diseases, and generate local employment.
- Programs, such as Adopt-a-Watt, Adopt-a-Highway, and Naming Rights, can foster and facilitate the implementation of other value extraction applications.

Disadvantages / Requirements

- Some sort of advertising are illegal and others are regulated and/or restricted by FHWA.
- Potential political and public opposition
- Some advertising (i.e., message and content) can be controversial and lead to misinterpretation.
- Demand some precaution with controversial advertisings.

- Different regulations and laws that dictate and control the use of advertising in public assets and highway ROW.
- May require some license or permit.
- May cause visual impacts (aesthetic).
- May impact on and/or be in conflict with Texas Highway Beautification Act (HBA) and State Rural Roads Act (RRA).
- High administration cost (e.g., intensive contractual and paper work).
- Requires several "small" contracts to offset the administrative costs.
- May entail safety concerns (e.g., driver distraction and obstacle).
- Requires a formalized, clear, and public (open) process (i.e., fair market price, equal right to all interested parties, auction and bid, specifications, and guidelines).

Solar Panel (ROW and Vacant Land)

Advantages

- Has no moving part, does not require water, does not make noise, and does not produce any waste or GHG emission.
- Solar energy is a key component of the U.S. national strategy for reducing carbon footprint and promoting renewable energy.
- Texas has a great solar energy potential.
- Renewable energy has gained momentum due to "an increase in environmental awareness, skyrocket oil and gas price, and national security concerns". Also, can protect the agency against oil price volatility.
- Texas energy production has not followed the State energy demand (i.e., consumption).
- Can help to reduce the dependence on fossil fuels and foreign energy.
- Using a value-based procurement (local vendors, maintenance expert, and workers) can promote economic development and create jobs.
- The technology is still evolving and becoming cheaper and more efficient

- Can be installed close to the end-user and with any scale (i.e., size), therefore not requiring long transmission lines and reducing heat loss – mainly in remote areas.
- Is an environmentally-friendly energy source and can generate electricity without disturbing the surrounding environment or community.
- Can enhance TxDOT image and bring political and public support.
- Is easy to implement if considered in highway new projects.
- Has low maintenance frequency and cost. Further, vendors provide 25-year warranty.
- Existing incentives granted by state and federal governments and REC credits.
- Can help TxDOT meet carbon emission and renewable energy consumption goals.
- The panels can be recycled.
- Solar energy is a safe source of electricity (i.e., does not pose any risk of explosion, fire, disasters, structural failure, or accidents).
- Can promote awareness and educate general public on green energy, importance of carbon reduction, and renewable energy.

Disadvantages / Requirements

- Feasibility and efficiency is very local-driven.
- Require a high up-front investment, what entails a long payback and commitment period.
- Requires a formalized procedure (i.e., impact evaluation, contractual agreements, and liabilities).
- Involves a public-private-partnership, therefore an intensive and burdensome contractual and legal work.
- Can use several, but complex, business models that vary according to the shared risks, liabilities, electricity buyer, and renewable energy credits.
- Has some patent issues.
- May cause some impacts on nearby communities (i.e., property value).

- Works only during the day (i.e., sunlight); otherwise need batteries or other electricity source.
- Relies upon the weather conditions, requiring batteries or other electricity source for more reliability
- Requires a clean, easy, independent, and safe access (i.e., aside the main road).
- Must comply with FHWA and ASSTHO regulations regarding the use of ROW.
- May need some security precaution against theft and vandalism
- Require considerations and a plan on the solar panel disposal, once the panels are composed by heavy metals, such as cadmium. Need a recycle program.
- May raise some safety concerns (e.g., roadside obstruction and driver's distraction), but site or guardrail can resolve these issues.
- Zoning law can preclude or impede the implementation.
- Has a low energy density production (i.e., requires somewhat area)
- Is still driven by incentives.
- May impact on Texas Highway Beautification Act.

Solar Panel (Building and Rest Area)

Advantages

- Has no moving part, does not require water, does not make noise, and does not produce any waste or GHG emission.
- Solar energy is a key component of the U.S. national strategy for reducing carbon footprint and promoting renewable energy.
- Texas has a great solar energy potential.
- Renewable energy has gained momentum due to "an increase in environmental awareness, skyrocket oil and gas price, and national security concerns". Also, can protect the agency against oil price volatility.
- Texas energy production has not followed the State energy demand (i.e., consumption).
- Can help to reduce the dependence on fossil fuels and foreign energy.

- Using a value-based procurement (local vendors, maintenance expert, and workers) can promote economic development and create jobs.
- The technology is still evolving and becoming cheaper and more efficient
- Can be installed close to the end-user and with any scale (i.e., size), therefore not requiring long transmission lines and reducing heat loss – mainly in remote areas.
- Is an environmentally-friendly energy source and can generate electricity without disturbing the surrounding environment or community.
- Can enhance TxDOT image and bring political and public support.
- Is easy to implement if considered in new buildings.
- Has low maintenance frequency and cost. Further, vendors provide 25-year warranty.
- Existing incentives granted by state and federal governments and REC credits.
- Can help TxDOT meet carbon emission and renewable energy consumption goals.
- The panels can be recycled.
- Solar energy is a safe source of electricity (i.e., does not pose any risk of explosion, fire, disasters, structural failure, or accidents).
- May not Involves a public-private-partnership.
- Can promote awareness and educate general public on green energy, importance of carbon reduction, and renewable energy.

Disadvantages / Requirements

- Feasibility and efficiency is very local-driven.
- Require a high up-front investment, what entails a long payback and commitment period.
- May involves a public-private-partnership, therefore an intensive and burdensome contractual and legal work.
- Requires a formalized procedure (i.e., impact evaluation, contractual agreements, and liabilities).

- Can use several, but complex, business models that vary according to the shared risks, liabilities, electricity buyer, and renewable energy credits.
- May cause some impacts on nearby communities (i.e., property value).
- Works only during the day (i.e., sunlight); otherwise need batteries or other electricity source.
- Relies upon the weather conditions, requiring batteries or other electricity source for more reliability
- May need some security precaution against theft and vandalism
- Require considerations and a plan on the solar panel disposal, once the panels are composed by heavy metals, such as cadmium. Need a recycle program.
- Zoning law can preclude or impede the implementation.
- Has a low energy density production (i.e., requires somewhat area)
- May require some update and/or revamp on the existing electrical installation and systems.
- Is still driven by incentives.

Wind Turbine (ROW and Vacant Land)

Advantages

- Some regions of Texas (i.e., CREZ) has a great wind energy potential
- New technologies (i.e., small wind turbines) can help to overcome space issues, reduce up-front investment, and others barriers.
- Has high electricity production per area
- Does not require water and does not produce any waste or GHG emission.
- Can generate energy any time of the day.
- Wind turbine is a key component of the U.S. national strategy for reducing carbon footprint and promoting renewable energy.
- Renewable energy has gained momentum due to "an increase in environmental awareness, skyrocket oil and gas price, and national security concerns". Also, can protect the agency against oil price volatility.

- Texas energy production has not followed the State energy demand (i.e., consumption).
- Can help to reduce the dependence on fossil fuels and foreign energy.
- Using a value-based procurement (local vendors, maintenance expert, and workers) can promote economic development and create jobs.
- The technology is still evolving and becoming cheaper and more efficient
- Can be installed close to the end-user and with any scale (i.e., size), therefore not requiring long transmission lines and reducing heat loss – mainly in remote areas.
- Is an environmentally-friendly energy source
- Can enhance TxDOT image and bring political and public support.
- Is easy to implement if considered in highway new projects.
- Existing incentives granted by state and federal governments and REC credits.
- Can help TxDOT meet carbon emission and renewable energy consumption goals.
- Can promote awareness and educate general public on green energy, importance of carbon reduction, and renewable energy.
- Is more cost-efficient than other renewable energy source (i.e., $ per KWh generated) and is still evolving.
- Involves intense work-force, contributing thus for employment.

Disadvantages / Requirements

- Feasibility and efficiency (i.e., energy production) is very local-driven.
- Can highly impacts on nearby communities and environment (e.g., property value, noise, bird kill, shade, oil leaks, visual aesthetics, tourism, public safety, and quality of life, visual intrusion, and flickering of light)
- Has somewhat intensive maintenance
- Need of construction and maintenance plan (i.e., transport, minimal distance between turbines, installation, access and maintenance procedures). Can potentially impact on traffic and road structure.

- Require a high up-front investment, what entails a long payback and commitment period.
- Requires a formalized procedure (i.e., impact evaluation, contractual agreements, and liabilities).
- Involves a public-private-partnership, therefore an intensive and burdensome contractual and legal work.
- Can use several, but complex, business models that vary according to the shared risks, liabilities, electricity buyer, and renewable energy credits.
- Has some patent issues.
- May cause some impacts on nearby communities (i.e., property value).
- Relies somewhat upon the weather conditions , requiring batteries or other electricity source for more reliability
- May impact on Texas Highway Beautification Act.
- Requires a clean, easy, independent, and safe access (i.e., aside the main road).
- Must comply with FHWA and ASSTHO regulations regarding the use of ROW.
- May raise some safety concerns (e.g., roadside obstruction, blade failure, oil spill on the road, turbine catching on fire, and driver's distraction), but site can resolve these issues.
- Zoning law can preclude or impede the implementation (e.g., height limit).
- The wind turbine/system must comply with local electrical code requirements, the National Electrical Code (NEC), and Fire Protection Association.
- May require some licenses and permits (e.g., FAA permit)
- Can interfere on telecommunication, radio, internet, TV, and radar signals
- Is still driven by incentives.

Wind Turbine (Building and Rest Area)

Advantages

- Some regions of Texas (i.e., CREZ) has a great wind energy potential

- New technologies (i.e., small wind turbines) can help to overcome space issues, reduce up-front investment, and others barriers.
- Has high electricity production per area
- Does not require water and does not produce any waste or GHG emission.
- Can generate energy any time of the day.
- Wind turbine is a key component of the U.S. national strategy for reducing carbon footprint and promoting renewable energy.
- Renewable energy has gained momentum due to "an increase in environmental awareness, skyrocket oil and gas price, and national security concerns". Also, can protect the agency against oil price volatility.
- Texas energy production has not followed the State energy demand (i.e., consumption).
- Can help to reduce the dependence on fossil fuels and foreign energy.
- Using a value-based procurement (local vendors, maintenance expert, and workers) can promote economic development and create jobs.
- The technology is still evolving and becoming cheaper and more efficient
- Can be installed close to the end-user and with any scale (i.e., size), therefore not requiring long transmission lines and reducing heat loss – mainly in remote areas.
- Is an environmentally-friendly energy source
- Can enhance TxDOT image and bring political and public support.
- Is easy to implement if considered in new buildings.
- Existing incentives granted by state and federal governments and REC credits.
- Can help TxDOT meet carbon emission and renewable energy consumption goals.
- Can promote awareness and educate general public on green energy, importance of carbon reduction, and renewable energy.
- Is more cost-efficient than other renewable energy source (i.e., $ per KWh generated) and is still evolving.
- Involves intense work-force, contributing thus for employment.

Disadvantages / Requirements

- Feasibility and efficiency (i.e., energy production) is very local-driven.
- Can highly impacts on nearby communities and environment (e.g., property value, noise, bird kill, shade, oil leaks, visual aesthetics, tourism, public safety, and quality of life, visual intrusion, and flickering of light)
- Has somewhat intensive maintenance
- Need of construction and maintenance plan (i.e., transport, minimal distance between turbines, installation, access and maintenance procedures).
- Require a high up-front investment, what entails a long payback and commitment period.
- Requires a formalized procedure (i.e., impact evaluation, contractual agreements, and liabilities).
- May involves a public-private-partnership, therefore an intensive and burdensome contractual and legal work.
- Can use several, but complex, business models that vary according to the shared risks, liabilities, electricity buyer, and renewable energy credits.
- May cause some impacts on nearby communities (i.e., property value).
- Relies somewhat upon the weather conditions , requiring batteries or other electricity source for more reliability
- May raise some safety concerns (e.g., blade failure, oil spill, and turbine catching on fire).
- Zoning law can preclude or impede the implementation (e.g., height limit).
- The wind turbine/system must comply with local electrical code requirements, the National Electrical Code (NEC), and Fire Protection Association.
- May require some licenses and permits (e.g., FAA permit)
- Can interfere on telecommunication, radio, internet, TV, and radar signals
- Is still driven by incentives.

Geothermal Energy

Advantages

- Does not depend on weather conditions, day-time, or season. Therefore, does not require back-up battery.
- Geothermal power plants are reliable and can be implemented anywhere (i.e., urban center and remote areas) in any scale.
- Can be implemented in small scale and almost everywhere in Texas.
- Can be installed close to the end-user and with any scale (i.e., size), therefore not requiring long transmission lines and reducing heat loss – mainly in remote areas.
- Is an environmentally-friendly energy source
- Geothermal Heat Pump can be used anywhere in Texas and have short payback period
- Geothermal Heat Pump is regarded as the most energy-efficient, environmentally clean, and cost-effective method of temperature control.
- Is a key component of the U.S. national strategy for reducing carbon footprint and promoting renewable energy.
- Renewable energy has gained momentum due to "an increase in environmental awareness, skyrocket oil and gas price, and national security concerns". Also, can protect the agency against oil price volatility.
- Texas energy production has not followed the State energy demand (i.e., consumption).
- Can help to reduce the dependence on fossil fuels and foreign energy.
- Can enhance TxDOT image and bring political and public support.
- Is easy to implement if considered in highway new projects.
- Existing incentives granted by state and federal governments and REC credits.
- Can help TxDOT meet carbon emission and renewable energy consumption goals.
- Can promote awareness and educate general public on green energy, importance of carbon reduction, and renewable energy.

- May not Involves a public-private-partnership.
- Geothermal power plant has comparatively small surface footprint.
- Can be used as de-icing mechanisms for pavement, therefore enhancing safety, reducing costs, and avoiding contamination of roadside soil by chemical and salty substances

Disadvantages / Requirements

- Type of application and feasibility are highly dependent on the underground characteristics and quality of the resource (i.e., temperature, depth, fluid characteristics, ease and rate the fluid can be extracted and reinjected). Its cost can significantly increase if the useful resource is located deep (i.e., high drilling cost).
- Geothermal power plant has a medium to long payback period
- Geothermal power plant requires a formalized procedure (i.e., impact evaluation, contractual agreements, liabilities, licenses, and permits)
- May involve a public-private-partnership, therefore an intensive and burdensome contractual and legal work.
- Can use several, but complex, business models that vary according to the shared risks, liabilities, electricity buyer, and renewable energy credits.
- May have some patent issues.
- May cause some impacts on nearby communities and/or wildlife habitat (i.e., property value, noise, steam).
- May raise some safety concerns (e.g., steam).
- Zoning law can preclude or impede the implementation (e.g., height limit).
- May require some licenses and permits (e.g., NEPA permit)
- May involve a high up-front investment, depending the size and complex of the system.
- May raise issues regarding ownership and use of natural and underground resources. May require involvement of NEPA and environmental agencies.

- Its major issue is perhaps the use of water. Geothermal energy production requires large volume of water that often contains dissolved toxic substances.
- May raise some environmental concerns (i.e., water consumption and aquifer contamination).
- May require some precaution to avoid explosion and/or fire when drilling wells.

Carbon Sequestration

Advantages

- Can help to reduce carbon footprint and combat global warming
- Can help to enhance TxDOT image
- Vegetation on ROW can be beneficial to road preservation (i.e., erosion prevention and reduction)
- Can help enhance the habitat surrounding the road and create a natural barrier for animals, helping preserve species.
- Can improve air quality by reducing the amount of CO2 and GHG on the atmosphere. Therefore, can help to prevent human respiratory diseases and enhance life quality.
- Can help TxDOT to divert and concentrate more focus and investments on highway system improvements (i.e., new projects and pavement maintenance), thereby potentially generating societal benefits such as: job creation, less traffic congestion, and lower freight costs (i.e., lower food, material, and product prices).
- Can enhance road safety and prevent roadside erosion (e.g., help preserve the pavement)
- Can provide a natural protection barrier for coastal roads, along hills and valleys, and against animals, thereby reducing animal-vehicle collisions and accidents.
- The federal government has given special attention to these types of applications in U.S. congressional debates centered preceding national climate change legislation. Therefore, it can bring political and public support.

- Some State beautification programs, such as the Green Ribbon Project – a corridor aesthetic and landscape master plan – requires TxDOT to plant a certain number of bushes and trees per year along TxDOT ROW. TxDOT could potentially receive credits from these programs. Also, bushes and trees absorb more carbon than grass and flowers (i.e., more efficient).

Disadvantages / Requirements

- Has to be clearly demonstrated as additional amount of carbon is being sequestrated to be counted and considered as carbon credit.
- The potential carbon that can be sequestrated varies with the site characteristics (i.e., soil, vegetation, and weather). Further, Texas has an enormous variability of soil and weather conditions that directly influences the capacity, feasibility, and cost of sequestrating carbon
- Requires involvement of very specialized staff (i.e., carbon aggregator and carbon verifier).
- Requires a long-term commitment (i.e., around 30 years) to qualify for carbon sequestration program.
- May impact on Texas Highway beautification program (i.e., wildflower program).
- May impose some safety concerns (e.g., some vegetation can attract animals, be a roadside obstruction, and reduce visibility and sight range).
- Carbon credit does not have a solid and well-established market yet. Carbon price floats, making economic analysis uncertain, complex, and difficult.
- There is no conclusive research on the efficiency of carbon sequestration, the establishment of a carbon baseline, and the real rate of carbon sequestrated by grass. Also, lacks of established protocol for grass vegetation.
- May raise some concerns from utility providers about liability on any damage on the vegetation planted along the ROW. Utility providers will seek and lobby to have priority over a carbon sequestration program application (long-term commitment)

- Lacks of regulations and/or direction in terms of the DOT's ownership on carbon credits generated by vegetation management practices on federal lands and how these carbon credits can be traded by a public agency.

Biomass and Biofuel

Advantages

- Texas contains one of the most diverse and most accommodating growing environments in the United States, and boasts a plethora of potential biomass-based renewable energy sources.
- The areas along the Gulf Coast and Northeast have the highest potential for biomass production because of existing refining capacity, strong producer networks, and available fertile land.
- Can promote economic development and create jobs
- The equipment used is similar to mowing equipment.
- Activities undertaken are very similar to mowing activities.
- Can produce biofuel without competing with food market.
- Can reduce and solve roadside maintenance and pest control problems.
- Requires low up-front investment
- Vegetation on ROW can be beneficial to road preservation (i.e., erosion prevention and reduction). Also, a good vegetation management strategy enhances road safety and prevents erosion. Vegetation along highway ROW defers erosion by reducing landslides, controlling evasive plant species, retaining stormwater, and holding snow (i.e., living snow fence).
- Same precautions and traffic control used to mowing activities can be adapted to plant and harvest crops.
- Biofuel combustion emits considerable less carbon than fossil fuel.
- The ethanol and biodiesel market has gained prominence worldwide due to increasing fossil fuel prices and pollution concerns.

- Can help to avoid the expansion of farming into environmentally sensitive areas; a commonly challenge found with conventional biofuel production
- Biofuel is non-toxic to humans and animals as well as biodegradable (i.e., disposal and waste are absorbed by the environment without being polluting).
- Using DOT ROW for biomass production can thus reduce the need for using farm land for energy crop production; thereby alleviating pressure on food and other commodities' price.

Disadvantages / Requirements

- Its feasibility and productivity (cost-effectiveness) depends on soil and weather conditions. Further, the production of each specific crop will largely be determined by available land, rainfall, competition, producer interest, economic incentives, and equipment needed.
- Water availability is crucial for most agriculture activity. It is generally believed that it would be very difficult to cultivate crops for biofuel production in areas with less than 14 to 16 inches of rainfall
- Logistic considerations (e.g., planting, harvesting, transporting, biorefinery, and access)
- Requires a formalized procedure (i.e., impact evaluation, contractual agreements, and liabilities). Also, questions about how to establish the business models and explore agricultural activities on public lands.
- May raise some concerns from utility providers about liability on any damage on the vegetation planted along the ROW. Utility providers will seek and lobby to have priority over a biomass production application (long-term commitment).
- May require intensive coordination with utility providers and agricultural activities – such as, plowing, tilling, harvesting, and mowing. Vegetation roots may impact on underground utilities (e.g., gas lines, oil lines, electricity, telephone, water, and fiber optics) that are also using the ROW. Contractual and legal issues with responsibilities and liabilities

- The use of de-icing products (e.g., salt) and run-off water can affect and change the proprieties of the soil in the ROW, hindering the growth of crops.
- Some crops and vegetation (e.g., switchgrass) has notorious difficult for establishment. Some takes up to 3years, even when some chemical fertilizers were used.
- Investment in a GIS database that captures the geospatial characteristics of TxDOT's ROW would aid in the identification and determination of which ROW parcels are appropriate for biomass production.
- May compete with and/or affects the ongoing roadside beautification and wildflower programs. Some crops do not promote the same aesthetical effect the flowers that integrate these programs have.
- Involves several variables and uncertainties, making the economic analysis complex and unique for each circumstance.
- In Texas, the ethanol and biodiesel market is not as prominent partly because grain has mostly been produced for animal – mostly cattle – consumption.
- May impose some safety concerns (e.g., some vegetation can attract animals, be a roadside obstruction, and reduce visibility and sight range).
- Licenses and permits required to exploit public land for agricultural activities.
- Has to comply with FHWA and ASSTHO regulations.

Wildlife Crossing

Advantages

- Texas has been the state with the highest number of fatalities from animal-vehicle crashes since 1996
- FHWA "identified 21 federally listed threatened or endangered animal species in the U. S. for which road mortality was documented as a major threat to their survival. Wildlife crossing can help reduce and mitigate this problem. It can thus integrate habitats, reduce animal mortality, and help to save endangered species.

- Has been the most successful way to reduce both habitat fragmentation and wildlife-vehicle collisions caused by roads
- The construction of wildlife crossing can create jobs, usually in remote communities maximizing social benefit.
- A well designed wildlife crossing can effectively enhance the roadway safety and diminish the number of animal-vehicle accidents.
- Can reduce expenditures on road maintenance (e.g., removing animal carcass and investigating and reporting accidents). Thus, the government can direct larger portion of the budget to other priorities and, hence, benefiting the society.
- Can prevent potential lawsuit against TxDOT and liability over accidents and fatalities.
- Can reduce human fatalities, accidents, and consequently car insurance costs.
- Several federal funding programs exist to finance wildlife crossing projects
- Can be easily implemented and with lower cost if considered in new highway projects
- Can bring political and public support and enhance TxDOT image
- The implementation of wildlife crossing structures has received substantial support from the U.S. congress. The approval of a federal highway bill – i.e., the Transportation Equity Act (TEA-21), guaranteed the availability of federal funds for wildlife crossing structures on existing roads, as well as new road projects.
- All new road projects are required to have an environmental impact study and mitigation strategy for fauna and flora.
- DOT's efforts and attitudes toward the environment and wildlife preservation can be fundamental to reduce public controversy and outcry against projects.
- Several federal funding sources can be used to support and afford the construction of wildlife crossings. Further federal programs can also grant funding for wildlife crossings such as, U.S. Fish and Wildlife Service (FWS), Natural Resource Assistance Grant Programs, and Cooperative Endangered Species Conservation Fund.

- Can be eligible for funding support from private foundations
- Has the highest net benefit minus cost balance in preventing animal-vehicle collisions.

Disadvantages / Requirements

- The effectiveness and efficiency of wildlife crossing structures are largely a function of the location, type, and dimensions of the crossings and, hence, are site-specific. The attributes of wildlife crossings thus have to be carefully studied and planned to accommodate the species targeted and the surrounding landscape.
- Requires extensive study and data regarding migration routes to identify the best location of the crossing (i.e., hot spot)
- Require wildlife crossing experts in the design team.
- May impose some construction challenges to be implemented in existing roads (e.g., supply chain, execution methods, and safety concerns).
- Traffic control and detours may also be required.
- Some engineering and technical solution may be inconvenient and expensive.

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APPENDIX IV: EVALUATION MATRIX STATEMENTS AND CRITERIA

Property Management

1. Trained in-house staff in ROW and Real Estate management.

Feasibility	Impact
Technical	
Economic	

2. In-house staff member to champion the evaluation and implementation of a property management application.

Feasibility	Impact
Technical	
Economic	

3. Ease of integrating property management application in TxDOT's organizational and decision-making structure.

Feasibility	Impact
Technical	

4. Availability of resources to update databases and/or GIS inventory of assets.

Feasibility	Impact
Technical	Political/Public

5. In-house resource to systematically review and assess current asset and future asset needs.

Feasibility	Impact
Technical	Political/Public

6. Willingness to invest in resources such as, information system, website, and GIS system.

Feasibility	Impact
Technical	Political/Public
Economic	

7. Access to TxDOT's property inventory to determine characteristics/features of property assets (e.g., size, location, value, maintenance cost, and overall condition).

Feasibility	Impact
Technical	

8. Ability to communicate, involve, and share information with general public and stakeholders about the Value Extraction Application project (i.e., transparency and equal access to information).

Feasibility	Impact
Technical	Political/Public

9. Current value (i.e., market/Real Estate value) of the property.

Feasibility	Impact
Technical	Political/Public
Legal	
Economic	

10. Current maintenance expenses on the property asset and potential savings if disposing of the property.

Feasibility	Impact
Economic	

11. Formal procedures/guidelines available to conduct/implement TxDOT property management program.

Feasibility	**Impact**
Technical	Political/Public
Legal	

12. Anticipated impacts on nearby community of "new" property use (i.e., new owner or lessee), including potential to mitigate anticipated impacts.

Feasibility	**Impact**
	Political/Public
	Environmental
	Safety
	Social

13. Anticipated environmental impacts and mitigation measurements of "new" property use.

Feasibility	**Impact**
Legal	Environmental
Economic	Social

14. Permit or license required for "new" property use.

Feasibility	**Impact**
Legal	
Economic	

15. Financial resources of and warranties (i.e., bond approval and surety) provided by the developer interested in buying/leasing/swapping property.

Feasibility	**Impact**
Legal	
Economic	

16. Anticipated direct and indirect jobs created and economic development impacts resulting from "new" use of property.

Feasibility	**Impact**
Economic	Political/Public
	Social

17. Anticipated benefits to TxDOT (e.g., financial, technical, and safety) of disposing of "obsolete" assets.

Feasibility	**Impact**
Technical	Political/Public
Economic	Safety
	Social

18. Potential concerns anticipated by General Land Office (GLO) or another public agency (e.g., FHWA, DOE, and DOD).

Feasibility	**Impact**
Legal	Political/Public

19. Potential conflict with zoning law, city's master plan, and transportation's plan.

Feasibility	**Impact**
Legal	Political/Public
	Social

20. Anticipated political and public opposition to transaction (e.g., controversy and potential impacts triggered by the "new" use).

Feasibility	Impact
	Political/Public

21. Legal constraints/issues that can jeopardize the transaction.

Feasibility	Impact
Legal	

22. Available legal consultants/resources to implement TxDOT property management program.

Feasibility	Impact
Legal	
Economic	

23. Available legal consultants/resources to advise and review transactions and contractual agreements.

Feasibility	Impact
Legal	
Economic	

24. Resources required to train or acquire in-house legal resources/counsel.

Feasibility	Impact
Economic	Political/Public

25. TxDOT's exposure in terms of liability and risks.

Feasibility	Impact
Legal	Political/Public
Economic	

26. Investment required by TxDOT to implement the Value Extraction Application.

Feasibility	Impact
Economic	Political/Public

Rest Areas

1. Trained in-house staff in ROW and Real Estate management.

Feasibility	Impact
Technical	
Economic	

2. In-house staff member to champion the evaluation and implementation of the Value Extraction Application.

Feasibility	Impact
Technical	
Economic	

3. If retrofitting rest areas, available in-house staff to specify and oversee design and construction (retrofit) of rest area.

Feasibility	Impact
Technical	
Economic	

4. Available data on number of vehicles passing by (and visiting) the rest area.

Feasibility	Impact
Technical	

5. If considering privatization or a private partnership investor/developer(s) interested in managing/operating rest area.

Feasibility	**Impact**
Technical	
Economic	

6. Access to TxDOT rest area inventory to determine characteristics/features (e.g., size, location, value, maintenance cost, and overall condition) of rest area.

Feasibility	**Impact**
Technical	

7. Ability to communicate, involve, and share information with general public and stakeholders about the Value Extraction Application project (i.e., transparency and equal access to information).

Feasibility	**Impact**
Technical	Political/Public

8. Current value (i.e., market/Real Estate value) of the property.(i.e., rest area).

Feasibility	**Impact**
Technical	Political/Public
Legal	
Economic	

9. Current maintenance expenses on the rest area and potential savings from implementing the Value Extraction Application.

Feasibility	**Impact**
Economic	Political/Public

10. Formal procedures/guidelines available to TxDOT to implement public-private partnership agreements and or privatize rest areas.

Feasibility	**Impact**
Technical	Political/Public
Legal	

11. Anticipated impacts of privatizing the rest area on nearby community (i.e., economic and social impacts), including potential to mitigate anticipated impacts.

Feasibility	**Impact**
	Political/Public
	Environmental
	Safety
	Social

12. Anticipated environmental impacts and mitigation measures.

Feasibility	**Impact**
Legal	Environmental
Economic	Social

13. Permit(s) or license(s) required.

Feasibility	**Impact**
Legal	
Economic	

14. Financial resources of and warranties (i.e., bond approval and surety) provided by the developer interested in leasing or partnering with TxDOT.

Feasibility	**Impact**
Legal	
Economic	

15. Anticipated direct and indirect jobs created and economic development impacts.

Feasibility	**Impact**
Economic	Political/Public
	Social

16. Anticipated benefits to the region or state (e.g., increase local or state taxes).

Feasibility	**Impact**
Economic	Political/Public
	Environmental
	Safety
	Social

17. Anticipated benefits to TxDOT (e.g., financial, technical, and safety).

Feasibility	**Impact**
Technical	Political/Public
Economic	Safety
	Social

18. Potential concerns anticipated by General Land Office (GLO) or another public agency (e.g., FHWA, DOE, and DOD).

Feasibility	**Impact**
Legal	Political/Public

19. Potential conflict with zoning law, city's master plan, and transportation's plan.

Feasibility	**Impact**
Legal	Political/Public
	Social

20. Anticipated political and public opposition to project (e.g., controversy and potential impacts triggered by rest area privatization).

Feasibility	Impact
	Political/Public

21. Potential risks and implications associated with considered business model (e.g., private-public-partnership, lease, easement, and sale).

Feasibility	Impact
Legal	Political/Public
Economic	

22. Legal constraints and barriers that can impede/preclude the project (e.g., rest area privatization).

Feasibility	Impact
Legal	Political/Public

23. Resources required to train and acquire in-house legal resources/counsel.

Feasibility	Impact
Legal	
Economic	

24. Available legal consultants/resources to advise and review transactions and contractual agreements.

Feasibility	Impact
Legal	
Economic	

25. TxDOT's exposure in terms of liability and risks.

Feasibility	Impact
Legal	Political/Public
Economic	

26. Compliance with Interstate Oasis Program, FHWA, AASTHO, and other's agency requirements and policies.

Feasibility	Impact
Technical	Social
Legal	
Economic	

27. Investment required by TxDOT to implement the Value Extraction Application.

Feasibility	Impact
Economic	Political/Public

Airspace Leasing: Building

1. Trained in-house or consultant staff to analyze the project, specifications, and potential impacts, and challenges.

Feasibility	Impact
Technical	
Economic	

2. Staff to specify and oversee design and construction of the project.

Feasibility	Impact
Technical	
Economic	

3. In-house staff member to champion the evaluation and implementation of the Value Extraction Application.

Feasibility	**Impact**
Technical	
Economic	

4. Available in-house or consultant safety and security experts to conduct safety assessment, advise the design, and provide insight in the drafting of the concept and leasing agreement.

Feasibility	**Impact**
Technical	Safety
Economic	

5. Project characteristics (e.g., footprint) and potential impacts on traffic, utilities, community, and environment (e.g., congestion, aesthetics, privacy, shade, and property value) that could impact project/application feasibility.

Feasibility	**Impact**
Technical	Political/Public
	Environmental
	Safety
	Social

6. Site characteristics (i.e., location, logistics, access, environment, and infrastructure) that could impact project/application feasibility.

Feasibility	**Impact**
Technical	Environmental
Economic	Safety

7. Ability to communicate, involve, and share information with general public and stakeholders about the Value Extraction Application project (i.e., transparency and equal access to information).

Feasibility	**Impact**
Technical	Political/Public

8. Current value (i.e., market/Real Estate value) of the property.in the area.

Feasibility	**Impact**
Technical	Political/Public
Legal	
Economic	

9. Formal procedures/guidelines available to conduct/implement an airspace leasing program (i.e., agreement, design, construction, and maintenance).

Feasibility	**Impact**
Technical	Political/Public
Legal	

10. The project is designed and implemented as a component/together with a new highway project (i.e., already included in the highway design).

Feasibility	**Impact**
Technical	
Economic	

11. Anticipated impacts of the project (i.e., “new owner or lessee”) on nearby community (e.g., traffic congestion, shade, privacy, noise, and property values, including potential to mitigate anticipated impacts.

Feasibility	**Impact**
	Political/Public
	Environmental
	Safety
	Social

12. Anticipated environmental impacts and mitigation measure for “new” property use/project.

Feasibility	**Impact**
Legal	Environmental
Economic	Social

13. Construction plan includes measures to avoid/reduce traffic congestion, dust, noise, unsafe situations, accidents, and other negative community impacts.

Feasibility	**Impact**
Technical	Environmental
Economic	Safety
	Social

14. Traffic control plan during construction and anticipated safety training required.

Feasibility	**Impact**
Technical	Safety
Economic	

15. Building and tunnel comply with all safety requirements (e.g., lighting, exhaustion, ventilation, drainage, access, and fire protection).

Feasibility	**Impact**
Technical	Safety
Economic	

16. Compliance with FHWA, AASTHO, and other agency requirements.

Feasibility	**Impact**
Technical	Safety
Legal	
Economic	

17. Anticipated future highway system needs (i.e., traffic volume, lanes, and clearances) that could require future road expansion.

Feasibility	**Impact**
Technical	Social
Legal	
Economic	

18. Permit or license required to execute/construct project.

Feasibility	**Impact**
Legal	
Economic	

19. Financial resources of and warranties (i.e., bond approval and surety) provided by the project developer.

Feasibility	**Impact**
Legal	
Economic	

20. Anticipated direct and indirect jobs created and economic development impacts resulting from the project.

Feasibility	**Impact**
Economic	Political/Public
	Social

21. Anticipated benefits to the region or state (e.g., increase local or state taxes).

Feasibility	**Impact**
Economic	Political/Public
	Environmental
	Safety
	Social

22. Anticipated benefits to TxDOT (e.g., financial, technical, and safety).

Feasibility	**Impact**
Technical	Political/Public
Economic	Safety
	Social

23. Potential concerns anticipated by General Land Office (GLO) or another public agency (e.g., FHWA, DOE, and DOD).

Feasibility	**Impact**
Legal	Political/Public

24. Potential conflict with zoning law, city's master plan, and transportation's plan.

Feasibility	**Impact**
Legal	Political/Public
	Social

25. Anticipated political and public opposition to transaction (e.g., controversy and potential impacts triggered by the "new" project).

Feasibility	Impact
	Political/Public

26. Potential risks and implications associated with considered business model (e.g., private-public-partnership, lease, easement, and sale).

Feasibility	Impact
Legal	Political/Public
Economic	

27. Legal constraints/concerns that can impede or prevent the transaction/project.

Feasibility	Impact
Legal	

28. Available legal consultants/resources to implement TxDOT's airspace leasing program.

Feasibility	Impact
Legal	
Economic	

29. Available legal consultants/resources to advise and review transactions and contractual agreements.

Feasibility	Impact
Legal	
Economic	

30. Resources required to train or acquire in-house legal resources/counsel.

Feasibility	Impact
Economic	Political/Public

31. TxDOT's exposure in terms of liability and risks.

Feasibility	Impact
Legal	Political/Public
Economic	

32. Investment required by TxDOT to implement the Value Extraction Application.

Feasibility	Impact
Economic	Political/Public

Airspace Leasing Parking Lot

1. Trained in-house or consultant staff to analyze the project, specifications, and potential impacts, and challenges.

Feasibility	Impact
Technical	
Economic	

2. In-house staff member to champion the evaluation and implementation of the Value Extraction Application.

Feasibility	Impact
Technical	
Economic	

3. Available in-house or consultant safety and security experts to conduct safety assessment, advise the design, and provide insight in the drafting of the concept and leasing agreement.

Feasibility	**Impact**
Technical	Safety
Economic	

4. Current demand/need for additional parking space in the area.

Feasibility	**Impact**
Economic	Political/Public
	Social

5. Project characteristics and potential impacts on traffic, utilities, community, and environment (e.g., drainage and runoff) that could impact project/application feasibility.

Feasibility	**Impact**
Technical	Political/Public
	Environmental
	Safety
	Social

6. Site characteristics (i.e., location, clearances, visibility, access, and infrastructure) that could impact project/application feasibility.

Feasibility	**Impact**
Technical	Environmental
Economic	Safety

7. Ability to communicate, involve, and share information with general public and stakeholders about the Value Extraction Application project (i.e., transparency and equal access to information).

Feasibility	**Impact**
Technical	Political/Public

8. Current value (i.e., market/Real Estate value) of the property.

Feasibility	**Impact**
Technical	Political/Public
Legal	
Economic	

9. Formal procedures/guidelines available to conduct/implement an airspace leasing program (i.e., agreement, design, construction, and maintenance).

Feasibility	**Impact**
Technical	Political/Public
Legal	

10. The parking lot is designed and implemented as a component/together with a new highway project (i.e., already included in the highway design).

Feasibility	**Impact**
Technical	
Economic	

11. Anticipated traffic impacts of the new parking lot.

Feasibility	**Impact**
	Political/Public
	Environmental
	Safety
	Social

12. Anticipated environmental impacts and mitigation measure for parking lot project.

Feasibility	**Impact**
Legal	Environmental
Economic	Social

13. Construction plan includes measures to avoid/reduce traffic congestion, dust, noise, unsafe situations, accidents, and other negative community impacts.

Feasibility	**Impact**
Technical	Environmental
Economic	Safety
	Social

14. Required investments in technologies and systems (e.g., parking meters and surveillance systems).

Feasibility	**Impact**
Technical	
Economic	

15. Compliance with FHWA, AASTHO, and other agency requirements.

Feasibility	**Impact**
Technical	Safety
Legal	
Economic	

16. Parking lot design complies with safety requirements (e.g., curbs, fences, lighting, access, fire protection, pedestrian access, and surveillance).

Feasibility	**Impact**
Technical	Safety
Economic	

17. Permit or license required to execute/construct project.

Feasibility	**Impact**
Legal	
Economic	

18. Financial resources of and warranties (i.e., bond approval and surety) provided by the project developer.

Feasibility	**Impact**
Legal	
Economic	

19. Anticipated direct and indirect jobs created and economic development impacts resulting from the project.

Feasibility	**Impact**
Economic	Political/Public
	Social

20. Anticipated benefits to the region or state (e.g., increase local or state taxes).

Feasibility	**Impact**
Economic	Political/Public
	Environmental
	Safety
	Social

21. Anticipated benefits to TxDOT (e.g., financial, technical, and safety).

Feasibility	**Impact**
Technical	Political/Public
Economic	Safety
	Social

22. Potential concerns anticipated by General Land Office (GLO) or another public agency (e.g., FHWA, DOE, and DOD).

Feasibility	**Impact**
Legal	Political/Public

23. Potential conflict with zoning law, city's master plan, and transportation's plan.

Feasibility	**Impact**
Legal	Political/Public
	Social

24. Anticipated political and public opposition to transaction (e.g., controversy and potential impacts triggered by the "new" project).

Feasibility	**Impact**
	Political/Public

25. Potential risks and implications associated with considered business model (e.g., private-public-partnership, lease, easement, and sale).

Feasibility	**Impact**
Legal	Political/Public
Economic	

26. Legal constraints/concerns that can impede or prevent the transaction/project.

Feasibility	**Impact**
Legal	

27. Available legal consultants/resources to implement TxDOT's airspace leasing program.

Feasibility	**Impact**
Legal	
Economic	

28. Available legal consultants/resources to advise and review transactions and contractual agreements.

Feasibility	**Impact**
Legal	
Economic	

29. Resources required to train or acquire in-house legal resources/counsel.

Feasibility	**Impact**
Economic	Political/Public

30. TxDOT's exposure in terms of liability and risks.

Feasibility	Impact
Legal	Political/Public
Economic	

31. Investment required by TxDOT to implement the Value Extraction Application.

Feasibility	Impact
Economic	Political/Public

Airspace Leasing: Utility

1. Trained in-house or consultant staff to analyze the project, specifications, and potential impacts, and challenges.

Feasibility	Impact
Technical	
Economic	

2. In-house staff member to champion the evaluation and implementation of the Value Extraction Application.

Feasibility	Impact
Technical	
Economic	

3. Available in-house or consultant safety and security experts to conduct safety assessment, advise the design, and provide insight in the drafting of the concept and leasing agreement.

Feasibility	Impact
Technical	Safety
Economic	

4. Interested parties (i.e., potential developers) have been identified or have approached TxDOT.

Feasibility	Impact
Technical	
Economic	

5. Utility is considered private (i.e., will require airspace leasing agreement).

Feasibility	Impact
Legal	Political/Public

6. Project characteristics and potential impacts on traffic, utilities, community, and environment (e.g., water or soil contamination, explosive, and safety concerns) that could impact project/application feasibility.

Feasibility	Impact
Technical	Political/Public
	Environmental
	Safety
	Social

7. Site characteristics (i.e., location, clearances, visibility, access, and infrastructure) that could impact project/application feasibility.

Feasibility	Impact
Technical	Environmental
Economic	Safety

8. Anticipated future highway system needs (i.e., traffic volume, lanes, and clearances) that could require future road expansion.

Feasibility	**Impact**
Technical	Social
Legal	
Economic	

9. Current TxDOT demand/need for utility (e.g., electricity required to power Dynamic Message Signs and/or need for telecommunication signal (e.g., cell phone and internet, or for transmission of data).

Feasibility	**Impact**
Technical	Political/Public
Economic	Safety
	Social

10. Potential for competing with private sector (e.g., existing private tower near TxDOT property considered for airspace leasing).

Feasibility	**Impact**
Legal	Political/Public

11. The utility is designed and implemented as a component together with a new highway project (i.e., already included in the highway design).

Feasibility	**Impact**
Technical	
Economic	

12. Ability to communicate, involve, and share information about the project/application with general public and stakeholders (i.e., transparency and equal opportunity).

Feasibility	**Impact**
Technical	Political/Public

13. Current value (i.e., market/Real Estate value) of the property

Feasibility	**Impact**
Technical	Political/Public
Legal	
Economic	

14. Formal procedures/guidelines available to conduct/implement an airspace leasing program (i.e., agreement, design, construction, and maintenance).

Feasibility	**Impact**
Technical	Political/Public
Legal	

15. Potential impacts on road maintenance plan and operations (e.g., utilities crossing the road, antenna installation, and utility maintenance).

Feasibility	**Impact**
Technical	Safety
Economic	

16. Anticipated environmental impacts and mitigation measures..

Feasibility	**Impact**
Legal	Environmental
Economic	Social

17. Potential risk of accidents/unsafe situations (e.g., explosion precaution, electrical discharge/shock, leak detection, valves, clear zone, and accidents).

Feasibility	**Impact**
Technical	Political/Public
Legal	Environmental
Economic	Safety

18. Construction plan includes measures to avoid/reduce traffic congestion, noise, unsafe situations, accidents, and other negative community impacts.

Feasibility	**Impact**
Technical	Environmental
Economic	Safety
	Social

19. Required investments in technologies and systems.

Feasibility	**Impact**
Technical	
Economic	

20. Compliance with FHWA, AASTHO, and other agency requirements.

Feasibility	**Impact**
Technical	Safety
Legal	
Economic	

21. Permit or license required to execute/construct project.

Feasibility	**Impact**
Legal	
Economic	

22. Federal Aviation Administration (FAA) and Department of Defense (DOD) approved and granted permit for the project (i.e., if the project is located within 3-5 miles from a public or military airport, or has tower higher than 200ft).

Feasibility	**Impact**
Legal	
Economic	

23. Financial resources of and warranties (i.e., bond approval and surety) provided the project developer.

Feasibility	**Impact**
Legal	
Economic	

24. Anticipated direct and indirect jobs created and economic development impacts resulting from the project.

Feasibility	**Impact**
Economic	Political/Public
	Social

25. Anticipated benefits to the region or state (e.g., increase local or state taxes).

Feasibility	**Impact**
Economic	Political/Public
	Environmental
	Safety
	Social

26. Anticipated benefits to TxDOT (e.g., financial, technical, and safety).

Feasibility	**Impact**
Technical	Political/Public
Economic	Safety
	Social

27. Potential concerns anticipated by General Land Office (GLO) or another public agency (e.g., FHWA, DOE, and DOD).

Feasibility	**Impact**
Legal	Political/Public

28. Potential conflict with zoning law, city's master plan, and transportation's plan.

Feasibility	**Impact**
Legal	Political/Public
	Social

29. Anticipated political and public opposition to transaction (e.g., controversy and potential impacts triggered by the "new" project).

Feasibility	**Impact**
	Political/Public

30. Potential risks and implications associated with considered business model (e.g., private-public-partnership, lease, easement, and sale).

Feasibility	**Impact**
Legal	Political/Public
Economic	

31. Legal constraints/concerns that can impede or prevent the transaction/project.

Feasibility	Impact
Legal	

32. Available legal consultants/resources to implement TxDOT's airspace leasing program.

Feasibility	Impact
Legal	
Economic	

33. Available legal consultants/resources to advise and review transactions and contractual agreements

Feasibility	Impact
Legal	
Economic	

34. Resources required to train or acquire in-house legal resources/counsel

Feasibility	Impact
Legal	
Economic	

35. TxDOT's exposure in terms of liability and risks (e.g., utility relocation).

Feasibility	Impact
Legal	Political/Public
Economic	

36. Investment required by TxDOT to implement the Value Extraction Application

Feasibility	Impact
Economic	Political/Public

Advertising

1. Trained in-house or consultant staff to analyze the project, specifications, and potential impacts, and challenges.

Feasibility	**Impact**
Technical	
Economic	

2. In-house staff member to champion the evaluation and implementation of the Value Extraction Application.

Feasibility	**Impact**
Technical	
Economic	

3. Interested parties have been identified or have approached TxDOT.

Feasibility	**Impact**
Technical	
Economic	

4. Available data/information on traffic exposure (i.e., visibility).

Feasibility	**Impact**
Technical	

5. Identified and selected advertising mode (e.g., brochures, outdoor advertising, blue signs, live vegetation, or naming rights).

Feasibility	**Impact**
Technical	Political/Public
Legal	
Economic	

6. Project characteristics and potential impacts on traffic, road maintenance, utilities, nearby communities, and the environment.

Feasibility	**Impact**
Technical	Political/Public
	Environmental
	Safety
	Social

7. Site characteristics (i.e., location, clearances, visibility, access, and infrastructure) that could impact project/application feasibility.

Feasibility	**Impact**
Technical	Environmental
Economic	Safety

8. Anticipated future highway system needs (i.e., traffic volume, lanes, and clearances) that could require future road expansion.

Feasibility	**Impact**
Technical	Social
Legal	
Economic	

9. Ability to communicate, involve, and share information with general public and stakeholders about the Value Extraction Application project (i.e., transparency and equal access to information).

Feasibility	**Impact**
Technical	Political/Public

10. Current value (i.e., market/Real Estate value) of the property.

Feasibility	**Impact**
Technical	Political/Public
Legal	
Economic	

11. Formal procedures/guidelines available to conduct/implement advertising program (e.g., staff, specifications, and agreements).

Feasibility	**Impact**
Technical	Political/Public
Legal	

12. Anticipated environmental impacts and mitigation measures..

Feasibility	**Impact**
Legal	Environmental
Economic	Social

13. Potential risk of accidents/unsafe situations (e.g., crash, clear zones, and driver distraction).

Feasibility	**Impact**
Technical	Safety
Legal	
Economic	

14. Potential educational benefits associated with advertising content (i.e., message and images).

Feasibility	Impact
Legal	Political/Public
	Environmental
	Safety
	Social

15. Required investments in technologies and systems (e.g., electricity, internet, and fiber optics).

Feasibility	Impact
Technical	
Economic	

16. Compliance with FHWA, AASTHO, TxDOT State Rural Act, and other agencies' requirements

Feasibility	Impact
Technical	Safety
Legal	
Economic	

17. Permit or license required to execute/construct project.

Feasibility	Impact
Legal	
Economic	

18. Compliance with Texas Highway Beautification Act (HBA).

Feasibility	Impact
Legal	Political/Public

19. Anticipated direct and indirect jobs created and economic development impacts resulting from the project.

Feasibility	**Impact**
Economic	Political/Public
	Social

20. Anticipated benefits to the region or state (e.g., increase local or state taxes).

Feasibility	**Impact**
Economic	Political/Public
	Environmental
	Safety
	Social

21. Anticipated benefits to TxDOT (e.g., financial, technical, and safety).

Feasibility	**Impact**
Technical	Political/Public
Economic	Safety
	Social

22. Potential concerns anticipated by General Land Office (GLO) or another public agency (e.g., FHWA, DOE, and DOD).

Feasibility	**Impact**
Legal	Political/Public

23. Potential conflict with zoning law, city's master plan, and transportation's plan.

Feasibility	**Impact**
Legal	Political/Public
	Social

24. Anticipated political and public opposition to transaction (e.g., controversy and potential impacts triggered by the "new" project).

Feasibility	Impact
	Political/Public

25. Potential risks and implications associated with considered business model (e.g., private-public-partnership, lease, easement, and sale)

Feasibility	Impact
Legal	Political/Public
Economic	

26. Legal constraints/concerns that can impede or prevent the transaction/project

Feasibility	Impact
Legal	

27. Available legal consultants/resources to implement TxDOT's advertising program.

Feasibility	Impact
Legal	
Economic	

28. Available legal consultants/resources to advise and review transactions and contractual agreements.

Feasibility	Impact
Legal	
Economic	

29. Resources required to train or acquire in-house legal resources/counsel.

Feasibility	Impact
Economic	Political/Public

30. TxDOT's exposure in terms of liability and risks.

Feasibility	Impact
Legal	Political/Public
Economic	

31. Investment required by TxDOT to implement the Value Extraction Application.

Feasibility	Impact
Economic	Political/Public

Solar Panels (ROW & Vacant Land)

1. Trained in-house or consultant staff to analyze the project, specifications, and potential impacts, and challenges.

Feasibility	Impact
Technical	
Economic	

2. In-house staff member to champion the evaluation and implementation of the Value Extraction Application.

Feasibility	Impact
Technical	
Economic	

3. Available in-house or consultant safety and security experts to conduct safety assessment, advise the design, and provide insight in the drafting of the concept and leasing agreement.

Feasibility	**Impact**
Technical	Safety
Economic	

4. Interested parties (i.e., potential developers) have been identified or have approached TxDOT.

Feasibility	**Impact**
Technical	
Economic	

5. Project/application will assist TxDOT in meeting renewable energy consumption and carbon emissions goals.

Feasibility	**Impact**
Legal	Political/Public
Economic	Environmental

6. Project characteristics and potential impacts on traffic (e.g., driver distraction), community (e.g., property values), and the environment.

Feasibility	**Impact**
Technical	Political/Public
	Environmental
	Safety
	Social

7. Site characteristics (i.e., location, solar potential, clearances, access, and infrastructure) that could impact project/application feasibility.

Feasibility	**Impact**
Technical	Environmental
Economic	Safety

8. Anticipated future highway system needs (i.e., traffic volume, lanes, and clearances) that could require future road expansion.

Feasibility	**Impact**
Technical	Social
Legal	
Economic	

9. The solar project is designed and implemented as a component together with a new highway project (i.e., already included in the highway design).

Feasibility	**Impact**
Technical	
Economic	

10. Ability to communicate, involve, and share information with general public and stakeholders about the Value Extraction Application project (i.e., transparency and equal access to information).

Feasibility	**Impact**
Technical	Political/Public

11. Access to vendors/solar specialists (e.g., for installation and maintenance).

Feasibility	**Impact**
Technical	Political/Public
Economic	Social

12. Current TxDOT demand/need for electricity at the project site (e.g., lighting pole and signs).

Feasibility	**Impact**
Economic	

13. Ability/cost to connect to the grid (e.g., distance from transmission lines).

Feasibility	**Impact**
Technical	
Economic	

14. Need for backup system for solar project (i.e., battery or on-grid electricity source) to supply TxDOT's electricity needs.

Feasibility	**Impact**
Technical	Environmental
Economic	Social

15. Available infrastructure (e.g., fiber optic or wireless signal) at site to support and facilitate monitoring and management of the project/output.

Feasibility	**Impact**
Technical	
Economic	

16. Current value (i.e., market/Real Estate value) of the property.

Feasibility	**Impact**
Technical	Political/Public
Legal	
Economic	

17. Formal procedures/guidelines available to conduct/implement solar energy project (i.e., agreement, design, construction, and maintenance).

Feasibility	**Impact**
Technical	Political/Public
Legal	

18. Potential impacts of the solar project on road maintenance and operations (e.g., impact of solar panel maintenance).

Feasibility	**Impact**
Technical	Safety
Economic	

19. Anticipated environmental impacts and mitigation measures.

Feasibility	**Impact**
Legal	Environmental
Economic	Social

20. Potential risk of accidents/unsafe situations (e.g., accidents, driver distraction, clear zones, guard rails, and adequate access to site).

Feasibility	**Impact**
Technical	Safety
Legal	
Economic	

21. Compliance with Texas Highway Beautification Act (HBA).

Feasibility	**Impact**
Legal	Political/Public

22. Construction plan includes measures to avoid/reduce traffic congestion, noise, unsafe situations, accidents, and other negative community impacts.

Feasibility	**Impact**
Technical	Environmental
Economic	Safety
	Social

23. Required investments in technologies and systems.

Feasibility	**Impact**
Technical	
Economic	

24. Compliance with FHWA, AASTHO, National Electrical Code, Fire Protection Association, and other agency requirements.

Feasibility	**Impact**
Technical	Safety
Legal	
Economic	

25. Permit or license required to execute/construct project.

Feasibility	**Impact**
Legal	
Economic	

26. Federal Aviation Administration (FAA) has approved and granted permit for the solar project (i.e., if the project is located within 3-5 miles from a public or military airport).

Feasibility	**Impact**
Legal	
Economic	

27. Net metering applies.

Feasibility	**Impact**
Economic	

28. Federal and State incentives, as well as Renewable Energy Credits (REC) are available.

Feasibility	**Impact**
Economic	Political/Public

29. Potential concerns about "free access" to TxDOT's property (i.e., facility, land, or ROW) by third party.

Feasibility	**Impact**
Legal	Political/Public
	Safety

30. Financial resources of and warranties (i.e., bond approval and surety) provided by the project developer.

Feasibility	**Impact**
Legal	
Economic	

31. Potential for adopting a value-based procurement strategy (e.g., include considerations beyond project cost, such as social benefits and environmental impacts).

Feasibility	**Impact**
Economic	Political/Public
	Environmental
	Social

32. Anticipated direct and indirect jobs created and economic development impacts resulting from the project.

Feasibility	**Impact**
Economic	Political/Public
	Social

33. Anticipated benefits to the region or state (e.g., increase local or state taxes).

Feasibility	**Impact**
Economic	Political/Public
	Environmental
	Safety
	Social

34. Anticipated benefits to TxDOT (e.g., financial, technical, and safety).

Feasibility	**Impact**
Technical	Political/Public
Economic	Safety
	Social

35. Potential concerns anticipated by General Land Office (GLO) or another public agency (e.g., FHWA, DOE, and DOD).

Feasibility	**Impact**
Legal	Political/Public

36. Potential conflict with zoning law, city's master plan, and transportation's plan.

Feasibility	**Impact**
Legal	Political/Public
	Social

37. Anticipated political and public opposition to transaction/project (e.g., controversy and potential impacts triggered by the "new" project)

Feasibility	**Impact**
	Political/Public

38. Potential risks and implications associated with considered business model (e.g., private-public-partnership, lease, easement, and sale), as well as incentives and REC ownership.

Feasibility	**Impact**
Legal	Political/Public
Economic	

39. Legal constraints/concerns that can impede or prevent the transaction/project.

Feasibility	**Impact**
Legal	

40. Patents and associated costs that could impact project/application feasibility.

Feasibility	Impact
Legal	
Economic	

41. Available legal consultants/resources to implement TxDOT's solar program.

Feasibility	Impact
Legal	
Economic	

42. Available legal consultants/resources to advise and review transactions and contractual agreements.

Feasibility	Impact
Legal	
Economic	

43. Resources required to train or acquire in-house legal resources/counsel.

Feasibility	Impact
Economic	Political/Public

44. TxDOT's exposure in terms of liability and risks (e.g., solar array relocation or damage).

Feasibility	Impact
Legal	Political/Public
Economic	

45. Investment required by TxDOT to implement the Value Extraction Application.

Feasibility	Impact
Economic	Political/Public

Solar Panels (Office & Facilities)

1. Trained in-house or consultant staff to analyze the project, specifications, and potential impacts, and challenges.

Feasibility	**Impact**
Technical	
Economic	

2. In-house staff member to champion the evaluation and implementation of the Value Extraction Application.

Feasibility	**Impact**
Technical	
Economic	

3. Available in-house or consultant safety and security experts to conduct safety assessment, advise the design, and provide insight in the drafting of the concept and leasing agreement.

Feasibility	**Impact**
Technical	Safety
Economic	

4. Interested parties (i.e., potential developers) have been identified or approached TxDOT.

Feasibility	**Impact**
Technical	
Economic	

5. Project/application will assist TxDOT in meeting renewable energy consumption and carbon emissions goals.

Feasibility	**Impact**
Legal	Political/Public
Economic	Environmental

6. Site/building characteristics (i.e., location, solar potential, access, and infrastructure) that could impact project/application feasibility.

Feasibility	**Impact**
Technical	
Economic	

7. Building/facility's electrical system has been/can be retrofitted to use solar energy.

Feasibility	**Impact**
Technical	
Economic	

8. The roof area/external area is large enough to generate sufficient energy to meet the building/facility's energy demand.

Feasibility	**Impact**
Economic	Environmental

9. The solar project is financially feasible.

Feasibility	**Impact**
Economic	

10. The solar project is designed and implemented as a component of building/facility (i.e., included in the building/facility design).

Feasibility	**Impact**
Technical	
Economic	

11. Ability to communicate, involve, and share information with general public and stakeholders about the Value Extraction Application project (i.e., transparency and equal access to information)

Feasibility	**Impact**
Technical	Political/Public

12. Access to vendors/ solar panel specialists (e.g., for installation and maintenance).

Feasibility	**Impact**
Technical	Political/Public
Economic	Social

13. Current TxDOT demand/need for electricity at the site (e.g., building/facility electricity usage).

Feasibility	**Impact**
Economic	

14. Ability/cost to connect to the grid (e.g., distance from transmission lines).

Feasibility	**Impact**
Technical	
Economic	

15. Need for backup system for solar project (i.e., battery or on-grid electricity source) to supply TxDOT's electricity needs.

Feasibility	**Impact**
Technical	Political/Public
Economic	Environmental

16. Formal procedures/guidelines available to conduct/implement solar energy project (i.e., agreement, design, construction, and maintenance).

Feasibility	**Impact**
Technical	Political/Public
Legal	

17. Anticipated environmental impacts and mitigation measures.

Feasibility	**Impact**
Legal	Environmental
Economic	Social

18. Potential risk of accidents/unsafe situations.

Feasibility	**Impact**
Technical	Safety
Legal	
Economic	

19. Required investments in technologies and systems.

Feasibility	**Impact**
Technical	
Economic	

20. Compliance with FHWA, AASTHO, National Electrical Code, Fire Protection Association, and other agency requirements.

Feasibility	**Impact**
Technical	Safety
Legal	
Economic	

21. Permit or license required to execute/construct project.

Feasibility	**Impact**
Legal	
Economic	

22. Federal Aviation Administration (FAA) has approved and granted permit for the solar project (i.e., if the project is located within 3-5 miles from a public or military airport).

Feasibility	**Impact**
Legal	
Economic	

23. Net metering applies.

Feasibility	**Impact**
Economic	

24. Federal and State incentives, as well as Renewable Energy Credits (REC) are available.

Feasibility	**Impact**
Economic	Political/Public

25. Potential concerns about “free access” to TxDOT’s property (i.e., facility or building) by third party.

Feasibility	**Impact**
Legal	Political/Public
	Safety

26. Financial resources of and warranties (i.e., bond approval and surety) provided by the project developer.

Feasibility	**Impact**
Legal	
Economic	

27. Potential for adopting a value-based procurement strategy (e.g., include considerations beyond project cost, such as social benefits and environmental impacts).

Feasibility	**Impact**
Economic	Political/Public
	Environmental
	Social

28. Anticipated benefits to TxDOT (e.g., financial, technical, and social).

Feasibility	**Impact**
Technical	Political/Public
Economic	Social

29. Potential concerns anticipated by General Land Office (GLO) or another public agency (e.g., FHWA, DOE, and DOD).

Feasibility	**Impact**
Legal	Political/Public

30. Anticipated political and public opposition to solar project (e.g., controversy and potential impacts triggered by the "new" project).

Feasibility	**Impact**
	Political/Public

31. Potential risks and implications associated with considered business model (e.g., private-public-partnership, lease, easement, and sale), as well as incentives and REC ownership.

Feasibility	**Impact**
Legal	Political/Public
Economic	

32. Legal constraints/concerns that can impede or prevent the transaction/project.

Feasibility	**Impact**
Legal	

33. Available legal consultants/resources to implement TxDOT solar program.

Feasibility	**Impact**
Legal	
Economic	

34. Available legal consultants/resources to advise and review transactions and contractual agreements.

Feasibility	Impact
Legal	
Economic	

35. Resources required to train or acquire in-house legal resources/counsel.

Feasibility	Impact
Economic	Political/Public

36. TxDOT's exposure in terms of liability and risks (e.g., solar array relocation or damage).

Feasibility	Impact
Legal	Political/Public
Economic	

37. Investment required by TxDOT to implement the Value Extraction Application.

Feasibility	Impact
Economic	Political/Public

Wind Turbine (ROW & Vacant Land)

1. Trained in-house or consultant staff to analyze the project, specifications, and potential impacts, and challenges.

Feasibility	Impact
Technical	
Economic	

2. In-house staff member to champion the evaluation and implementation of the Value Extraction Application.

Feasibility	**Impact**
Technical	
Economic	

3. Available in-house or consultant safety and security experts to conduct safety assessment, advise the design, and provide insight in the drafting of the concept and leasing agreement.

Feasibility	**Impact**
Technical	Safety
Economic	

4. Interested parties (i.e., potential developers) have been identified or have approached TxDOT.

Feasibility	**Impact**
Technical	
Economic	

5. Project/application will assist TxDOT in meeting renewable energy consumption and carbon emissions goals.

Feasibility	**Impact**
Legal	Political/Public
Economic	Environmental

6. Project characteristics and potential impacts on traffic (e.g., driver distraction) and nearby community (e.g., property value, noise, shade, and tourism).

Feasibility	**Impact**
Technical	Political/Public
	Environmental
	Safety
	Social

7. Site characteristics (i.e., location, wind potential, clearances, access, and infrastructure) that could impact project/application feasibility.

Feasibility	**Impact**
Technical	Environmental
Economic	Safety

8. Anticipated future highway system needs (i.e., traffic volume, lanes, and clearances) that could require future road expansion.

Feasibility	**Impact**
Technical	Social
Legal	
Economic	

9. The wind project is designed and implemented as a component together with a new highway project (i.e., already included in the highway design).

Feasibility	**Impact**
Technical	
Economic	

10. Ability to communicate, involve, and share information with general public and stakeholders about the Value Extraction Application project (i.e., transparency and equal access to information).

Feasibility	**Impact**
Technical	Political/Public

11. Access to vendors/ wind turbine specialists (e.g., for installation and maintenance).

Feasibility	**Impact**
Technical	Political/Public
Economic	Social

12. Current TxDOT demand/need for electricity at the project site (e.g., lighting pole and signs).

Feasibility	**Impact**
Economic	

13. Ability/cost to connect to the grid (e.g., distance from transmission lines).

Feasibility	**Impact**
Technical	
Economic	

14. Need for backup system for wind project (i.e., battery or on-grid electricity source) to supply TxDOT's electricity needs.

Feasibility	**Impact**
Technical	Political/Public
Economic	Environmental
	Social

15. Available infrastructure (e.g., fiber optic or wireless signal) at site to support and facilitate monitoring and management of the wind energy project/output.

Feasibility	**Impact**
Technical	
Economic	

16. Current value (i.e., market/Real Estate value) of the property.

Feasibility	**Impact**
Technical	Political/Public
Legal	
Economic	

17. Formal procedures/guidelines available to conduct/implement wind energy project (i.e., agreement, design, construction, and maintenance).

Feasibility	**Impact**
Technical	Political/Public
Legal	

18. Potential impacts of the wind project on road maintenance and operations (e.g., impact of wind turbine installation and maintenance)

Feasibility	**Impact**
Technical	Safety
Economic	

19. Anticipated environmental impacts and mitigation measures.

Feasibility	**Impact**
Legal	Environmental
Economic	Social

20. Potential risk of accidents/unsafe situations (e.g., accidents, blade failure, fire, blade flickering, oil leaks, snow throw, driver distraction, clear zone, guard rails, and adequate access to site).

Feasibility	**Impact**
Technical	Environmental
Legal	Safety
Economic	

21. Compliance with Texas Highway Beautification Act (HBA).

Feasibility	**Impact**
Legal	Political/Public

22. Construction plan includes measures to avoid/reduce traffic congestion, noise, unsafe situations, accidents, and other negative community impacts.

Feasibility	**Impact**
Technical	Environmental
Economic	Safety
	Social

23. Required investments in technologies and systems.

Feasibility	**Impact**
Technical	
Economic	

24. Compliance with FHWA, AASTHO, National Electrical Code, Fire Protection Association, and other agency requirements.

Feasibility	**Impact**
Technical	Safety
Legal	
Economic	

25. Permit or license required to execute/construct project.

Feasibility	**Impact**
Legal	
Economic	

26. Potential interference with nearby telecommunication, radar, and/or wireless signals.

Feasibility	**Impact**
Legal	Political/Public
	Safety
	Social

27. Federal Aviation Administration (FAA) and Department of Defense (DOD) approved and granted permit for the project (i.e., if the project is located within 3-5 miles from a public or military airport, or the wind turbine is higher than 200ft)

Feasibility	**Impact**
Legal	
Economic	

28. Net metering applies.

Feasibility	**Impact**
Economic	

29. Federal and State incentives, as well as Renewable Energy Credits (REC) are available.

Feasibility	Impact
Economic	Political/Public

30. Potential concerns about “free access” to TxDOT’s property (i.e., land or ROW) by third party.

Feasibility	Impact
Legal	Political/Public
	Safety

31. Financial resources of and warranties (i.e., bond approval and surety) provided by the project developer.

Feasibility	Impact
Legal	
Economic	

32. Potential for adopting a value-based procurement strategy (e.g., include considerations beyond project cost, such as social benefits and environmental impacts).

Feasibility	Impact
Economic	Political/Public
	Environmental
	Social

33. Anticipated direct and indirect jobs created and economic development impacts resulting from the project.

Feasibility	**Impact**
Economic	Political/Public
	Social

34. Anticipated benefits to the region or state (e.g., increase local or state taxes).

Feasibility	**Impact**
Economic	Political/Public
	Environmental
	Safety
	Social

35. Anticipated benefits to TxDOT (e.g., financial, technical, and safety).

Feasibility	**Impact**
Technical	Political/Public
Economic	Safety
	Social

36. Potential concerns anticipated by General Land Office (GLO) or another public agency (e.g., FHWA, DOE, and DOD).

Feasibility	**Impact**
Legal	Political/Public

37. Potential conflict with zoning law, city's master plan, and transportation's plan.

Feasibility	**Impact**
Legal	Political/Public
	Social

38. Anticipated political and public opposition to wind energy project (e.g., controversy and potential impacts triggered by the "new" project).

Feasibility	Impact
	Political/Public

39. Potential risks and implications associated with considered business model (e.g., private-public-partnership, lease, easement, and sale), as well as incentives and REC ownership.

Feasibility	Impact
Legal	Political/Public
Economic	

40. Legal constraints/concerns that can impede or prevent the transaction/project.

Feasibility	Impact
Legal	

41. Patents and associated costs that could impact project/application feasibility.

Feasibility	Impact
Legal	
Economic	

42. Available legal consultants/resources to implement TxDOT wind program.

Feasibility	Impact
Legal	
Economic	

43. Available legal consultants/resources to advise and review transactions and contractual agreements.

Feasibility	Impact
Legal	
Economic	

44. Resources required to train or acquire in-house legal resources/counsel.

Feasibility	Impact
Economic	Political/Public

45. TxDOT's exposure in terms of liability and risks (e.g., wind turbine relocation or damage).

Feasibility	Impact
Legal	Political/Public
Economic	

46. Investment required by TxDOT to implement the Value Extraction Application.

Feasibility	Impact
Economic	Political/Public

Wind Turbine (Office & Facilities)

1. Trained in-house or consultant staff to analyze the project, specifications, and potential impacts, and challenges.

Feasibility	Impact
Technical	
Economic	

2. In-house staff member to champion the evaluation and implementation of the Value Extraction Application

Feasibility	**Impact**
Technical	
Economic	

3. Available in-house or consultant safety and security experts to conduct safety assessment, advise the design, and provide insight in the drafting of the concept and leasing agreement.

Feasibility	**Impact**
Technical	Safety
Economic	

4. Interested parties (i.e., potential developers) have been identified or approached TxDOT.

Feasibility	**Impact**
Technical	
Economic	

5. Project/application will assist TxDOT in meeting renewable energy consumption and carbon emissions goals.

Feasibility	**Impact**
Legal	Political/Public
Economic	Environmental

6. Project characteristics and potential impacts on traffic (e.g., driver distraction) and nearby community (e.g., property value, noise, shade, and tourism) that could impact project/application feasibility.

Feasibility	**Impact**
Technical	Political/Public
	Environmental
	Safety
	Social

7. Site/building characteristics for implementation of the wind system project (i.e., location, wind potential, access, and infrastructure) that could impact project/application feasibility.

Feasibility	**Impact**
Technical	
Economic	

8. Building/facility's electrical system has been/can be retrofitted to use wind system.

Feasibility	**Impact**
Technical	
Economic	

9. The roof area/external area is large enough to generate sufficient energy to meet the building/facility's energy demand.

Feasibility	**Impact**
Economic	Environmental

10. The wind project is financially feasible.

Feasibility	Impact
Economic	

11. The wind project is designed and implemented as a component of building/facility (i.e., included in the building/facility design).

Feasibility	Impact
Technical	
Economic	

12. Ability to communicate, involve, and share information with general public and stakeholders about the Value Extraction Application project (i.e., transparency and equal access to information).

Feasibility	Impact
Technical	Political/Public

13. Access to vendors/ wind turbine specialists (e.g., for installation and maintenance).

Feasibility	Impact
Technical	Political/Public
Economic	Social

14. Current TxDOT demand/need for electricity at the site (e.g., building/facility electricity usage).

Feasibility	Impact
Economic	

15. Ability/cost to connect to the grid (e.g., distance from transmission lines).

Feasibility	**Impact**
Technical	
Economic	

16. Need for backup system for wind project (i.e., battery or on-grid electricity source) to supply TxDOT's electricity needs.

Feasibility	**Impact**
Technical	Political/Public
Economic	Environmental
	Social

17. Formal procedures/guidelines available to conduct/implement wind energy project (i.e., agreement, design, construction, and maintenance).

Feasibility	**Impact**
Technical	Political/Public
Legal	

18. Anticipated environmental impacts and mitigation measures.

Feasibility	**Impact**
Legal	Environmental
Economic	Social

19. Potential risk of accidents/unsafe situations (e.g., accident, electrical shock, blade failure, fire, blade flickering, oil leak, and snow throw).

Feasibility	**Impact**
Technical	Safety
Legal	
Economic	

20. Required investments in technologies and systems.

Feasibility	**Impact**
Technical	
Economic	

21. Compliance with FHWA, AASTHO, National Electrical Code, Fire Protection Association, and other agency requirements.

Feasibility	**Impact**
Technical	Safety
Legal	
Economic	

22. Permit or license required to execute/construct project.

Feasibility	**Impact**
Legal	
Economic	

23. Potential interference with nearby telecommunication, radar, and/or wireless signal.

Feasibility	**Impact**
Legal	Political/Public
	Safety
	Social

24. Federal Aviation Administration (FAA) and Department of Defense (DOD) approved and granted permit for the project (i.e., if the project is located within 3-5 miles from a public or military airport, or the wind turbine is higher than 200ft).

Feasibility	**Impact**
Legal	
Economic	

25. Net metering applies.

Feasibility	**Impact**
Economic	

26. Federal and State incentives, as well as Renewable Energy Credits (REC) are available.

Feasibility	**Impact**
Economic	Political/Public

27. Potential concerns about "free access" to TxDOT's property (i.e., office and facility) by third party.

Feasibility	**Impact**
Legal	Political/Public
	Safety

28. Financial resources of and warranties (i.e., bond approval and surety) provided by the project developer.

Feasibility	**Impact**
Legal	
Economic	

29. Potential for adopting a value-based procurement strategy (e.g., include considerations beyond project cost, such as social benefits and environmental impacts).

Feasibility	Impact
Economic	Political/Public
	Environmental
	Social

30. Anticipated benefits to TxDOT (e.g., financial, technical, and social).

Feasibility	Impact
Technical	Political/Public
Economic	Social

31. Potential concerns anticipated by General Land Office (GLO) or another public agency (e.g., FHWA, DOE, and DOD).

Feasibility	Impact
Legal	Political/Public

32. Anticipated political and public opposition to transaction (e.g., controversy and potential impacts triggered by the "new" project).

Feasibility	Impact
	Political/Public

33. Potential risks and implications associated with considered business model (e.g., private-public-partnership, lease, easement, and sale), as well as incentives and REC ownership.

Feasibility	Impact
Legal	Political/Public
Economic	

34. Legal constraints/concerns that can impede or prevent the transaction/project.

Feasibility	**Impact**
Legal	

35. Available legal consultants/resources to implement TxDOT wind program.

Feasibility	**Impact**
Legal	
Economic	

36. Available legal consultants/resources to advise and review transactions and contractual agreements.

Feasibility	**Impact**
Legal	
Economic	

37. Resources required to train or acquire in-house legal resources/counsel.

Feasibility	**Impact**
Economic	Political/Public

38. TxDOT's exposure in terms of liability and risks (e.g., wind turbine relocation or damage).

Feasibility	**Impact**
Legal	Political/Public
Economic	

39. Investment required by TxDOT to implement the Value Extraction Application.

Feasibility	**Impact**
Economic	Political/Public

Geothermal Energy

1. Trained in-house or consultant staff to analyze the project, specifications, and potential impacts, and challenges.

Feasibility	**Impact**
Technical	
Economic	

2. In-house staff member to champion the evaluation and implementation of the Value Extraction Application.

Feasibility	**Impact**
Technical	
Economic	

3. Available in-house or consultant safety and security experts to conduct safety assessment, advise the design, and provide insight in the drafting of the concept and leasing agreement.

Feasibility	**Impact**
Technical	Safety
Economic	

4. Interested parties (i.e., potential developers) have been identified or have approached TxDOT.

Feasibility	**Impact**
Technical	
Economic	

5. Project/application will assist TxDOT in meeting renewable energy consumption and carbon emissions goals.

Feasibility	**Impact**
Legal	Political/Public
Economic	Environmental

6. Project characteristics and potential impacts on traffic (e.g., driver distraction) and nearby community (e.g., property value, noise, steam, water disposal, and aquifer).

Feasibility	**Impact**
Technical	Political/Public
	Environmental
	Safety
	Social

7. Site characteristics (i.e., location, clearances, visibility, access, and infrastructure) that could impact project/application feasibility.

Feasibility	**Impact**
Technical	Environmental
Economic	Safety

8. Quality of the underground resource (i.e., temperature, depth, water, ease to drill) is coherent with the intended application (i.e., direct use of hot water, geothermal heat pump, pavement de-icing, and electricity generation).

Feasibility	**Impact**
Technical	
Economic	

9. The roof and/or external area is large enough to install the geothermal energy system (i.e., power plant and/or geothermal heat pump) demanded in the building/facility or to generate sufficient energy to the building/facility's energy demand.

Feasibility	**Impact**
Technical	Environmental
Economic	

10. The geothermal project is financially feasible.

Feasibility	**Impact**
Economic	

11. Anticipated future highway system needs (i.e., traffic volume, lanes, and clearances) that could require future road expansion.

Feasibility	**Impact**
Technical	Social
Legal	
Economic	

12. The geothermal energy is designed and implemented as a component together with a new highway or building project (i.e., already included in the highway or building design).

Feasibility	**Impact**
Technical	
Economic	

13. Building/facility's electrical and/or HVAC systems have been/can be retrofitted to use geothermal energy (i.e., power plant and/or geothermal heat pump).

Feasibility	**Impact**
Technical	
Economic	

14. Ability to communicate, involve, and share information about the project/application with general public and stakeholders (i.e., transparency and equal opportunity).

Feasibility	**Impact**
Technical	Political/Public

15. Access to vendors/ geothermal energy specialists (e.g., for installation and maintenance).

Feasibility	**Impact**
Technical	Political/Public
Economic	Social

16. Current TxDOT demand/need for electricity at the project site (e.g., lighting pole and signs).

Feasibility	**Impact**
Economic	

17. Ability/cost to connect to the grid (e.g., distance from transmission lines).

Feasibility	**Impact**
Technical	
Economic	

18. Available infrastructure (e.g., fiber optic or wireless signal) at site to support and facilitate monitoring and management of the project/output.

Feasibility	**Impact**
Technical	
Economic	

19. Current value (i.e., market/Real Estate value) of the property.

Feasibility	**Impact**
Technical	Political/Public
Legal	
Economic	

20. Formal procedures/guidelines available to conduct/implement geothermal energy project (i.e., agreement, design, construction, and maintenance).

Feasibility	**Impact**
Technical	Political/Public
Legal	

21. Potential impacts of the geothermal project on road maintenance and operations (e.g., impact of geothermal system installation and maintenance).

Feasibility	**Impact**
Technical	Safety
Economic	

22. Anticipated environmental impacts and mitigation measures.

Feasibility	**Impact**
Legal	Environmental
Economic	Social

23. Potential risk of accidents/unsafe situations (e.g., steam, water, icing, snow, roadside erosion, explosion, fire, pavement failure, clear zones, and guard rails).

Feasibility	**Impact**
Technical	Environmental
Legal	Safety
Economic	

24. Compliance with Texas Highway Beautification Act (HBA).

Feasibility	**Impact**
Legal	Political/Public

25. Construction plan includes measures to avoid/reduce traffic congestion, noise, unsafe situations, accidents, and other negative community impacts.

Feasibility	**Impact**
Technical	Environmental
Economic	Safety
	Social

26. Required investments in technologies and systems.

Feasibility	**Impact**
Technical	
Economic	

27. Compliance with FHWA, AASTHO, National Electrical Code, Fire Protection Association, and other agency requirements.

Feasibility	**Impact**
Technical	Safety
Legal	
Economic	

28. Permit or license required to execute/construct project, including use of underground resources.

Feasibility	Impact
Legal	
Economic	

29. Federal Aviation Administration (FAA) has approved and granted permit for the project (i.e., if the project is located within 3-5 miles from a public or military airport).

Feasibility	Impact
Legal	
Economic	

30. Net metering applies.

Feasibility	Impact
Economic	

31. Federal and State incentives, as well as Renewable Energy Credits (REC) are available.

Feasibility	Impact
Economic	Political/Public

32. Potential concerns about "free access" to TxDOT's property (i.e., facility, land, or ROW) by third party.

Feasibility	Impact
Legal	Political/Public
	Safety

33. Financial resources of and warranties (i.e., bond approval and surety) provided by the project developer.

Feasibility	**Impact**
Legal	
Economic	

34. Potential for adopting a value-based procurement strategy (e.g., include considerations beyond project cost, such as social benefits and environmental impacts).

Feasibility	**Impact**
Economic	Political/Public
	Environmental
	Social

35. Anticipated direct and indirect jobs created and economic development impacts resulting from the project.

Feasibility	**Impact**
Economic	Political/Public
	Social

36. Anticipated benefits to the region or state (e.g., increase local or state taxes).

Feasibility	**Impact**
Economic	Political/Public
	Environmental
	Social

37. Anticipated benefits to TxDOT (e.g., financial, technical, and safety).

Feasibility	**Impact**
Technical	Safety
Economic	

38. Potential concerns anticipated by General Land Office (GLO) or another public agency (e.g., FHWA, DOE, and DOD).

Feasibility	**Impact**
Legal	Political/Public

39. Potential conflict with zoning law, city's master plan, and transportation's plan.

Feasibility	**Impact**
Legal	Political/Public
	Social

40. Anticipated political and public opposition to transaction (e.g., controversy and potential impacts triggered by the "new" project).

Feasibility	**Impact**
	Political/Public

41. Potential risks and implications associated with considered business model (e.g., private-public-partnership, lease, easement, and sale), as well as incentives and REC ownership.

Feasibility	**Impact**
Legal	Political/Public
Economic	

42. Legal constraints/concerns that can impede or prevent the transaction/project, including ownership over underground resources.

Feasibility	**Impact**
Legal	

43. Patents and associated costs that could impact project/application feasibility.

Feasibility	**Impact**
Legal	
Economic	

44. Available legal consultants/resources to implement TxDOT's geothermal energy program.

Feasibility	**Impact**
Legal	
Economic	

45. Available legal consultants/resources to advise and review transactions and contractual agreements.

Feasibility	**Impact**
Legal	
Economic	

46. Resources required to train or acquire in-house legal resources/counsel.

Feasibility	**Impact**
Economic	Political/Public

47. TxDOT's exposure in terms of liability and risks (e.g., geothermal system relocation or damage).

Feasibility	Impact
Legal	Political/Public
Economic	

48. Investment required by TxDOT to implement the Value Extraction Application.

Feasibility	Impact
Economic	Political/Public

Carbon Sequestration

1. Trained in-house or consultant staff to analyze the project, and potential impacts, and challenges.

Feasibility	Impact
Technical	
Economic	

2. In-house staff member to champion the evaluation and implementation of the Value Extraction Application.

Feasibility	Impact
Technical	
Economic	

3. Available in-house or consultant safety and security experts to conduct safety assessment, advise the design, and provide insight in the drafting of the concept and leasing agreement.

Feasibility	Impact
Technical	Safety
Economic	

4. Available in-house or consultant carbon sequestration experts (i.e., carbon verifier and carbon aggregator) to participate in the implementation.

Feasibility	**Impact**
Technical	
Economic	

5. Project/application will assist TxDOT in meeting carbon emission goals.

Feasibility	**Impact**
Legal	Political/Public
Economic	Environmental

6. Project characteristics and potential impacts on traffic, utilities, community, and environment (e.g., drainage).

Feasibility	**Impact**
Technical	Political/Public
	Environmental
	Safety
	Social

7. Site characteristics (i.e., location, soil quality, average rainfall, visibility, access, and infrastructure) that could impact project/application feasibility.

Feasibility	**Impact**
Technical	Environmental
Economic	Safety

8. Anticipated future highway system needs (i.e., traffic volume, lanes, and clearances) that could require future road expansion.

Feasibility	**Impact**
Technical	Social
Legal	
Economic	

9. The carbon sequestration program is designed and implemented as a component together with a new highway project (i.e., already included in the highway design).

Feasibility	**Impact**
Technical	
Economic	

10. Anticipated potential of sequestrating carbon from the existing/native vegetation.

Feasibility	**Impact**
Technical	Environment
Economic	

11. Current carbon sequestration baseline at the site has been established.

Feasibility	**Impact**
Technical	
Economic	

12. Amount of "additional carbon" that is expected to potentially be sequestrated with the carbon sequestration program.

Feasibility	**Impact**
Economic	Environment

13. Available carbon sequestration protocol for the vegetation envisioned to be used.

Feasibility	**Impact**
Technical	

14. Carbon market (i.e., formal or informal) to trade or sell carbon credits and current carbon price (i.e., flotation) have been identified.

Feasibility	**Impact**
Technical	
Economic	

15. Ability to communicate, involve, and share information about the project/application with general public and stakeholders (i.e., transparency).

Feasibility	**Impact**
Technical	Political/Public

16. Formal procedures/guidelines available to conduct/implement TxDOT's carbon sequestration program (i.e., agreement, trade, and vegetation).

Feasibility	**Impact**
Technical	Political/Public
Legal	

17. Potential impacts of the carbon sequestration project on road maintenance and operations.

Feasibility	**Impact**
Technical	Safety
Economic	

18. Anticipated environmental impacts and mitigation measures.

Feasibility	**Impact**
Legal	Environmental
Economic	Social

19. Potential risk of accidents/unsafe situations (e.g., safety zone, animal attraction, roadside erosion, runoff water, and guard rails).

Feasibility	**Impact**
Technical	Environmental
Legal	Safety
Economic	

20. Compliance with Texas Highway Beautification Act (HBA).

Feasibility	**Impact**
Legal	Political/Public

21. Current State programs (HBA, Wildflower, and Green Ribbon projects) and existing obligations to plant along the highways (i.e., that could be used to receive carbon credits).

Feasibility	**Impact**
Legal	Political/Public
Economic	

22. Compliance with FHWA, AASTHO, and other agency requirements.

Feasibility	**Impact**
Technical	Safety
Legal	
Economic	

23. Federal and State incentives, as well as Renewable Energy Credits (REC) are available.

Feasibility	**Impact**
Economic	Political/Public

24. Anticipated direct and indirect jobs created and economic development impacts resulting from the project.

Feasibility	**Impact**
Economic	Political/Public
	Social

25. Anticipated benefits to the region or state (e.g., increase local or state taxes).

Feasibility	**Impact**
Economic	Political/Public
	Environmental
	Social

26. Anticipated benefits to TxDOT (e.g., financial, technical, and safety).

Feasibility	**Impact**
Technical	Safety
Economic	

27. Potential concerns anticipated by the General Land Office (GLO) or another public agency (e.g., FHWA, DOE, DOD, and utility company).

Feasibility	**Impact**
Legal	Political/Public

28. Potential conflict with zoning law, city's master plan, and transportation's plan

Feasibility	Impact
Legal	Political/Public
	Social

29. Anticipated political and public opposition to carbon sequestration project (e.g., controversy and potential impacts triggered by the "new" project).

Feasibility	Impact
	Political/Public

30. Potential risks and implications associated with considered business model (e.g., private-public-partnership, lease, easement, and sale), as well as incentives and REC ownership.

Feasibility	Impact
Legal	Political/Public
Economic	

31. Legal constraints/concerns that can impede or prevent the transaction/project, including participation in carbon market and ownership over carbon credits.

Feasibility	Impact
Legal	

32. Available legal consultants/resources to implement TxDOT carbon sequestration program.

Feasibility	Impact
Legal	
Economic	

33. Available legal consultants/resources to advise and review transactions and contractual agreements.

Feasibility	Impact
Legal	
Economic	

34. Resources required to train or acquire in-house legal resources/counsel.

Feasibility	Impact
Economic	Political/Public

35. TxDOT's exposure in terms of liability and risks (e.g., damage on vegetation).

Feasibility	Impact
Legal	Political/Public
Economic	

36. Investment required by TxDOT to implement the Value Extraction Application.

Feasibility	Impact
Economic	Political/Public

Biomass & Biofuel

1. Trained in-house or consultant staff to analyze the project, specifications, and potential impacts, and challenges.

Feasibility	Impact
Technical	
Economic	

2. In-house staff member to champion the evaluation and implementation of the Value Extraction Application.

Feasibility	**Impact**
Technical	
Economic	

3. Available in-house or consultant safety and security experts to conduct safety assessment, advise the design, and provide insight in the drafting of the concept and leasing agreement.

Feasibility	**Impact**
Technical	Safety
Economic	

4. Interested parties (i.e., farmers or private companies) have been identified or approached TxDOT.

Feasibility	**Impact**
Technical	
Economic	

5. Available in-house or consultant biomass & biofuel specialists (e.g., agronomist).

Feasibility	**Impact**
Technical	
Economic	

6. Project/application will assist TxDOT in meeting renewable energy and carbon emission goals.

Feasibility	**Impact**
Legal	Political/Public
Economic	Environmental

7. Project characteristics and potential impacts on traffic, utilities, community, and environment (e.g., drainage and property value).

Feasibility	**Impact**
Technical	Political/Public
	Environmental
	Safety
	Social

8. Site characteristics (i.e., location, soil quality and compaction, average rainfall, ease to mow, logistics, clearances, visibility, access, and infrastructure) that could impact project/application feasibility.

Feasibility	**Impact**
Technical	Environmental
Economic	Safety

9. Anticipated future highway system needs (i.e., traffic volume, lanes, and clearances) that could require future road expansion.

Feasibility	**Impact**
Technical	Social
Legal	
Economic	

10. The biomass & biofuel program is designed and implemented as a component together with a new highway project (i.e., already included in the highway design).

Feasibility	**Impact**
Technical	
Economic	

11. Needs for fertilize, herbicide, and/or irrigation.

Feasibility	**Impact**
Technical	Political/Public
Economic	Environmental

12. Potential yield and biofuel production capacity of the crop/vegetation.

Feasibility	**Impact**
Technical	
Economic	

13. Available biomass & biofuel market to trade or process biomass (e.g., biorefinery).

Feasibility	**Impact**
Technical	
Economic	

14. Ability to communicate, involve, and share information with general public and stakeholders about the Value Extraction Application project (i.e., transparency and equal access to information).

Feasibility	**Impact**
Technical	Political/Public

15. Current value (i.e., market/Real Estate value) of the property.

Feasibility	**Impact**
Technical	Political/Public
Legal	
Economic	

16. Formal procedures/guidelines available to conduct/implement TxDOT's biomass & biofuel program (i.e., agreement, trade, biofuel refine, and farming procedures).

Feasibility	**Impact**
Technical	Political/Public
Legal	

17. Potential impacts of biomass & biofuel program on road maintenance and operations (e.g., impacts of planting, harvesting, and transporting biomass).

Feasibility	**Impact**
Technical	Safety
Economic	

18. Anticipated environmental impacts and mitigation measures.

Feasibility	**Impact**
Legal	Environmental
Economic	Social

19. Potential risk of accidents/unsafe situations (e.g., safety zone, machinery access, animal attraction, roadside erosion, runoff water, and guard rails).

Feasibility	**Impact**
Technical	Environmental
Legal	Safety
Economic	

20. Compliance with Texas Highway Beautification Act (HBA) and Wildflower program.

Feasibility	**Impact**
Legal	Political/Public

21. Current State programs (HBA, Wildflower, and Green Ribbon projects) and existing obligations to plant along the highways (i.e., that could be used to extract biomass & biofuel).

Feasibility	**Impact**
Legal	Political/Public
Economic	

22. Existing training requirements (i.e., safety) and traffic control plan to staff and third parties involved in planting and harvesting.

Feasibility	**Impact**
Technical	Safety
Economic	

23. Compliance with FHWA, AASTHO, and other agency requirements.

Feasibility	**Impact**
Technical	Safety
Legal	
Economic	

24. Permit or license required to execute/construct project (e.g., agricultural activities on public land).

Feasibility	**Impact**
Legal	
Economic	

25. Federal and State incentives, as well as Renewable Energy Credits (REC) are available.

Feasibility	**Impact**
Economic	Political/Public

26. Potential concerns about “free access” to TxDOT’s property (i.e., land and ROW) by third party.

Feasibility	**Impact**
Legal	Political/Public
	Safety

27. Anticipated direct and indirect jobs created and economic development impacts resulting from the project.

Feasibility	**Impact**
Economic	Political/Public
	Social

28. Anticipated benefits to the region or state (e.g., increase local or state taxes).

Feasibility	**Impact**
Economic	Political/Public
	Environmental
	Social

29. Anticipated benefits to TxDOT (e.g., financial, technical, and safety).

Feasibility	**Impact**
Technical	Safety
Economic	

30. Potential concerns anticipated by the General Land Office (GLO) or another public agency (e.g., FHWA, DOE, DOD, and utility company).

Feasibility	**Impact**
Legal	Political/Public

31. Potential conflict with zoning law, city's master plan, and transportation's plan.

Feasibility	**Impact**
Legal	Political/Public
	Social

32. Anticipated political and public opposition to biomass & biofuel project (e.g., controversy and potential impacts triggered by the "new" project).

Feasibility	**Impact**
	Political/Public

33. Potential risks and implications associated with considered business model (e.g., private-public-partnership, lease, easement, and sale), as well as incentives and REC ownership.

Feasibility	**Impact**
Legal	Political/Public
Economic	

34. Legal constraints/concerns that can impede or prevent the transaction/project, including ownership over biomass harvested.

Feasibility	**Impact**
Legal	

35. Patents and associated costs that could impact project/application feasibility.

Feasibility	**Impact**
Legal	
Economic	

36. Available legal consultants/resources to implement TxDOT biomass & biofuel program.

Feasibility	Impact
Legal	
Economic	

37. Available legal consultants/resources to advise and review transactions and contractual agreements.

Feasibility	Impact
Legal	
Economic	

38. Resources required to train or acquire in-house legal resources/counsel.

Feasibility	Impact
Economic	Political/Public

39. TxDOT's exposure in terms of liability and risks (e.g., damage on plantation).

Feasibility	Impact
Legal	Political/Public
Economic	

40. Investment required by TxDOT to implement the Value Extraction Application.

Feasibility	Impact
Economic	Political/Public

Wildlife Crossing

1. Trained in-house or consultant staff to analyze the project, specifications, and potential impacts, and challenges.

Feasibility	**Impact**
Technical	
Economic	

2. In-house staff member to champion the evaluation and implementation of the Value Extraction Application.

Feasibility	**Impact**
Technical	
Economic	

3. Available in-house or consultant safety and security experts to conduct safety assessment, advise the design, and provide insight in the drafting of the concept and leasing agreement.

Feasibility	**Impact**
Technical	Safety
Economic	

4. Available in-house staff to specify and oversee design and construction of the project.

Feasibility	**Impact**
Technical	
Economic	

5. Available in-house or consultant wildlife crossing experts to conduct and advise design concept.

Feasibility	Impact
Technical	
Economic	

6. Target species (e.g., deer, reptiles, and small mammals) have been identified.

Feasibility	Impact
Technical	

7. Available data/information on animal migratory routes and movement (i.e., hot spot location).

Feasibility	Impact
Technical	

8. Project characteristics and potential impacts on traffic and community (e.g., habitat integration and wildlife preservation).

Feasibility	Impact
Technical	Political/Public
	Environmental
	Safety
	Social

9. Site characteristics (i.e., location, clearances, visibility, and infrastructure) that could impact project/application feasibility.

Feasibility	Impact
Technical	Environmental
Economic	Safety

10. Anticipated future highway system needs (i.e., traffic volume, lanes, and clearances) that could require future road expansion.

Feasibility	**Impact**
Technical	Social
Legal	
Economic	

11. Frequency of occurrence of fatal accidents resulted from vehicle-animal-crash at the site and potential reduction with the wildlife crossing project.

Feasibility	**Impact**
Legal	Political/Public
Economic	Safety

12. The wildlife crossing project is designed and implemented as a component together with a new highway project (i.e., already included in the highway design).

Feasibility	**Impact**
Technical	
Economic	

13. Available infrastructure (e.g., fiber optic and wireless signal) at the site to support and facilitate monitoring and management of effectiveness and use of the wildlife crossing project.

Feasibility	**Impact**
Technical	
Economic	

14. Ability to communicate, involve, and share information with general public and stakeholders about the Value Extraction Application project (i.e., transparency and equal access to information).

Feasibility	**Impact**
Technical	Political/Public

15. Formal procedures/guidelines available to conduct/implement TxDOT's wildlife crossing program (i.e., agreement, design, construction, and maintenance).

Feasibility	**Impact**
Technical	Political/Public
Legal	

16. Potential impacts of the wildlife crossing project on road maintenance and operations.

Feasibility	**Impact**
Technical	Safety
Economic	

17. Anticipated environmental impacts and mitigation measures.

Feasibility	**Impact**
Legal	Environmental
Economic	Social

18. Potential risk of accidents/unsafe situations (e.g., clear zone, clear sight, lighting, signs, traffic control, access, fence, and guard rail, as well as during construction) and mitigation measurements.

Feasibility	**Impact**
Technical	Safety
Legal	
Economic	

19. Existing training requirements (i.e., safety) and traffic control plan to staff and third parties involved in the construction of the wildlife crossing.

Feasibility	**Impact**
Technical	Safety
Economic	

20. Compliance with FHWA, AASTHO, and other agency requirements.

Feasibility	**Impact**
Technical	Safety
Legal	
Economic	

21. Permit or license required to execute/construct project.

Feasibility	**Impact**
Legal	
Economic	

22. Federal and State funds and/or incentives for wildlife crossing projects are available.

Feasibility	**Impact**
Economic	Political/Public

23. Anticipated sponsors for wildlife crossing projects (e.g., ONGs and insurance companies).

Feasibility	**Impact**
Legal	Political/Public
Economic	

24. Anticipated car insurance cost reduction. .

Feasibility	**Impact**
Economic	Political/Public
	Social

25. Anticipated direct and indirect jobs created and economic development impacts resulting from the project.

Feasibility	**Impact**
Economic	Political/Public
	Social

26. Anticipated benefits to TxDOT (e.g., financial, technical, and safety).

Feasibility	**Impact**
Technical	Political/Public
Economic	Safety

27. Potential concerns anticipated by the General Land Office (GLO) or another public agency (e.g., FHWA, DOE, DOD, and utility company).

Feasibility	**Impact**
Legal	Political/Public

28. Potential conflict with zoning law, city's master plan, and transportation's plan.

Feasibility	Impact
Legal	Political/Public
	Social

29. Anticipated political and public opposition to wildlife crossing project (e.g., controversy and potential impacts triggered by the "new" project).

Feasibility	Impact
	Political/Public

30. Potential risks and implications associated with considered business model (e.g., private-public-partnership, lease, easement, and sale), including incentives, sponsorship, and donation.

Feasibility	Impact
Legal	Political/Public
Economic	

31. Legal constraints/concerns that can impede or prevent the transaction/project.

Feasibility	Impact
Legal	

32. Available legal consultants/resources to implement TxDOT's wildlife crossing program.

Feasibility	Impact
Legal	
Economic	

33. Available legal consultants/resources to advise and review transactions and contractual agreements.

Feasibility	**Impact**
Legal	
Economic	

34. Resources required to train or acquire in-house legal resources/counsel.

Feasibility	**Impact**
Economic	Political/Public

35. TxDOT's exposure in terms of liability and risks (i.e., during construction and after completion).

Feasibility	**Impact**
Legal	Political/Public
Economic	

36. Investment required by TxDOT to implement the Value Extraction Application.

Feasibility	**Impact**
Economic	Political/Public

APPENDIX V: SUMMARY OF BEST PRACTICES AND PILOT PROJECTS

Property Management

The California Department of Transportation (Caltrans) is the best example of how to implement a robust, efficient, and successful property management program. Caltrans' property management program revolves around a well-developed and comprehensive website that contains detailed information regarding auction procedures, leasing guidelines, and property announcements. Currently, Caltrans has about 12 managers and 48 employees in 12 districts involved in property management, whom are not dedicated 100% to the program. In summary, the property management program is divided into three value extraction functions: Airspace & ROW leasing, property management, and excess land sales. The airspace leasing component generated about $25 million in FY2009 with the leasing of airspace beneath viaducts for parking lots, leasing airspace over freeways, and leasing right-of-ways for telecommunication antennas. The property management division has secured about $12 millions in revenue per year, mostly from the leasing of property in two significant corridors owned by Caltrans. Finally, the excess land component is responsible for lands or properties that are not needed or will not be used within 20 years and secured nearly $11.5 million in revenue that came from selling 290 parcels.

Property Management (Rest Area)

The Interstate Oasis program was launched in 2006 by the FHWA to overcome the problem of a lack of rest areas and the barriers to rest area privatization, as well as to reduce the financial and administrative costs of the State DOTs. Interstate Oasis program is a public-private-partnership defined by FHWA as an off-freeway facility that aims to supplement the public rest area. To qualify as an Interstate Oasis, the facility has to comply with a list of requirements and specifications, including a standardized design, offering of products and services to the public, 24-hour access to restrooms, and parking

for autos and heavy trucks. Furthermore, a specific and unique logo has to be adopted to identify the units that are part of the program.

Another important example of how to extract value from rest areas is presented by the Oases complex in Illinois. The complex comprises seven private and commercialized rest areas that are located on the I-294/94, I-90, and I-88 tollways and offers several services, such as gas station, car wash, food court, shopping, and ATM.

Airspace Leasing (Building)

In Boston, the airspace over the Massachusetts Turnpike holds at least three formalized airspace leasing agreements for buildings, which have been topic of research, inclusively. The first is the Copley Place, a 3.5 million square-feet complex constructed in 1986 that comprises hotel, retail store, office, parking and housing. The second in Columbus Center, a complex of buildings that occupies 7 acres divided into 4 parcels of air rights and totalizes 1.4 million square-feet of construction. The Columbus Center consists of hotel, restaurant, retail store, health club, residential building, and parking. The last is The One Kenmore that occupies 1 parcel of airspace and is still in development. When concluded, The One Kenmore will have 1.2 million square-feet of construction, including office, health club, grocery store, community center, and parking. The economic feasibility of all three projects was ensured by an airspace premium funding granted by the City of Boston. This fund was needed because the land value in Boston in the outset of the projects was not yet high to spark and encourage private investment. In terms of benefits, the City of Boston could reconnect the neighbors that have been divided by the highway corridor, generate new tax revenue, and create permanent jobs with the economic development.

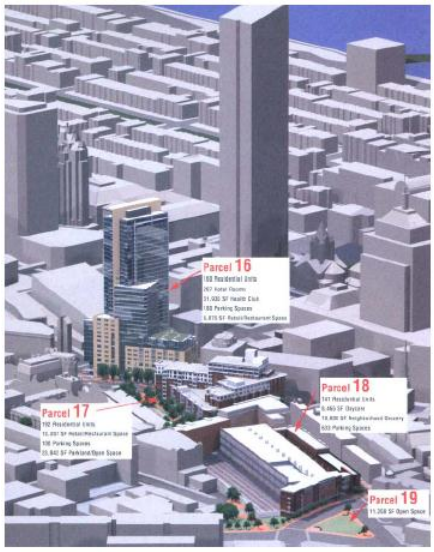

Figure V.1: Boston Airspace Program
Source: Savvides (2005)

Airspace Leasing (Parking lot)

The California Department of Transportation (Caltrans) has extensively used airspace leasing for parking lots as a value extraction application. Caltrans has entered into both long-term and short-term leasing agreement for parking. In general, the private sector has approached Caltrans to lease available spaces. Some parking lot structures are, however, leased to parking companies via a competitive bid for two or three years. To announce the bidding process, Caltrans resorts to Frameworks such as, Craigslist and email. In addition, park-and-ride lots usually somewhat distant from downtown areas are typically leased to independent car sellers or for community events on, for example, weekends. These park-and-ride leases, usually, involve community centers that are responsible for providing security and cleaning the area. The community centers, typically, pay a lower rate for leasing the park-and-ride lot. Caltrans currently has around 400 parking lot leasing agreements that generate a reasonable level of income.

In Texas, some examples of parking lots beneath TxDOT highways can also be encountered. However, TxDOT comments that the agreement typically involves other public agency (e.g., city, court house, and DPS) and does not include any financial payment or benefit.

Airspace Leasing (Utilities)

In 1999, "The Florida DOT reached a 30-year lease agreement with Lodestar Towers, Inc., allowing Lodestar Towers, Inc. to lease access to the Department's limited access rights-of-way in return for compensation formulated as a percentage of the gross revenues received from renting antenna space to commercial wireless service providers". The public private lease agreement was developed in compliance with the Department's Telecommunications Policy, whose goal is "to consolidate wireless tower use to the Department's limited access rights-of-way by providing equal access and opportunity to all wireless service providers. This strategy encourages wireless service providers to

collocate on towers located on the Department's limited access rights-of-way instead of developing numerous new tower sites in local communities. The resulting reduction of the number of towers and the location of needed towers as far from residential areas as possible facilitates the intent of the lease to support the wireless service providers while minimizing wireless tower proliferation". "To date, Lodestar Towers, Inc. has constructed 26 towers on the Department's rights-of-way. Another 22 proposed towers are under siting and design review by the Department" (Florida ITS, 2001).

Figure V.2: Antenna Tower

Source: Florida ITS (2001)

The California Department of Transportation (Caltrans) received $7.3 million in revenue in FY 2008 from its airspace leasing program, of which $1.3 million came from 52 cell towers (Caltrans, 2009). Caltrans's Leasing Program Administration personnel regard the cost-effectiveness of cell towers to be a major benefit. Cell towers do not require extensive maintenance on the sites and generate reasonable revenues (Caltrans, 2009). Caltrans's Airspace program for telecommunications is administrated by an agent and five-person team that are responsible for managing the relationship with renters, seeking business opportunities, and implementing the procedures needed for leasing (Caltrans, 2009). Most of the airspace leasing agreements involve telecommunication providers, which encompass 20 different companies. Most of the telecommunication leasing agreements are located in urban areas (about 90%) and all of them are in accordance with the Caltrans's master license agreement that grants a 5 year license for a specific site, with the option to renew the license five times for 5 years each.

In Texas, TxDOT estimates to receive between $2 million to $4 million from an informal and inactive program. TxDOT also believes that formalizing this program could bring more management efficiency and incomes to the state.

Advertising

In Washington, Rest areas are equipped with brochure dispensers that are rented to vendors and companies. The vendor can rent dispenser space at a rest area or at several rest areas (i.e., packages). The rent price varies depending on the number of rest areas in the rent package and/or the size of the panel.

Another interesting application of this value extraction option is found in Toronto, Canada, where the vegetation along the highway that links the international airport to downtown is used to advertise companies.

Blue signs (or Logo signs) are definitely the most common advertising type encountered throughout the U.S. highway system and is used mainly to inform travelers about services along the road.

Naming Right is also a very popular advertising program used by the private sector and that has been adopt by the public sector in certain circumstances, such as train station, airports, toll booth, rest areas, highway corridors. Here, a private company pays a Naming Right fee in exchanging of having its company name and/or logo associated with the property (e.g., rest areas, toll plaza, bridge, and highway).

In general, there are two nationwide programs concerning sponsorship for littering removal and roadside maintenance: The Adopt A Highway Maintenance Corporation (AHMC) and the Adopt A Highway - Litter Removal Service of America (AAH-LRSA). AHMC and AAH-LRSA provide the opportunity to brand a private company name and logo while supporting the community your customers live and work in. Companies that make a commitment to finance litter pick up along a stretch of highway, receive a sign that identifies them as a community minded, environmentally conscious business.

Another sort of sponsorship that can be used by TxDOT to fund some following VEA projects (i.e., renewable energy project) is called Adopt-A-Watt. Like Adopt-a-Highway, in an Adopt-a–Watt agreement companies can sponsor or fund clean energy and alternative fuel projects in exchanging of having their name advertised and acknowledged. Also, a sign template – that complies with FHWA Acknowledgment Sign

Standards - is provided (see Figure 5.15). The two most popular programs are Sponsor-able Photo-Voltaic Light (SPVL) and Sponsor-able Photo-Voltaic Display (SPVD). In the case of solar lights, the sponsorship fees start at $2.000 per year, while for solar arrays the sponsorship fees start at $11.000 with a 3 year minimum commitment in both cases.

Solar Panel (ROW and Vacant Land)

Oregon DOT (ODOT) is the pioneer in implementing solar panels in highway ROW. In December 2008, ODOT concluded the installation of the first solar arrays project at the interchange of IH-5 (see Figure 5.8). The arrays can produce up to 117 KWh annually, i.e., 1/3 of the energy needed on the site. Basically, the solar arrays feed the grid with the electricity produced during the day whereas at night the grid supplies the electricity for interchange lighting.

Currently, SMUD Sacramento (California) is exploring a 594 solar panels project. Also, Caltrans is analyzing the feasibility of installing solar charge stations for electrical vehicles along highways, as well as the installation of solar panels for light poles.

In 2010 the Ohio DOT, in conjunction with the University of Toledo, installed a 100KW solar array – composed by 966 rigid solar panels and 198 flexible solar panels – in the ROW off IH-280 and Greenbelt Parkway in Toledo, OH. The solar array provide the entire electricity demanded at the Veteran's Glass City Skyway Bridge, which has a 196-foot lighted pylon containing 384 light emitting diode fixtures

A number of solar projects can be found in European and Oceania transportation ROW. Germany, for example, has invested € 11 million in a solar panel project on top of a tunnel on highway A3 that has a 2.8 MW capacity. It is expected that the investment cost will be recovery in 16 years from cost savings. The 16,000 solar modules occupy 2.7 km and will provide electricity to nearly 600 houses. In Australia and some European countries, solar panels have a "dual use". Besides energy generation, the panels also act as sound barriers.

Figure V.3: Solar Panel in Sacramento, CA

Source: Volpe Center (2011)

Figure V.4: Solar Roadside Barrier

Source: Volpe Center (2011)

Figure V.5: Flexible Solar Panels

Source: Volpe Center (2011)

Figure V.6: Solar-Sound Barrier

Source: Volpe Center (2011)

Solar Panel (Building and Rest Area)

Wyoming DOT has 19 rest areas that use solar power to provide an estimated half of the rest areas' energy needs. To bring more attention and curiosity about renewable energy and GHG emission reduction, Wyoming DOT installed solar "flowers" at a rest area on Interstate 70 near Parachute in August 2011. In this case, the solar panels have also an aesthetical function and educational purpose.

Figure V.7: Solar Roof

Source: Green Solar (2010)

In Texas, solar panels will be installed at two new rest areas along I-20.

Wind Turbine (ROW and Vacant Land)

Although wind turbines along highway ROW are becoming increasingly common in Europe (e.g., Denmark, Germany, and the Netherlands), in the U.S. the value extraction application have not received great attention from the DOTs. One of the few examples can be found in the MassDOT (former Massachusetts Turnpike Authority), where a 400-foot-tall wind turbine with the potential to generate 1.5 MW has been considered to be installed in the middle of the 68-acre site, reaching around 1,500ft of set-back from the highway. This device is expected to generate 3,000 MWh of electricity per year, enough to supply the energy need of nearly 400 households. The land holding is adjacent to the Blandford service area.

The Ohio DOT (ODOT) is installing a small 32KW wind turbine at a maintenance facility in Northwood, adjacent to highway ROW along I-68. The wind turbine is approximately 100 feet tall and is located 140 feet from the roadway (i.e., setback). The wind system proposed is intended to help to provide up to 65% of the electricity consumed by the facility.

TAK Studio envisioned light poles connected with wind turbines that would harvest the traffic turbulence and convert into electricity to supply the energy needed to illuminate the highways. The Israel National Roads Company is conducting the feasibility studies (i.e., front-end planning) to install small wind turbines tied in lighting poles along the coastal road, taking advantage of sea winds; and in Twain, where small wind turbines are being incorporated with parking lots.

The Colorado DOT (CDOT), Ohio DOT, MassDOT, and Illinois DOT that have worked with local consulting companies and/or universities to identify opportunity zones and sites suitable for renewable energy and revenue generating projects on highway ROW, rest areas, and weigh stations. The identification has been made by overlaying ROW maps and geographic information system (GIS) data layers of potential renewable energy source (i.e., solar, wind, geothermal, and biomass resource maps).

Figure V.8: Wind Turbine
Source: NY-Attraction (2011)

Figure V.9: Wind farm along a highway
Source: Dreamstime (2011)

Wind Turbine (Building and Rest Area)

A number of examples exist where wind turbines have been installed at rest areas and buildings to provide energy and promote renewable energy generation. A wind turbine project is also currently being explored at the Blandford rest area on the Massachusetts Turnpike. A 400-foot-tall wind turbine with the potential to generate 1.5 MW is being considered. This device is expected to generate 3,000 MWh of electricity per year, enough to supply the energy need of nearly 400 households.

The Ohio DOT (ODOT) is installing a small 32KW wind turbine at a maintenance facility in Northwood, adjacent to highway ROW along I-68. The wind turbine is approximately 100 feet tall and is located 140 feet from the roadway (i.e., setback). The wind system proposed is intended to help to provide up to 65% of the electricity consumed by the facility

The Israel National Roads Company is conducting the feasibility studies (i.e., front-end planning) to install small wind turbines tied in lighting poles along the coastal road, taking advantage of sea winds; and in Twain, where small wind turbines are being incorporated with parking lots

In Texas, two 50 KWh wind turbines have been installed at two rest areas – on I-40 close to Amarillo and close to Lubbock.

Figure V.10: Small Wind Turbine
Source: WindEnergy7 (2008)

Figure V.11: Small Wind Turbine
Source: BBC (2005)

Figure V.12: Wind Turbine on a facility
Source: Hemphill (2009)

Geothermal Energy

Geothermal heat pump is widely and commonly used in offices and residences to reduce energy consumption from HVAC systems. The size and complexity of GHP systems depends on the use of HVAC system and how much electricity is intended to be saved.

Geothermal systems – similar to GHP – have been applied as a de-icing mechanism on highways since late 40's. In this system, "heat pipes" are embedded in the pavement, where snow or ice layers have been constantly critical. According to up-to-date observations, it has been estimated that geothermal systems could keep the pavement free of snow and ice at temperature as low as -10°F (-23°C). Several DOTs have been adopted the geothermal system in very specific location, such as New Jersey, South Dakota, Wyoming, and Virginia, as well as countries such as, Japan, Switzerland, and Argentina

Ultimately, a broader approach has been undertaken by Colorado DOT (CDOT), Ohio DOT, MassDOT, and Illinois DOT that have worked with local consulting companies and/or universities to identify opportunity zones and sites suitable for renewable energy and revenue generating projects on highway ROW, rest areas, and weigh stations. The identification has been made by overlaying ROW maps and geographic information system (GIS) data layers of potential renewable energy source (i.e., solar, wind, geothermal, and biomass resource maps)

Carbon Sequestration

Carbon sequestration is the process of capturing and removing CO_2 and other forms of carbon from the atmosphere and, then, "storing" it in "reservoirs". A variety of techniques to sequester carbon exist, but the focus here is exclusively on vegetation management.

There is no formal carbon sequestration program in the U.S. besides the pilot programs and research studies conducted in states such as, New Mexico and Utah.

Figure V.13: Carbon Sequestration
Source: FHWA (2010)

The Carbon Sequestration Pilot Program (CSPP), led by FHWA' Office of Natural and Human Environment (ONHE) and the New Mexico Department of Transportation (NWDOT), reported that in addition to improved vegetation management, carbon sequestration allows for: "(1) selling carbon credits on an appropriate GHG market or registry for revenue, (2) using carbon credits to offset the DOT's emissions, or (3) using the credits toward meeting statewide objectives".

Biomass and Biofuel

The Utah DOT launched a research project in 2006 in conjunction with Utah State University (USU) to assess the feasibility of planting drought-tolerant crops such as canola, safflower, and dwarf sunflower along the ROW in a non-irrigated environment. The idea - as envisioned by the researchers - is to harvest enough seed to produce in-house biodiesel for the UDOT's fleet, including heavy diesel machineries and snow plows. As a result of the research, USU and UDOT could identify minimum requirements to initiate a biomass program.

The North Caroline DOT (NCDOT) initiated in 2009 its biomass and biofuel project. Currently, the NCDOT's project is recognized as one of the largely successful biomass projects nationwide, mostly because of the state moist climate, fertile soil, and support from the State legislature. The project started with four 1-acre plots of canola or sunflower crops. These crops were selected by NCDOT, in conjunction with North Caroline State University, because their estimated greater potential of yield in ROW scenario. NCDOT has been working with seasonally rotated crops on the same plot, thereby being able to meet or exceed national standards for crop production. In 2010, NCDOT extracted 3,000 lb of canola seed, which yielded 100 gallons of virgin oil. The virgin oil produced 150 gallons of B100, which was cut with conventional diesel to generate approximately 600 gallons of B20. The NCDOT used the B20 to fuel its dump trucks, tractors, and other equipment.

Figure V.14: Harvesting biomass on ROW
Source: Volpe Center (2011)

Another pilot project is being conducted by Genera Energy LCC – a for-profit limited liability company wholly owned by the University of Tennessee Research Foundation – in partnership with Tennessee DOT. The objective of the pilot project is to verify if switchgrass – one of the primary feedstock used to produce cellulosic ethanol and native for all American states – planted along the highway ROW can yield reduced maintenance costs due to less mowing activities and erosion on the roadside, as well as generate revenue from biomass for biofuel production.

Wildlife Crossing

Wildlife overpasses are very common in Europe. In North America, however, where there are only six examples of these structures of which two are located in the Banff National Park in Alberta, Canada.

The Banff National Park and Trans-Canada Highway (in Alberta, Canada) have perhaps the "most recognizable wildlife crossings in the world" with 22 underpasses and two overpasses.

The highway IH-75 (Florida) has 24 highway underpasses and 12 bridges that were modified for wildlife crossings along 40 miles. These crossing structures are "specifically designed to target and protect the endangered Florida panther".

The Hoge Veluwe National Park – in the Netherlands - has three wildlife overpasses (called Ecoducts) across highway A50. It is estimated that in one year almost 5,000 deer and wild bears used at least one of the crossing structure.

Several DOTs and Research Center have conducted studies regarding how to identify best location for wildlife crossing and design the structure effectively, including a Wildlife Decision Guide Framework.

APPENDIX VI: LIST OF STAKEHOLDERS

Property Management

- Local government
  - Zoning/Planning department
  - Mayor/Council
- State government & Legislators
- Nearby landowners
- Nearby Businesses
- General public
- Potential buyers, developers, or investors
- Employees
- Transit agency
- Transportation Agencies (FHWA and AASHTO)
- Environmental Agencies
- General Land Office (GLO)

Property Management (Rest Area)

- Local government
  - Zoning/Planning department
  - Mayor/Council
- State government & Legislators
- Nearby landowners
- Nearby Businesses
- General public
- Potential Developers or Investors
- TXDOT Employees
- Transportation Agencies (FHWA and AASHTO)
- Utility providers

- Environmental Agencies
- Community Representatives
- General Land Office (GLO)

Airspace Leasing (Building)

- Local government
    - Zoning/Planning department
    - Mayor/Council
- Nearby landowners
- Nearby Businesses
- Nearby Residents
- General public
- Potential Developers
- TXDOT Employees
- Transit agency
- Utility providers
- Environmental Agencies
- Community Representatives
- Transportation Agencies (FHWA and AASHTO)

Airspace Leasing (Parking lot)

- Local government
    - Zoning/Planning department
    - Mayor/Council
    - Public Works/Transportation department
- Nearby landowners
- Nearby businesses
- Nearby Residents

- General public
- TXDOT Employees
- Police and fire Departments
- Transit agency
- Environmental Agencies
- Community Representatives
- Transportation Agencies (FHWA and AASHTO)
- Department of Public Safety

Airspace Leasing (Utilities)

- Local government
    - Zoning/Planning department
    - Mayor/Council
- Utility Providers
- Telecommunication Companies
- Tower Leasing Companies
- Oil & Gas Companies
- General Public
- FHWA
- Nearby Residents
- Nearby landowners
- TXDOT Employees
- Transit agency
- Federal Aviation Administration (FAA)
- Environmental Agencies
- Community Representatives
- State representatives for district
- Transportation Agencies (FHWA and AASHTO)

Advertising

- State government & Legislators
- Local Zoning/Planning department
- Advertising and Marketing Companies
- Nearby landowners
- Nearby Businesses
- Nearby Residents
- General public
- TXDOT Employees
- Transit agency
- Environmental Agencies
- Transportation Agencies (FHWA and AASHTO)

Solar Panel (ROW and Vacant Land)

- Local government
    - Public Works/City/Transportation department
    - Zoning/Planning department
    - Mayor/Council
- State government & Legislators
- Nearby landowners
- Community Representatives
- General public
- Developers or Investors
- TXDOT Employees
- Transit agency
- General Land Office (GLO)
- Utility Providers
- Department of Energy (DOE)

- Transportation Agencies (FHWA and AASHTO)
- Federal Aviation Administration (FAA)
- Environmental Agencies
- Solar Panel Vendors
- Telecommunication Companies
- Department of Defense (DOD)

Solar Panel (Building and Rest Area)

- Local government
    - Public Works/City/Transportation department
    - Zoning/Planning department
    - Mayor/Council
- State government & Legislators
- Nearby landowners
- Community Representatives
- General public
- Developers or Investors
- TXDOT Employees
- Transit agency
- General Land Office (GLO)
- Utility Providers
- Department of Energy (DOE)
- Transportation Agencies (FHWA and AASHTO)
- Federal Aviation Administration (FAA)
- Environmental Agencies
- Solar Panel Vendors
- Telecommunication Companies
- Department of Defense (DOD)

Wind Turbine (ROW and Vacant Land)

- Local government
  - Public Works/City/Transportation department
  - Zoning/Planning department
  - Mayor/Council
- State government & Legislators
- Nearby landowners
- Community Representatives
- General public
- Developers or Investors
- TXDOT Employees
- Transit agency
- General Land Office (GLO)
- Utility Providers
- Department of Energy (DOE)
- Transportation Agencies (FHWA and AASHTO)
- Federal Aviation Administration (FAA)
- Environmental Agencies
- Wind Turbine Vendors
- Telecommunication Companies
- Department of Defense (DOD)

Wind Turbine (Building and Rest Area)

- Local government
  - Public Works/City/Transportation department
  - Zoning/Planning department
  - Mayor/Council
- State government & Legislators

- Nearby landowners
- Community Representatives
- General public
- Developers or Investors
- TXDOT Employees
- Transit agency
- General Land Office (GLO)
- Utility Providers
- Department of Energy (DOE)
- Transportation Agencies (FHWA and AASHTO)
- Federal Aviation Administration (FAA)
- Environmental Agencies
- Wind Turbine Vendors
- Telecommunication Companies
- Department of Defense (DOD)

Geothermal Energy

- Local government
    - Public Works/City/DOT
    - Mayor/Council
    - Zoning/Planning department
- State government & Legislators
- Nearby landowners
- Community Representatives
- General public
- Developers or Investors
- TXDOT Employees
- Transit agency

- General Land Office (GLO)
- Utility providers
- Department of Energy (DOE)
- Transportation Agencies (FHWA and AASHTO)
- Federal Aviation Administration (FAA)
- Environmental Agencies
- Geothermal System Vendors
- Department of Defense (DOD)

Carbon Sequestration

- Local government
    - Public Works/City/DOT
    - Zoning/Planning department
- State government & Legislators
- Nearby landowners
- General public
- Developers or Investors
- TXDOT Employees
- General Land Office (GLO)
- Utility providers
- Department of Energy (DOE)
- Transportation Agencies (FHWA and AASHTO)
- Environmental Agencies
- Carbon Sequestration Experts
- Carbon Market Personnel

Biomass and Biofuel

- Local government

    - Public Works/City/DOT
    - Mayor/Council
    - Zoning/Planning department
- State government & Legislators
- Nearby landowners or Farmers
- Community Representatives
- General public
- Developers or Investors
- TXDOT Employees
- Utility providers
- Transit agency
- General Land Office (GLO)
- Department of Energy (DOE)
- Transportation Agencies (FHWA and AASHTO)
- Environmental Agencies
- Biofuel Suppliers (i.e., Gas Stations)
- Biofuel Companies (i.e., Biorefineries)

Wildlife Crossing

- Local government
    - Public Works/City/DOT
    - Mayor/Council
    - Zoning/Planning department
- State government & Legislators
- Nearby landowners
- Community Representatives
- General public
- Developers or Investors

- TXDOT Employees
- Transit agency
- General Land Office (GLO)
- Insurance Companies
- Transportation Agencies (FHWA and AASHTO)
- Environmental Agencies
- Department of Defense (DOD)

APPENDIX VII: QUESTIONNAIRES FOR RESEARCH INTERVIEWS

Topic: TxDOT Property Management - Leasing and Surplus Sales

a. How is TxDOT property management division organized and structured (e.g., excess land, airspace leasing, ROW, buildings, and rest areas)?

b. How many people are working on this division? What are their qualifications?

c. Is TxDOT aware of how other DOTs undertake the property management programs (e.g., Caltrans)?

d. How is the process of identifying excess land or property to sell/lease (i.e., identify future needs)? Who are responsible for conducting this assessment?

e. What type of property is commonly involved? Where is it located (e.g., urban or rural)?

f. What is the most common type of transaction (e.g., swap, lease, and sale)?

g. How often does TxDOT undertake its inventory assessment?

h. Is TxDOT benefited by selling/leasing land/property?

i. How does TxDOT keep/maintain its inventory control (e.g., database and GIS)?

j. Does TxDOT control or monitor the future use of the property (i.e., by the new owner/user)?

k. How does TxDOT conduct the process of leasing/selling (i.e., announcement – for example: via website, email list, and Craig's list)

l. What are the current TxDOT numbers for the following points?

   i. Annual incoming from leasing (# of properties)

ii. Annual # of sales (type of property)

iii. Annual # of swap (type of property)

m. Who are involved in the negotiation or decision making process?

n. What are the main barriers to expand and formalize this program?

Topic: Rest Areas Management in Texas

a. How many rest areas are closed in Texas (from the total of 80 rest areas)? Also, does TxDOT have any intention or perspective to close more or any rest area?

b. How is rest area privatization seen by TxDOT and politicians?

c. What the average monthly total cost to maintain a rest area in Texas? How about the cost by item (i.e., electricity, staff, maintenance, and so on)? Could TxDOT provide this information?

d. What is the main maintenance cost?

e. Is there any vendor machine or revenue source in TxDOT's rest areas (or at least at the ones on State Highway)?

f. What would be a good and feasible opportunity for generating revenue (e.g., souvenirs, advertising, internet, and touristic attraction)?

g. Is there any sort of advertising being used in rest areas? What is the total revenue generated by this business?

h. What are the most often complains from users about TxDOT's rest area services?

i. Are TxDOT's rest areas equipped cooling or heating systems? How about other special infrastructures? (e.g. hot water, electricity source for users, and etc)

j. How many rest areas have any sort of renewable energy source (i.e., solar, wind, and geothermal)? What is the anticipated or actual cost saving entailed by these systems?

k. How old – in average - are the electrical installations of the rest areas? Has TxDOT faced any technical barrier or difficult when installing renewable energy systems?

l. How many people visit TxDOT's rest areas annually?

m. How is advertising at rest areas seen by TxDOT?

n. Do all rest areas provide free internet access? How does the website www.TexTreks.com work? How is the contractual agreement with the internet provider? Does TxDOT earn any revenue from existing advertising in the website? Why doesn't TxDOT exploit more the website TexTreks to generate revenue? What are the main obstacles?

o. Who manage the TexTreks.com? Does TxDOT envision any idea to make the website more user-friendly and well-known?

p. Has the idea of selling internet access (or advertising in the website) been brought up or thought by TxDOT?

q. Is there any involvement of nearby communities for maintaining/preserving the rest areas?

r. Does the current number of opening rest areas suffice the demand? If not, how many rest areas TxDOT need to construct to meet the needs?

s. What kind of services do the rest areas lack of providing?

t. How many people are employed in the rest area division?

u. In there any difference among rest areas in Interstate Highways, State Highways, and Toll Highways (e.g., policy, regulation, design, service, and features)? Is commercialization or privatization allowed in States ROW and rest areas?

v. What can be done to minimize rest area's maintenance cost?

w. Is there any community engagement involving rest area maintenance? Is it possible to integrate nearby communities and rest areas?

Topic: TxDOT Vegetation and Grass Management

a. How much does TxDOT spend monthly for mowing ROW?

b. How often is the ROW mowed?

c. What is the highest height of vegetation allowed on ROW (i.e., that will not hamper the safety)?

d. Where are the locations that planting is difficult due to soil conditions?

e. How is the mowing activity performed (i.e. equipment or manually)

f. What are the precautions taken for traffic security and pavement/shoulders preservation (i.e. to avoid mower damage the road)

g. Is any ROW being used for farming? Leasing?

h. What is the current area of ROW with grass?

Topic: Texas Highway Beautification Act

a. How do you see the use of ROW for biomass production and carbon sequestration?

Topic: Current TxDOT airspace leasing program for communication antenna (wireless)

a. What is the current TxDOT need for communication towers?

b. Does TxDOT lease space on its towers to private companies? How many contracts does TxDOT currently have with communication companies?

c. How do these contracts work (i.e. responsibilities, liabilities, leasing time, maintenance, and access)?

d. How is this business opportunity seen by TxDOT?

e. How a better coverage of wireless, internet, and cell phone signals enhance and facilitate TxDOT information system? Is it possible to measure the benefits?

Topic: Property Management

a. How long does the formal property management program exist?

b. What is the current structure of the property management program (i.e., number of staff members, is the program management concentrated on the main office or divided by district)?

c. How is the DOT's inventory managed and controlled (e.g. GIS, database)?

d. What type of deal is done do the most (e.g. leasing, sale, swap)? How are the deals done (e.g. public auctions)?

e. How are the excess lands or properties identified to be traded? How is potential future needs addressed?

f. How is the minimum price established?

g. Is the DOT website the only tool used to divulgates available asset?

h. Does the DOT oversee or control the use of land by the new owner or lessee?

i. How long is the leasing contract, in general?

j. What are the major barriers and benefits of this program (e.g. legal, environmental, and social)?

k. What is the annual average revenue generated by this program?

l. Is any public outreach promoted or conducted before announcing the available land or property?

Topic: Airspace Leasing for Communication Antenna (wireless)

a. How many contracts does the DOT currently have with communication companies? What is the annual revenue generated by this program?

b. How is this business opportunity seen by the DOT?

c. How do these contracts work (e.g., responsibilities, liabilities, leasing time, maintenance, and access)? Does the DOT have multiple contracts (i.e., with different companies)?

d. How is the DOT benefited from a better coverage of wireless, internet, and cell phone signals (e.g., enhanced information system)? Is it possible to Economically measure the benefits?

e. Where are the most of the towers/antennas located (i.e., rural, semi-urban, or urban area)?

f. What are the social benefits, resulting from the program, identified by the DOT?

g. What are the environmental Impacts identified by DOT? How could they be addressed or mitigated?

h. What are the major legal issues faced by the DOT?

i. How is the Safety Issues caused by the towers along the ROW addressed?

j. Does the maintenance of antennas and towers impact or disrupt the traffic flow?

Topic: Airspace Leasing for Utilities and Parking Lot

a. How does the utility accommodation program work within the DOT? Does any shared resources contract exist (e.g., fiber optics)?

b. What types of utilities can the DOT charge leasing fee?

c. How does the parking lot program work? Is the parking lot space leased for private companies and/or cities? Does the DOT manage any parking lot?

d. How is the place for parking lot identified? Who identifies it (i.e., the DOT or the interested party)?

e. How long is the leasing contract for each use?

f. How many contracts does the DOT currently have (i.e. for utilities and for parking lot)?

g. What is the current revenue generated by each use?

h. Does the DOT require any safety consideration when leasing for parking lot beneath the viaducts or bridges (e.g., prohibition of flammable substances and limited use)?

i. Does the DOT measure any social benefit from leasing airspace for parking lot?

j. How does the DOT assess/analyze future road expansion when they decide whether to lease for utilities or communication towers?

k. Does the DOT lease airspace beneath viaducts for other purpose, besides parking lot?

Topic: Solar Highways

a. What were the barriers faced by the DOT to implement the solar project?

b. How was the place chosen? What were the criteria?

c. How did the DOT select/choose its private-partner?

d. How was the political involvement (i.e., leadership support)? How did the DOT bring these leaders into the project? How important is this support for the project's viability?

e. How was the public reception? Did the DOT promote any public outreach?

f. What was exactly the DOT investment? Is the DOT receiving any revenue from the project or only saving electricity cost?

g. How important were the federal and state incentives for the project viability?

h. What is the expected payback period for the project?

i. How is the project currently going on?

j. How is the maintenance carried out? Does it provoke any traffic disruption?

k. Have public complains or accidents had thus far?

l. Is solar project feasible in rural/remote areas? What is the impact/benefit of lack of transmission lines at the site?

m. What are the lessons learned. How were the following issues addressed?

    i. Safety

1. Clear zone
2. Reflectivity
3. Traffic control

ii. Grid Interconnection

iii. Shading

iv. Security

n. What are the main differences of the solar panel technologies and projects from Dec/2008 to now (e.g., cost, incentives, and efficiency)?

o. What are the DOT's next steps regarding solar projects on ROW?

Topic: Solar Roads

a. How does exactly the solar road work? What are the construction and technical requirements?

b. How can the problem of irregular surface of the pavement base & sub-base (i.e. where the panels will be installed) be addressed? Is there any special treatment or construction procedure envisioned?

c. Is the load capacity of the solar panel the same as for concrete/asphalt pavements (i.e., heavy load truck concerns)?

d. What sites/locations will solar roads be more feasible (urban vs. rural)?

e. How could solar road projects be implemented (i.e. partnership DOT and utility company). Have legal issue or consideration been considered?

f. In case of public-private partnership, who would have the ownership over the pavement (e.g., for maintenance)?

g. Has the DOT promoted any public outreach regarding solar road projects? How was the public reception?

h. What was exactly the support of the U.S. DOT to the research project (e.g., investment, participation, any other help)?

i. How would the maintenance be performed (e.g., cleaning, changing panels, and infrastructure repair)? Have potential traffic disruption and safety concern been evaluated? How often would the panel maintenance be needed?

j. What is the estimated cost of the solar pavement (i.e., solar panel and construction)?

k. Have any economic analysis been conducted? How important are the incentives to the viability of the project?

l. What is the expected payback period for the Utility Company/Investor?

m. What is the difference between normal solar panels and the ones for pavement? Is there any vendor involved in the development of the special panels? How is market for this new technology envisioned?

n. How is the research project currently going on?

o. What are the lessons learned thus far? How have the following main issues been addressed?

    i. Safety
        1. Skid resistance / roughness
        2. Reflectivity
        3. Traffic control (maintenance)
    ii. Grid Interconnection
    iii. Construction issues

iv. Others

p. How is the estimated energy production of solar road in urban centers (i.e., with intense traffic congestion)

q. What are the next steps within Solar Roads?

Topic: Biomass & Biofuel using Switchgrass

a. How were the sites selected? What were the criteria and considerations?

b. Who will be responsible for planting, harvesting, and selling the seeds? How do the contracts with farmers currently work? Are they going to be extended to ROW?

c. Which areas do you think would be more appropriated to purse this alternative?

i. In very remote/rural areas or even in places distant from biorefineries, the cost of harvesting and hauling would be greater, making the alternative less feasible? Also, can switchgrass lose or diminish their energy (ethanol) potential?

ii. Can switchgrass be planted anywhere? What are the minimal requirements/conditions?

iii. What are the ideal characteristics of ROW to implement this program?

d. What are the main obstacles/barriers for implementing this program?

e. Wouldn't harvest/haul machinery represent a risk for the traffic safety or damage the ROW and the road itself?

f. Is there any government/political involvement on the project?

g. Can planting switchgrass on ROW attract animals?

h. Can this program be integrated with carbon sequestration?

i. What is the estimated cost-benefit (i.e., cost/Revenue or cost saving)?

j. Has any result about the feasibility of the program be drawn or concluded?

k. Does the DOT have any GIS/Database of the characteristics and conditions of its ROW network?

l. Is any public involvement envisioned? If yes, who will be involved (e.g., farmers and communities) Is any public outreach currently be conducted? How?

m. How can the following considerations be addressed when using switchgrass:
   i. Safety (tall grass – vision barrier)
   ii. Structural Integrity (encroachment & erosion by the vegetation)
   iii. Establishment and Harvesting
   iv. Economics
   v. Wildlife Impacts
   vi. Ecology/Environmental Impacts

n. Is the use of water or fertilizer needed during the planting for establishment of the vegetation?

o. In areas where there are utilities buried, could planting and harvesting represent a risky/hazardous situation, mainly when using switchgrass that is 10' tall and has long and strong roots?

p. Does the research have any resulted thus far?

Topic: Biomass & Biofuel using Oilseed Crops

a. Who will be responsible for planting, harvesting, and selling the seeds?

b. Where would be more appropriated to purse this alternative? What should be considered?

ii. In very remote/rural areas or even in places distant from biorefineries, the cost of harvesting and hauling would be greater, making the alternative less feasible?

iii. Drought-tolerant crops are being used. Does it mean that they can be planted anywhere? What are the minimal conditions for the establishment of these crops?

c. Is any public involvement envisioned? If yes, who will be involved (e.g., farmers and communities) Is any public outreach currently be conducted? How?

d. What are the main obstacles/barriers for implementing this program?

e. Wouldn't harvest/haul machinery represent a risk for the traffic safety or damage the ROW and the road itself?

f. Is there any government/political involvement on the project?

g. Can planting crops on ROW attract animals?

h. Can this program be integrated with carbon sequestration?

i. What is the estimated cost-benefit (i.e., cost/Revenue or cost saving)?

j. Has any result about the feasibility of the program be drawn or concluded?

k. Does the DOT have any GIS/Database of the characteristics and conditions of its ROW network?

l. A list of some considerations is usually mentioned when discussing the implementation of biomass & biofuel on ROW, as following:

i. Safety
ii. Structural Integrity
iii. Establishment and Harvesting
iv. Economics
v. Wildlife Impacts
vi. Ecology/Environmental Impacts
vii. Water Quality
viii. Grower Concerns

Could theses points be better explained and developed?

m. Is the use of water or fertilizer needed during the planting for establishment of the seeds?

n. To use the biofuel on the DOT's fleet, all cars, trucks, and machines have to be somewhat and somehow changed or modified to Hybrid? Has the initial cost for the DOT be analyzed and included into the economic analysis? Would this change be gradual? Also, Hybrid vehicles are typically more expensive. How could DOT justify this investment?

o. Has swicthgrass been envisioned to be used in lieu of seed crops??

p. In areas where there are utilities buried, could planting and harvesting represent a risky/hazardous situation?

q. What is the difference in terms of production/planting between Biodiesel and Ethanol?

r. Could conditions of the soil on right of way (e.g., deicing materials, oil, run-off water) hinder the growth of crop?

s. Does the research/pilot project have any resulted thus far?

Topic: Carbon Sequestration

a. How is the baseline of carbon sequestration established? Since only additional carbon counts, could this represent an insignificant amount of carbon sequestrated possible to offset the process cost? What would be break-even point?

b. What are the main costs incurred when implementing the program (e.g. Carbon Verifier, Carbon Aggregator, or cost of planting (water, fertilizer))?

c. The price of carbon on the Chicago Exchange Markets floats up-down frequently. How could the economic feasibility of this program be estimated with reasonable certainty?

d. What are the major barriers/obstacles to implement carbon sequestration program?

e. Carbon sequestration requires a long-term commitment. What is the general time-period? How could DOT plan, predict, and address future expansion or use of ROW (e.g. utilities) in a way that did not affect the CS program?

Topic: Wildlife Crossing

a. What are technical requirements and barriers to implement wildlife crossing (e.g., best location, data and survey needed, type (overpass, underpass), characteristics and features (vegetation, approach zone, size))?

b. How can environmental and social benefits be measured?

c. What is the expected number of accident reduced with each wildlife crossing?

d. What are the means to fund and finance wildlife crossing projects (federal or state incentives, and donations)? How could the DOT receive these incentives (e.g., solar highway in Oregon was possible only via Public-Private Partnership)?

e. What are the major points that could help the DOT buy this idea in?

f. What are the results and lessons learned acquired from other projects (e.g., cost, benefits measured, accident reduction, how the place was selected, was it built in a new road or existing road, challenges during construction)?

g. Is there any other information that would be important and interesting for the DOT to know?

h. How are the government and public involved? Are they supportive?

i. Can wildlife crossing be implemented in urban areas? Do you have any example?

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