Additional Road Investments Needed to Support Oil & Gas Production and Distribution in North Dakota

Upper Great Plains Transportation Institute
North Dakota State University
Presentation Topics

- Overview of study and results
- Details of Analysis
- Details of paved road analysis
  - Types of improvements, costs, and effects
- Details of unpaved road analysis
  - Types of improvements and analysis methods
- Conclusions and discussion
Study Overview

- **Purpose:**
  - Forecast road investment needs in oil and gas producing counties of North Dakota over the next 20 years

- **Objective:**
  - Quantify the additional investments necessary for efficient year-round transportation for the oil industry while providing travelers with acceptable roadway service
Study Overview

- **Scope:** The focus is on roads owned or maintained by local governments – e.g. counties and townships.

- **Study Area:** 17 oil and gas producing counties
  - Counties include: Billings, Bottineau, Bowman, Burke, Divide, Dunn, Golden Valley, McHenry, McKenzie, Mclean, Mercer, Mountrail, Renville, Slope, Stark, Ward, and Williams
Primary Data Sources

- Analysis based on: oil production forecasts, traffic data, county road surveys
- Types of roads analyzed: paved, graveled, and graded & drained
- 2010 survey → information on impacted routes and conditions
- 2008 survey → information on typical road characteristics
Production Forecasting

- Oil & Gas Division of North Dakota Industrial Commission
  - Existing and near-term drilling locations
  - Based upon current rig activity and permit applications through end of 2010

- Future locations of rigs estimated from lease data from North Dakota Land Department
Drilling Phases

- Initial phase: lease expirations 2010-2015
  - Assume drilling begins in final year of lease
- Fill-in phase: 3-5 additional wells placed
- Private leases will occur in same areas as public leases
- 21,250 wells drilled in next 10-20 years
- Assume 1,500/year → 14 years to drill 21,250 wells
Traffic Prediction Model

- Forecasted output of wells is routed over road network using detailed GIS model
- Oil movements converted to equivalent truck trips following least-cost routes
- Projected inputs (e.g., sand and water) and outbound movements (salt water) similarly routed
- Movements of specialized equipment (such as workover rigs) included
Road Investment Analysis

- Predicted inbound and outbound movements accumulated for each impacted segment
- Oil-related trips combined with baseline (non-oil) traffic to estimate total traffic load on each road
- Economic/engineering methods used to estimate additional investment needs
Field Data: Traffic Counts

- Counters deployed at 100 locations
- Raw data adjusted
  - To represent traffic for 24-hour period
  - Monthly variation
- ADT=145; Trucks=61 (26 multi-units)
- Paved roads ≈ 100 trucks/day
- Data used to calibrate trip model and estimate baseline traffic loads
### Estimated Investment Needs

**2012-2013 -- 2030-2031 (Millions)**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Unpaved Roads</td>
<td>$567.00</td>
</tr>
<tr>
<td>Paved Roads</td>
<td>$340.10</td>
</tr>
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<td>All Roads</td>
<td>$907.10</td>
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<tr>
<td>3% Inflation</td>
<td>$1,099.30</td>
</tr>
<tr>
<td>5% Inflation</td>
<td>$1,266.57</td>
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</tbody>
</table>
## Investment Needs by Biennium (Millions)

<table>
<thead>
<tr>
<th>Biennium</th>
<th>Unpaved</th>
<th>Paved</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012-2013</td>
<td>$114.90</td>
<td>$118.20</td>
<td>$233.10</td>
</tr>
<tr>
<td>2014-2015</td>
<td>$114.90</td>
<td>$149.90</td>
<td>$264.80</td>
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<td>2016-2017</td>
<td>$75.90</td>
<td>$17.00</td>
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<tr>
<td>2018-2019</td>
<td>$36.90</td>
<td>$20.70</td>
<td>$57.60</td>
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Details of Analysis

- Data Collection
- Network Flow Modeling
- Unpaved Analysis
- Paved Analysis
Data Collection

- Roadway Data
  - Traffic Classification
  - Traffic Counts
  - Condition Data
- Cost and Practices Data
- Oil Development Data
  - Number and Locations of Wells
  - Inputs to Production
    - Origins and Destinations
  - Production Output
    - Origins and Destinations
Roadway Data

- Traffic Classification
  - Maps sent to county point person with instructions to classify roadways by traffic levels
  - Used to identify potential sample traffic count sites

- Traffic Counts
  - Selected using the classification data provided by the county point people
  - Used to calibrate the GIS network routing model and to verify vehicle classification
  - Photos were taken of many of the road segments where counters were placed, and used to verify surface type and condition data
Survey of County Contacts

- Component costs - Unpaved
  - Gravel
  - Blading
  - Location
  - Delivery
  - Placement
  - Dust suppressant
  - Paving costs
Cost and Practices Data

- Survey of County Contacts
  - Maintenance Practices
    - Gravel Overlay Interval
    - Gravel Overlay Thickness
    - Blading Interval
    - Dust Suppressant Usage
Cost and Practices Data

- County Level Cost Calculations
  - Due to the variations in reported costs and practices, unpaved costs were calculated at the county level
  - Reflects actual practices and actual costs at the time of the analysis
Roadway Data

- **Condition Data**
  - Maps were sent to the county point person with instructions to classify roadways by surface condition.
  - Specific classification instructions were given, per the *South Dakota Pavement Condition Survey Guide*.
  - 692 miles listed as either poor or very poor condition.
Oil Development Data

- Numbers and Locations of Wells
  - Initial rig and well locations obtained from NDIC Oil & Gas Division website
  - Forecasted locations estimated from ND Land Department GIS shapefiles of public land leases
    - Leases for public lands only
    - Private land development assumed to be in the same geographic region as the public leases
    - Buffer public lands to estimate development areas on private land
Oil Development Data

- Forecasted locations estimated from ND Land Department GIS shapefiles of public land leases
  - ND Land Department data has lease expiration dates
  - Assumption that drilling will occur in the final year of the lease, and is a single well
  - Oil & Gas estimates 1,450-2,940 wells/year – 2,140 expected, 21,250 in 10 to 20 years
  - Lease expirations available through 2015
  - Post 2015 – filling in phase of drilling
    - 4-6 additional wells on the site
Oil Development Data

- Inputs
  - Data collected from Oil & Gas, NDDOT, and industry representatives
  - The goal was to quantify the number and type of truck trips that the well drilling process generates
  - The major trip generators were water, equipment and sand
## Bakken Well Inputs

### Table 1. Rig Related Movements Per Well

<table>
<thead>
<tr>
<th>Item</th>
<th>Number of Trucks</th>
<th>Inbound or Outbound</th>
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<tbody>
<tr>
<td>Sand</td>
<td>80</td>
<td>Inbound</td>
</tr>
<tr>
<td>Water (Fresh)</td>
<td>400</td>
<td>Inbound</td>
</tr>
<tr>
<td>Water (Waste)</td>
<td>200</td>
<td>Outbound</td>
</tr>
<tr>
<td>Frac Tanks</td>
<td>100</td>
<td>Both</td>
</tr>
<tr>
<td>Rig Equipment</td>
<td>50</td>
<td>Both</td>
</tr>
<tr>
<td>Drilling Mud</td>
<td>50</td>
<td>Inbound</td>
</tr>
<tr>
<td>Chemical</td>
<td>4</td>
<td>Inbound</td>
</tr>
<tr>
<td>Cement</td>
<td>15</td>
<td>Inbound</td>
</tr>
<tr>
<td>Pipe</td>
<td>10</td>
<td>Inbound</td>
</tr>
<tr>
<td>Scoria/Gravel</td>
<td>80</td>
<td>Inbound</td>
</tr>
<tr>
<td>Fuel trucks</td>
<td>7</td>
<td>Inbound</td>
</tr>
<tr>
<td>Frac/cement pumper trucks</td>
<td>15</td>
<td>Both</td>
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<tr>
<td>Workover rigs</td>
<td>1</td>
<td>Both</td>
</tr>
<tr>
<td>Total - One Direction</td>
<td>1,012</td>
<td></td>
</tr>
<tr>
<td>Total Trucks</td>
<td>2,024</td>
<td></td>
</tr>
</tbody>
</table>
Oil Development Data

- Outputs
  - Production (Oil & Gas)
    - County average IP rates
    - Production curve and pipeline access
    - Saltwater production
  - Oil collection/transload sites (Oil & Gas)
    - Current list of operating oil collection points
  - Saltwater Disposal Sites (Oil & Gas)
    - Current list of operating SWD sites
Network Flow Modeling

- Origins and Destinations
  - OD Pairs
    - Sand – Rig
    - Freshwater – Rig
    - Rig – Rig (Equipment)
    - Supplies (chemical, pipe, cement, fuel, etc.) – Rig
    - Rig - SWD
    - Rig – Collection Point
  - Assignment of Pairs
    - Closest destination chosen
    - Routing is based on the least cost path between origin and destination
Network Flow Modeling

Scenarios

- Baseline – Summer 2010
  - June Oil Sales
  - Existing Well and Rig Locations
  - Network Development and Refinement
Network Flow Modeling

- Forecast Flows
    - Associated Volumes
      - Inputs (Water, Sand, Equipment, etc.)
      - Output (Oil and SWD)
  - Model Forecasted Traffic Movements
    - Generate Volume Estimates for Individual Roadway Segments
Unpaved Road Analysis

- Estimation of the additional maintenance and improvement activities due to oil development

- Impacted Miles: 11,834 gravel, 884 graded & drained
Table 23. Miles of Unpaved Road Impacted by Oil-Related Traffic

<table>
<thead>
<tr>
<th>County</th>
<th>Gravel*</th>
<th>Graded &amp; Drained</th>
</tr>
</thead>
<tbody>
<tr>
<td>Billings</td>
<td>560</td>
<td>28</td>
</tr>
<tr>
<td>Bottineau</td>
<td>924</td>
<td>113</td>
</tr>
<tr>
<td>Bowman</td>
<td>230</td>
<td>42</td>
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<tr>
<td>Burke</td>
<td>912</td>
<td>106</td>
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<tr>
<td>Divide</td>
<td>1,076</td>
<td>63</td>
</tr>
<tr>
<td>Dunn</td>
<td>968</td>
<td>105</td>
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<tr>
<td>Golden Valley</td>
<td>413</td>
<td>40</td>
</tr>
<tr>
<td>McHenry</td>
<td>335</td>
<td>24</td>
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<tr>
<td>McKenzie</td>
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<td>69</td>
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<tr>
<td>McLean</td>
<td>451</td>
<td>34</td>
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<tr>
<td>Mercer</td>
<td>36</td>
<td>1</td>
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<tr>
<td>Mountrail</td>
<td>1,294</td>
<td>71</td>
</tr>
<tr>
<td>Renville</td>
<td>677</td>
<td>21</td>
</tr>
<tr>
<td>Slope</td>
<td>97</td>
<td>5</td>
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<tr>
<td>Stark</td>
<td>737</td>
<td>48</td>
</tr>
<tr>
<td>Ward</td>
<td>633</td>
<td>48</td>
</tr>
<tr>
<td>Williams</td>
<td>1,444</td>
<td>65</td>
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<tr>
<td>Total</td>
<td>11,834</td>
<td>884</td>
</tr>
</tbody>
</table>
Unpaved Roads

- Impacted means that at least one oil related truck was routed over the section in the network flow model
  - Impacts and needs vary by traffic levels

- Impact Classification
  - Low: 0-25 (10,930 miles)
  - Elevated: 25-50 (1,094 miles)
  - Moderate: 50-100 (409 miles)
  - High: 100+ (284 miles)
Unpaved Roads

Improvement Types

- Graded and Drained
  - Low: No additional improvements
  - Elevated: Maintenance increase
  - Moderate: Upgrade to gravel roadway (reconstruct)
  - High: Upgrade to gravel roadway (reconstruct)

Roadway Width

- Initial condition of graded and drained roads are often deficient with respect to roadway width
- Reconstruction includes regrading the road, and addition of width to a minimum of 24 feet with gravel overlay
Unpaved Roads

- Improvement Types
  - Gravel
    - Low: Decrease blading interval
    - Elevated: Decrease gravel interval by 33% (3-4 years)
    - Moderate: Decrease gravel interval by 50% (2-3 years)
    - High: Upgrade to double chip seal surface
  - Additional Enhancements/Improvements
    - Dust Suppressant
    - Reconstruction to eliminate deficiencies – roadway width and structural deficiencies
Unpaved Roads

Chip Seal Improvement

- Single Chip Seal
  - Constructed from a single application of binder followed by a single application of uniformly graded aggregate
  - Selected for normal situations where no special considerations would indicate that a special type of chip seal is warranted

Source: TRB: Chip Seal Best Practices
Unpaved Roads

- Chip Seal Improvement
  - Double Chip Seal
    - Constructed from two consecutive applications of both the bituminous binder followed by a single application of uniformly graded aggregate
    - Double chip seals have less noise from traffic, provide additional waterproofing, and a more robust seal in comparison with a single chip seal
    - Used in high stress situations, such as areas that have a high percentage of truck traffic or steep grades

Source: TRB: Chip Seal Best Practices
<table>
<thead>
<tr>
<th>County</th>
<th>Gravel</th>
<th>Graded &amp; Drained</th>
</tr>
</thead>
<tbody>
<tr>
<td>Billings</td>
<td>$18.30</td>
<td>$0.30</td>
</tr>
<tr>
<td>Bottineau</td>
<td>$6.60</td>
<td>$0.00</td>
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<tr>
<td>Bowman</td>
<td>$2.10</td>
<td>$0.00</td>
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<tr>
<td>Burke</td>
<td>$17.10</td>
<td>$0.80</td>
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<tr>
<td>Divide</td>
<td>$47.90</td>
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<tr>
<td>Dunn</td>
<td>$75.60</td>
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<tr>
<td>Golden Valley</td>
<td>$22.70</td>
<td>$0.30</td>
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<tr>
<td>McHenry</td>
<td>$3.30</td>
<td>$0.10</td>
</tr>
<tr>
<td>McKenzie</td>
<td>$81.70</td>
<td>$4.40</td>
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<tr>
<td>McLean</td>
<td>$21.10</td>
<td>$1.10</td>
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<tr>
<td>Mercer</td>
<td>$0.80</td>
<td>$0.00</td>
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<tr>
<td>Mountrail</td>
<td>$76.10</td>
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<tr>
<td>Renville</td>
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<td>$0.60</td>
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<td>Slope</td>
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<tr>
<td>Stark</td>
<td>$35.70</td>
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<tr>
<td>Ward</td>
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<td>Williams</td>
<td>$97.20</td>
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<td>Total</td>
<td>$548.90</td>
<td>$18.10</td>
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<td>--------------</td>
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<tr>
<td>Billings</td>
<td>$3.9</td>
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<tr>
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<td>Bowman</td>
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<tr>
<td>Burke</td>
<td>$3.2</td>
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<tr>
<td>Divide</td>
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<td>Dunn</td>
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<tr>
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<td>$0.1</td>
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<tr>
<td>McKenzie</td>
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<td>$18.2</td>
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<tr>
<td>McLean</td>
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<td>$4.0</td>
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<tr>
<td>Mercer</td>
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<td>$0.2</td>
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<tr>
<td>Mountrail</td>
<td>$15.9</td>
<td>$15.9</td>
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<tr>
<td>Renville</td>
<td>$1.9</td>
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<tr>
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<td>Ward</td>
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<tr>
<td>Williams</td>
<td>$20.2</td>
<td>$20.2</td>
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<tr>
<td>Total</td>
<td>$114.9</td>
<td>$114.9</td>
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</tbody>
</table>
Key Factors: Paved Road Analysis

- Thickness of aggregate base and asphalt surface layers
- Condition (extent of deterioration)
- Graded width
- Soil support (spring load restrictions)
- Truck weights and axle configurations
- Volume of oil-related traffic and other trucks
# Paved Road Thickness (Inches)

<table>
<thead>
<tr>
<th>Layers</th>
<th>Mean</th>
<th>Minimum</th>
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</thead>
<tbody>
<tr>
<td>CMC</td>
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<tr>
<td>Base</td>
<td>5.3</td>
<td>2.0</td>
</tr>
<tr>
<td>Surface</td>
<td>4.4</td>
<td>2.5</td>
</tr>
<tr>
<td>Local</td>
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</tr>
<tr>
<td>Base</td>
<td>4.5</td>
<td>2.0</td>
</tr>
<tr>
<td>Surface</td>
<td>3.5</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Medium-design: 4" AC, 8" Aggregate Base, 8" Subbase
Paved Road Conditions

- 68 miles in poor or very poor condition
  - Experiencing heavy oil-related traffic
  - Cannot be cost-effectively resurfaced
  - Must be reconstructed

- 334 miles in fair condition
  - Expected to deteriorate rapidly under heavy truck traffic
  - Reduced service lives
Spring Load Restrictions

- Relative damage from load may increase by 400%
- > 80% of miles are subject to 6- or 7-ton load restrictions or 65,000-lb gross weight
  - Reduced payloads for trucks
- Ideally, the most heavily traveled oil routes should be free from seasonal restrictions
- Reconstruction only guaranteed solution
Graded Roadway Width

- Determines if thick overlays are feasible without narrowing lanes and shoulders
- \( \approx 50\% \) of county roads \( \leq 28 \) ft wide
- Narrower roads affect roadway capacity (e.g., vehicles per hour) as well as safety
  - Predicted crash rate for a two-lane road with 11-ft lanes and 2-ft shoulders is 1.38 x crash rate with 12-ft lanes and 6-ft shoulders
Reduced Road Service Lives

- Using AASHTO design equations, the service life of each impacted road is projected with and without oil traffic.
- The average reduction in life is five years.
- Williams, McKenzie, and Mountrail Counties have the most predicted miles with reduced service lives.
Type of Road Improvements

- **Reconstruction**: $1.25 million per mile
  - Eliminate spring restrictions
  - Standard lanes with shoulders
  - Improved base-surface thickness ratio

- **Structural overlay**: $300,000 per mile

- **Base-case**: thin overlay

- **Renewal costs**: $8.90 per front-haul truck mile
Annual Road Maintenance

- Maintenance includes two optimally-timed seal coats, crack sealing, patching, striping, etc.
- Increases by 50% when traffic increases from low to medium levels
- Increases by 35% when traffic increases from medium to high levels
- Excludes administrative overhead
### Additional Paved Road Funding Needs (Million $2010)

<table>
<thead>
<tr>
<th>Improvement Type</th>
<th>Miles</th>
<th>Needs</th>
</tr>
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<tbody>
<tr>
<td>Maintenance</td>
<td>958.4</td>
<td>$41.60</td>
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<tr>
<td>Overlay</td>
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<tr>
<td>Reconstruction</td>
<td>225.6</td>
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<tr>
<td>Renewal</td>
<td>483.4</td>
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<tr>
<td>All Types</td>
<td></td>
<td>$338.90</td>
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## Estimated Investment Needs

### 2012-2013 -- 2030-2031 (Millions)

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</tbody>
</table>
Conclusion and Discussion

- Estimates for oil-impacted roads only
- Needs in addition to other road needs
- Investments will provide improved service for all road users; benefits include:
  - Year-round legal loads on key paved roads
  - Wider safer roads with more capacity
  - Reduced transportation cost
  - Lower life-cycle costs (incl. road user cost)