Energy Development and US Infrastructure

November 9, 2016

Today's Presenters

- **Moderator**
  Seri Park, Assistant Professor, Villanova University
- **Energy Development and Our Nation's Infrastructure**
  Leslie McCarthy, Associate Professor, Villanova University
- **Energy Sector Use of Rural Low Volume Roads**
  Mark J. Nahra, County Engineer, Woodbury County, IA
- **Impact of Energy Development on Texas Highways**
  Jon Epps, Executive Associate Director, Texas Transportation Institute

NCHRP is...

A state-driven national program

- The state DOTs, through AASHTO's Standing Committee on Research...
  - Are core sponsors of NCHRP
  - Suggest research topics and select final projects
  - Help select investigators and guide their work through oversight panels

NCHRP delivers...

Practical, ready-to-use results

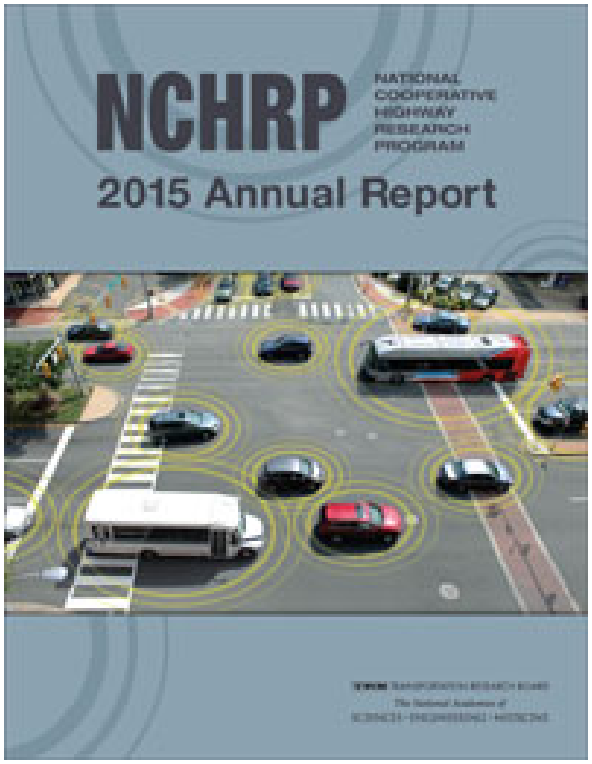
- Applied research aimed at state DOT practitioners
- Often become AASHTO standards, specifications, guides, manuals
- Can be directly applied across the spectrum of highway concerns: planning, design, construction, operation, maintenance, safety

A range of approaches and products

- Traditional NCHRP reports
- Syntheses of highway practice
- IDEA Program
- Domestic Scan Program
- Quick-Response Research for AASHTO
- Other products to foster implementation:
  - *Research Results Digests*
  - *Legal Research Digests*
  - *Web-Only Documents and CD-ROMs*

NCHRP Webinar Series

- Part of TRB's larger webinar program
- Opportunity to interact with investigators and apply research findings.



Today's First Presenter

- **Energy Development and Our Nation's Infrastructure**

  Leslie McCarthy, Associate Professor, Villanova University

TRB WEBINAR
ENERGY DEVELOPMENT AND U.S. INFRASTRUCTURE
NOVEMBER 9, 2016

Energy Development and Our Nation's Infrastructure

Leslie Myers McCarthy, Ph.D., P.E.
Assoc. Professor, Villanova University

NCHRP Synthesis Project 469

- Principal Investigators: Leslie McCarthy, Anthony Giancola, & Seri Park
- Project Duration: October 2013 – September 2014
- TRB Program Officer: Jo Allen Gause
- Expert Panel: FHWA, ND DOT,

Texas DOT, PennDOT, Oregon DOT,

Scott County MN, Penn State Univ.,

Woodbury County, Iowa

- Final Report: NCHRP Synthesis 469

Courtesy: TxDOT

NCHRP Synthesis 469 Objectives

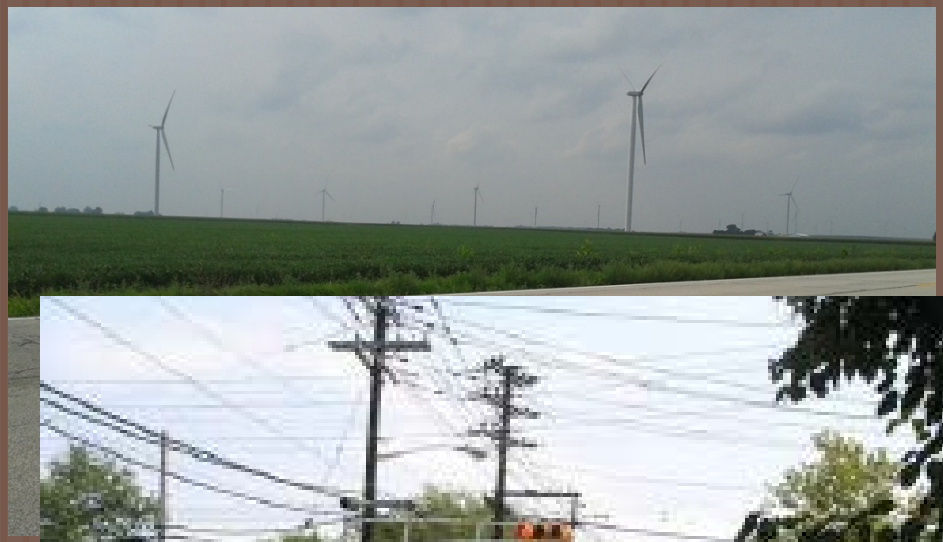
- **Goals:**
  - Document impacts of the energy sector on roads and bridges
  - Identify state-of-the-practice strategies used by DOTs and local agencies to minimize and mitigate those impacts
  - Help transportation managers understand and communicate energy development impacts on roads and bridges, and choose strategies for managing them

Project Approach

- Major Tasks:

1. Review current practices by all states re: maintenance and planning in areas affected by energy development.
2. Survey all state DOTs & identify 5 states for further study
3. Interview DOT staff, local agencies, and industry for input in the 5 case example states
4. Conduct detailed phone interviews to obtain specific details.

Data Collection



Assess costs & damages to infra

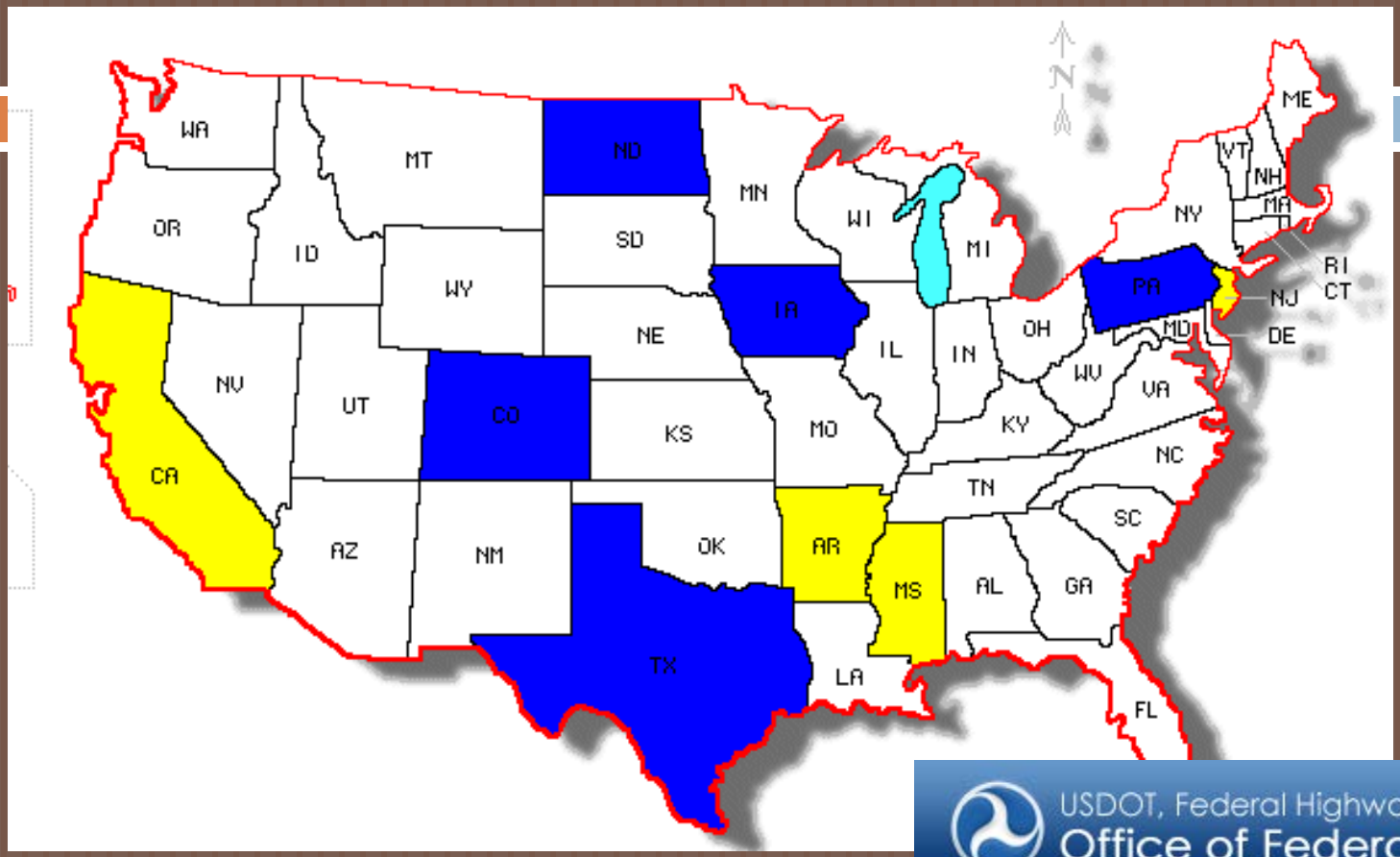
T

Photo: DVRPC Freight Planning

Safety and Geometry

Engineering methods used for heavy loads

Agencies Interviewed



USDOT, Federal Highway Administration
Office of Federal Lands Highway

- DOTs, Counties, TTAP, and…
- Geographic distribution to include diversity in terms of climate, energy types, and development level
- Significant Impacts observed from survey responses

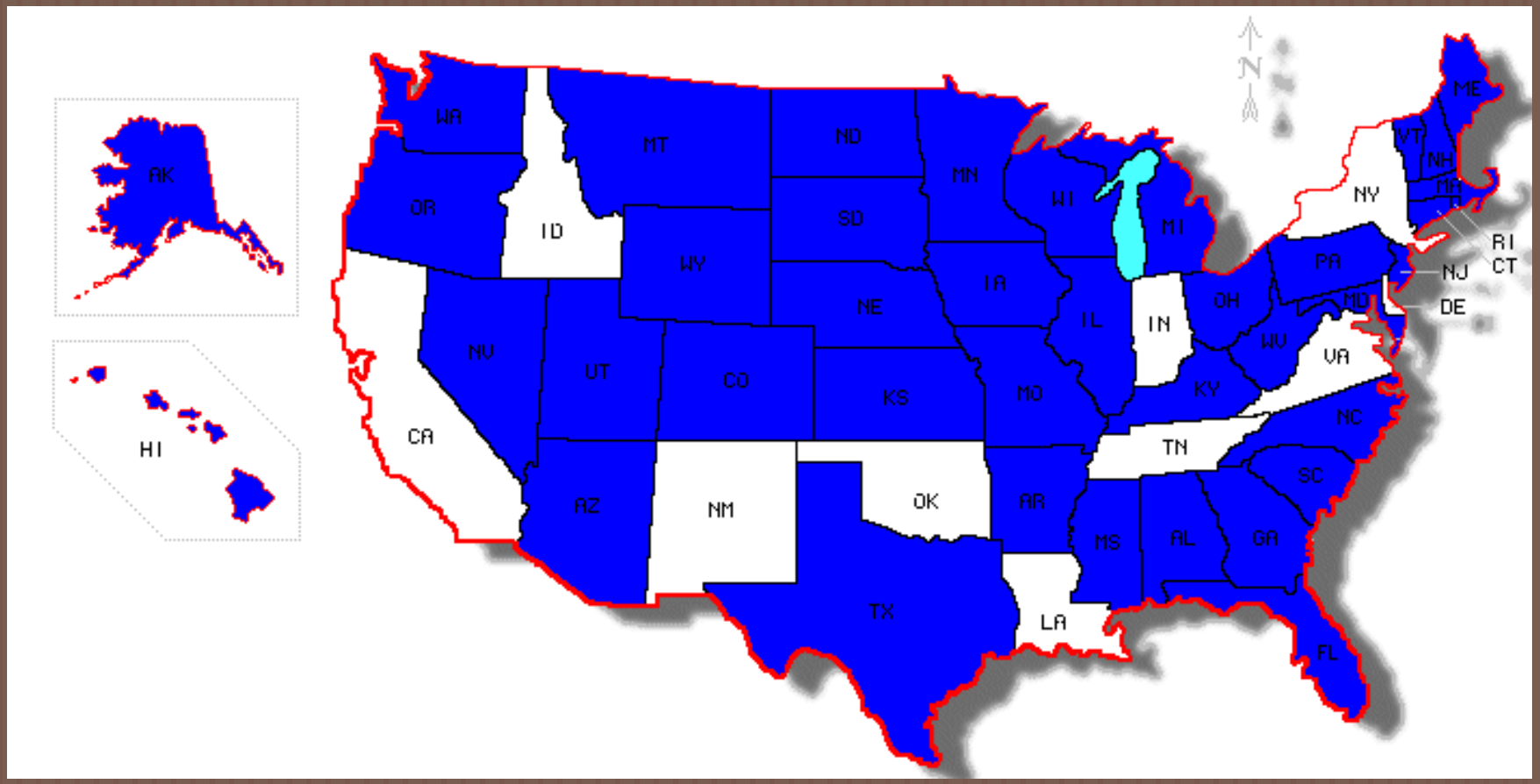
Energy Sectors by Number of States

Energy Sector	Number of States
Biofuels	47
Coal	25
Natural Gas	33
Nuclear	31
Oil	31
Solar	23
Wind	39

Adapted from U .S. Energy Mapping System

Synthesis Survey Responses

41 DOTs gave survey responses (rate of 80%)



Publications

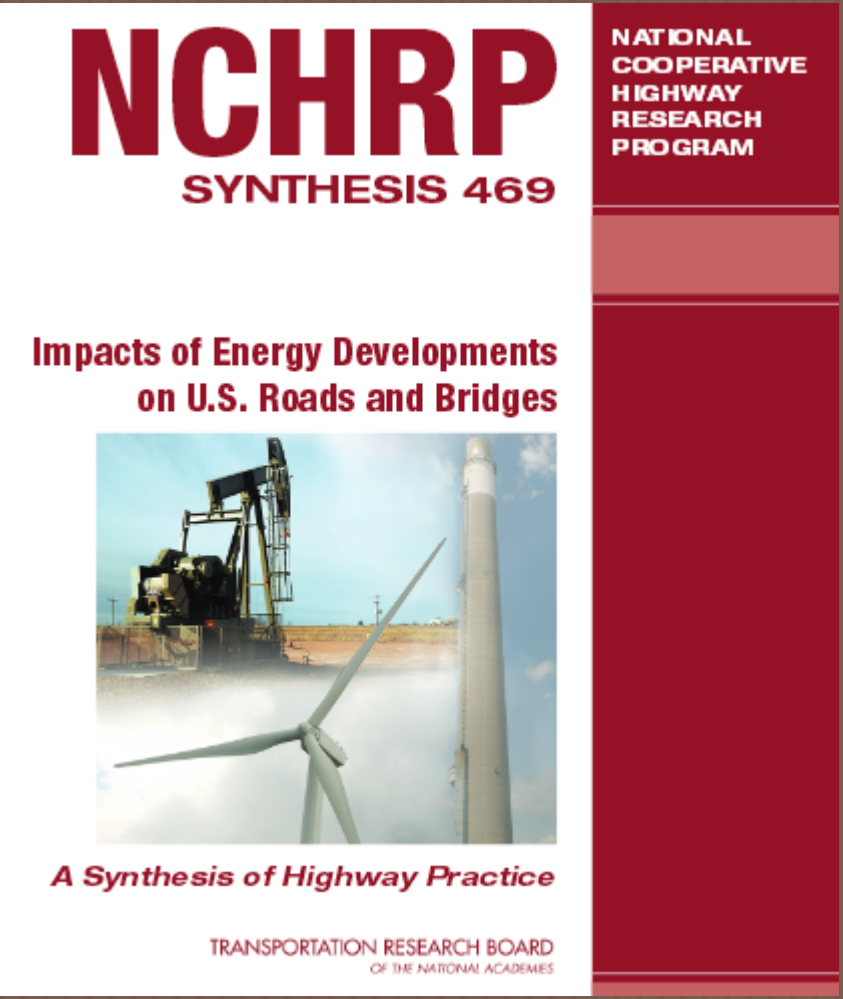
More detailed information can be found in:

FHWA Public Roads Magazine

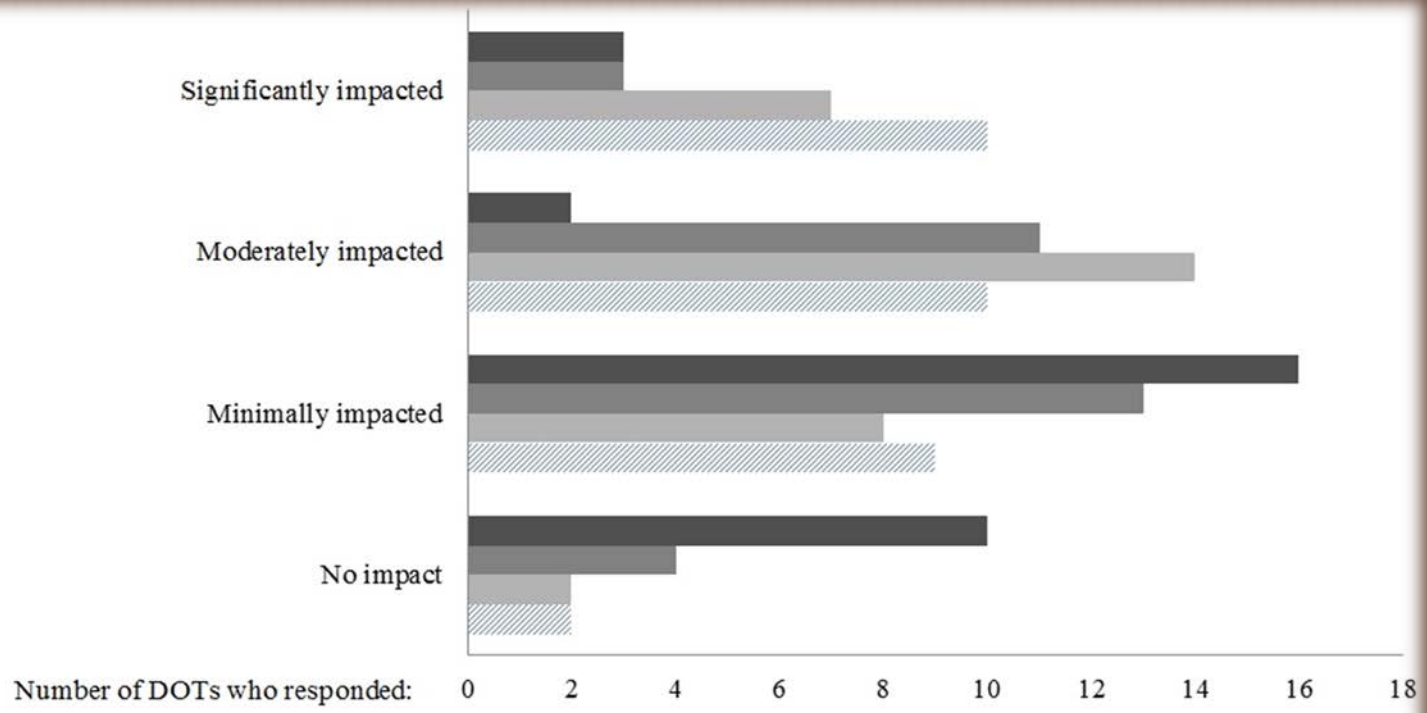
(Sept/Oct 2015 issue)

NCHRP Synthesis Report 469 (2015)

http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_469.pdf

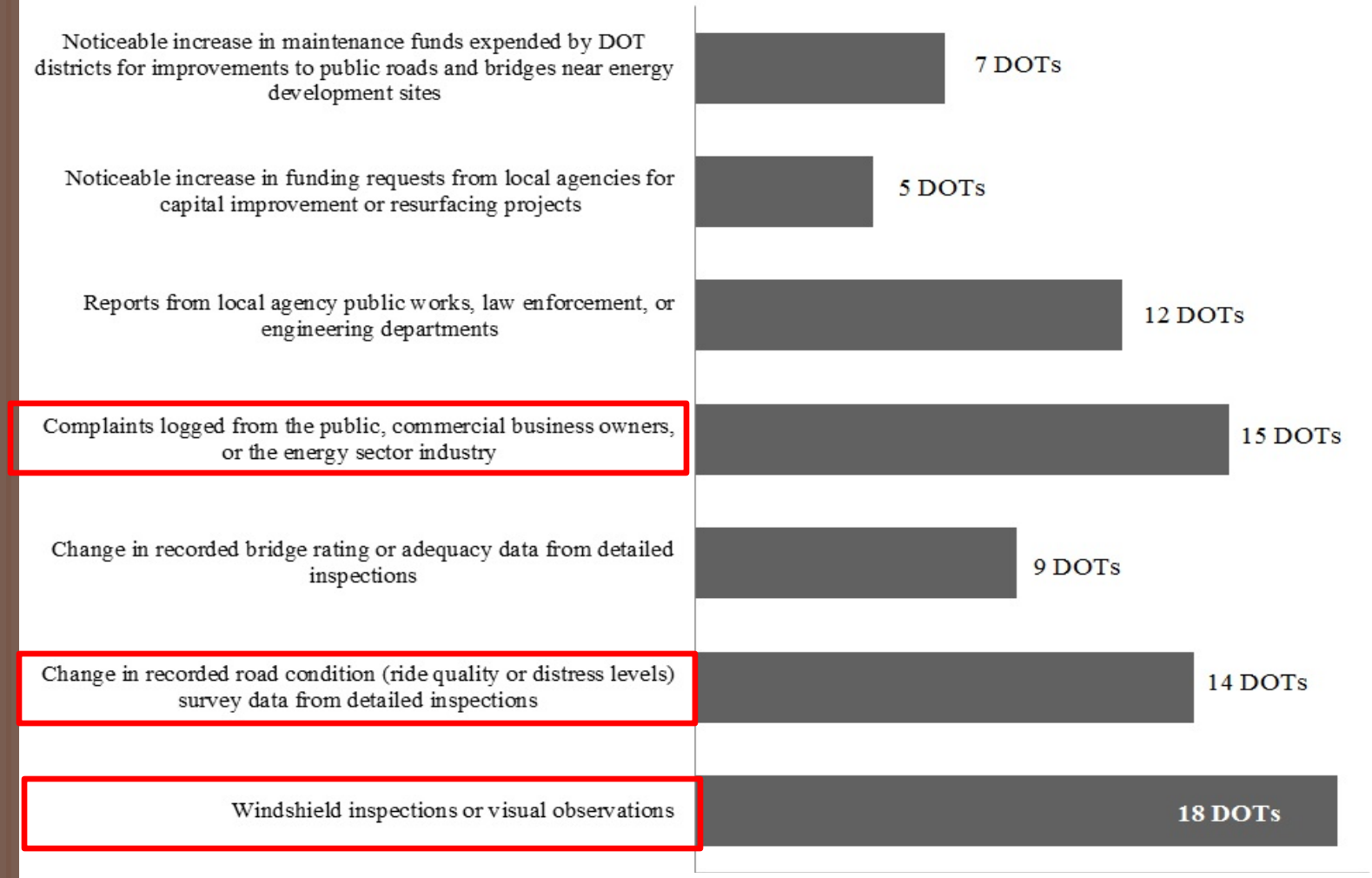


Rating of energy development impact level by facility type

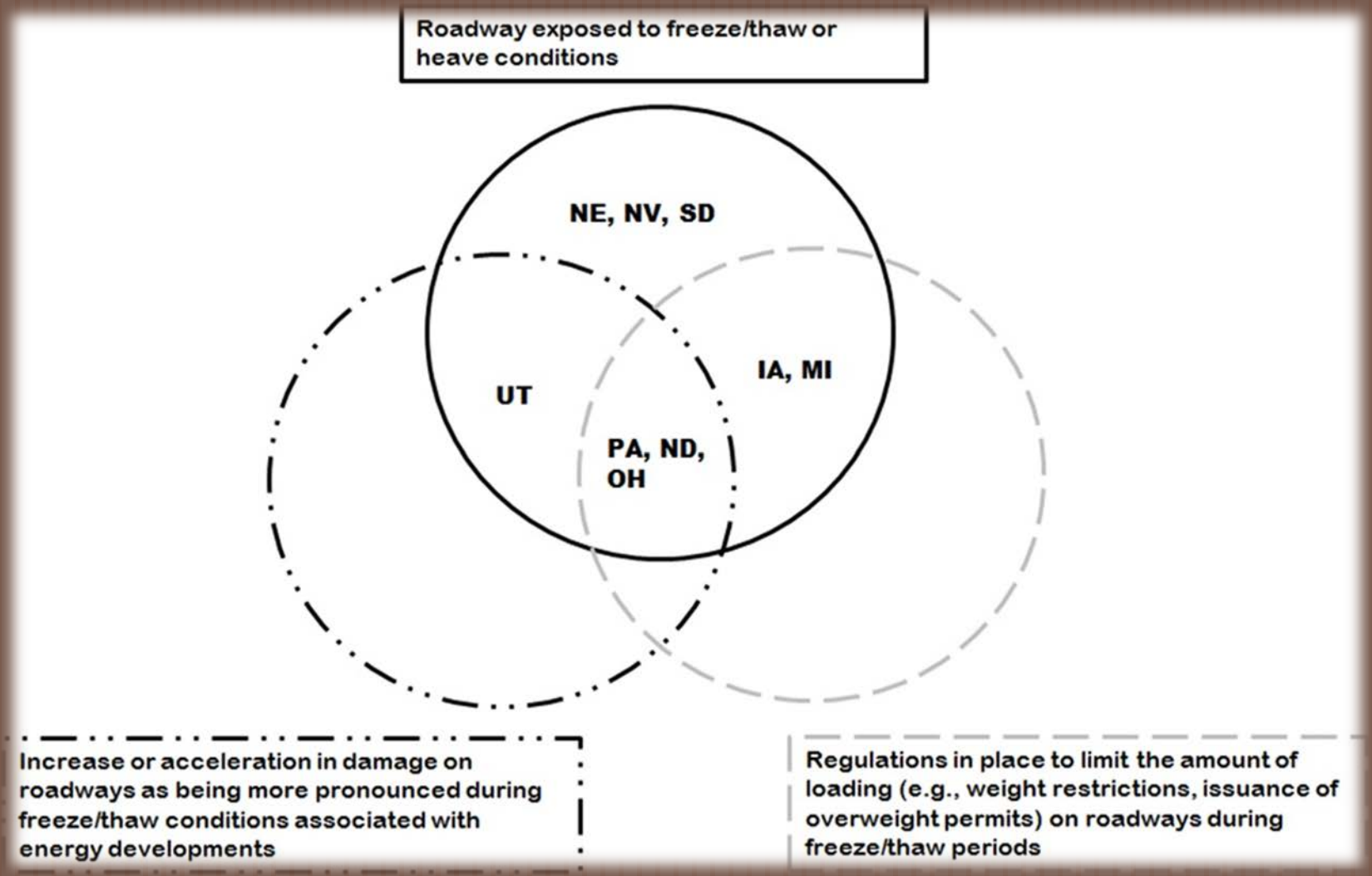


	No impact	Minimally impacted	Moderately impacted	Significantly impacted
Interstates or freeways	10	16	2	3
Primary (National Highway System or state highway system)	4	13	11	3
Secondary (minor arterials or collectors/distributors)	2	8	14	7
Secondary (local roads)	2	9	10	10

Damage or performance-related issues on infrastructure due to energy development activities



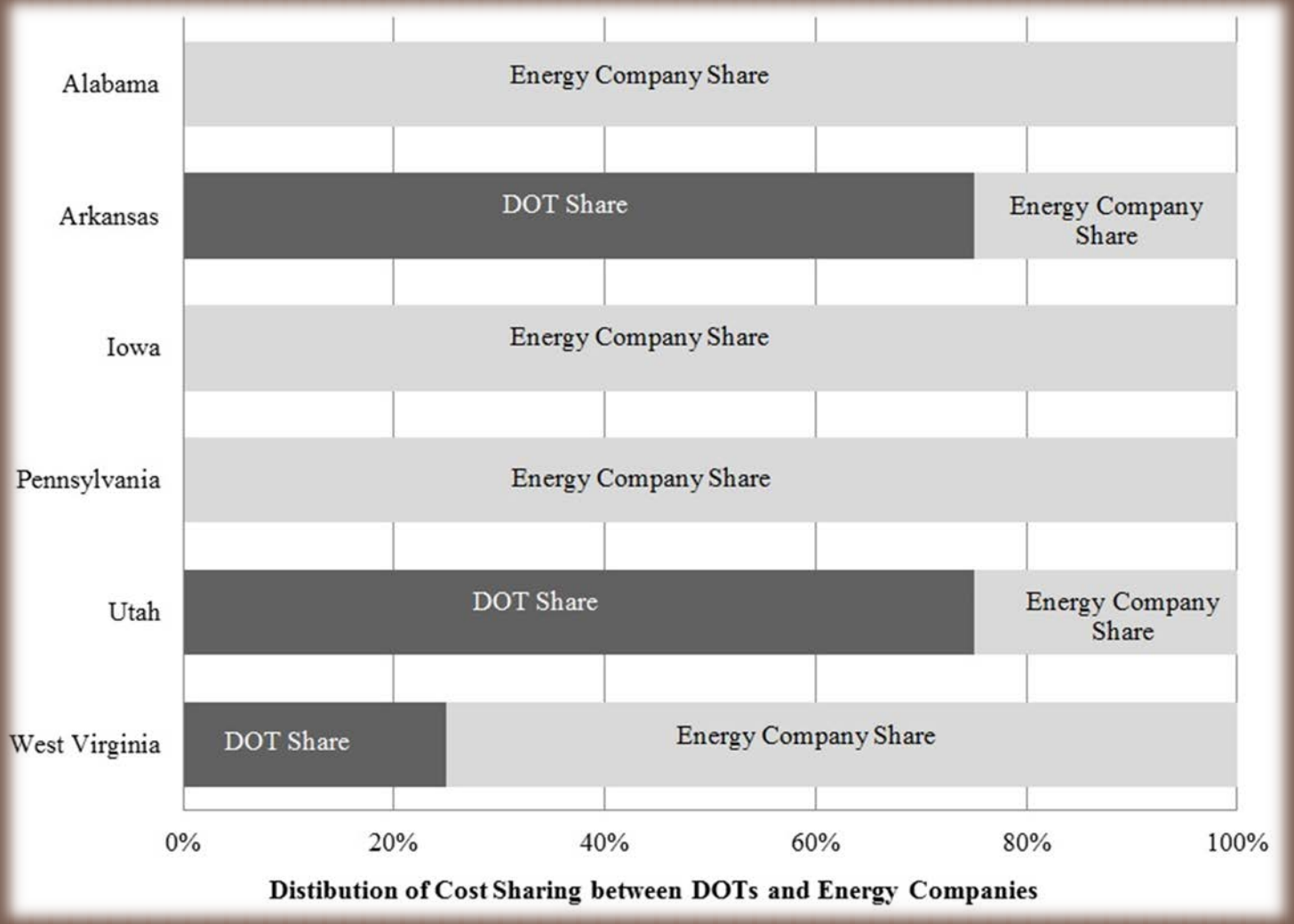
Roadway Exposure Conditions and Amount of Damage Reported



Methods Reported to Assess Costs

State	Practices for Assessing Infrastructure Costs
Iowa	Permit cost quantification (Cost Data)
Minnesota	Web-based road wear cost calculator (Tool)
Montana	Continuous monitoring of population and traffic growth (Planning)
Texas	Task force of state agency, local government, & energy industry representatives (Coordination)
Utah	Asset management and maintenance system (Database)

Level of Cost Sharing between DOTs and Energy Companies



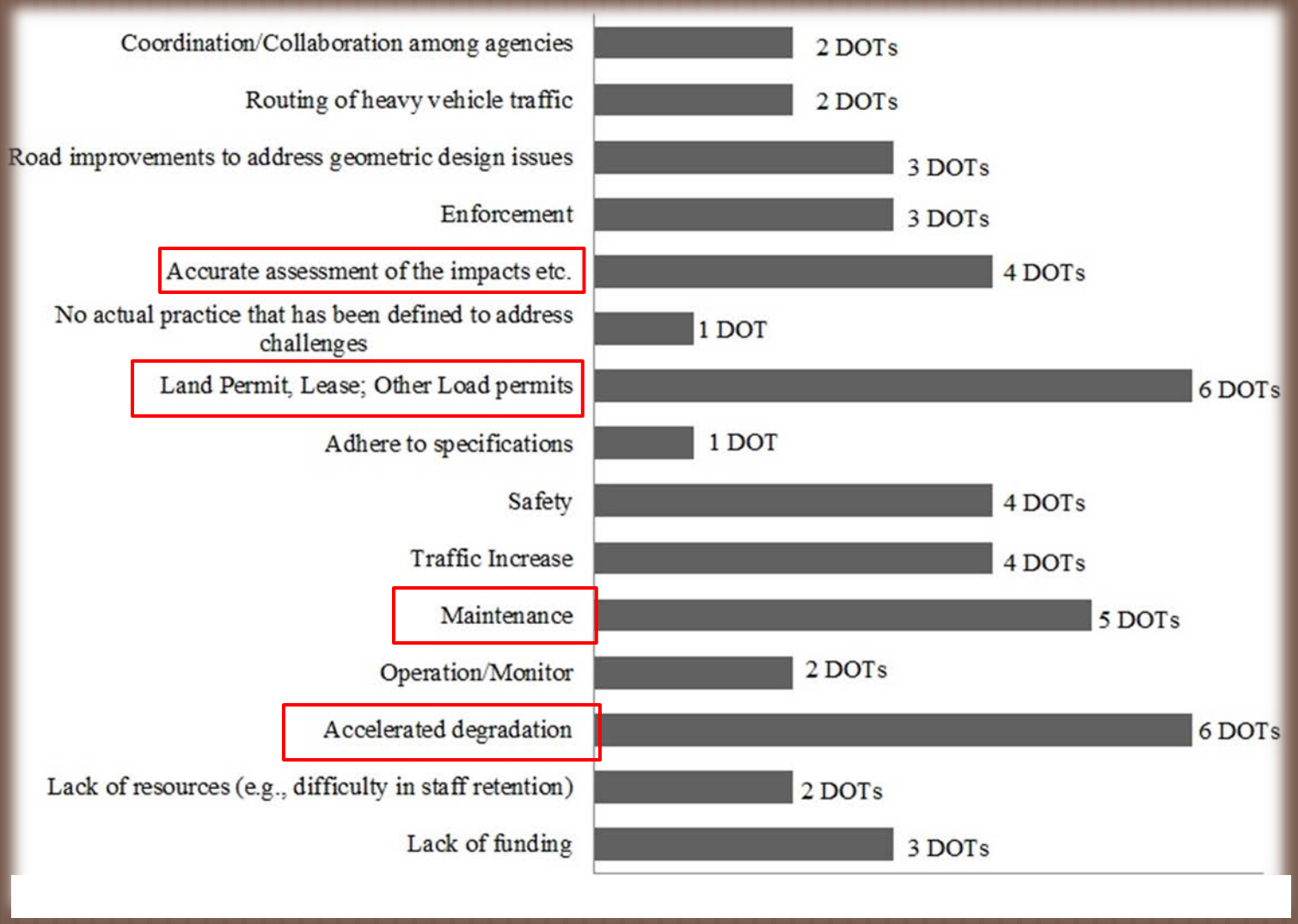
Safety Strategies Used and Rated Effectiveness

Measures Reported	States	
	Measure Rated as **Very Effective**	Measure Rated as Somewhat Effective
Reinforcement of roads (e.g., use of geotextiles, stabilization of aggregates or subgrade)	West Virginia	Iowa, Nebraska, Pennsylvania, Utah
Roadway geometric feature modifications (e.g., widening paved shoulder, horizontal curve re-alignment, etc.)	Arkansas, Colorado, Iowa, Kansas, Texas	Alabama, Montana, North Dakota, Pennsylvania, Utah
More frequent use of law enforcement (e.g., limit the traffic especially during the periodic heavy rainfall)	Colorado	Arkansas, Montana, Pennsylvania, Texas, Utah
Encourage or require the use of detours and alternate routing for heavy trucks	Colorado, Iowa, West Virginia	South Carolina, Minnesota, Nebraska, Pennsylvania, Utah
Install additional signage to warn motorists of heavy truck traffic volumes in the area	West Virginia	Alabama, Pennsylvania, Utah
Lower the posted speed limit		Colorado, Montana, Pennsylvania
Specific state or local legislation or regulations that apply to specific energy development industries (e.g., adequate public facilities ordinances, specific road and bridges design standards, etc.).	Colorado	Alabama, Pennsylvania
Temporary measures such as roadway embankments	Kansas	Pennsylvania
Campaigning and public outreach (e.g., ProgressZone in state of North Dakota)	North Dakota	Colorado, Pennsylvania, Texas, Utah
Use of intelligent transportation systems (e.g., advance warning systems)	Alabama, Colorado	Pennsylvania, Utah

Traffic Operation Strategies Used and Rated Effectiveness

Measures	States	
	Measure Rated as **Very Effective**	Measure Rated as Somewhat Effective
Encourage use of detours or alternate routing for heavy trucks	Iowa	Pennsylvania, South Carolina
Install increased signage to warn motorists of heavy truck traffic volumes	Utah	Alabama, Pennsylvania, Texas
Use of intelligent transportation systems (e.g., advance warning systems)	Utah	Alabama, Colorado, Pennsylvania
Collaborate with energy development companies to adjust the timing and logistics of the truck movements (e.g., staged truck routing schedule)	Iowa, West Virginia	Colorado, Pennsylvania, South Carolina

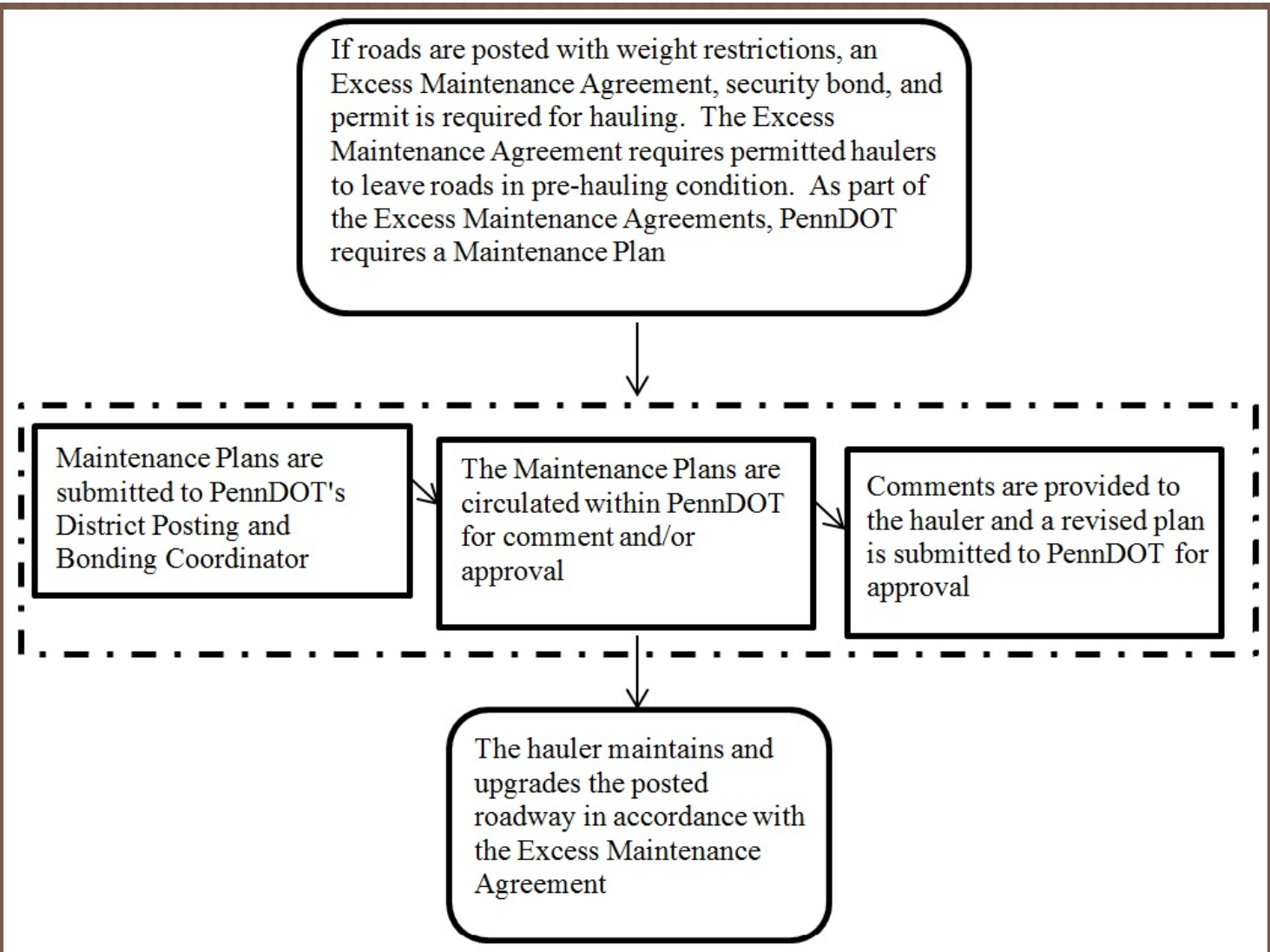
Defining Challenges



Tools to Address Challenges

State	Tools Reported To Address Challenges
Colorado	Local agencies are developing fees to address issues with infrastructure damage.
Missouri	An approach where the permit fee applied is commensurate with the number of permits issued in order to address funding issues.
Nebraska	The cost is being extracted from the corresponding annual budget, as the amount is not significant.
North Dakota	The state legislature has provided general fund money from the oil extraction fund to the DOT and local jurisdictions for road and bridge improvements.
Pennsylvania	The energy development sector is responsible for the excess maintenance costs, inspection fees, and roadway condition survey costs.
Texas	A unique relationship between the current/future energy sectors and railroad commission has been developed. Standard lease agreement with an associated fee. Temporary use of water lines to reduce roadway truck volumes.

Steps in the process for maintaining roads bonded by unconventional energy industries in PA



Conclusions

- Strong correlation between increase in negative impacts on safety and infrastructure deterioration


Photo: Texas Dept of Transportation

- Increase in the issuance of Oversize and/or Overweight (OS/OW) permits

Conclusions

- Engineering approaches:
  - increase the lane widths (and adding a pave shoulder)
  - increasing pavement thickness
  - stabilization of unpaved roadway surface layers
- Repair funds:
  - Combination of local and state funding
- Compensation to state and local damaged roads:
  - Various mechanisms
    - Development impact fees; user fee-based; energy-related permit fees; donation agreements
- Most common type of contractual agreement:
  - Use of state or local permits

Future Research Opportunities

Lack of…

1. Quantitative info on specific economic & social impacts
2. Safety and crash statistic data, especially for low volume roads
3. Info on existing low volume road pavement designs
4. Consistent, accurate approach for estimating damage & predicting pavement remaining service life
5. Investigation into detour routing
6. Info on extent of damage on high-type roadways

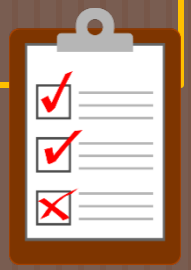
Moving Forward

Must balance competing outcomes of energy development & transportation

Data Collection
- **Adequate staff resources**
- **Efficient methods for comprehensive crash data**
- **Use of available electronic databases**

Periodic review of effectiveness of practices

Identify Performance Metrics



Engage freight planning divisions at DOTs, MPOs and RPOs


Photo: Alaska Pipeline


Photo: C. Barkan

Potential Mitigation Techniques

- Long-life flexible, rigid, or composite pavement designs.
- Asphalt or concrete mixture designs that resist heavy loads.
- Predetermined alternate routing for trucks based on structural condition ratings or inspection data.
- Temporary structural monitoring (sensors) on the most vulnerable bridges, culverts, or other structures.
- Use of ITS for advance warning systems, such as curve warning, real - time traffic congestion, and traffic incidents.
- Tagging of energy developer transport vehicles with GPS transponders.
- Increase signage to warn motorists of heavy truck traffic volumes.
- Media safety campaigns and increased enforcement.
- Collaboration with energy development companies.

Social Impacts of Fracking
A Pennsylvania Case Study

- Fracking associated with More Heavy Truck Crashes
  - Heavy Truck crashes rose 7.2% in heavily-fracked rural PA counties
- Fracking associated with More Social Disorder
  - Disorderly conduct arrests increased by 17.1% compared to 12.7 % in unfracked rural counties
- Fracking associated with More Cases of Sexually transmitted infections
  - After fracking, average increase in chlamydia & gonorrhea increased 62% greater in heavily fracked compared to unfracked rural counties

*Food & Water Watch Report Sept 2013 report

Questions / Comments?

- Contact Info
  - Leslie McCarthy: leslie.mcarthy@villanova.edu
  - Seri Park: seri.park@villanova.edu
  - Anthony Giancola: tonygiancola@rcn.com


Photo: Texas Dept of Transportation

Energy Sector Use of Rural Low Volume Roads

NCHRP 469: Impacts of Energy Developments of U.S. Roads and Bridges

Mark J. Nahra P.E.
Woodbury County Engineer (Iowa)
November 9, 2016

Iowa's Energy Sector

- Rural Product
  - Grain Crops
  - Biomass/Corn Stover
  - Wind
- Energy Produced
  - Ethanol and Biodiesel
  - Cellulosic Ethanol
  - Electricity

Energy issues in other states

- Local officials in other states have dealt with other parts of the energy sector.
  - Oil and Natural Gas development
  - Fracking – water and material transport
  - Logging

Energy Industry Effects on LVR

- Change in traffic patterns
  - Hauls to grain elevators, rail terminals, and river access changed as plants have located in new areas.
  - Ethanol plants located close to production – centroid location
- Increased loads
  - Construction traffic to wind generation sites
  - Corn yields increased over 100% in past 25 years
    - Corn hauled to farm storage or new plant sights that may not be along developed roads.

Iowa's Current County Road System

- 89,000 miles of county roads
  - 17,775 miles of HMA and PCC paved roads
  - 69,000 miles of gravel roads
    - Most graded before 1960
    - Minimal gravel base
- Most are on 66 foot wide rights of way
- Intersections have inadequate turning radii for long loads.

Wind Farm Construction

-Construction loads are severe.

-Road Damage has occurred.

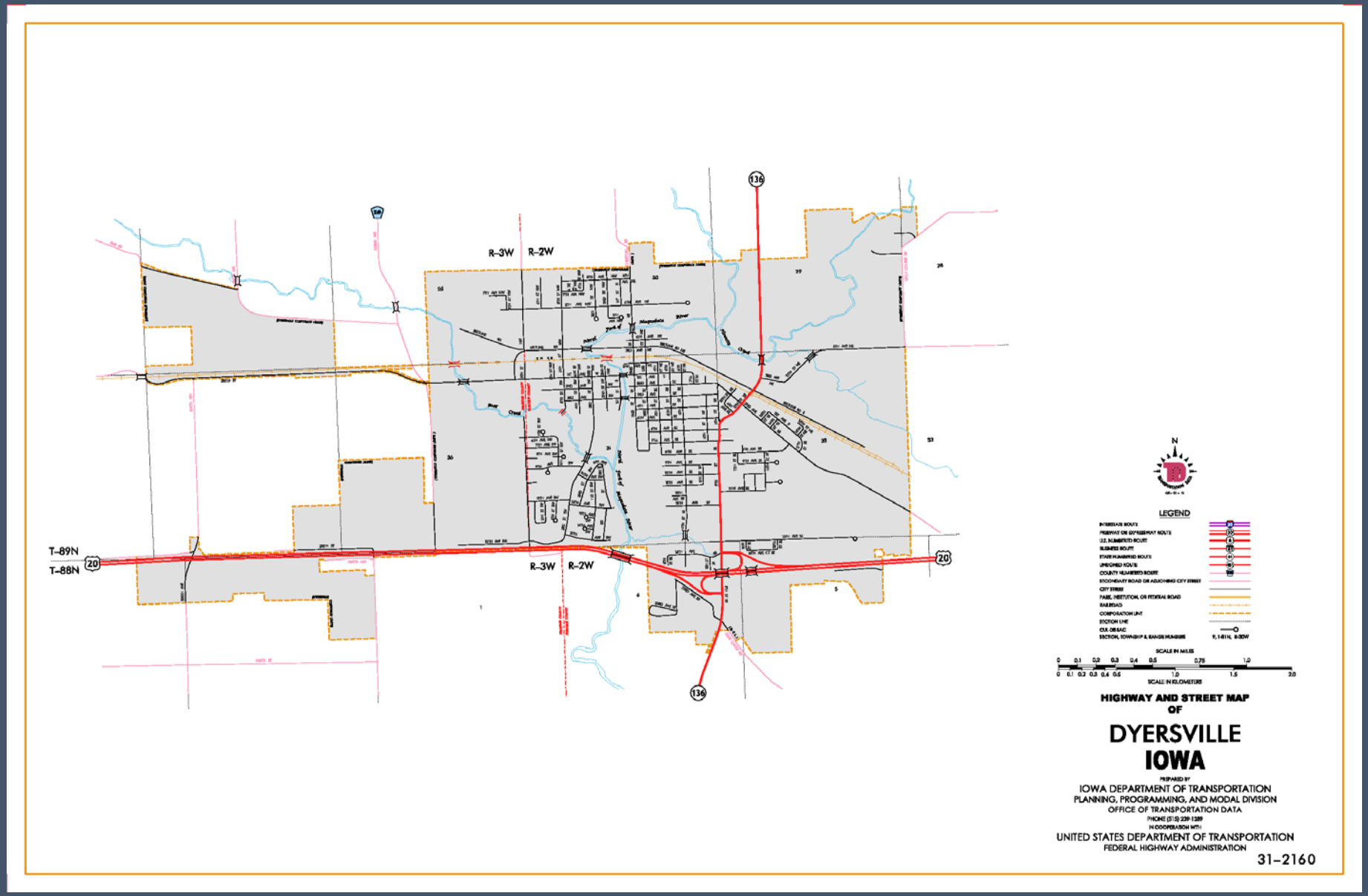
-Up to 450 Cubic Yards of Concrete per wind turbine base

-45-50 loaded of concrete trucks per base.

Paying for road improvements/repairs

- Are we just asking for it? Do our economic development efforts and competing for new industry set us up for extra costs?
  - Counties sometimes encourage energy development with property tax credits
  - Valuation of energy production facilities can be a property tax windfall
  - Cities “steal” county developments by annexation

City Annexation



Energy Industry Effects on LVR

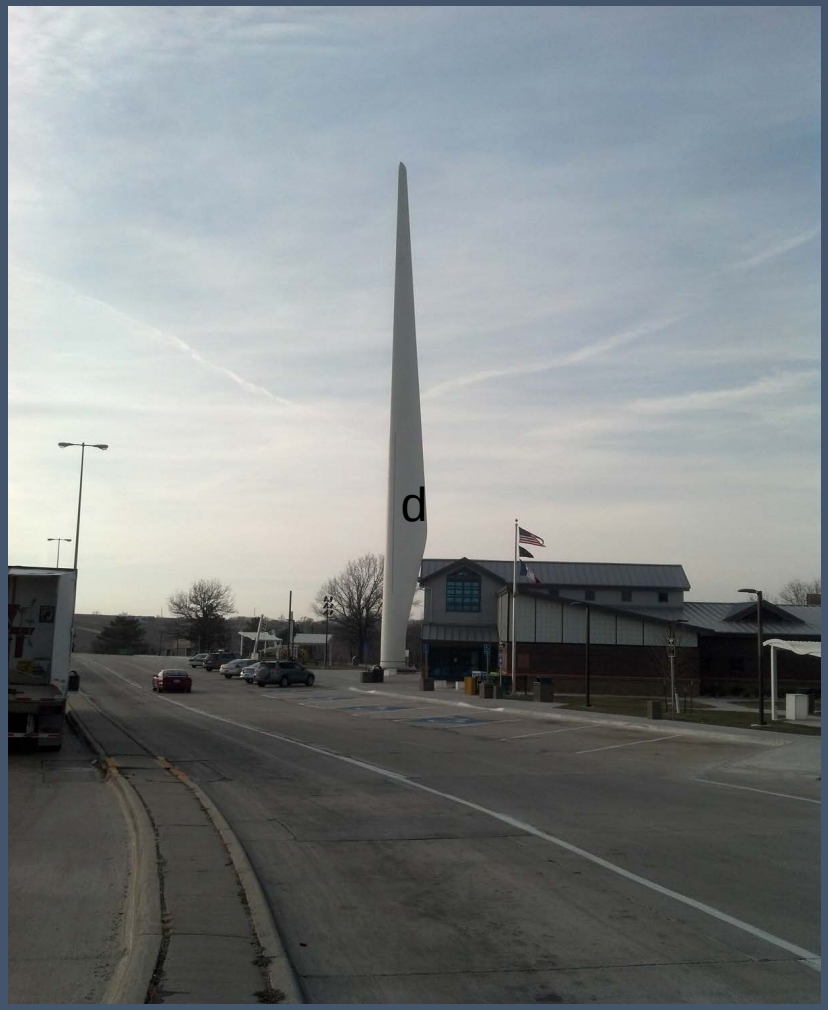
- Large loads delivering components
  - Turning radius on many rural intersections too tight for long loads
  - Temporary road embankments built to accommodate machinery movement
- Pavement life consumed
  - Construction loads: concrete, aggregate and steel for wind farms consume pavement life

Megaloads on County Highways

Courtesy of Mitchell County Engineers Office

Long Loads

Extremely long loads



Iowa BioFuel Production

- Iowa tops the nation in production of ethanol for fuel
  - Iowa produces 3.534 billion gallons per year
  - Number 1 in the nation, Nebraska no. 2 @ 1.6 billion gallons per year
- Iowa is now number 2 for wind generation of electricity (trailing only Texas)

Woodbury County

A recent research study (IHRB TR-608) calculates the amount of money needed to hold roads at their current condition level

- Paved Roads $24,000 per mile per year
- Gravel Roads $ 8,000 per mile per year
- Dirt Roads $ 1,000 per mile per year
- Based on this, Woodbury County should budget $16,200,000 per year
- Current FY 2017 Budget is $12,600,000

- Paying for development is not easy when you already have a shortfall for meeting basic needs.

The search for answers

- What research has been conducted on the effects of the energy industry on our roads, and what are the results?
- What other indicators do we have on the effects of the energy industry on low volume roads?
- How can we address the impacts of significant increases in low volume road traffic from developments in the energy industry?

Research done in Iowa

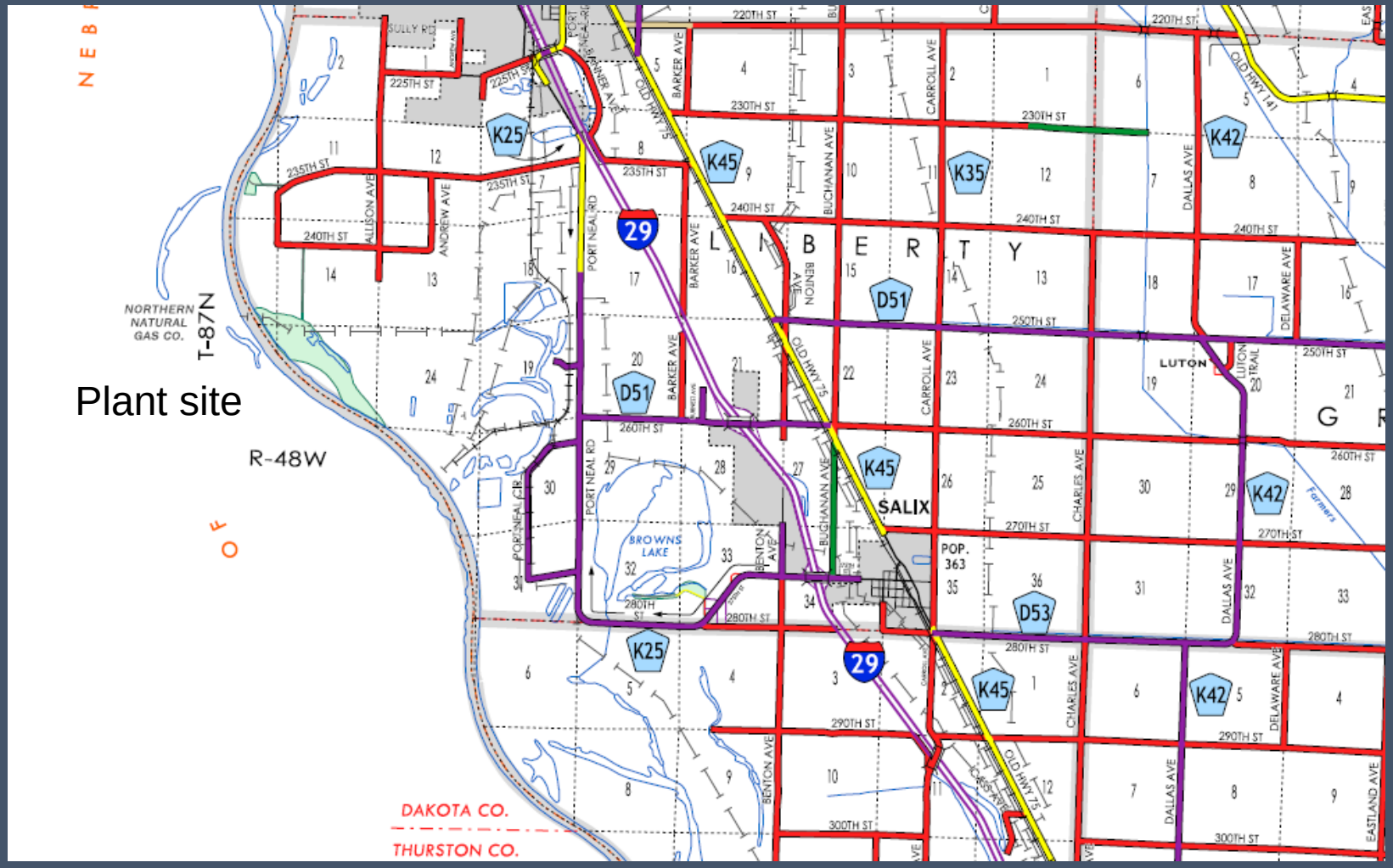
- TR-593: Iowa's Renewable Energy and Infrastructure Impacts
- HR-1073: Heavy Agricultural Loads on Pavements and Bridges
- TR-548: Investigation of the Impact of Rural Development on the Secondary Road System

- These studies helped identify and quantify the problems.

New Attempts to Capture Funds for Road Repairs/Restoration

- Tax Increment Financing
- Adjacent property designated as an “Urban Renewal District” to allow funds raised to be targeted to development.
- Roads can be designated as the “urban renewal district”
- Funds used to repair and regrade roads

Woodbury County Urban Renewal District



County Zoning

- Counties are beginning to use zoning to assist with managing wind farm development
- Areas targeted for wind farm development are accounted for as a permitted land use in zoning ordinance.
- Awareness of this potential use allows planning.
- County can be ready when the industry knocks on the door.
- Zoning doesn’t prohibit or encourage wind farm development, but it assures that there is a conversation before the ready mix starts rolling.

Zoning for Energy Sector Impacts

SPECIAL USE APPLICATION, REVIEW AND APPROVAL CRITERIA FOR A COMMERICAL WIND ENERGY PROJECT (CWEP) FOR THE ZONING REGULATIONS OF COFFEY COUNTY, KANSAS.

Note: See Section 4-101B18 in the A-1 Agricultural District for Wind Energy Projects, Commercial as a Special Use.

A. Purpose.

The purpose of this statement is to outline required information for application of a Special Use and review and approval criteria for a Commercial Wind Energy Project (CWEP). A Development Plan is to be submitted with the application. These criteria are written to:

- Assist the Applicant and relevant authorities:
- Provide details of the CWEP;
- Provide information so individuals may gain an understanding of the CWEP;
- Provide a basis for public discussion and informed comment on the CWEP;
- Provide information regarding significant environmental, social, cultural and economic effects related to the CWEP: and,
- Provide a background on which decision makers will consider the project.

Information in the Application and Development Plan shall be as current as possible at the time of submission. Where information is unavailable or not yet finalized, estimates and/or alternative options shall be provided and noted as estimates or alternatives. Not all matters in the criteria are relevant to all aspects of the project. Only those matters relevant to the particular project need be addressed.

B. Intent.

These criteria are intended to:

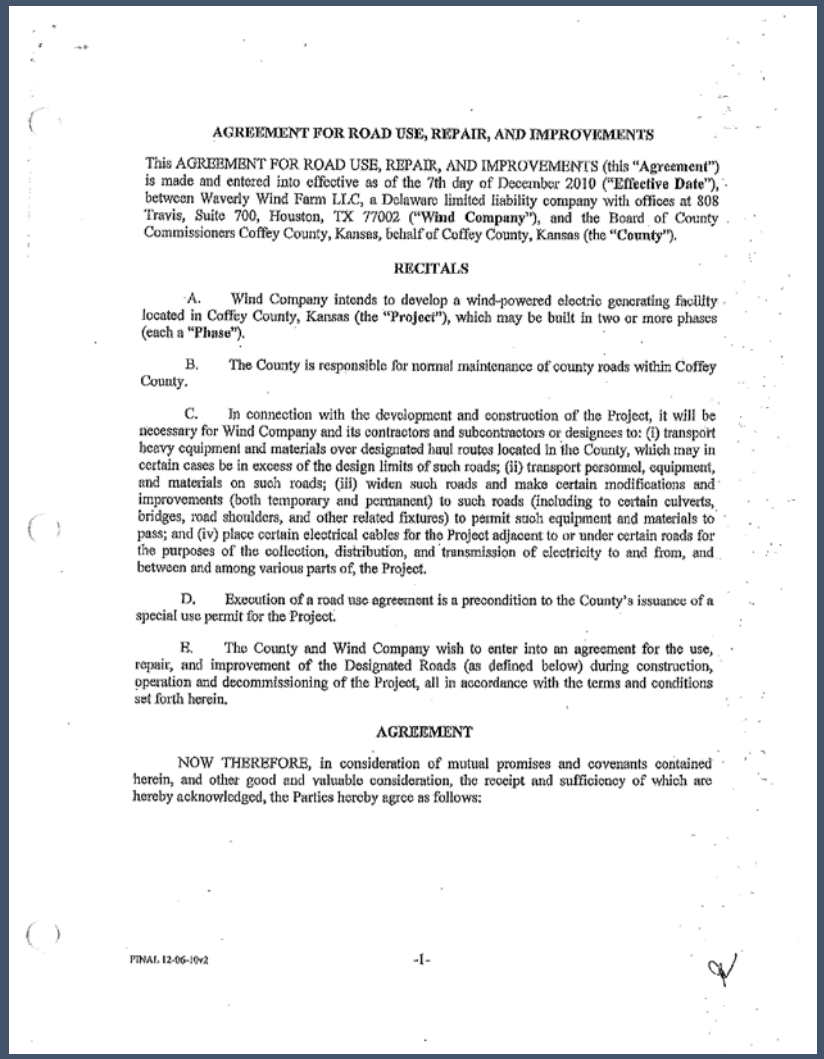
- Address major issues associated with the project; however, they are not all inclusive. Issues not listed may be deemed significant and issues may emerge as significant (studies, public input) during the course of review.
- These criteria are not intended to regulate the installation of the smaller individual private wind energy conversion systems. (See Section 6-100B14 and Section 2-102 for definition of Height, Maximum.)

Courtesy of Coffey County, KS

Costs of Road Accommodations

- In addition to zoning, counties have made wind farm developer liable for road improvement costs.
- Preconstruction agreements are put into place.
- De-mobilization of wind farm is also an issue.
  - Wind generators have a finite life span of 10-20 years on components.
  - Plans need to be made for de-construction or component replacement at some time in the future.

Agreements prior to construction



AGREEMENT FOR ROAD USE, REPAIR, AND IMPROVEMENTS

This AGREEMENT FOR ROAD USE, REPAIR, AND IMPROVEMENTS (this "**Agreement**") is made and entered into effective as of the 7th day of December 2010 ("**Effective Date**"), between Waverly Wind Farm LLC, a Delaware limited liability company with offices at 808 Travis, Suite 700, Houston, TX 77002 ("**Wind Company**"), and the Board of County Commissioners Coffey County, Kansas, behalf of Coffey County, Kansas (the "**County**").

RECITALS

A. Wind Company intends to develop a wind-powered electric generating facility located in Coffey County, Kansas (the "**Project**"), which may be built in two or more phases (each a "**Phase**").

B. The County is responsible for normal maintenance of county roads within Coffey County.

C. In connection with the development and construction of the Project, it will be necessary for Wind Company and its contractors and subcontractors or designees to: (i) transport heavy equipment and materials over designated haul routes located in the County, which may in certain cases be in excess of the design limits of such roads; (ii) transport personnel, equipment, and materials on such roads; (iii) widen such roads and make certain modifications and improvements (both temporary and permanent) to such roads (including to certain culverts, bridges, road shoulders, and other related fixtures) to permit such equipment and materials to pass; and (iv) place certain electrical cables for the Project adjacent to or under certain roads for the purposes of the collection, distribution, and transmission of electricity to and from, and between and among various parts of, the Project.

D. Execution of a road use agreement is a precondition to the County's issuance of a special use permit for the Project.

E. The County and Wind Company wish to enter into an agreement for the use, repair, and improvement of the Designated Roads (as defined below) during construction, operation and decommissioning of the Project, all in accordance with the terms and conditions set forth herein.

AGREEMENT

NOW THEREFORE, in consideration of mutual promises and covenants contained herein, and other good and valuable consideration, the receipt and sufficiency of which are hereby acknowledged, the Parties hereby agree as follows:

FINAL 12-06-10v2 -1-

- Courtesy of Coffey County, KS

Counties are becoming more proactive

- Talk to your neighbors and other states
- As wind farms grow in other areas of the country, lessons learned by counties can help everyone.
- Use groups like NACE and other statewide associations to assist in preparing for industry expansion.
- The need for new energy sources will not go away, use your opportunity to prepare for potential development if you have resource potential in your area.

Questions?

Impact of Energy Development on Texas Highways

TRB Webinar: Energy Development & US Infrastructure

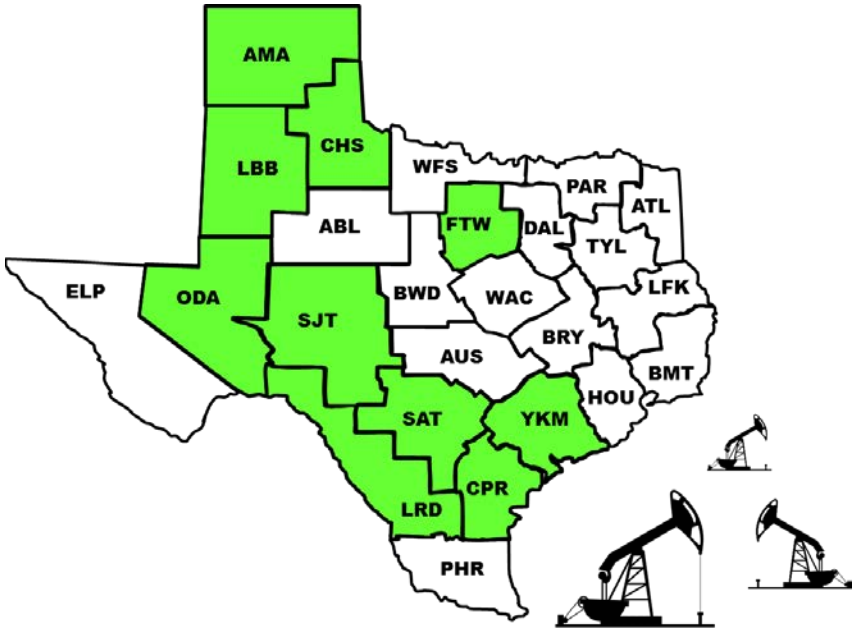
November 9, 2016

Jon Epps

Texas A&M Transportation Institute

TxDOT-TTI Joint Effort

- **Purpose**
  - Support for districts
  - Administrative/ management information
- **TxDOT**
  - Special unit (pavement asset management)
- **TTI**
  - Interdisciplinary Research/support team



Improve Available Information

- Current repair strategies
- Factors involved in selecting strategies
- Determination of condition of existing pavement
- Define traffic (oil/gas development & production)
- Pavement thickness requirements
- Performance of repair strategies

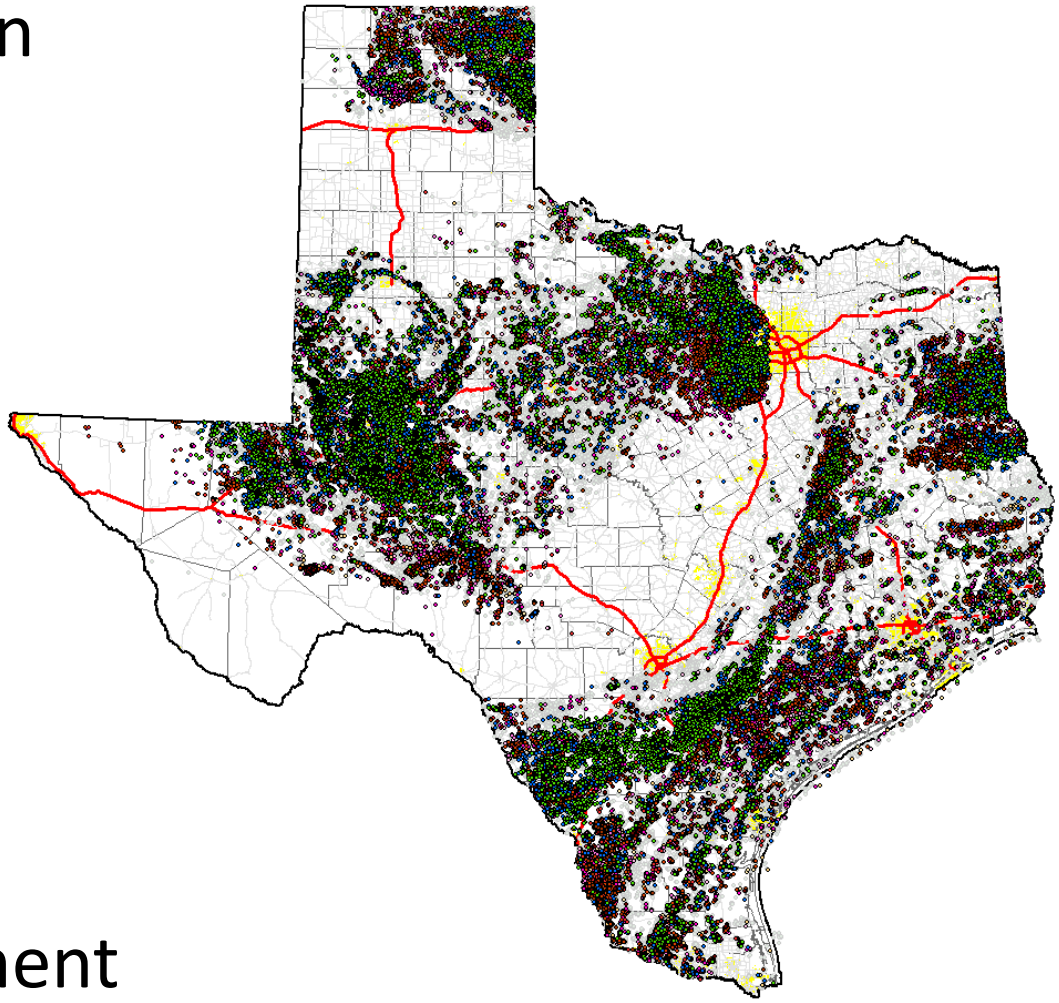
Documents

- Energy Sector Briefs (ESB)
- Implementation Reports (IR)
- Technical Memorandum (TM)
- Research Reports (RR)

Background

- **Well development**
  - 1,000 to 4,000 loaded trucks
- **Well operation**
  - Crude oil haul
  - Salt water haul
  - Re-stimulation (2,000 plus or minus)
  - Service equipment

- **Oil/Gas permits issued/year-10,000 to 24,000**
- **Well development**
  - Site preparation
  - Drilling
  - Completion
  - Operating Infrastructure
- **Well operation**
  - Crude haul
  - Salt water haul
  - Re-stimulation
  - Service equipment



Background

Economic Impact

- **West Texas**
  - $14.5 billion in 2012
  - 21,450 jobs
  - $1 billion in wages
  - $475 million in state revenue

Background

Economic Impact

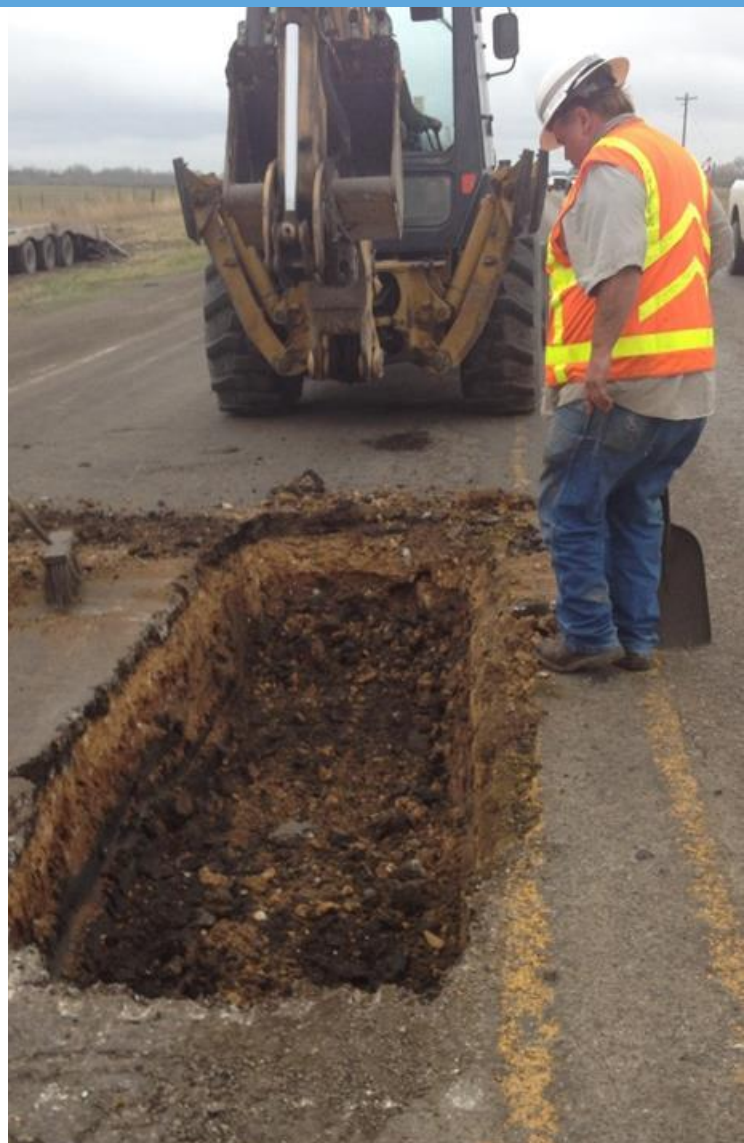
- **South Texas**
  - $46 billion in 2012
  - 89,000 jobs

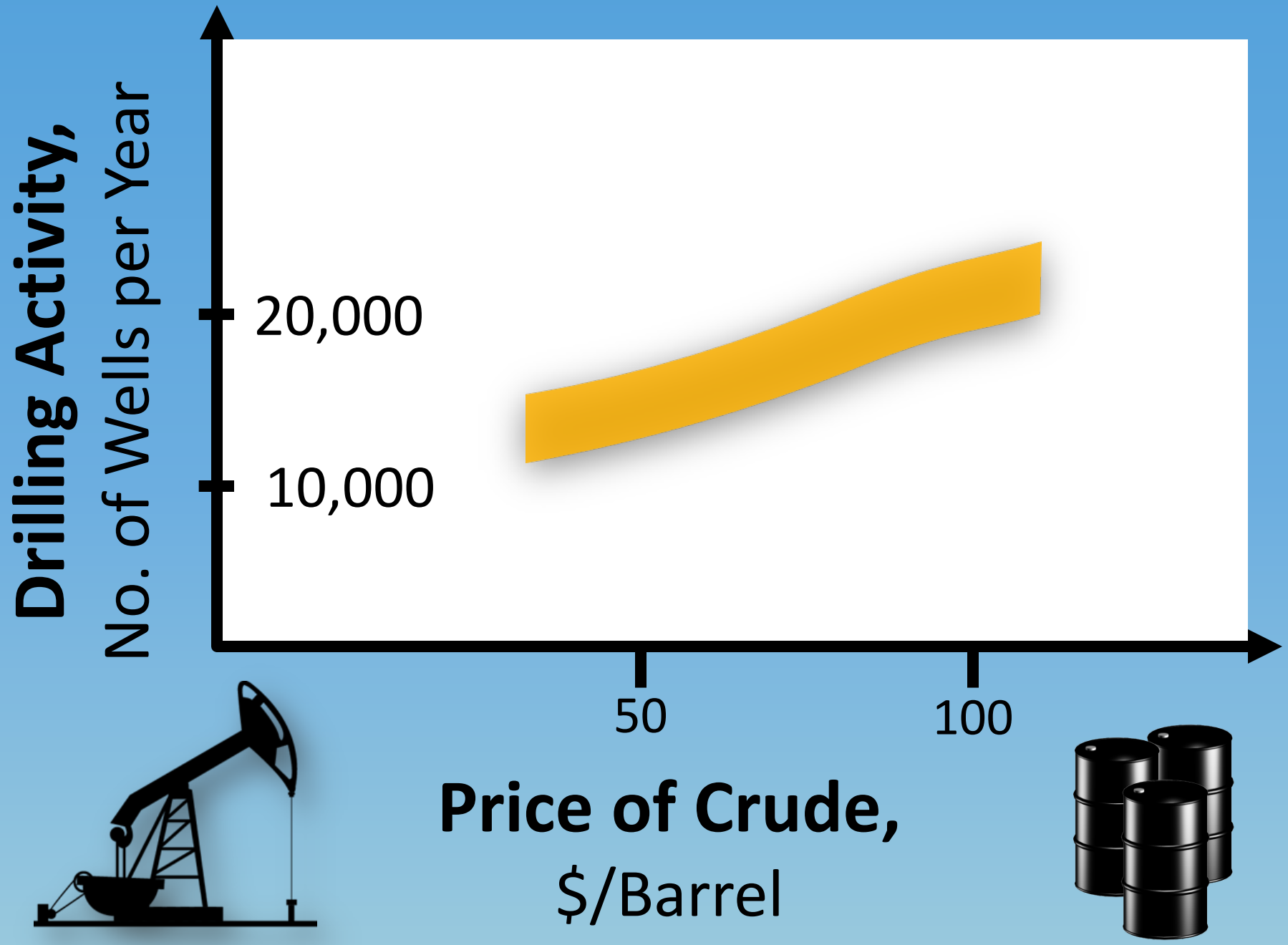
Road Impacts

- **Impacts**
  - FM roadways
  - SH and US highways
  - IH highways
- **Estimated damage per year**
  - $1 billion to TxDOT system
  - $1 billion to local government system

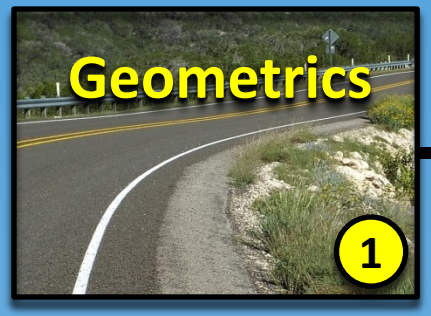
Roadway Impacts

- **Maintenance costs**
  - From $500 to $1,500 per year
  - To $35,000 to $45,000 per year
- **Cost to industry (no repair)**
  - $1.5 to $3.5 billion per year
    - Equipment damage
    - Lower operating speeds
- **TxDOT expenditures annually**
  - TxDOT-$500 million
  - Local gov't-$200 million



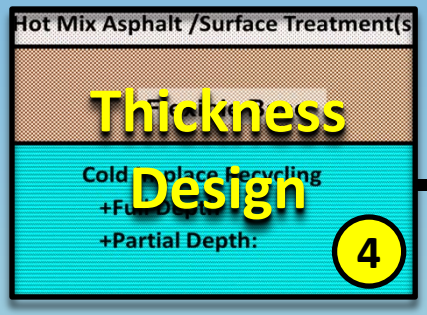

Drilling Activity,
No. of Wells per Year
20,000
10,000
50
100
Price of Crude,
$/Barrel

Guidelines


Geometrics
1


Pavement Condition
2


Traffic
3


Hot Mix Asphalt /Surface Treatment(s
Thickness Design
+Partial Depth:
4


Constraints
5

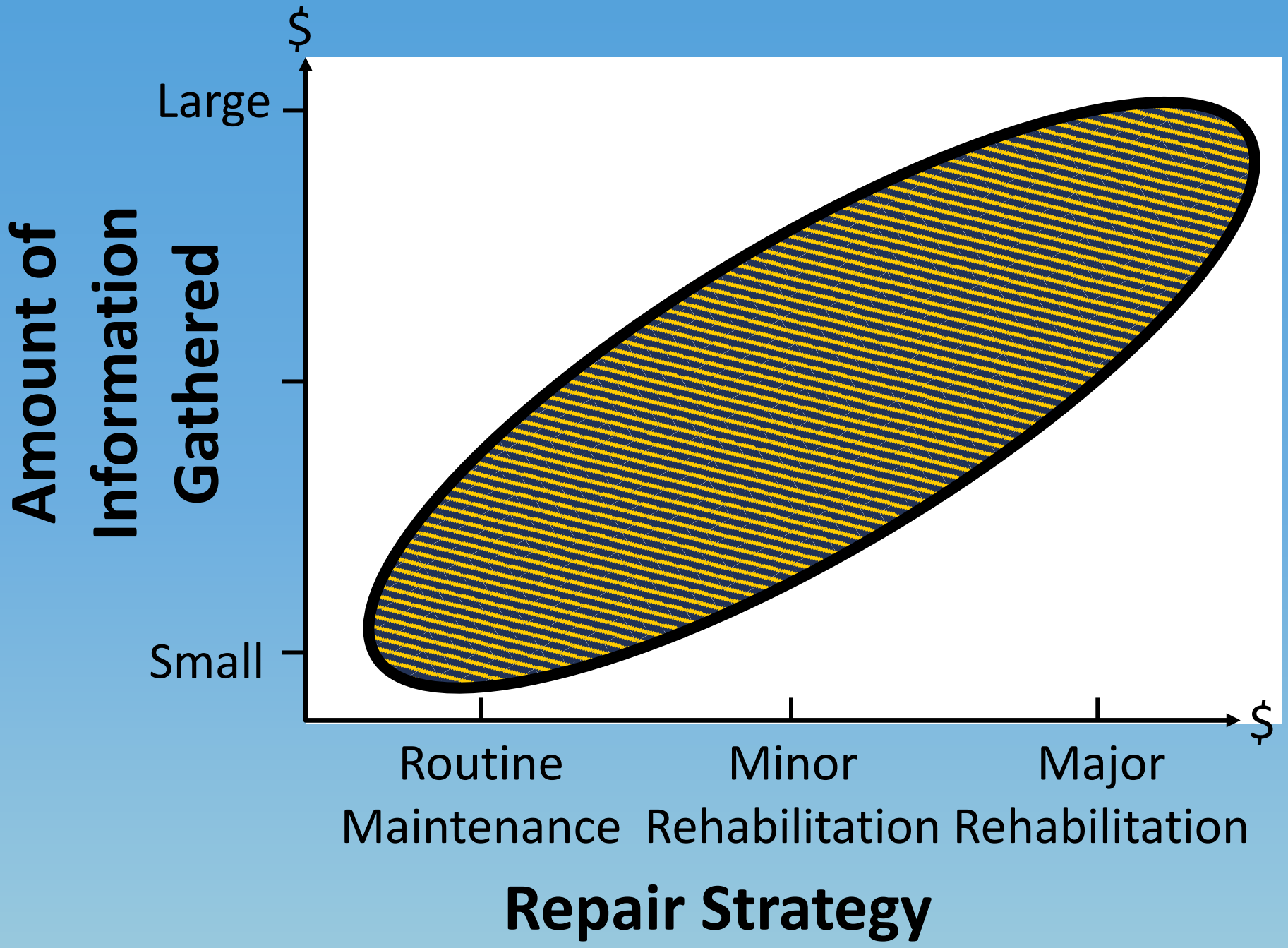

Routine Maintenance
6


Preventive Maintenance
7


Rehabilitation
8


Economics
9


Select Method
10


$
Large
Small
Amount of Information Gathered
$
Routine Maintenance
Minor Rehabilitation
Major Rehabilitation
Repair Strategy

Step 2 - Pavement Condition

Anticipated Maintenance/ Rehabilitation	Pavement Condition Investigation	
	Level	Activities
Routine Maintenance	1	Historic records/visual condition & perhaps GPR
Preventive Maintenance	1 & 2	GPR/FWD & perhaps DCP
Rehabilitation	1, 2 &3	Field sampling and laboratory testing

Step 1 - Geometrics/Pavement Characteristics

- Most important considerations
  - Quantity of existing materials
  - Width of lanes
  - Width of paved shoulder
  - Vertical controls

Step 2- Pavement Condition

- Level 1-Visual Condition Survey
  - Type of Distress
  - Severity of Distress
  - Extend of Distress

Step 2 – Pavement Condition
GPR

Step 2 – Pavement Condition
FWD

Step 2
Pavement Condition

Dynamic Cone Penetrometer

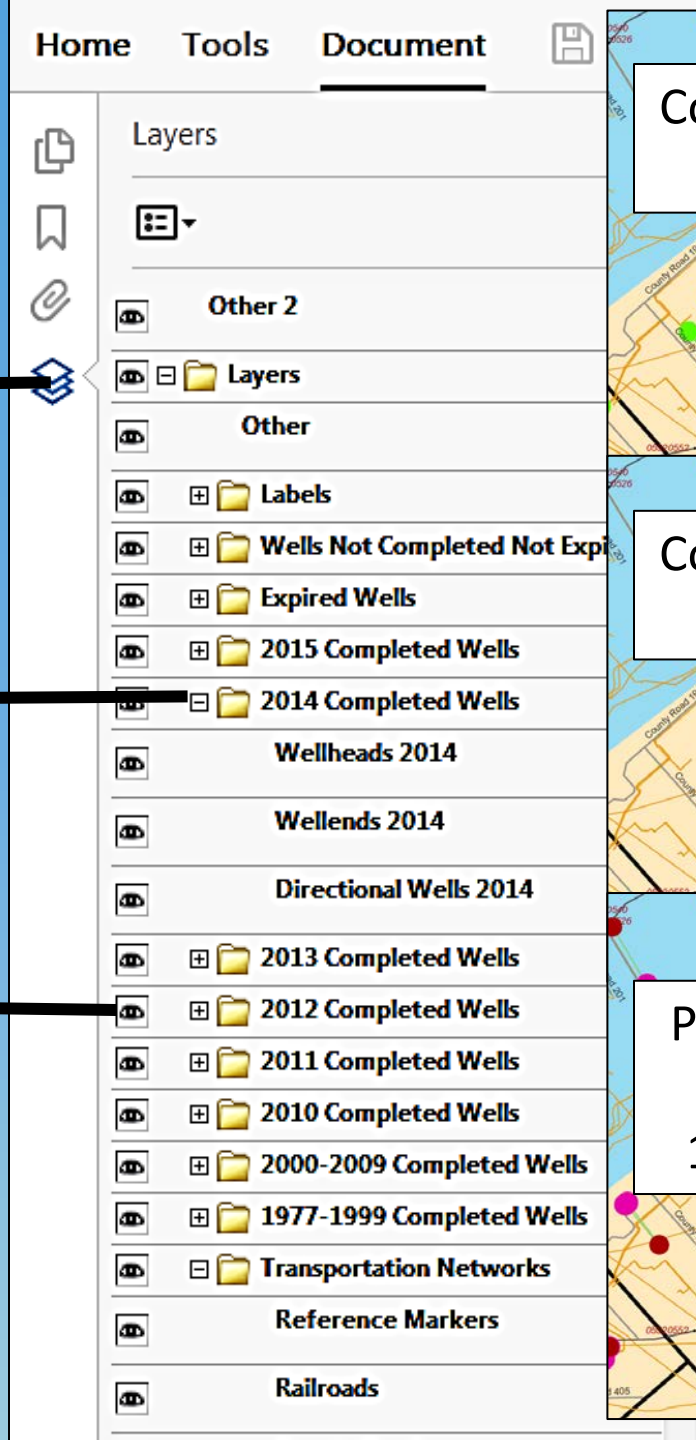
Step 2 Pavement Condition

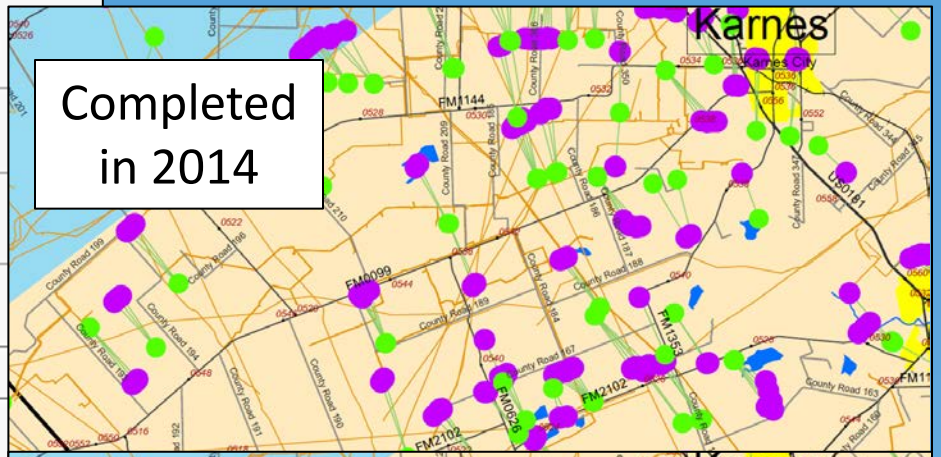
Step 2 – Pavement Condition Lab Testing

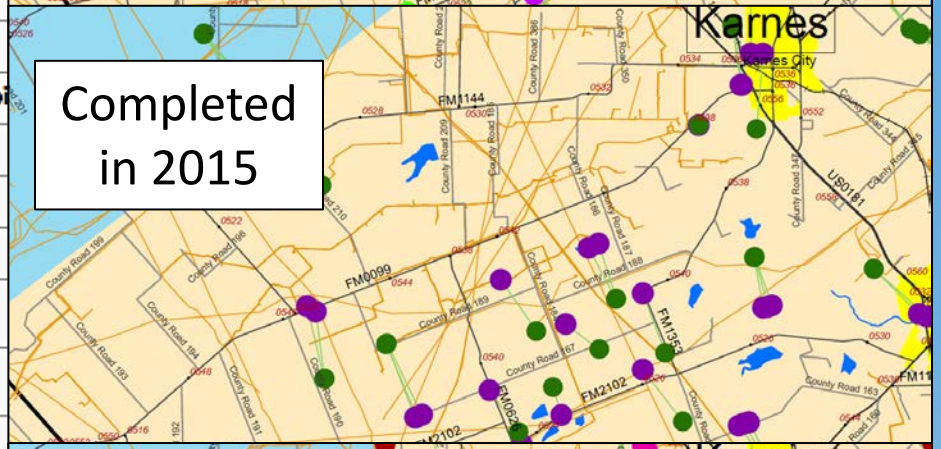
Open the layer panel

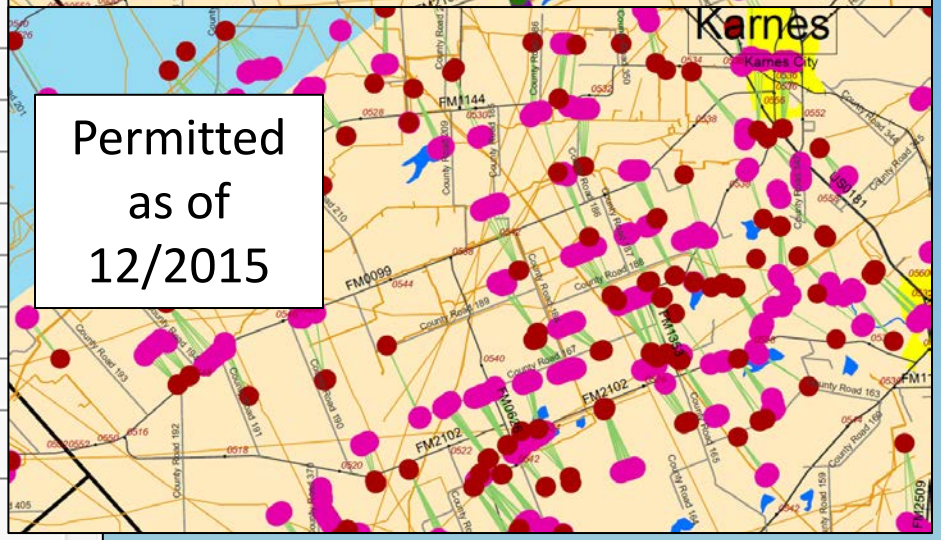
Expand/ collapse a folder

Turn layer on/off

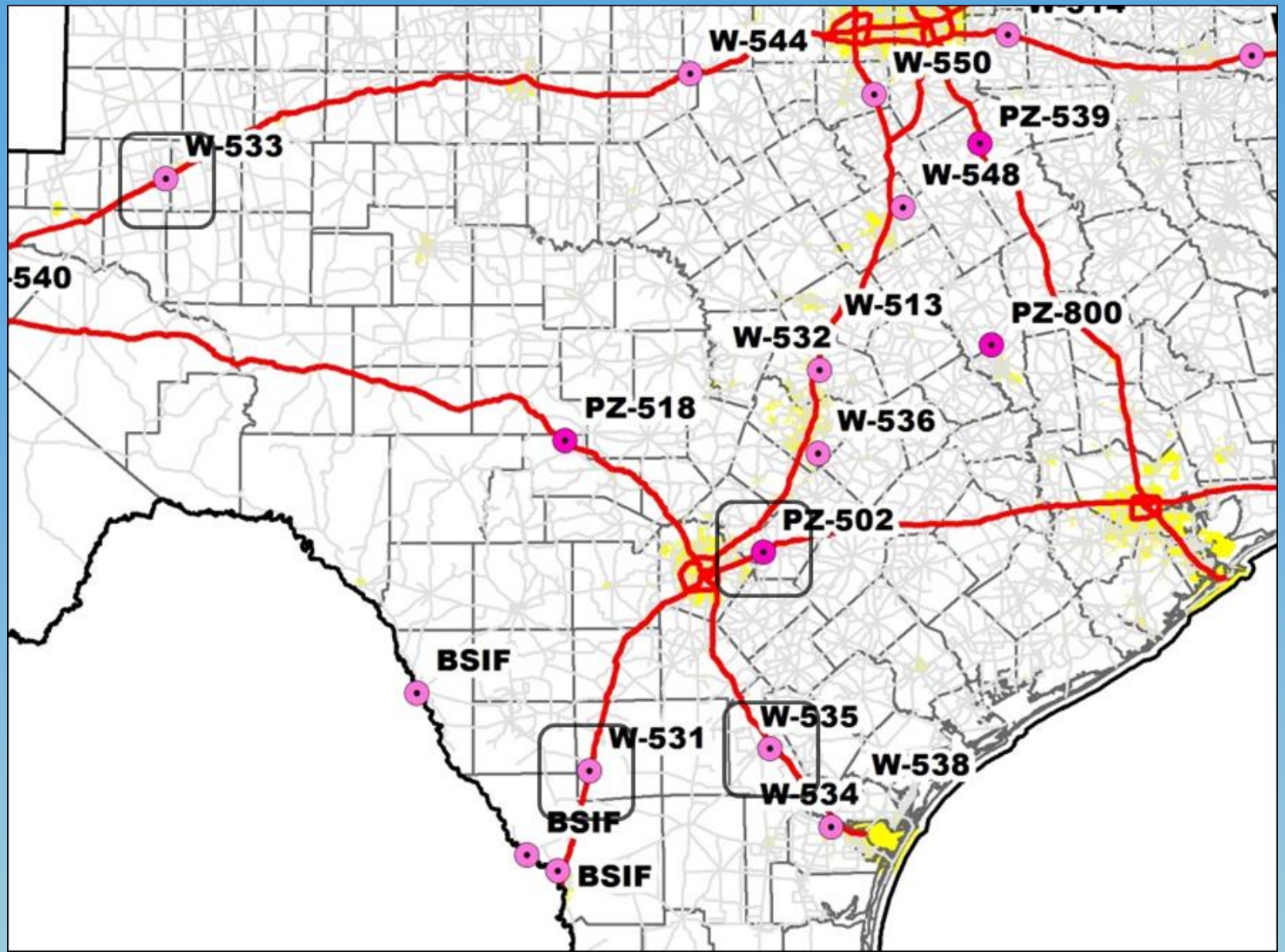




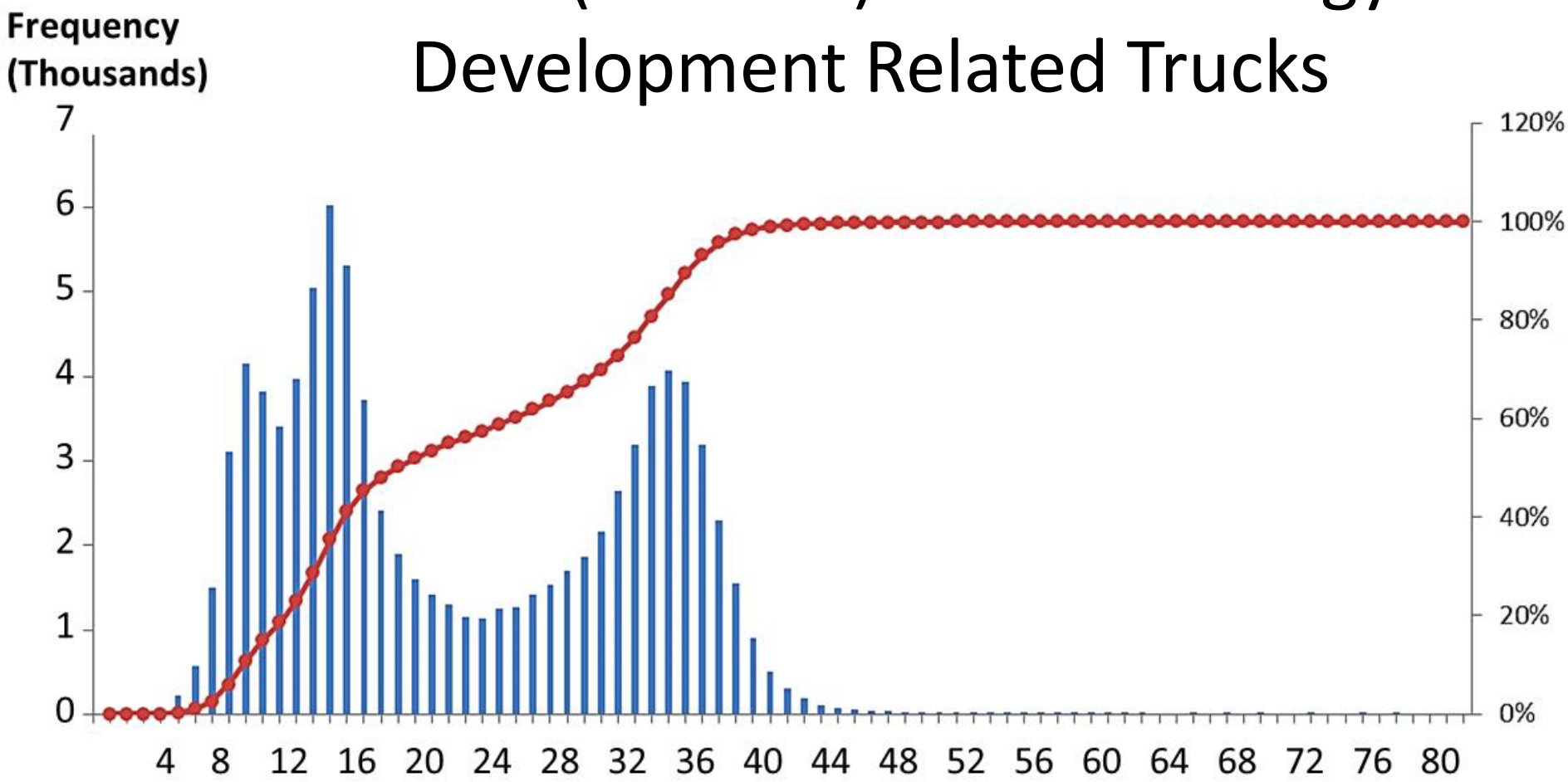




WIM Stations



Axle Load Distribution: Tandem Axles 5-Axle (or more) Possible Energy Development Related Trucks



Axle Group Weights, lbs (Thousands)

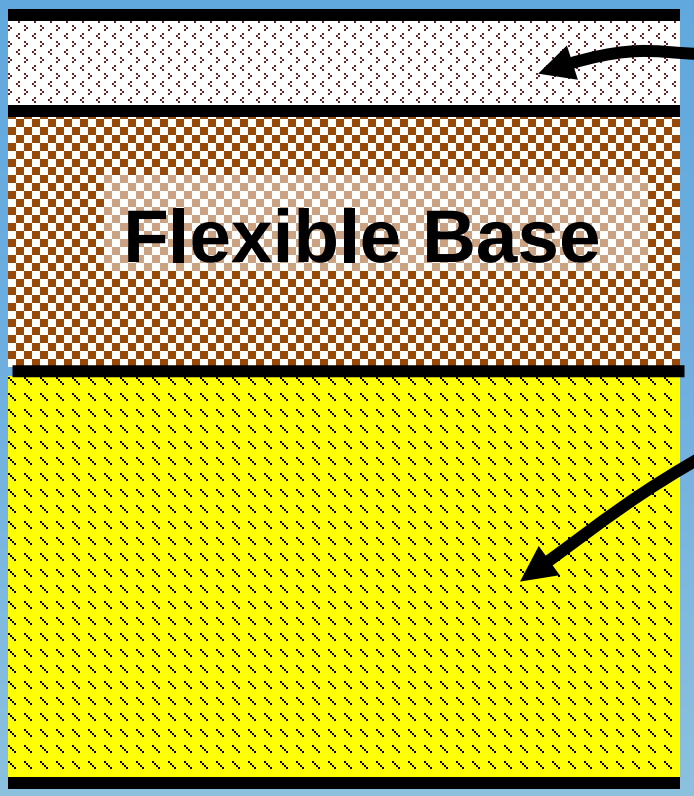
Number of Trucks per Phase

Well Development	Number of Trucks		
	Barnett Shale	Eagle Ford Shale	Permian Basin
Drilling pad and construction equipment	70	70	70
Drilling rig	4	4	4
Drilling fluid and materials	59	59	59
Drilling equipment: casing, drilling pipe	54	54	54
Fracking equipment: pump trucks, tanks	74	74	74
Fracking water:	533	1,021	527
Fracking water (steel tank)	373	715	369
Fracking water (aluminum tank)	160	306	158
Fracking sand:	57	147	66
Fracking sand (steel tank)	40	103	46
Fracking sand (aluminum tank)	17	44	20
Other additives and fluids	4	24	11
Flowback water removal	133	255	132
Total	**988**	**1,708**	**997**

Traffic/No. of Wells

Traffic, ESAL	<0.5 Million	0.5-1.5 Million	1.5-3.0 Million	3.0-4.0 Million	4.0-5.0 Million	>5.0 Million
EF #Wells	<10	10-90	90-200	200-270	270-340	Use Formalized Design
PB #Wells	<20	20-110	110-250	250-340	340-440	
BS #Wells	<40	40-210	210-470	470-640	640-810	

Step 4 – Thickness Design



Hot Mix Asphalt /Surface Treatment(s)

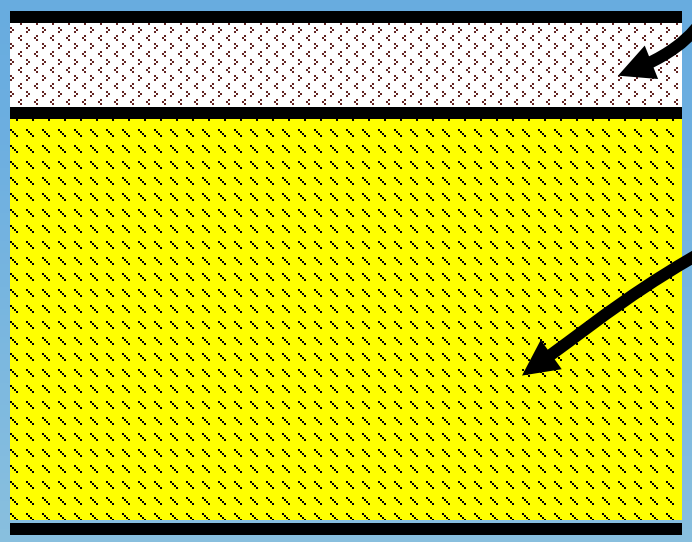
Cold In-place Recycling
- Cement
- Asphalt
- No stabilizer

+Full Depth

+Partial Depth:

Subgrade

Step 4 – Thickness Design



Hot Mix Asphalt /Surface Treatment(s)

Cold In-place Recycling
- Cement
- Asphalt
- No stabilizer

+Full Depth

+Partial Depth:

Material Properties

Energy Sector Pavement Design Catalog for 4-Layer (Surface, Flex Base, FDR, Subgrade) Pavement (Flex Base Thickness in Inches

Traffic, ESAL	<0.5 Million			0.5-1.5 Million			1.5-3.0 Million			3.0-4.0 Million			4.0-5.0 Million			>5.0 Million
EF #Wells	<10			10-90			90-200			200-270			270-340			Use Formalized Design
PB #Wells	<20			20-110			110-250			250-340			340-440			
BS #Wells	<40			40-210			210-470			470-640			640-810			
	Eagle Ford (Subgrade Modulus < 7ksi)															
Surface	2 CST	4" HMA	6" HMA	2 CST	4" HMA	6" HMA	2 CST	4" HMA	6" HMA	2 CST	4" HMA	6" HMA	2 CST	4" HMA	6" HMA	
CM 6"	11	7	6	12	8	6	12	9	7	-	-	7	-	-	7	
CM 8"	9	6	6	10	6	6	10	7	6	-	-	6	-	-	6	
AE/NS 6"	12	8	6	12	9	7	12	10	7	-	-	8	-	-	8	
AE/NS 8"	12	6	6	12	7	6	12	10	7	-	-	8	-	-	8	
	Medium Subgrade (Subgrade Modulus < 7 – 15 ksi)															
CM 6"	7	6	6	10	6	6	12	6	6	-	-	6	-	-	6	
CM 8"	6	6	6	7	6	6	10	6	6	-	-	6	-	-	6	
AE/NS 6"	12	6	6	12	6	6	12	6	6	-	-	6	-	-	6	
AE/NS 8"	12	6	6	12	6	6	12	6	6	-	-	6	-	-	6	
	Permian Basin (Subgrade Modulus > 15 ksi)															
CM 6"	6	6	6	6	6	6	10	6	6	12	-	6	-	-	6	
CM 8"	6	6	6	6	6	6	10	6	6	12	-	6	-	-	6	
AE/NS 6"	6	6	6	9	6	6	12	6	6	12	-	6	-	-	6	
AE/NS 8"	6	6	6	8	6	6	12	6	6	12	-	6	-	-	6	

BS # Wells: Number of wells serviced by road in Barnett Shale; PB = Permian Basin; EF = Eagle Ford Shale

CM 6" = Cement Modified FDR, 6 in. thick

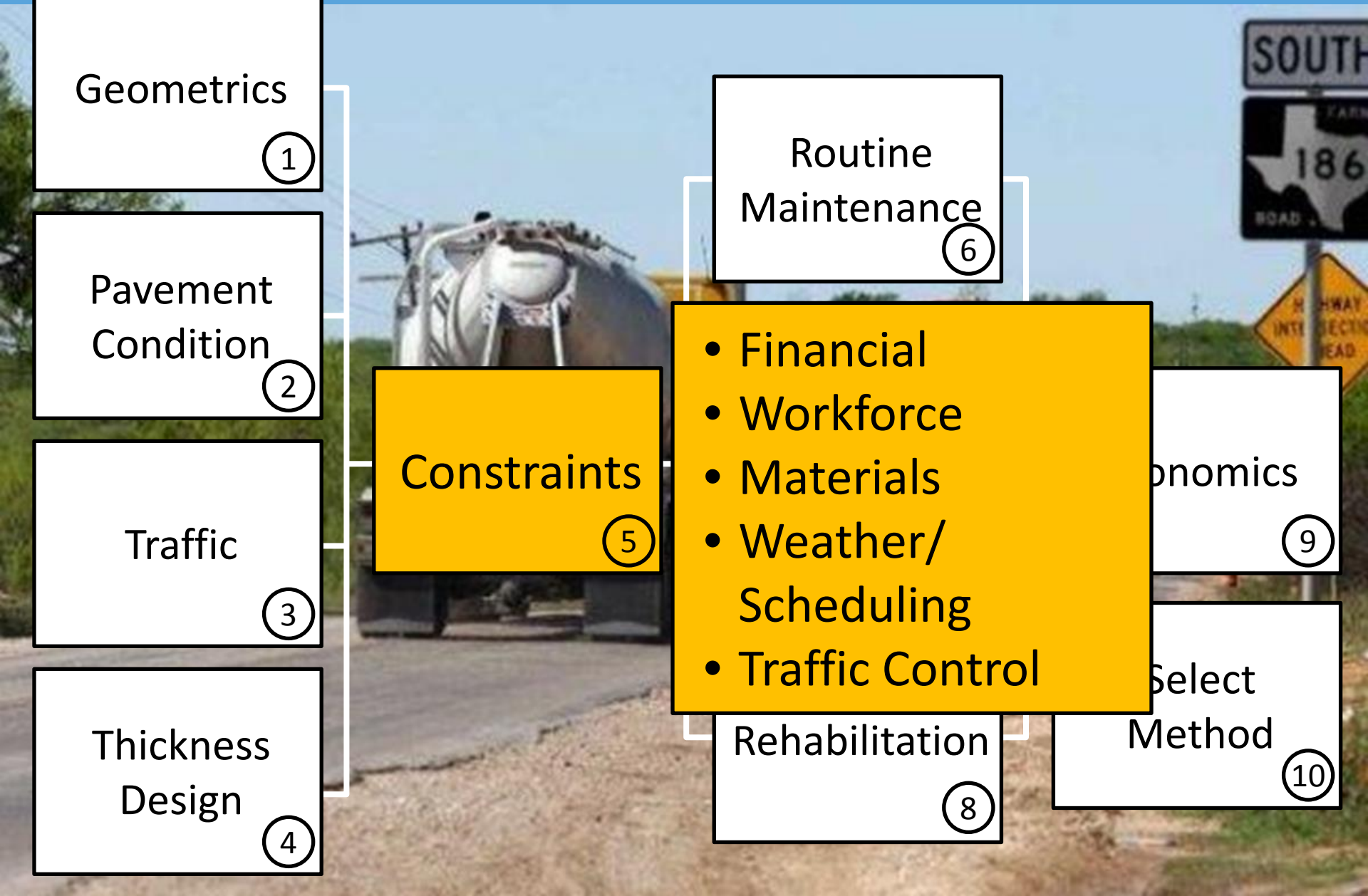
CM 8" = Cement Modified FDR, 8 in. thick

AE/NS 6" = Asphalt Emulsion FDR or Non-Stabilized FDR, 6 in. thick

AE/NS 8" = Asphalt Emulsion FDR or Non-Stabilized FDR, 8 in. thick

Not Recommended – Premature Failure Expected

TxDOT-TTI Joint Effort - Repair Guidelines



Geometrics (1)

Pavement Condition (2)

Traffic (3)

Thickness Design (4)

Constraints (5)

- Financial
- Workforce
- Materials
- Weather/ Scheduling
- Traffic Control

Routine Maintenance (6)

Rehabilitation (8)

onomics (9)

Select Method (10)

Structural Design Considerations

Subgrade	Shoulder Widths, Ft	
	Recommended	Minimum
Soft	6	4
Stiff	4	2

Repair Strategies

Routine Maintenance

- Shallow Patch
- Deep Patch
- Level-up
- Shoulder/Edge Repair

Preventive Maintenance

- Fog Seal
- Seal Coat (Chip Seal)
- Slurry/Micro Seal
- Hot Mix Asphalt

Rehabilitation/ Strengthening

- Subgrade Stabilization
- FDR
- Flex Base
- Surface Treatment
- Hot Mix Asphalt

Expected Outcomes

- **Select Repair Strategies** that will
  - Improve opportunities for correct decisions
  - Reduce risk of incorrect decisions
- **Reduce repair cost**
  - First cost
  - Life cycle cost
- **Reduce traffic disruption**
- **Improve safety**

Step 8 - Rehabilitation

Lubbock

Documents

- Energy Sector Briefs (ESB)
- Implementation Reports (IR)
- Technical Memorandum (TM)
- Research Reports (RR)