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16. Abstract

This research project evaluates numerous transportation issues and develops findings and/or recommendations based on results. This project has been structured to address some of the emerging, critical, and unique considerations related to transportation.

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TXDOT ADMINISTRATION SUPPORT: FY13

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Texas Department of Transportation
and the
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DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the FHWA or TxDOT. This report does not constitute a standard, specification, or regulation.

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TABLE OF CONTENTS

Page

LIST OF TABLES

Page

WORK REQUEST #27: IMPACTS OF REDUCED PAVEMENT REHABILITATION AND MAINTENANCE ON ENERGY DEVELOPMENT IN TEXAS

INTRODUCTION

The energy sector of the economy is extremely important to the state of Texas as it provides a large number of jobs for not only exploration, drilling, and production operations but also for materials production, equipment manufacturing, and technology development associated with the industry. This sector of the economy has increased substantially since 2008 with considerable efforts now directed toward oil/gas, wind, and solar sources of energy.

The development and production of energy requires the movement of the workforce, materials, and equipment. Heavy vehicles are required to move materials and equipment. These significant increases in traffic impact the performance and safety of the roadways. The human and economic impacts of the increase in accident rate, while substantial and in the millions of dollars, are not considered in this study.

Texas completed 15,000 oil/gas wells in 2012 (*1*) using between 800 and 900 drilling rigs (*2*). Oil/gas wells using horizontal drilling and hydraulic fracturing technology require between 1,000 and 2,000 heavy vehicle trips per well (*3,4, 5, 6, 7, 8, 9, 10, 11, 12, 13*).[1] Additional truck traffic is generated during the early life of most well as crude oil is often hauled from the well site until crude oil pipelines are installed. The economic impact of this traffic on state and local roadway rehabilitation and maintenance costs is substantial.

A recent report from the Texas A&M Transportation Institute indicates that the costs of the impact of energy development traffic is conservatively of the order of $1 billion annually to the roadways under the jurisdiction of TxDOT and about $1 billion annually to roadways under the jurisdiction of local governments (*14*). These costs are associated only with Farm to Market type roadways for the state system and do not include additional damage resulting from the oil/gas traffic on state, U.S., and Interstate designated highways.

If funds are not available from the state or local governments to rehabilitate and maintain the roadways used by the oil/gas industry, a substantial cost is incurred by the oil/gas industry due to the increased operating costs for the vehicles and the associated increase in haul times used for well development and service. It is estimated that on average $2.5 billion in additional annual operating costs will be incurred by the energy sector due to the deteriorating condition of the Texas highway system. The actual annual cost could be as high as $3.5 billion.

BACKGROUND

In order to calculate the cost of deteriorated roads to the energy sector, basic information was obtained from a number of sources. Based on this information assumptions were made and the

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[1] Interview with South Texas Rancher, February 25, 2013.

economic impact estimated. Key information and the sources of this information are summarized below. Note that while some information was received from energy industry sources, the report has not been reviewed by the energy industry.

Number of Drilling Operations

Texas oil/gas well drilling statistics are available from the Railroad Commission of Texas (1) and are summarized in Appendix A and Table A-1. The number of drilling permits issued annually over the period 2000 to 2012 was 16,650. The average annual total number of wells drilled for the same period was 13,413. During the 12 year period from 2000 to 2012, the peak well completion period occurred from 2007 to 2009 with an average number of wells completed in excess of 21,000 per year. The total number of wells completed in 2012 was 15,060. Ninety to 95 plus percent of these completions are for new wells (1). The remaining drilling operations are typically for re-enter and re-completions (1). It is reasonable to expect well completions to average in the range of 10,000 to 15,000 over the next several years.

Number of Vehicles Utilized to Site, Drill, Complete, and Operate a Well

The number of heavy vehicles necessary to supply the well sites depends on a number of factors including geological formation, completion requirements, and the need to haul water and crude oil during production.

Appendix B contains a summary of a limited literature search to determine the heavy truck traffic requirements for oil/gas well development. Studies conducted in New York (Table B-2 [*13*]), Texas (Table B-3 [3]), and Utah (Table B-1[7]) provided the most detailed data. These data are for those wells utilizing hydraulic fracturing completion technology. Wells that utilize horizontal drilling technology require more water for hydraulic fracturing than those using vertical drilling and hydraulic fracturing (Table B-2[*13*]). The movement of water/fluids/crude oil for hydraulic fracturing, flowback, and production generates a substantial number of heavy truck trips.

Fresh Water

Typical hydraulic fracturing operations have fresh water requirements in the range of from 0.7 to 8.0 million gallons (Tables B-5 and B-6). Typical quantities of fresh water used per oil/gas wells in Texas are of the order of 3.5 to 5.0 million gallons. Most of the fresh water needed for hydraulic fracturing is presently transported by pipeline from a temporary well or surface water impoundment.[2] The number of drilling and completion operations transporting fresh water to the well site is likely of the order of 10 to 20 percent.

Flowback Water

Flowback water resulting from the hydraulic fracturing operation is substantial at a well site. Not all of the fresh water injected into the well becomes flowback fluid. One estimate of the quantity of flowback fluid was about 50 to 60 percent of the water injected into the formation.1 A second

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[2] Interview with Small Oil/Gas Well Developer, March 1, 2013.

estimate indicates that this ranges from 25 to 100 percent (*12*). Flowback water contains chemicals and salt water that must be disposed in an acceptable facility. This requires truck hauls in most cases. The quantity of flowback water can be substantial during the early life of the well.

Produced Water

Produced water or formation water is a term typically used for the water removed from the well during the production phase of the well. The source of the water is the geologic formation drilled. During the life of the well, the produced water can become a large quantity and the cost of disposal of the water becomes greater than the revenue obtained from the crude oil sale.

Some of the flowback water obtained during the completion operation is produced water. Depending on the formation, the volume of produced water may account for 30 to 70 percent of the flowback water. Since flowback water contains a variety of chemicals and salts and produced water is typically high in salt, it must be disposed safely in an acceptable facility. This typically requires a truck haul. Salt water disposal wells are the most common method of water disposal at the present time. This typically requires a haul of from 15 to 45 miles.

Water recycling installations have been used at a few locations. This allows the reuse of the water and reduces the hauling of water.

Crude Oil

Crude oil produced early in the life of a well is typically hauled to a gathering site for pipeline transmission or hauled directly to a refinery. Early production at a well site can vary over a considerable range depending on the formation, completion operation, and other factors. Early production in South Texas can be at a 1500 to 4000 bbl. per day (63,000 to 168,000 gallons per day) rate with a drop off to 100 to 1000 bbl. per day (4,200 to 42,000 gallons per day) after one year. Note these figures vary substantially.

The length of time between well completion and when a pipe line is installed and used for crude oil transmission varies from about 4 to 12 months or longer (*19, 29*). It is estimated that over 60 percent of oil/gas wells completed use truck haul during the early production period. Typically pipe lines are installed initially for gas capture followed by crude oil transmission pipe lines.

Non-Fluid Truck Hauls

Tables B-1, B-2, and B-3 were used to estimate the number of heavy truck hauls not associated with the movement of fresh water, flowback water, produced water, and crude oil haul. The number of loaded trips typically ranges from about 200 to 550.

Percent of Well Using Hydraulic Fracturing

The Interstate Oil and Gas Compact Commission estimates that 90 percent of the domestic oil and gas wells use hydraulic fracturing technology to complete wells (*15*). Some experts indicated that 60 to 80 percent of the wells drilled in the U.S. will require hydraulic fracturing to remain in production (*16*). Estimates by Texas state regulators indicate that 85 percent of the wells drilled in Texas are utilizing hydraulic fracturing techniques *(1)*.

It is estimated that about 90 percent of all wells completed in Texas in the last few years and into the near future will use hydraulic fracturing technology. Nearly 100 percent of the wells in South Texas employ horizontal drilling and hydraulic fracturing completion techniques. Most wells in the North Texas area utilize either vertical drilling and hydraulic fracturing or horizontal drilling and hydraulic fracturing.

Estimated Heavy Vehicle Trips

Based on the information presented above it is estimated that the loaded heavy truck traffic can range from 1,000 to 3,000 trips for well development and early production (Table B-8). Nearly every loaded truck trip will require a return unloaded truck trip.

Vehicle Operating Costs

The operating costs of the vehicles in use by the energy sector are dependent in part upon the condition of the roadway network. Studies have shown that a slightly rough paved roadway will increase heavy vehicle fuel costs by about 5 percent (*17*). Vehicle maintenance costs are increased by a larger percentage on rough surfaced roadways (*17, 18, 19, 20, 21*).

Appendix C provides detailed information that suggests that truck operating costs on typical Texas highways should typically be in the range of $125 to $175 per hour of operating. Operating cost increases will likely be in the range of from $15 to $30 per operating hour due to rough roads. These costs are averages for both loaded and unloaded trucks.

In addition to the increase in truck operating costs due to road roughness, additional costs will be incurred due to the increase in time required to make the product haul trip. This increase in time could easily double as a truck moves from a relatively smooth road and operating at 60 mph to a rough road with operational speeds in the 30 mph range.

ECONOMIC IMPACT

The economic impact of oil/gas development and early well life operating vehicles traveling on roadways that are rough is substantial. Information collected and summarized allows an estimate of the economic impact to this portion of the energy sector of our economy.

Two major factors are considered: vehicle operating costs and additional time to operate the vehicles on the rough roads. Vehicle operating cost increases will be addressed first.

Note that the cost to the driving public and to other commercial vehicles traveling the rough roads has not been considered in these calculations. The impacts of the oil/gas development and service vehicles first appears on the Farm to Market roads due to their lighter design. The traffic volumes have been historically low on most of these roadways and hence the costs to the public have been relatively low as compared to the costs to the oil/gas industry shown below.

Vehicle Operating Cost Increases

Data used to estimate the economic impact associated with oil/gas well trucks operating on rough roads include: number of annual well completions, truck trips per well completion and early operations, percent of wells completed with hydraulic fracturing technology, hours for vehicles operating on rough roads, and vehicle operating cost increases associated with hauling on rough roads. Table D-1 in Appendix D provides information that can be used for this estimate. A range of the parameters identified above were used in this table to illustrate the sensitivity of the estimate to various factors. Recall that the estimate of truck trips associated with well development and service is for loaded trucks. Most of the trucks servicing oil/gas wells are loaded in one direction and unloaded in the other direction. Thus the truck trip numbers utilized in the calculations shown below are for the number of trips to and from the drill site. These are very conservative truck trip numbers.

Table 1 is a summary of the information contained in Appendix D to allow for a single estimate of the increase in truck operating costs associated with traveling on rough roads.

Table 1. Economic Impact to Oil/Gas Industry Trucks Operating on Rough Roads.

Assumption Set	No. of Annual Well Completions	Truck Trips per Well Completion and Early Operation	Percent Wells Using Fracturing	Hrs. Vehicles on Rough Road	Vehicle Operating Cost Increase, $/hr.	Economic Impact, Millions of Dollars
1	15,000	3,000	90	2	35	2,835
2	7,500	750	70	0.5	15	30
3	10,000	1,500	90	1	15	200
4	10,000	1,500	90	1	35	475
5	15,000	1,000	90	1	15	200
6	15,000	2,000	90	1	15	400
7	15,000	3,000	90	1	35	1,420
8	15,000	1,500	80	1	15	270
9	15,000	1,500	80	1	35	630
10	10,000	1,500	90	2	15	405
11	10,000	1,500	90	2	35	945
12	15,000	1,000	90	2	15	405
13	15,000	2,000	90	2	15	810
14	15,000	2,000	90	2	35	1,890
15	15,000	2,000	80	2	35	1,890
16	15,000	1,500	80	2	15	540
17	15,000	1,500	80	2	35	1,260

Based on the information summarized above it is not unreasonable to assume that the economic impact on the oil/gas industry as a result of increased roughness on roadways could easily be of the order of $500 million to $1.5 billion annually. If well development is at the upper end of the current trends, the majority of the well completions use horizontal drilling and hydraulic fracturing and the roads become moderately rough, the annual costs could exceed $1.5 billion annually.

Cost of Increases in Vehicle Haul Times

Assuming the roads become rough, the length of time for vehicles to haul into and out of a well site will increase. This time increase is estimated to be between 0.5 to 1.5 hours per vehicle servicing a well. With truck costs in the range of $125 to $175 per hour, a substantial cost increase will result as shown in Table 2. The costs associated with the additional haul times are in addition to the costs associated with vehicle operation. As shown below a cost increase in the range of $1 to $2 billion can result if roads become moderately rough.

Table 2. Cost and Vehicle Haul Times.

Assumption Set	No. of Annual Well Completions	Truck Trips per Well Completion and Early Operation	Vehicle Costs per Mile, Dollars	Increase Haul Time, Hrs.	Economic Impact, Millions of Dollars
1	15,000	3,000	175	1.5	11,800
2	7,500	750	125	0.5	350
3	10,000	1,500	150	1.0	2,250
4	10,000	1,500	125	1.0	1,875
5	10,000	1,500	175	1.0	2,625
6	10,000	1500	150	0.5	1,125
7	10,000	1500	125	0.5	935
8	10,000	1500	175	0.5	1,320

Economic Impact

The economic impact of rough roads on the oil/gas well development and early operation is approximately the sum of the increase in vehicle operating costs plus the costs associated with increase haul times to the well site. Vehicle operating costs can be expected to increase in the order of $500 million to $1.5 billion dollars annually. Haul time increases can be expected to increase the cost of well development and service in the $1 to $2 billion range. The summation of these two costs is of the order of $1.5 to $3.5 billion dollars annually.

TASK REPORT #1, WHITE PAPER, TEXAS WEIGHT DISTANCE FEE ON HEAVY VEHICLES

SUMMARY

This technical memorandum outlines a possible administrative and operational configuration for a truck fee system implemented with the goal of collecting revenues to offset continued road degradation from energy development activities. The system would have the following attributes:

- Fees are levied for travel to destinations within counties comprising an *energy zone*. The fee is not applicable to travel outside of these counties.
- All commercial vehicles with a destination lying within an energy zone county would be subject to the fee.
- Fees would be assessed through the Texas Department of Motor Vehicles' (TxDMV's) division of Commercial Vehicle Enforcement (CVE), using the same administrative systems for the permitting of oversize/overweight (OS/OW) vehicles.
- Truck owners would have the choice of applying for a travel permit through TxDMV or could use a certified in-vehicle device and in-vehicle telematics service providers to report mileage and pay the associated fee.

There are issues that would need to be addressed before the state could look to implementing this system. A robust analysis of the impact this system will have on the trucking and oil and natural gas industries is required, as well as an in-depth analysis of potential implementation costs is required. Additionally, significant attention should be given to developing a more comprehensive enforcement strategy.

INTRODUCTION

A spike in oil and natural gas production over the past five years from horizontal drilling and hydraulic fracturing ("fracking") has resulted in a major economic boom in areas of South Texas and North Central Texas. The counties comprising the Eagle Ford Shale formation in South Texas, for example, has benefited with landowners receiving significant royalty checks for energy developments on their property and local businesses benefiting from the increased supply of consumers resulting from the local job boom. However, these developments have come at a potentially steep cost. Heavy commercial and industrial equipment used in the extraction of energy resources is having a severe impact on roadways in these areas. Local and county roadways are generally not constructed to handle the level of heavy traffic being generated in support of these operations.

The Texas A&M Transportation Institute (TTI) estimates that the statewide cost to keep roads serving energy development areas in a serviceable condition is at least $885 million annually. However, it is likely that this estimate is extremely low, and actual costs would likely be much higher.

A September 2012 article from the *Austin American-Statesman* noted that the Texas Comptroller's Office reported over $44 billion in tax revenues from energy developments in fiscal year 2012, but that little if any of this revenue is going toward infrastructure development and maintenance (*22*). Furthermore, existing local transportation funding resources will be insufficient to address the continued degradation of these facilities. Consequently, the Texas Department of Transportation (TxDOT) is looking at new funding mechanisms to provide for these immediate needs.

Weight-distance fees are one possible option for generating the revenue required to maintain degraded roadway assets. These fees would levy a charge on heavy commercial vehicles that would vary based on the weight of the vehicle (with some possible variation based on axle configuration) and would be assessed on a per-mile basis. Such fees are currently used in Oregon, New Mexico, New York, and Kentucky. Additionally, weight-distance fees are an increasingly common revenue source in Europe. This report outlines a possible concept for the levying of a weight-distance fee in specific areas of Texas to account for road degradation due to energy-related activities.

SYSTEM OVERVIEW

The fee system proposed in this white paper is defined so that it can be feasibly implemented in the near term without significant expense in terms of additional infrastructure development, significant capability enhancement on the part of the administering entity, and excessive compliance costs for the trucking industry. Thus, the proposed weight-distance fee has the following elements:

- Fees are levied for travel to destinations within counties comprising an *energy zone*. The fee is not applicable to travel outside of these counties or through these counties.
- All commercial vehicles with a destination lying within an energy zone county would be subject to the fee.
- Fees would be assessed through the Texas Department of Motor Vehicles' (TxDMV's) division of Commercial Vehicle Enforcement (CVE), using the same administrative systems for the permitting of oversize/overweight (OS/OW) vehicles.
- Truck owners would have the choice of applying for a travel permit through TxDMV or can use a certified in-vehicle device and in-vehicle telematics service providers to report mileage and pay the associated fee.

This fee is being implemented as a mechanism to address excessive road degradation, implying that the fee should be applied to those vehicles causing the degradation: in this case vehicles involved directly in the energy extraction industry. To accurately account for the cost of damage, it might be desirable to charge based on actual weight with variations being provided based on axle configuration and other factors that would influence load distribution.

However, this level of charging complexity requires an equally complex assessment and enforcement regime. In the near term it would be prohibitive, from both a technology and cost standpoint, to assess fees that account for actual weight and apply only to those vehicles participating in a certain activity. Activity-based charging is particularly problematic because the types of vehicles used in the energy extraction industry might be used in other activities as well, such as general construction, farming, or other industries.

Given these difficulties, researchers recommend that upon initial implementation the fee be applied to all commercial vehicles destined for the charging area—in this case the particular counties comprising the energy zone. Researchers also recommend that if the weight of the vehicle is to be factored into fee calculation that it be accounted for based on self-reporting by the trucking firm or driver on a scale basis as opposed to reporting of actual weight.

All heavy commercial vehicles with a destination within the energy zone would be subject to the fee. In the long term, it may be desirable to levy fees only on those vehicles that are entering the charging area with the explicit purpose of aiding or engaging in energy development related activities. It may also be desirable in the long term to vary fee amounts based on the actual weight of the vehicle at the time of travel. However, pricing by activity and pricing by actual weight would present considerable challenges in terms of implementation and operations, and should therefore be excluded from the initial implementation.

Permitting Process

Truck owners would be assessed the fee under one of two charging regimes. Under the first regime (the manual system) trucking firms would simply apply for a permit to travel within a certain designated time period to a destination within the energy zone. This period of travel may be for a day, week, or any other period of time. Firms would apply for and TxDMV would issue permits. To facilitate this process, truck drivers and/or trucking firms would create a secure account on the pre-existing TxDMV web-based truck permitting site where they would register their vehicle with the TxDMV database.

Upon registering, the trucker would purchase and print a travel permit that would need to be kept in the vehicle when traveling within the charge zone. Permits would reflect the time period covered by the permit, the reported weight of the configuration the permit is being sought for, and the estimated mileage to be accrued over the period of the permit. All permits would require the trucker to log in to the system, and provide the appropriate details of the anticipated trip or period of travel. A fee for the associated characteristics would then be added to the permit.

Requiring all permit information to be logged through the TxDMV enables enforcement. The DPS already has access to various TxDMV systems and would be able to verify the validity of a printed permit through these connections during roadside inspections. Information regarding the purchased trip—including the vehicle's identifying information, trip date(s), mileage, and vehicle weight—would be available through this interface.

Under the second charging regime, truck owners would use a certified third party technology service provider for the permitting and payment process. These service providers would be responsible for collecting the required information from the vehicle owner, assessing the fee, collecting the fee, and remitting the payment along with travel information to TxDMV. Service providers would be free to structure their systems in any manner, so long as they were certified to meet basic standards and reported required fee assessment and enforcement information to the TxDMV system.

The energy zone would be composed of counties, and the boundary of the energy zone would be identified based on county boundaries. The TxDMV systems that would eventually support this fee are already set up to levy fees on a county-by-county basis. Trucks entering the energy zone would only be subject to a fee if their destination is a point within the energy zone, as the state would likely desire to avoid charging through traffic. For example, the Eagle Ford Shale region straddles several major Interstate and U.S. highways that are crucial to interstate and even international travel. Given the volume of trucks traversing these roadways, it would likely be infeasible to charge every single commercial vehicle simply traveling into the charge zone. Researchers therefore recommend that travel on Interstate and US highways be exempt from the charge. The DPS would enforce this destination requirement by visually inspecting driver logs and other assorted information that is available to the department under state law during roadside stops. DPS might also perform inspections at energy producing sites and verify permit status.

Operating Entities

This fee system would use both public and private entities for operations. DMV would be responsible for the public-sector aspect of the fee system. Various private technology and technology service providers would be responsible for the private aspects of operations. However, these private-sector vendors would be required to interface with the publicly-operated operational component of the system.

Manual System

TxDMV would be responsible for the operations of the data systems supporting the overall fee structure and would administer the manual portion of the fee that, which includes paper permits printed by the truck owner. The TxDMV currently administers seven types of OS/OW permits and issues an estimated 700,000 permits per year. Researchers recommend that the energy-sector fee be incorporated into the system that currently supports these fees.

Many of the fees currently administered by the TxDMV through this system already account for distance, weight, and location—the factors that would, in the long term, form the charging basis for the energy zone truck fee. For example, the TxDMV currently administers a single-trip permit that requires applicants to identify the start and end point of the trip that the permit is being sought for and to report the weight of the load to be hauled. The TxDMV also issues permits that account for the commodity being hauled and the type of vehicle. This could serve as a basis for activity-based charging in the long term.

Technology Enabled System

The imposition of this fee would represent a new compliance burden for truck owners and commercial operators within the energy zones. Researchers therefore recommend that a technology-based alternative to the manual system be offered to decrease the compliance burden. This system would make use of either dedicated onboard units or existing in-vehicle location and routing assistance systems, such as those already used in commercial fleets to collect data regarding vehicular travel. A trucker using the dedicated in-vehicle device would need to purchase and install a TxDMV-certified unit in his or her vehicle or use an approved location-based service, which would then monitor vehicular movement and charge the registered truck owner based upon travel within the designated geographic charge zone. Before entering a designated area, the trucker would need to input his or her vehicle weight into the onboard unit, which would then calculate the fee based on the distance driven.

This proposed implementation model would allow truck owners to use their existing in-vehicle telematics systems, commonly used for routing and other fleet management activities, to assess and pay the fee. These existing location-based services would have to be certified by the TxDMV or some other certifying entity if they are to be used by truck owners in the assessment and payment of the fee. This would not require the certification of every specific device to be used but rather the certification of the device and service model. The certification process would require no effort from the truck owner other than selecting an approved service provider. The certification model provided by Omniair, a consortium advocating for connected vehicle interoperability, could provide guidance in future certification efforts.

Support for the implementation of electronic-based fee systems by the trucking industry, both internationally and domestically, is highest when the technology is viewed as a means of reducing compliance costs for the industry. Many fee systems and fee administration systems require the tracking of miles traveled and the location of travel, the International Fuel Tax Agreement (IFTA) and International Registration Plan (IRP) being the most prominent examples. Both systems require Interstate truckers to maintain travel logs and report mileage as a means of allocating state fuel taxes and state registration fees among member states. Oregon currently levies a weight-distance fee in lieu of state diesel taxes on commercial vehicles, and an ongoing industry-sponsored pilot is currently evaluating technology options for the electronic reporting of mileage and electronic assessment of the fee. Likewise, the EROAD system offered in New Zealand is, at the most basic level, a fee assessment, measurement, and compliance platform that provides an automated alternative to the manual reporting of mileage otherwise required of the national road user charge.

Enforcement Entities

Enforcement of the proposed system would not require substantial changes to existing enforcement mechanisms. Commercial vehicle enforcement is currently carried out primarily by the Texas DPS Commercial Vehicle Enforcement Service (CVE). Officers regularly inspect weight, permitting, and other factors associated with commercial vehicle transport. The proposed system would require some adjustments, such as funding increases to manage the challenges associated with rural law enforcement (vehicle wear and tear, adequate housing, and fuel costs) and the cost purchasing additional equipment such as scales.

CVE patrols Texas, enforcing regulations on commercial vehicles. Troopers inspect many vehicles to verify compliance with a variety of regulations including weight, distance, and size. CVE already enforces regulations in the general geographic regions that might comprise an energy zone, and troopers indicated in interviews that they have already increased enforcement activities in response to energy development operations. Adapting current laws to charge energy-producing vehicles an additional fee based on size and weight would require scaling up existing enforcement but would not require significant changes in how enforcement is carried out. The challenges associated with implementation are discussed in greater depth below.

IMPLEMENTATION ISSUES

Much of the administrative and operational support structure for the proposed fee system is currently in place, particularly from the standpoint of TxDMV and DPS, both of which have a commercial vehicle enforcement section. However, there would need to be upgrades made to these existing systems.

Administrative Requirements

The TxDMV does not anticipate that administration would be a significant barrier to the implementation of a new fee system, even if it means the permitting of a significantly larger number of vehicles on an annual basis. The permitting system currently administered by TxDMV is largely automated and can be accessed by those seeking a permit through the internet. If TxDMV were to estimate the cost and time to upgrade its internal systems to support the new fee system, the agency would need to have the following information:

- The precise method of fee calculation.
- Whether the TxDMV would be responsible for assigning specific routes for short-term permits or whether applicants would provide a route themselves.
- The time periods that would be covered by the different types of permits.
- The geographic nature of the charging zone itself.
- The eventual distribution of the fee revenues.

While the Texas Comptroller of Public Accounts is ultimately responsible for the remitting of revenues from the permitting process to the various jurisdictions to which they are due, it is the responsibility of the TxDMV to determine the actual amount that is to be distributed. The amount that a particular county receives from state OS/OW permit fees is based on several factors including the miles traveled within the county by permit holders, and TxDMV is responsible for using this information to determine revenue allocations. It is likely that the TxDMV would have a similar responsibility for the allocation of revenues derived from this fee system, and the complexity of the allocation process would influence the administrative cost of the system.

In terms of the geographic nature of the zone, the system proposed in this document could be supported by current TxDMV permitting system, which is already set up to account for fees on a county-by-county basis. However, system upgrades would be more complicated if the geography of the charging zones were to be based on other factors. The system would most likely make use of geographic information system (GIS) data for the definition of the charging area by TxDMV. TxDMV currently uses GIS data for many of their location-based fees.

TxDMV does not anticipate that the participation of private third-party technology vendors and technology service providers would be problematic. The permitting system can be accessed by any party seeking a permit, meaning that new interfaces would not need to be developed to accommodate reporting of mileage by these vendors. In fact, TxDMV has examined allowing location-based service providers to report mileage on behalf of truck owners in the past but opted to not pursue this option due to a lack of demand by truckers and trucking firms. TxDMV noted that the types of trucks that typically must report mileage for OS/OW permits often do not use such systems. However, the inclusion of a large number of additional vehicles of differing classes and activity types would likely create this demand.

Enforcement Requirements

Enforcement of the system in the near term would fall almost entirely on state and local laws enforcement entities, most notably the Texas Department of Public Safety's (DPS) Commercial Vehicle Enforcement (CVE) program. The CVE is currently the primary entity responsible for the enforcement of the state's existing OS/OW permits. TxDMV does not have a significant enforcement role outside of supplying information to the CVE as part of existing roadside enforcement operations. However, it may be desirable in the long term to establish a robust back-office enforcement regime for the TxDMV. This will be discussed in subsequent sections.

Implementing a new fee for CVE to enforce would require scaling up operations in impacted areas. CVE would likely require additional resources to handle the logistics and increased labor. CVE would require additional funding for scaling up enforcement for a variety of reasons. First, it is difficult to patrol the geographically isolated, energy-producing regions. Fuel costs are volatile and often high, which makes patrolling large areas with a large number of vehicles unpredictable and expensive. Maintenance on vehicles that patrol large geographic areas is also expensive.

Incentivizing officers to live near or in these isolated areas is also difficult because these areas are not highly populated and do not have the required housing. Housing and even temporary housing can be prohibitively expensive due to high demand from energy production and a limited housing stock. Currently, officers operate out of regional offices that are not always ideally located for all patrols. For example, many CVE offices are concentrated along the border, as CVE is responsible for checking vehicles at border crossing.

Enforcing certain provisions of the new measures may require purchasing additional capital items and training new officers on the equipment. For example, enforcing the weight aspect of the fee may require purchasing additional mobile scales and training area officers.

Private-Vendor Certification

As noted earlier, many truck firms are likely to want to avoid the flat fee option but would prefer to use their existing location-based services as opposed to a dedicated in-vehicle unit for fee assessment. Consequently, TxDMV would need to establish requirements for the use of existing routing and logistics systems in assessing and paying the fee under the automated payment system. All third party technology systems would need to show that they can function in a consistent for the fulfillment of the fee systems goals and objectives, primarily the generation of revenue from commercial trucks. As part of this process a certifying agent would determine whether or not a candidate system meets the specified requirements and standards as set by the state. The state must be careful to not specifically define specific system capabilities such as anti-tampering measures, use of GPS data, and on-board functionality. This would result in standards that are too prescriptive and might favor certain applications over others.

A likely scenario for the certification process would involve the TxDMV setting a series of performance (as opposed to technical) standards, against which technology systems would be evaluated and certified. These standards would identify what the system must do and how well it must perform. It will be important in setting standards to make sure that they are not set so narrow as to stifle openness and innovation but remain narrow enough that the needs of the state are still met. An external third party would likely perform the certifications. This would likely occur under contract to the state but it is possible that the TxDMV itself could perform system certifications.

LONG-TERM ISSUES

The system proposed in this white paper is a short-term implementation that would help in addressing the immediate transportation revenue needs of energy-producing regions such as the Eagle Ford Shale. In the long term, it may be desirable to introduce more variation in the fee system, particularly with regard to charging by actual weight and charging by activity. These charging options are not included in the current proposal primarily because of either the need for extensive roadside infrastructure or the lack of a viable technology solution. However, in the long term they may become more feasible.

Accounting for Weight

An additional strategy to pursue in the long term with regard to accounting for weight might be to mandate the use of technologies that differentiate the truck from the load being hauled and to charge each one separately. This would allow owners of both the tractor units and the loads being hauled to register both separately, removing some of the compliance and tax burden from the tractor owner/operator. However, dynamic weight-reporting systems are currently unreliable, and in New Zealand they are thus non-evidentiary in enforcement proceedings.

Enhancing Enforcement

In the long term, it may be beneficial to issue windshield decals equipped with radio frequency identification (RFID) tags containing information related to the permit. Law enforcement could use handheld RFID readers to verify that a truck is in compliance. Checking the tag would reveal the vehicle's payment status, the declared weight, and the mileage purchased. However, this is likely to be a very expensive option, and a rigorous assessment of the potential cost would need to be undertaken before serious consideration can be given to it.

The state might also consider deploying a network of weigh-in-motion facilities coupled with automatic license plate recognition (ALPR) technology, particularly if the fee system shifts to permitting based on the actual weight of the vehicle. Weigh-in-motion technologies allow vehicle weight to be determined without the vehicle having to exit the roadway and are currently used throughout the United States. ALPR technology is currently used on toll facilities in Texas and is common in international truck-tolling applications for enforcement purposes. ALPR technologies are generally gantry-mounted and capture an image of the license plate of vehicles passing through the gantry. This image is forwarded to a back office where optical character recognition (OCR) software converts the image into a digital file that is then checked against an existing registry of license plate numbers.

A configuration that couples ALPR with weigh-in-motion would allow for the verification of reported vehicle weight because license plate images could be matched against the issued permit. A similar configuration is used as part of New Mexico's weight-distance fee program. However, researchers do not recommend this strategy at this time for near-term implementation because of the cost involved with adequately covering the required infrastructure assets in energy-producing regions.

As noted earlier, the TxDMV currently lacks a significant back office enforcement regime. The development of such systems in the long term would likely increase the abilities of TxDMV to identify fee evaders prior to their being stopped by uniformed law enforcement officers on the roadside. Such a system would likely involve the analysis of data to identify high risk offenders in support of targeted roadside checks and audits. For example, enforcement officers have found that in New Zealand, trucking firms with a history of repeated safety violations are more likely to be overdue or in violation of the nation's road user charge. Therefore, an analysis of safety related data might provide valuable insight into potential fee evaders.

Accounting for Activity

There is a strong desire from a policy perspective to charge only vehicles that are actively participating in energy-extraction-related activities. In the near term, it would be too difficult from both an administrative and an enforcement perspective to accomplish this. However, there are some technology options that might be considered in the long term. For example, it may be possible to rely on technology infrastructure assets at drilling platforms and other energy extraction sites. RFID or similar readers could be placed near the drilling site that could be coupled with RFID tags embedded in the TxDMV-issued travel permits. Vehicles entering the drilling location would have their permits identified by the reader, and a charge would be levied to the preexisting account. Vehicles traveling in the area for non-energy-related purposes would be able to avoid the technology and would not be subject to the fee.

However, this is likely to be an expensive technology option as RFID has a limited read field and a single site might require numerous gantries to provide adequate cover. A related alternative might be to use newer 5.9 GHz technologies that rely on a radial antenna at the center of the site to communicate in 360 degrees. However, cost is a challenge with this approach as well as outfitting every energy production site with the required equipment might be cost prohibitive.

IMPLEMENTATION PRIORITIES

Many initial steps must be taken before implementation of the fee system discussed in this document. They range from administrative to technical in nature and include:

- *Estimate industry impacts* – It is unknown at this time the effect that this fee system would have on commercial vehicle movement within and around energy zones. As an initial step the researchers recommend that the state undertake a study to evaluate how the fee will impact the trucking industry as well as the oil and gas industry.
- *Initiate stakeholder outreach* – Both the trucking and oil and gas industries have a significant stake in this proposed system, as they will bear the primary compliance burden and will supply the majority of the revenues. Both industries also have distinctly different business models that will have to adapt to this system. It is therefore imperative that they be brought into the development process to provide guidance on system design.
- *Estimate Implementation Costs* – It is difficult at this time to estimate the potential cost of this system, both with regard to cost to the state and cost to the trucking and oil and gas

industries. A robust analysis that identifies potential cost drivers and estimates for those cost drivers is needed.

- *Examine how private sector involvement would be facilitated* – Private sector technology vendors do not currently participate in the assessment of road user charges in Texas. It is unknown to what extent the industry can or will be involved in the system outlined herein. Researchers therefore recommend that the state issue a request for information (RFI) to solicit input from the telematics and in-vehicle services industry on this proposed concept.
- *Assess potential enforcement regimes* – The enforcement regime highlighted in this report is largely reliant on existing practices. However, the potential economic burden of this proposed system is high, creating a significant incentive to evade the fee. Roadside checks by uniformed law enforcement officers may be insufficient to maintain high levels of compliance. Researchers recommend that the state undertake an evaluation of existing commercial vehicle enforcement systems and identify how these systems can be augmented to improve potential compliance under this proposed system.

APPENDIX A. NUMBER OF WELLS

Texas drilling statistics are available from the Railroad Commission of Texas (1). Table A-1 provides a summary of the drilling statistics available (1). The average annual number of drilling permits issued annually over the period 2000 to 2012 was 16,650. The average annual total number of holes drilled for the period 2000 to 2012 was 13,413. The peak drilling period during the 13 year summarized was from 2007 to 2009. The total number of holes drilled in 2012 was 15,060.

Table A-2 indicates that the most active drilling areas of the state were the following areas: Midland, San Antonio, San Angelo, North Texas, and Refugio (1).

Table A-1. Texas Drilling Statistics (1).

Year	Drilling Permits	Total Holes Drilled*	Average Rotary Rig Count
2000	12,021	8,854	343
2001	12,227	10,005	462
2002	9,716	9,877	338
2003	12,664	10,420	448
2004	14,700	11,587	506
2005	16,914	12,664	662
2006	18,952	13,854	746
2007	19,994	20,619	834
2008	24,073	22,615	898
2009	12,212	20,956	432
2010	18,027	9,477	659
2011	22,480	8,391	910
2012	22,479	15,060	899
Average	16,650	13,413	626

*includes oil and gas wells and dry holes; does not include service wells

Table A-2. Drilling by Rail Road Commission District-2012.

District		Drilling Permits	Well Completions
Number	General Location		
1	San Antonio	3,966	1,698
2	Refugio	1,581	1,093
3	Southeast Texas	1,047	756
4	Deep South Texas	593	407
5	East Central Texas	250	215
6	East Texas	549	645
6E		74	10
7B	West Central Texas	1,048	678
7C	San Angelo	2,233	1,299
8	Midland	7,006	5,013
8A	Lubbock	1,026	592
9	North Texas	2,093	1,960
10	Panhandle	977	673

APPENDIX B. TRUCK TRAFFIC

INTRODUCTION

The number of trucks required to site, drill, complete, and operate an oil/gas well differs greatly depending on the formation and completion technology utilized. Information is presented below that illustrates the range of truck trips.

TRUCK TRAFFIC FOR VARIOUS WELL DEVELOPMENT OPERATIONS

Tables B-1, B-2, and B-3 provide information that defines the number of trucks per well development operations. Table B-1 shows data for a typical well in Utah (7), Table B-2 shows similar information collected by a New York State consultant (*13*), and Table B-3 provides information for a typical well in the North Texas area (3). Trucks are needed to haul equipment and a variety of materials.

Table B-4 indicates that truck traffic for well development can range from about 365 to 2,000 heavy trucks. This traffic number is for loaded trips. A return trip is typically empty in an oil/gas field environment. The weight of these vehicles (with few exceptions) is at the legal load limit of 80,000 lb in Texas. Based on limited number of weigh-in-motion devices a considerable amount of this traffic exceeds the legal load limit for axles and gross vehicle weight. A determination has not been made with regard to the distribution of load weights for this report. Information is summarized below that defines some of the operations that require considerable haul vehicles.

Drilling Waste

Drilling waste materials must be disposed at an acceptable site. This haul can be in excess of 100 miles and typically require 50 to 100 loads per well (7).

Fresh Water

Hydraulic fracturing operations require a large quantity of water. Table B-5 shows water needs for drilling and hydraulic fracturing for four shale production areas. Table B-6 provides data from several references illustrating the quantity of fresh water utilized. Water is used for the formation of drilling mud, for the drilling operation, and for the hydraulic fracturing operation. Fresh water demand can range from 0.7 to 8.0 million gallons per well.

Typical water demands for a Barnett Shale hydraulic fracturing operation are as follows:

- Vertical well – 1.2 million gallons.
- Horizontal well – 3.5 million gallons.

Typical demands for an Eagle Ford Shale hydraulic fracturing operation are in the range of 3.5 to 5 million gallons (5).

Hydraulic fracturing fluids are typically 99.5 percent water and 0.5 percent additives (5). More than 200 different compounds can be used as additives. Typically only about 5 plus or minus additives are used at a well site. Typical additives include: “slickwater,” which is primarily potassium chloride; biocides to prevent micro-organism growth and to reduce bio-fouling of the fractures; oxygen scavengers and other stabilizers, which prevent corrosion of metal pipes; diluted acids (typically hydrochloric or muriatic), which are used to remove drilling mud buildup within or near the wellbore area; gelling agents to help transport proppant material; and occasionally cross-linking agents to enhance the proppants. Proppants such as sand or ceramic materials are used to prop open the fractures (5).

When possible fresh water is obtained from a water well or impoundment at or near the oil/gas well site and the water is pumped to the well site from the water source. Since truck haul costs for water are relatively high, most drilling and completion operators use pipe water delivery as often as possible. It is estimated that only 10 to 20 percent of the fresh water is hauled to well sites in Texas.1 The use of truck haul and haul distances for water movement are minimized as much as possible.

Proppants

Typically sand and or ceramic materials are used in the hydraulic fracturing operation and are carried in the fluids. Data obtained from a New York State study indicated that between 1250 and 3500 tons of proppants are required per well (*12*). The number of trucks required to haul this material is in the range of 50 to 150 vehicles.

Flowback Fluid

After hydraulic fracture treatment the water-based fracturing fluid, mixed with some natural formation water, begins to flow back through the well casing to the well head. The majority of the fracturing fluid is recovered in a matter of several hours to a couple of weeks. In some cases flow back of fracturing fluid and produced water can continue for several months after production begins.

Not all of the fresh water injected into the well becomes flowback fluid. One estimate of the quantity of flowback fluid was about 50 to 60 percent of the water injected into the formation.1 A second estimate indicates that this ranges from 25 to 100 percent (*12*).

Depending on the shale basin, the volume of produced water may account for less than 30 percent to 70 percent of the original fracture fluid volume. The dissolved solids in these waters can vary from fresh water (less than 5,000 ppm Total Dissolved Solids [TDS] to various saline waters (from 5,000 ppm to 100,000 ppm TDS) (*11*). The quantity of flowback water and produced water can be substantial during the early life of the well as well as late in its production cycle.

Produced Fluid

Produced fluid is primarily salt water and is obtained from the well during the production cycle of the well life. This fluid is typically high in salts. During the later stages of well life, a substantial amount of produced water may to be handled.

Hydraulic fracture flowback fluid and formation water (produced water) that is produced with oil and gas must be disposed safely and “salt water disposal wells” (injection wells) are typically used.

Crude Oil

A substantial number of oil wells completed in the last few years in South Texas as well as other areas of the state have not had pipe lines at the well site for removal of the produced crude oil. Truck transport of the crude oil is required for some period of time (months to years). Well production is highly variable depending on the formation and completion characteristics used. Initial production can range to 1200 bbls per day at early production with a drop-off to 50–100 bbls per day later in the life of a well.1 Crude oil hauls can result in the utilization of 1 to 200 trucks per month (7). 1

Trucks for Water Haul

Table B-7 provides a convenient table for truck requirements for water haul. Assuming a well drilling and hydraulic fracturing operation requires 5.0 million gallons, flowback fluids at the 3.0 million gallon level and produced fluids at a level of 2 million gallons during the first several months (10 million total gallons of water), a truck demand of 1700 (Table B-7) is calculated. This assumes that all water is trucked to the well site and not pumped from a local well site.

Summary

Loaded truck trips in the 1,000 to 3,000 range are possible during well development and early operation (Table B-8). Nearly every loaded truck trip will require a return unloaded truck trip.

Table B-1. Truck Traffic per Well Site in Utah (7).

Activity	Number of Trucks	Comments
1. Construction Equipment	10-45	Depends on formation
2. Drilling Rig	30	
3. Drill Well	172-1,140	
a. Fresh Water	125-1,000	Used in drilling operation
b. Drilling-Waste Disposal	50-100	Waste rock/water hauled for disposal
c. Drill Mud/Fluid	10-20	Material used to form drilling mud
d. Cement	2-5 cement 2-4 fly ash	Fill voids in well casing
4. Rig Maintenance	10	Maintenance of drilling rig
5. Remove Drilling Rig	30	
6. Total Completion	130-135	
a. Construction	1-2	
b. Rig Set-up	3-4	
c. Well Tubing	1-2	
d. Perforate/lining	1-2	
e. Frac Sand/water	125	
7. Remove Completion Rig	20-25	
8. Close Reserve Pits	3-5	
9. Build Production Facility	10-12	
Total Large Trucks	365-1370	

Table B-2. Truck Traffic Estimates for Vertical and Horizontal Wells (*13*).

<table>
<tr><th>Activity</th><th colspan="2">Horizontal Well</th><th colspan="2">Vertical Well</th></tr>
<tr><th></th><th>Heavy Truck</th><th>Light Truck</th><th>Heavy Truck</th><th>Light Truck</th></tr>
<tr><td>Drill Pad Construction</td><td>45</td><td>90</td><td>32</td><td>90</td></tr>
<tr><td>Rig Mobilization</td><td>95</td><td rowspan="3">140</td><td>50</td><td rowspan="3">140</td></tr>
<tr><td>Drilling Fluids</td><td>45</td><td>15</td></tr>
<tr><td>Non-rig Drilling Equipment</td><td>45</td><td>10</td></tr>
<tr><td>Drilling (rig, crew, etc.)</td><td>50</td><td>140</td><td>30</td><td>70</td></tr>
<tr><td>Completion Chemicals</td><td>20</td><td rowspan="6">326</td><td>10</td><td rowspan="6">72</td></tr>
<tr><td>Completion Equipment</td><td>5</td><td>5</td></tr>
<tr><td>Hydraulic Fracturing Equipment</td><td>175</td><td>75</td></tr>
<tr><td>Hydraulic Fracturing Water</td><td>500</td><td>90</td></tr>
<tr><td>Hydraulic Fracturing Sand</td><td>23</td><td>5</td></tr>
<tr><td>Produced Water Disposal</td><td>100</td><td>42</td></tr>
<tr><td>Final Pad Prep</td><td>45</td><td>50</td><td>34</td><td>50</td></tr>
<tr><td>Miscellaneous</td><td></td><td>85</td><td></td><td>85</td></tr>
<tr><td>Total One Way, Loaded Trips/well</td><td>1,148</td><td>831</td><td>398</td><td>507</td></tr>
</table>

Source: *23*, *24* as reported to New York State Department of Environmental Conservation

Table B-3. Truck Traffic per Well Site in North Texas (3).

Activity	Truckloads	Comments
Pad site preparation, rig mobilization, drilling operation, and rig removal	187	
Hydraulic fracturing	997	Assumes 3.7 million gallons of water needed for fracturing (range 3.0 to 6.0 million depending on well requirements)
Maintenance	88	Salt water loads for gas well injections
Re-hydraulic fracturing	977	Required every few years

Table B-4. Total Heavy Truck Traffic for Well Site Development.

Location	Total Truck Traffic per Well Site	Comments
Utah (7)	365-1,370	Loaded traffic only
North Dakota (8)	2,000	Loaded traffic only
New York (*13*)	3,950	Two traffic (loaded and unloaded
Texas (3)	1,184	Loaded traffic only

Table B-5. Well Site Fresh Water Requirements.

Location	Fresh Water, gal- millions	Reference
Texas	1.2-5.0	17
Texas	4.2	19
Texas	2.0-6.0	3
Pennsylvania	5.6	21
Utah	0.7-5.8	22
U.S.	1.2-3.5	24
Texas	2.1	25
U.S.	2.0-4.0	26
New York	1.0-8.0	27
U.S. EPA	3.0-8.0	32

Table B-6. Estimated Water Needs for Drilling and Fracturing Wells in Select Shale Gas Plays (*11*).*

Location	Volume of Drilling Water per well (gal)	Volume of Fracturing Water per well (gal)	Total Volumes of Water per Well (gal)
Barnett Shale	400,000	2,300,000	2,700,000
Fayetteville Shale	60,000	2,900,000	3,060,000
Haynesville Shale	1,000,000	3,700,000	3,700,000
Marcellus Shale	80,000	3,800,000	3,800,000

*based on discussions with various operators

Table B-7. Truck Requirements for Water Haul.

Gallons/Well Completion	Tons/Well Completion	Trucks Required
1,000,000	4,170	174
2,000,000	8,340	348
3,000,000	12,510	521
4,000,000	16,680	695
5,000,000	20,850	869
6,000,000	25,020	1043
7,000,000	29,190	1216
8,000,000	33,360	1390
9,000,000	37,530	1564
10,000.000	41,700	1735
11,000,000	45,870	1911
12,000,000	50,040	2085

1. Fresh water weight is 8.34 lb per gallon.
2. Salt water weight is 8.55 lb per gallon depending on salinity.
3. Typical truck tare weight is 32,000 lb or 16 tons.
4. Legal load limit is 80,000 lb or 40 tons.
5. Payload is 48,000 lb or 24 tons.

Table B-8. Summary of Truck Requirements.

Activity	Range of Truck Requirements			Comments
	Low	Mediu m	High	
Fresh Water	70	140	210	4 million gallons per well, 20 percent of well haul fresh water, 8.34 lb/gallon
Flowback/Produced Water	360	710	1.070	Equal to fresh water utilization (4 million gallons, 8.56 lb/gallon
Crude Oil	500	1,000	1.500	1,000 bbls./day, 3, 6 and 9 months, 7.21 lb/gallon
Other Operations	200	400	550	Obtained from Tables B-1, B-2, and B-3
Totals	1.130	2.250	3.330	

Table B-9. Well Operations in Utah (7).

Activity	Number of Trucks	Comments
Crude Oil Transport	1-150 per month	
Water Removal	**4-150 per month**	
Maintenance	25-40	Acid, operational problems. Frequency depends on problems
Pressure Maintenance/Secondary Recovery		Highly variable

APPENDIX C. IMPACT OF ROAD ROUGHNESS ON TRUCK OPERATING COSTS

INTRODUCTION

If roadways become damaged during their life due to environmental and traffic loads, vehicle operating costs are impacted. The primary measure for measuring roadway damage and its relationship to vehicle operating costs is road roughness. The International Roughness Index (IRI) is the most common parameter used to measure road roughness and it is the parameter used in Texas. In order to determine the impact of rough roads on heavy vehicles associated with oil/gas well development and early operation, two key items of information are needed: vehicle operating costs and increase in operating cost associated with operating on rough roads. Information is presented below that defines these impacts based on a limited literature review.

TRUCK OPERATING COSTS

Vehicle operating cost components used by various calculation models very substantially. The widely used World Bank model (*25*) uses the following cost components: fuel, lubricant oil, tire wear, crew time, maintenance labor, maintenance parts, depreciation, interest, overhead, and cargo holding time. Other models provide a more detailed breakout of costs (*25, 26,27*, *28*).

A number of references were used to obtain a realistic estimate of heavy vehicle operating costs (*25, 26, 27, 28*, *29*, *30*, *31*). Based on this review and the need to use Texas haul costs, bid summary information from Texas were used as the basis for vehicle operating costs (*31*). Table C-1 provides a summary of the South Texas bid summary by specification item. These data indicate that the typical haul costs are of the order of 0.25 to 0.30 dollars per ton mile of product hauled. Assuming a 24 ton product delivery capacity for a typical truck (80,000 lb ton gross legal load and 32,000 lb vehicle tare weight) and a 40 to 60 mile average haul speed, truck rates are of the order of $125 to $175 per ton hour of operation. Data collected for other Texas sources indicate that a typical range for cost per truck operating hour is of the order of $150 per hour.

COST IMPACT OF ROUGH ROADS

The International Roughness Index (INR) is the most common index used to describe road roughness. Table C-2 shows a qualitative description of road roughness for different levels of IRI expressed in terms of meters/kilometer and inches/mile (*30*). Table C-3 shows IRI conversion between the two measurement systems for easy reference.

Table C-4 shows heavy vehicle operating cost increases resulting from an increase in road roughness (*30*). These data are based on a number of truck operating cost studies conducted throughout the world. Table C-5 presents a summary of other data indicating the increase in vehicle operating costs associated with an increase in roughness (*17*, *18*, *19*, *20*, *21, 25, 30, 32*). Heavy vehicles operating costs can increase in the range of 10 to 30 percent depending on the roughness of the road.

Table C-6 shows the range in truck operating costs that can be expected for various road conditions. Based on the data presented above it is estimated that the truck operating costs can increase in the range of $15 to $30 per operating hour.

Table C-1. Haul Costs per Ton Mile of Product Hauled (*31*).

Product			
Base Rock	**Average**	**Standard Deviation**	**Number of Data Points**
Base Rock (Flexible Base Course)	0.23	0.059	1260
Asphalt Binder	0.29	0.085	3799
Asphalt Mixture	0.27	0.055	2801

Table C-2. Qualitative Description of Roughness Measurements (*30*).

Road Roughness, IRI*		**Qualitative Description**	
Meters per kilometer/km	**Inches per mile**	**Paved Road**	**Unpaved Road**
0.0		Very Smooth	Very Smooth
2.0		Smooth	
4.0		Reasonable Smooth	Smooth
6.0		Medium Rough	
8.0		Rough	Reasonable Smooth
10.0		Very Rough	
12.0			Medium Rough
15.0			Rough
20.0			Very Rough

+International Roughness Index

Table C-3. IRI Unit Conversions.

Meters/Kilometer	**Inches/Mile**	**Inches/Mile**	**Meters/Kilometer**
0.5	32		
1.0	63	20	0.31
1.5	94	40	0.63
2.0	125	60	0.95
2.5	155	80	1.26
3.0	188	100	1.58
4.0	250	150	2.37
5.0	313	200	3.16
6.0	375	250	3.95
7.0	438	300	4.73
8.0	500	400	6.4
9.0	563	500	8.0
10.0	625	600	9.6

Table C-4. Heavy Vehicle Operating Costs and Road Roughness (*30*).

International Road Roughness		Cost Index	Percent Increase
Meters/Mile	Inches/Mile		
2	125	115.1	Base Roughness
3	188	118.7	3.1
4	250	122.8	6.7
5	313	127.6	10.9
6	375	133.1	15.6
7	438	139.7	21.4
8	500	147.4	28.1

Table C-5. Increase in Operating Costs for Trucks Operating on Rough Roads.

Reference		Increase in Operating Costs, Percent*
Description	Reference No.	
WesTrack	6	30-50
2030 Report	9,10	80
Urban Mobility Report	7,8	25-50
World Bank	13	20-30
University of Minnesota	14	15-25
World Bank	30	15-30

*increase in cost estimated for a rough road versus a smooth road

Table C-6. Truck Operating Cost Increase Associated with Travel on Rough Roads.

Truck Operating Costs, $/hr.	Increase in Truck Operating Costs for different Percent Increases, Dollars/Hr.				
	10	15	20	25	30
125	12.5	18.75	25.00	31.50	37.50
150	15.00	22.50	30.00	37.50	45.00
175	17.50	26.50	35.00	43.75	52.50

APPENDIX D. CALCULATIONS

Table D-1. Economic Impact of Road Conditions on Vehicle Operating Costs.

Well Completions	Trucks/Well Completion	% Wells Fracturing	Hrs. on Rough Road	Cost Increase, $/hr.	Cost Increase, $
7,500	750	70	0.5	15	29,531,250
7,500	750	70	0.5	35	68,906,250
7,500	750	70	1	15	59,062,500
7,500	750	70	1	35	137,812,500
7,500	750	70	2	15	118,125,000
7,500	750	70	2	35	275,625,000
7,500	750	80	0.5	15	33,750,000
7,500	750	80	0.5	35	78,750,000
7,500	750	80	1	15	67,500,000
7,500	750	80	1	35	157,500,000
7,500	750	80	2	15	135,000,000
7,500	750	80	2	35	315,000,000
7,500	750	90	0.5	15	37,968,750
7,500	750	90	0.5	35	88,593,750
7,500	750	90	1	15	75,937,500
7,500	750	90	1	35	177,187,500
7,500	750	90	2	15	151,875,000
7,500	750	90	2	35	354,375,000
7,500	1,000	70	0.5	15	39,375,000
7,500	1,000	70	0.5	35	91,875,000
7,500	1,000	70	1	15	78,750,000
7,500	1,000	70	1	35	183,750,000
7,500	1,000	70	2	15	157,500,000
7,500	1,000	70	2	35	367,500,000
7,500	1,000	80	0.5	15	45,000,000
7,500	1,000	80	0.5	35	105,000,000
7,500	1,000	80	1	15	90,000,000
7,500	1,000	80	1	35	210,000,000
7,500	1,000	80	2	15	180,000,000
7,500	1,000	80	2	35	420,000,000
7,500	1,000	90	0.5	15	50,625,000
7,500	1,000	90	0.5	35	118,125,000
7,500	1,000	90	1	15	101,250,000
7,500	1,000	90	1	35	236,250,000
7,500	1,000	90	2	15	202,500,000
7,500	1,000	90	2	35	472,500,000

Table D-1. Economic Impact of Road Conditions on Vehicle Operating Costs.

Well Completions	Trucks/Well Completion	% Wells Fracturing	Hrs. on Rough Road	Cost Increase, $/hr.	Cost Increase, $
7,500	1,500	70	0.5	15	59,062,500
7,500	1,500	70	0.5	35	137,812,500
7,500	1,500	70	1	15	118,125,000
7,500	1,500	70	1	35	275,625,000
7,500	1,500	70	2	15	236,250,000
7,500	1,500	70	2	35	551,250,000
7,500	1,500	80	0.5	15	67,500,000
7,500	1,500	80	0.5	35	157,500,000
7,500	1,500	80	1	15	135,000,000
7,500	1,500	80	1	35	315,000,000
7,500	1,500	80	2	15	270,000,000
7,500	1,500	80	2	35	630,000,000
7,500	1,500	90	0.5	15	75,937,500
7,500	1,500	90	0.5	35	177,187,500
7,500	1,500	90	1	15	151,875,000
7,500	1,500	90	1	35	354,375,000
7,500	1,500	90	2	15	303,750,000
7,500	1,500	90	2	35	708,750,000
7,500	2,000	70	0.5	15	78,750,000
7,500	2,000	70	0.5	35	183,750,000
7,500	2,000	70	1	15	157,500,000
7,500	2,000	70	1	35	367,500,000
7,500	2,000	70	2	15	315,000,000
7,500	2,000	70	2	35	735,000,000
7,500	2,000	80	0.5	15	90,000,000
7,500	2,000	80	0.5	35	210,000,000
7,500	2,000	80	1	15	180,000,000
7,500	2,000	80	1	35	420,000,000
7,500	2,000	80	2	15	360,000,000
7,500	2,000	80	2	35	840,000,000
7,500	2,000	90	0.5	15	101,250,000
7,500	2,000	90	0.5	35	236,250,000
7,500	2,000	90	1	15	202,500,000
7,500	2,000	90	1	35	472,500,000
7,500	2,000	90	2	15	405,000,000
7,500	2,000	90	2	35	945,000,000
7,500	3,000	70	0.5	15	118,125,000
7,500	3,000	70	0.5	35	275,625,000
7,500	3,000	70	1	15	236,250,000

Table D-1. Economic Impact of Road Conditions on Vehicle Operating Costs.

Well Completions	Trucks/Well Completion	% Wells Fracturing	Hrs. on Rough Road	Cost Increase, $/hr.	Cost Increase, $
7,500	3,000	70	1	35	551,250,000
7,500	3,000	70	2	15	472,500,000
7,500	3,000	70	2	35	1,102,500,000
7,500	3,000	80	0.5	15	135,000,000
7,500	3,000	80	0.5	35	315,000,000
7,500	3,000	80	1	15	270,000,000
7,500	3,000	80	1	35	630,000,000
7,500	3,000	80	2	15	540,000,000
7,500	3,000	80	2	35	1,260,000,000
7,500	3,000	90	0.5	15	151,875,000
7,500	3,000	90	0.5	35	354,375,000
7,500	3,000	90	1	15	303,750,000
7,500	3,000	90	1	35	708,750,000
7,500	3,000	90	2	15	607,500,000
7,500	3,000	90	2	35	1,417,500,000
10,000	750	70	0.5	15	39,375,000
10,000	750	70	0.5	35	91,875,000
10,000	750	70	1	15	78,750,000
10,000	750	70	1	35	183,750,000
10,000	750	70	2	15	157,500,000
10,000	750	70	2	35	367,500,000
10,000	750	80	0.5	15	45,000,000
10,000	750	80	0.5	35	105,000,000
10,000	750	80	1	15	90,000,000
10,000	750	80	1	35	210,000,000
10,000	750	80	2	15	180,000,000
10,000	750	80	2	35	420,000,000
10,000	750	90	0.5	15	50,625,000
10,000	750	90	0.5	35	118,125,000
10,000	750	90	1	15	101,250,000
10,000	750	90	1	35	236,250,000
10,000	750	90	2	15	202,500,000
10,000	750	90	2	35	472,500,000
10,000	1,000	70	0.5	15	52,500,000
10,000	1,000	70	0.5	35	122,500,000
10,000	1,000	70	1	15	105,000,000
10,000	1,000	70	1	35	245,000,000
10,000	1,000	70	2	15	210,000,000
10,000	1,000	70	2	35	490,000,000

Table D-1. Economic Impact of Road Conditions on Vehicle Operating Costs.

Well Completions	Trucks/Well Completion	% Wells Fracturing	Hrs. on Rough Road	Cost Increase, $/hr.	Cost Increase, $
10,000	1,000	80	0.5	15	60,000,000
10,000	1,000	80	0.5	35	140,000,000
10,000	1,000	80	1	15	120,000,000
10,000	1,000	80	1	35	280,000,000
10,000	1,000	80	2	15	240,000,000
10,000	1,000	80	2	35	560,000,000
10,000	1,000	90	0.5	15	67,500,000
10,000	1,000	90	0.5	35	157,500,000
10,000	1,000	90	1	15	135,000,000
10,000	1,000	90	1	35	315,000,000
10,000	1,000	90	2	15	270,000,000
10,000	1,000	90	2	35	630,000,000
10,000	1,500	70	0.5	15	78,750,000
10,000	1,500	70	0.5	35	183,750,000
10,000	1,500	70	1	15	157,500,000
10,000	1,500	70	1	35	367,500,000
10,000	1,500	70	2	15	315,000,000
10,000	1,500	70	2	35	735,000,000
10,000	1,500	80	0.5	15	90,000,000
10,000	1,500	80	0.5	35	210,000,000
10,000	1,500	80	1	15	180,000,000
10,000	1,500	80	1	35	420,000,000
10,000	1,500	80	2	15	360,000,000
10,000	1,500	80	2	35	840,000,000
10,000	1,500	90	0.5	15	101,250,000
10,000	1,500	90	0.5	35	236,250,000
10,000	1,500	90	1	15	202,500,000
10,000	1,500	90	1	35	472,500,000
10,000	1,500	90	2	15	405,000,000
10,000	1,500	90	2	35	945,000,000
10,000	2,000	70	0.5	15	105,000,000
10,000	2,000	70	0.5	35	245,000,000
10,000	2,000	70	1	15	210,000,000
10,000	2,000	70	1	35	490,000,000
10,000	2,000	70	2	15	420,000,000
10,000	2,000	70	2	35	980,000,000
10,000	2,000	80	0.5	15	120,000,000
10,000	2,000	80	0.5	35	280,000,000
10,000	2,000	80	1	15	240,000,000

Table D-1. Economic Impact of Road Conditions on Vehicle Operating Costs.

Well Completions	Trucks/Well Completion	% Wells Fracturing	Hrs. on Rough Road	Cost Increase, $/hr.	Cost Increase, $
10,000	2,000	80	1	35	560,000,000
10,000	2,000	80	2	15	480,000,000
10,000	2,000	80	2	35	1,120,000,000
10,000	2,000	90	0.5	15	135,000,000
10,000	2,000	90	0.5	35	315,000,000
10,000	2,000	90	1	15	270,000,000
10,000	2,000	90	1	35	630,000,000
10,000	2,000	90	2	15	540,000,000
10,000	2,000	90	2	35	1,260,000,000
10,000	3,000	70	0.5	15	157,500,000
10,000	3,000	70	0.5	35	367,500,000
10,000	3,000	70	1	15	315,000,000
10,000	3,000	70	1	35	735,000,000
10,000	3,000	70	2	15	630,000,000
10,000	3,000	70	2	35	1,470,000,000
10,000	3,000	80	0.5	15	180,000,000
10,000	3,000	80	0.5	35	420,000,000
10,000	3,000	80	1	15	360,000,000
10,000	3,000	80	1	35	840,000,000
10,000	3,000	80	2	15	720,000,000
10,000	3,000	80	2	35	1,680,000,000
10,000	3,000	90	0.5	15	202,500,000
10,000	3,000	90	0.5	35	472,500,000
10,000	3,000	90	1	15	405,000,000
10,000	3,000	90	1	35	945,000,000
10,000	3,000	90	2	15	810,000,000
10,000	3,000	90	2	35	1,890,000,000
15,000	750	70	0.5	15	59,062,500
15,000	750	70	0.5	35	137,812,500
15,000	750	70	1	15	118,125,000
15,000	750	70	1	35	275,625,000
15,000	750	70	2	15	236,250,000
15,000	750	70	2	35	551,250,000
15,000	750	80	0.5	15	67,500,000
15,000	750	80	0.5	35	157,500,000
15,000	750	80	1	15	135,000,000
15,000	750	80	1	35	315,000,000
15,000	750	80	2	15	270,000,000
15,000	750	80	2	35	630,000,000

Table D-1. Economic Impact of Road Conditions on Vehicle Operating Costs.

Well Completions	Trucks/Well Completion	% Wells Fracturing	Hrs. on Rough Road	Cost Increase, $/hr.	Cost Increase, $
15,000	750	90	0.5	15	75,937,500
15,000	750	90	0.5	35	177,187,500
15,000	750	90	1	15	151,875,000
15,000	750	90	1	35	354,375,000
15,000	750	90	2	15	303,750,000
15,000	750	90	2	35	708,750,000
15,000	1,000	70	0.5	15	78,750,000
15,000	1,000	70	0.5	35	183,750,000
15,000	1,000	70	1	15	157,500,000
15,000	1,000	70	1	35	367,500,000
15,000	1,000	70	2	15	315,000,000
15,000	1,000	70	2	35	735,000,000
15,000	1,000	80	0.5	15	90,000,000
15,000	1,000	80	0.5	35	210,000,000
15,000	1,000	80	1	15	180,000,000
15,000	1,000	80	1	35	420,000,000
15,000	1,000	80	2	15	360,000,000
15,000	1,000	80	2	35	840,000,000
15,000	1,000	90	0.5	15	101,250,000
15,000	1,000	90	0.5	35	236,250,000
15,000	1,000	90	1	15	202,500,000
15,000	1,000	90	1	35	472,500,000
15,000	1,000	90	2	15	405,000,000
15,000	1,000	90	2	35	945,000,000
15,000	1,500	70	0.5	15	118,125,000
15,000	1,500	70	0.5	35	275,625,000
15,000	1,500	70	1	15	236,250,000
15,000	1,500	70	1	35	551,250,000
15,000	1,500	70	2	15	472,500,000
15,000	1,500	70	2	35	1,102,500,000
15,000	1,500	80	0.5	15	135,000,000
15,000	1,500	80	0.5	35	315,000,000
15,000	1,500	80	1	15	270,000,000
15,000	1,500	80	1	35	630,000,000
15,000	1,500	80	2	15	540,000,000
15,000	1,500	80	2	35	1,260,000,000
15,000	1,500	90	0.5	15	151,875,000
15,000	1,500	90	0.5	35	354,375,000
15,000	1,500	90	1	15	303,750,000

Table D-1. Economic Impact of Road Conditions on Vehicle Operating Costs.

Well Completions	Trucks/Well Completion	% Wells Fracturing	Hrs. on Rough Road	Cost Increase, $/hr.	Cost Increase, $
15,000	1,500	90	1	35	708,750,000
15,000	1,500	90	2	15	607,500,000
15,000	1,500	90	2	35	1,417,500,000
15,000	2,000	70	0.5	15	157,500,000
15,000	2,000	70	0.5	35	367,500,000
15,000	2,000	70	1	15	315,000,000
15,000	2,000	70	1	35	735,000,000
15,000	2,000	70	2	15	630,000,000
15,000	2,000	70	2	35	1,470,000,000
15,000	2,000	80	0.5	15	180,000,000
15,000	2,000	80	0.5	35	420,000,000
15,000	2,000	80	1	15	360,000,000
15,000	2,000	80	1	35	840,000,000
15,000	2,000	80	2	15	720,000,000
15,000	2,000	80	2	35	1,680,000,000
15,000	2,000	90	0.5	15	202,500,000
15,000	2,000	90	0.5	35	472,500,000
15,000	2,000	90	1	15	405,000,000
15,000	2,000	90	1	35	945,000,000
15,000	2,000	90	2	15	810,000,000
15,000	2,000	90	2	35	1,890,000,000
15,000	3,000	70	0.5	15	236,250,000
15,000	3,000	70	0.5	35	551,250,000
15,000	3,000	70	1	15	472,500,000
15,000	3,000	70	1	35	1,102,500,000
15,000	3,000	70	2	15	945,000,000
15,000	3,000	70	2	35	2,205,000,000
15,000	3,000	80	0.5	15	270,000,000
15,000	3,000	80	0.5	35	630,000,000
15,000	3,000	80	1	15	540,000,000
15,000	3,000	80	1	35	1,260,000,000
15,000	3,000	80	2	15	1,080,000,000
15,000	3,000	80	2	35	2,520,000,000
15,000	3,000	90	0.5	15	303,750,000
15,000	3,000	90	0.5	35	708,750,000
15,000	3,000	90	1	15	607,500,000
15,000	3,000	90	1	35	1,417,500,000
15,000	3,000	90	2	15	1,215,000,000
15,000	3,000	90	2	35	2,835,000,000

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