Quantifying Environmental Impacts of Pavements

Annual Conference
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Mount Pleasant, MI

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Baltimore, MD
Special Thanks

- Bob “Mr. Smoothie” Orthmeyer (RC)
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- Buzz Powell (NCAT)
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- Imad Al Qadi (University of Illinois)
- Karim Chatti (MSU)
- Jim Musselman (FL DOT)
Preamble

David Brower,

“We do not inherit the land from our fathers, we borrow it from our children.”

The environment is very important!
“If you can’t measure it, you can’t manage it.”

Peter Drucker

“A company’s primary responsibility is to **serve its customers**, to provide the goods or services which the company exists to produce. Profit is not the primary goal but rather an essential condition for the company’s continued existence.”
Quick Reference for You

September/October | 2012 | Volume 17 | Number 5

Asphalt Pavement Smoothness: Quantifying the Environmental Impacts

A study was conducted to evaluate the environmental impacts of various asphalt pavement smoothness levels. The study aimed to determine the most effective methods for quantifying the environmental impacts of asphalt pavements.

By Fenwick Paine

A key question in the study was: "How can we quantify the environmental impacts of asphalt pavements?" The study concluded that quantifying environmental impacts is crucial for making informed decisions about asphalt pavement maintenance and construction.

For more information or to download the full report, visit www.asphalt.org/download/quantifying-environmental-impacts.
A Historical Perspective...

**Customer Service**

- There is no one perfect pavement, a pavement should meet the needs of the community and no more.

---

**Community Needs** *(Local to National)*

**Safety** *(Geometrics, Friction, SafetyEdge™...)*

**Economics** *(LCCA, Commerce, Growth)*

**Ride** *(Smoothness, Texture)*

**Environment** *(Natural Resources, Recycled Products, Noise, Emissions...)*
Key Pavement Question

Where are the greatest potentials, within our control, for reducing environmental impacts???
Pavement Life-Cycle

http://www.dot.ca.gov/newtech/roadway/pavement_lca/index.htm

Extraction Production Transport
Traffic Delay On-site Equipment
Rolling Resistance Carbonation Lighting Albedo Leachate
Traffic Delay Extraction Production Transport
Traffic Delay Salvage Transport...

Materials
Construction
Use
Maintenance, Preservation Rehabilitation
End-of-Life
Ex. Estimate of Total US Emissions for Hot-Mix Asphalt Production

• Our Nation:
  – In 2011, 380 million tons of asphalt mix

• Typical HMA Production Parameters
  – No. 2 Oil, 4% Stockpile Moisture
  – 330°F Mix Temperature (350°F Stack)

• Total Estimated Annual HMA Emissions ~
  – 8,222,000 US tons CO$_2$e
Usage

Percentage of Total Asphalt Production in US
source: National Asphalt Pavement Association

<table>
<thead>
<tr>
<th>Year</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usage</td>
<td>4.7%</td>
<td>11.8%</td>
<td>~22%+</td>
<td>~25-30%</td>
</tr>
</tbody>
</table>

Source: National Asphalt Pavement Association
As the US continues to move from Hot-Mix to Warm Mix, it is equivalent to removing 1.5 million cars of the road each year!

Total Predicted WMA Annual Emissions ~ 6,087,000 US tons CO$_2$e at 265°F
Various Thoughts on Use Phase

Relative Fuel Savings

- MIRIAM: 0.0%
- NCHRP: -0.9%
- MIT: 4.0% (HT), 7.0%
- TRB: 1.5%
- Others: 0.5%

Asphalt Savings | Concrete Savings
Concrete Fact:

Concrete roads are 4% to 7% more fuel efficient

888-4-CHANNEY
Chaney Enterprises
ChaneyEnterprises.com/concretepays

How is this information being used?
Proving the Adage

For every Ph.D. there is an equal and opposite Ph.D.
Various Modeling Approaches

Texture + IRI + Speed = RR

Deflection = RR

Texture + IRI + Grade, Super-elevation + Pavement Type + Speed + Air Temp = VOC

NCHRP 1-45
Today’s Visit
Understanding Use Phase

Vehicle Operation – Fuel Economy & Emissions

1. Identify Relationships Needed for Analysis
2. Identify Sources
3. Define Pavement Section(s)
4. Conduct Scenario Analysis
Fuel Efficiencies

• What is the US fleet-wide average for passenger cars (2011)?

A. 18.5 mpg
B. 21.5 mpg
C. 23.0 mpg
D. 25.5 mpg
Fuel Efficiencies

- 18 Wheeler mpg diesel (carrying freight)
  - Low side ~ 4.5 mpg
  - High side ~ 11 mpg
  - Average ~ 7 mpg (used in analysis)
Reasonable to Assume
(But for Today: let’s Assume NO Change)

Historic and Projected Fuel Economy

- Hybrids and other advancements
- Freight Load limits may raise from 80 to 99kips (VT, ME)

Fleet-wide Average, mpg

1/1/1992 1/1/2011 1/1/2030
Time, Years
What are the relationships between RR, fuel consumption, & Emissions?
Ongoing Effort

MIRIAM: MODELS FOR ROLLING RESISTANCE IN ROAD INFRASTRUCTURE ASSET MANAGEMENT SYSTEMS

Bjarne Schmidt, Danish Road Directorate, Denmark
Factors Effecting Fuel Efficiencies
Total Driving Resistance

Vehicle Driving Resistance

Vehicle Propulsion
- Inertial
- Gravitational
- Engine
- Auxiliary Equipment

Vehicle Aerodynamics
- Body Air
- Tire Air

Vehicle Rolling
- Tire/Road Rolling
- Bearing
- Transmission
- Suspension

IRI/MPD
Rolling Resistance (RR)
Fuel Consumption & Emissions

• Present Knowledge
  – Bjarne Schmidt, DRI, Denmark

• Passenger Car at 60 mph
  – 50% of fuel consumption to overcome RR

• Truck at 50 mph
  – 40% of fuel consumption to overcome RR

• On Average
  ~25% of fuel consumption is used to overcome RR
Tire Wear, Traction, & Force Generation
Automotive View on Rolling Resistance

- Operation of a mid-sized gasoline fueled car like a Chevrolet Malibu or Ford Focus.
Alternatively: **Highway Driving**

*(Source: M’gineering, LLC: Dr. Mariom Pottinger)*

![Highway Driving Graph]

- **Fuel** (100%)
- **Engine** (69%)
- **Driveline** (5%)
- **Tire** (7%)

- **Rolling Resistance**
- **Braking**
- **Aero**
- **Accessories**
- **Standby**
- **Losses**
- **Potential**
Fuel Consumptions to Overcome RR

RR Loss / Driveline Potential

Passenger Car

<table>
<thead>
<tr>
<th>Pavement Perspective</th>
<th>50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRI - 60 mph Denmark</td>
<td></td>
</tr>
<tr>
<td>DRI - Ave</td>
<td>25%</td>
</tr>
<tr>
<td>Urban</td>
<td>31%</td>
</tr>
<tr>
<td>Highway</td>
<td>35%</td>
</tr>
</tbody>
</table>

M’gineering, LLC
So Abbot, rolling resistance accounts for about a third of fuel consumption? But who’s on first?
From a Pavement Perspective
What is in Our Control?

- Texture, $f(t)$
- Stiffness, $f(d)$
- Temperature, $f(n)$
- Smoothness, $f(t)$
Understanding Tire/Pavement Interaction

• Key Reference:
  – Tyre/Road Noise Reference Book

Ulf Sandberg

Jerzy A. Ejsmont
## Pavement Texture Ranges

*Defined by Sandberg, et.al.*

<table>
<thead>
<tr>
<th>Texture Range</th>
<th>Texture Wavelength (mm)</th>
<th>Typical Peak Amplitudes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mega-</td>
<td>50 - 500</td>
<td>0.1 – 50</td>
</tr>
<tr>
<td>Macro-</td>
<td>0.5 – 50</td>
<td>0.1 – 20</td>
</tr>
<tr>
<td>Micro-</td>
<td>&lt; 0.5</td>
<td>0.001-0.5</td>
</tr>
</tbody>
</table>
PIARC Pavement Surface Characterizes
(Scale: $\mu$m, $10^{-6}$ m)

<table>
<thead>
<tr>
<th>Texture</th>
<th>Microtexture</th>
<th>Macrotexture</th>
<th>Mega</th>
<th>Roughness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ride Quality (IRI)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rolling Resistance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vehicle Wear</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In-Vehicle Noise</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tire-Pavement Noise</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Splash &amp; Spray</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wet Weather Friction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry Weather Friction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tire Wear</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Key:
- Bad Impact
- Good Impact
Dependent on Similar Textural Range
(Scale: $\mu m$, $10^{-6} m$)

- **Texture**
  - Microtexture
  - Macrotecture
  - Mega
  - Roughness

- **Ride Quality (IRI)**

- **Rolling Resistance (RR)**

**Key:**
- **Bad Impact**
- **Good Impact**

- **Measure** = Texture (Macro, Mega, Roughness)
- **Measure** = Ride Quality
- **Outcome** = Rolling Resistance = $f$(IRI, Texture...)

Texture
As Relates to Rolling Resistance
When did Engineers first start exploring concepts of rolling resistance on pavements?

A. Mid 1800’s (Horse-drawn carriages)
B. Early 1900’s (Trail Road Associations)
C. Mid 1900’s (Bureau of Public Roads)
D. Late 1900’s (pending ‘97 Kyoto Protocol)
E. I like Ice cream
A LITTLE HISTORY... 1845

Robert W. Thompson, a Scottish engineer, received a British patent for his new pneumatic carriage tire greatly reducing rolling resistance force.
1888 ~ 40 YEARS LATER...

John Boyd Dunlop, who knew nothing of Thompson, invented the pneumatic tire to improve the horrible ride of the now common bicycle.

Right tire – right time
Business boomed!
Dunlop just rolled his tire across the courtyard. His would go far enough to hit the wall. The solid tire would not. (AASHTO TP 001) 😊
Fast Forward 165 years

- Rolling Resistance
  - Direct Measurement
  - Modeling RR from Pavement Surface Characteristics
Round Robin Test (RRT) at IFSTTAR in Nantes

BRRC

BRRC (Belgium)

TUG = Techn Univ of Gdansk (Poland)

BASt

(BASt (Germany))
US RR Device?

• Most research in the US has focused on tire and vehicle drag...

• Automotive perspective.
MIRIAM Modeling Rolling Resistance

Texture + IRI + Speed = RR
RRC = C_1 + C_2 \cdot MPD + C_3 \cdot IRI + C_4 \cdot IRI \cdot (V - V_{ref})

For a car:
RRC = 0.0148 + 0.0020 \cdot MPD + 0.00064 \cdot IRI + 0.00005 \cdot IRI \cdot (V - 20)

For a truck:
RRC = 0.0061 + 0.0014 \cdot MPD + 0.00095 \cdot IRI + 0.000076 \cdot IRI \cdot (V - 20)

Where:
- MPD: Mean Profile Depth (macrotexture) in mm
- IRI: International Roughness Index in mm/m
- V: Vehicle Speed in meter/second
What is the potential impact of RR on fuel efficiency?
EU – Energy Conservation in Road Pavement Design

10% RR ~ 3% Fuel Consumption
Stiffness
Stiffness Concept

Ideal Spring: load/unload (no losses)
Stiffness Concept
Ideal Spring: load/unload
Hysteresis effect
Energy Loss during load/unload

Load (kN)

Displacement (μm)
Benbow et al. (2007) Lab Study at TRL, indicated a positive effect of stiffness; however, the effect was not statistically significant.

Hysteresis effect measured with a Falling Weight Deflectometer (FWD) on a concrete pavement (left), compared to an asphalt pavement (right).
However... NCHRP 1-45 VOC Model
All Things Equal *(Similar in concept to MIT)*
IRI = 95 in/mile, MPD = 0.05 in, 80°F

Percent difference in fuel consumption per vehicle type
Air temperature = 86 °F (30 °C)
1-45 Model Fuel Consumption for Asphalt & Concrete

NCHRP 1-45 Models - Articulated Truck

Gallons of Fuel / 1000 miles

<table>
<thead>
<tr>
<th>Speed</th>
<th>55mph</th>
<th>45mph</th>
<th>35mph</th>
</tr>
</thead>
<tbody>
<tr>
<td>7%</td>
<td>20%</td>
<td>RR</td>
<td>Drivetrain</td>
</tr>
<tr>
<td>4%</td>
<td>13%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

AC Dynamic Modulus $|E^*|$ at 10 Hz, ksi

Air Temperature, °F or Speed, mph

57
NHS Scenario

• Analysis Period = 30 years
• 2-way AADT_{24hour} ~ 29,800 vehicles/ day
• 29% Trucks (Total Rural Interstate - IDOT)
• 36% Passenger Vehicles
• 35% Lt. Wt. Trucks (including SUV’s)

• 80 million Total Design ESALs (2,680 kESAL/yr)
• Project Length is 25 miles
Comparison Section

Glooptonite™

• Constant Surface, “Fair Condition”
  – IRI = 112 inches/mile
    1.77 m/km
  – MPD = 0.900 mm
GPS-1 (AC) IRI Model

- IRI\(_{(t)}\) = -0.143 + 1.0765(\text{IRI}_0) + 0.0424(\delta \text{ Time}) + 0.0094(\text{Traction}^{1/2} / \text{SN}^5) + 0.0012 (\delta \text{ Time} * \text{PL}) + 0.006(\delta \text{ Time} * \text{BaseP200})

- Based on 168 sections

- 40% of the GPS-1 sections were deassigned
  - Deassignment due to owner agency overlay
  - Average age at deassignment – 15 years
  - Average IRI at deassignment – 107 in/mile
SPS-9: Validation of SHRP Asphalt Specification and Mix Design – Superpave®

- Simplified IRI Model for Superpave (Interstate)

\[
IRI_t = IRI_0 + 1.4 \text{ Time (yr), in/mile}
\]

\[
IRI_t = 65 + 1.5 \times t \ (Scenario), \text{ year 1 to 18}
\]

\[
IRI_t = 85 + 1.8 \times t \ (Scenario), \text{ overlay @ 18+}
\]

<table>
<thead>
<tr>
<th>Road Type</th>
<th>n</th>
<th>IRI₀</th>
<th>Slope, δIRI/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interstate</td>
<td>7</td>
<td>49</td>
<td>1.4</td>
</tr>
<tr>
<td>US Route</td>
<td>7</td>
<td>68</td>
<td>0.8</td>
</tr>
<tr>
<td>State Road</td>
<td>2</td>
<td>62</td>
<td>0.4</td>
</tr>
</tbody>
</table>
LTPP IRI Models
AC Sections (GPS-1 & Superpave®)
LTPP Data - Concrete
GPS-3 (JPCP) – Doweled & GPS-4 (JRCP)

\[ IRI_t = 0.12284 + 0.94229 \times IRI_0 - 0.00733 \times (\text{Time} \times PCC_{\text{ten}}) \]
Our understanding of concrete pavement roughness has advanced considerably...
Curling and Warping is a function of:

- CTE of the concrete
- Weather Conditions
  (esp. cloud cover, temperature)
- Joint “Freedom”
  (function of width, joint reinforcement, etc)
- Some sites fluctuate as much as 40 in/mile ½ Car IRI
  ~ 11% Δ in RCC\textsubscript{MIRIAM} or 3.4% Δ in fuel/emissions
- Others around 10 in/mile (from day to night)
What about Texture?
• Megatexture Texture Data:
  – US currently does not collect texture on a project or network level on roadways
Texture $f(t)$

- Macrotexture, MPD ($mm$)
  - Static Method (CTMeter)

- Data Sources:
  - LTPP, CT SPS 9
  - Virginia Smart Road, *Environmental Effects Only*
  - NCHRP 634, Long. Textured Concrete Pavement
  - NCAT Test Track
  - Future FHWA PCC Study
  - Future FHWA LTPP
Environmental Impact

Special Thanks to Edgar de León Izeppi

Virginia Smart Road

MPD (mm) by CTMeter™

Year


9.5mm Superpave
19mm SMA
9.5mm OGFC
12.5mm SMA
Tined CRCP

SM 9.5 D SuperPave
SMA 9.5 D
OGFC
Tined CRCP
2009 CT DOT
LTPP SPS 9 Sections,
Constructed in 1998 (t = 11 years)

<table>
<thead>
<tr>
<th>LTPP SPS 9 Section ID</th>
<th>Average MPD (CT Meter), mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>090901</td>
<td>0.81</td>
</tr>
<tr>
<td>090902</td>
<td>1.04</td>
</tr>
<tr>
<td>090903</td>
<td>0.91</td>
</tr>
<tr>
<td>090960</td>
<td>1.02</td>
</tr>
<tr>
<td>090961</td>
<td>1.27</td>
</tr>
<tr>
<td>090962</td>
<td>1.32</td>
</tr>
<tr>
<td>Average</td>
<td>1.06</td>
</tr>
</tbody>
</table>
• 16 Sections
• PG 67 & PG 76
• HMA / WMA
• 0 to 50% RAP
• 10 to 40 m ESAL’s

Ave. Initial Texture (mm) = 0.431
Ave. Change ($\delta$MPD / $\delta$mESALs) = 0.017, ranging from -0.015 to 0.023
Average $R^2 = 0.70$
RR Inputs based on SPS-9 IRI and NCAT Texture Model, Overlay at year 18

Rolling Resistance Analysis
MIRIAM Model: f(IRI, MPD, V)

Analysis Period, years

IRI, m/km

Texture, mm

Glooptonite™

Baseline IRI
IRI (m/km)
Baseline MPD
MPD (mm)
CT SPS-9 Ave
VA SmartRoad
MIRIAM RRC \( f(\text{IRI, MPD}) \)

Flexible Scenario

![Graph showing Rolling Resistance over Analysis Period]

- **Gloopontite™**
- **Flexible Section**

Analysis Period, years

0  5  10  15  20  25  30

Rolling Resistance

- Additional Savings

RRC

0.0000  0.0050  0.0100  0.0150  0.0200  0.0250  0.0300
## Texturing of Concrete Pavements
**NCHRP 634 – 2009 Report**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Sections</td>
<td>38</td>
</tr>
<tr>
<td>No. of States</td>
<td>7</td>
</tr>
<tr>
<td>Ave. Service Life</td>
<td>7.7 years (5 to 15)</td>
</tr>
<tr>
<td>Ave. MPD</td>
<td>0.80 mm</td>
</tr>
<tr>
<td>Min. MPD</td>
<td>0.25 at 6 years</td>
</tr>
<tr>
<td>Max. MPD</td>
<td>1.58 at 6 years</td>
</tr>
<tr>
<td>Range MPD</td>
<td>1.33 (166% of Ave.)</td>
</tr>
<tr>
<td>St. Dev. (s)</td>
<td>0.299</td>
</tr>
</tbody>
</table>

![Graph showing relationship between MPD and Service Life](image)
Basic Model for Tined Concrete Pavement

(Harman PCC\textsubscript{Tined} Texture Model)

Tined Concrete Pavement
Smart Road - NCHRP Report 634

\[ y = 0.016x + 0.78 \]
\[ R^2 = 0.5 \]

- Ave Data
- Model
- Model + 2\(\sigma\)
- Model - 2\(\sigma\)

MPD, mm

Service Life, years
RR Inputs based on GPS-3 IRI and Harman $PCC_{Tined}$ Texture Model

**Rolling Resistance Analysis**

MIRIAM Model: $f(\text{IRI, MPD, V})$

- Baseline IRI
- IRI (m/km)
- Baseline MPD
- MPD (mm)
MIRIAM RRC $f(\text{IRI, MPD})$

Rigid Scenario

![Graph showing Rolling Resistance over Analysis Period, years]
• The purpose of the presentation is to demonstrate how these analysis tools can be used (period)

• It is not to compare Superpave SPS/Test Track Sections to LTPP GPS Concrete Sections.
Accounting for IRI/Macrotexture (MPD) Within 2% of each other

IRI / MPD MIRIAM RRC Model
- \( RCC = C_1 + C_2 \cdot MPD + C_3 \cdot IRI + C_4 \cdot IRI (V - V_{ref}) \)
WesTrack Fuel Consumption

“Pavement roughness had a significant impact on fuel consumption of trucks applying loads to WesTrack pavement test sections. Under otherwise identical conditions, trucks used 4.5% less fuel on smooth (post rehabilitation) than on rough (pre rehabilitation) pavement.”

• NCHRP Report 455, p. 483
**Summary of MIRIAM Models Similar to WesTrack (4.5%)**

<table>
<thead>
<tr>
<th>Impact of Good to Poor</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexible Scenarios</td>
<td>5.0%</td>
</tr>
<tr>
<td>Rigid Scenarios</td>
<td>4.9%</td>
</tr>
</tbody>
</table>
MIRIAM Model Breakdown

Example Concrete Section 30 year Period

Contribution of Macrotexture (MPD) and Ride (IRI)

- $f(MPD)$
- $f(IRI, V)$

**IRI / MPD MIRIAM RRC Model**

- $RCC = C_1 + C_2 \cdot MPD + C_3 \cdot IRI + C_4 \cdot IRI \left( V - V_{ref} \right)$
NCHRP 1-45: Effect of Pavement Conditions on VOC Within 0.4% of each other

NCHRP 1-45 VOC Models
- Partial Costs – Fuel Consumption ONLY
- Not included: Tire wear, repair & maintenance
## Summary of Modeling

<table>
<thead>
<tr>
<th>Analysis Method</th>
<th>Delta</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIRIAM $f$(MPD, IRI, V)</td>
<td>2%</td>
</tr>
<tr>
<td>1-45 VOC Models @ 77°F / 55mph</td>
<td>0.38%</td>
</tr>
</tbody>
</table>
### 2009 NHS

- **40% of All Traffic**
- **75% of All Freight Traffic**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Mileage of NHS</th>
<th>~Miles Traveled</th>
<th>Sustainability CO$_2$e(*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>8%</td>
<td>11%</td>
<td>4.8% Additional</td>
</tr>
<tr>
<td>IRI &gt; 170 in/mile</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fair</td>
<td>66%</td>
<td>69%</td>
<td>Net 0%</td>
</tr>
<tr>
<td>Good</td>
<td>26%</td>
<td>20%</td>
<td>2.5% savings</td>
</tr>
<tr>
<td>IRI ≤ 95 in/mile</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- (*) – compared to Glooptonite™ with MIRIAM
“Simple Math”

- If Fair is similar to Glooptonite™, and
  - 11% miles traveled generates 4.8% additional, and
  - 20% of miles traveled generates 2.5% less...

Net: +11%(4.8%) – 20%(2.5%) < ZERO (0%)

Poor  Good
In 2011, the US consumed about...

<table>
<thead>
<tr>
<th>Billion Gallons</th>
<th>Gasoline</th>
<th>Diesel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>134</td>
<td>30</td>
</tr>
</tbody>
</table>
$ Bottom Line $

EIA projection (9/12)

<table>
<thead>
<tr>
<th>Price per Gallons</th>
<th>Gasoline</th>
<th>Diesel</th>
</tr>
</thead>
<tbody>
<tr>
<td>$5.00</td>
<td>$3.64</td>
<td>$4.01</td>
</tr>
<tr>
<td>$4.50</td>
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<tr>
<td>$4.00</td>
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<tr>
<td>$3.50</td>
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<tr>
<td>$3.00</td>
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<tr>
<td>$2.50</td>
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<tr>
<td>$2.00</td>
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</tr>
<tr>
<td>$1.50</td>
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<td></td>
</tr>
<tr>
<td>$1.00</td>
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<tr>
<td>$0.50</td>
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</tr>
<tr>
<td>$-</td>
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</tbody>
</table>
AAA

September 17, 2012 national average price for a gallon of regular unleaded gasoline is $3.86

Source: AAA (FuelGaugeReport.AAA.com)
### $\$ $ Bottom Line Line $\$ $

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Annual Usage (Gallons)</th>
<th>Unit Cost ($/Gallon)</th>
<th>Total Cost (Dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>134,000,000,000</td>
<td>$3.75</td>
<td>$500 Billion</td>
</tr>
<tr>
<td>Diesel</td>
<td>30,000,000,000</td>
<td>$4.00</td>
<td>$120 Billion</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td>$620 Billion</td>
</tr>
</tbody>
</table>

### Condition

<table>
<thead>
<tr>
<th>Condition</th>
<th>~Miles Traveled</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>11%</td>
<td>-2%</td>
</tr>
<tr>
<td>IRI &gt; 170 in/mile</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fair</td>
<td>69%</td>
<td>+2%</td>
</tr>
<tr>
<td>Good</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td>IRI ≤ 95 in/mile</td>
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<td></td>
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</tbody>
</table>
Potential Return on Investment

Step 1

- In addition to maintaining the current condition
- Increase GOOD by 2%↑ & Decrease the POOR by 2%↓

<table>
<thead>
<tr>
<th>Year</th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Challenge</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

2% increase in GOOD and 2% decrease in POOR.
Potential Return on Investment

Step 2

- 2% of the POOR 2009 NHS is 3,200 c.l. miles
- ~$577,000 rehab cost per c.l. mile (*)

- 160,000 miles x 2% = 3,200 c.l. miles

(*) – Rehab Cost based on FL DOT 2012 Urban Interstate Asphalt Costs
Mill & Resurface 3 Lane Urban Road with Center Turn Lane and 4' Bike Lanes
Potential Return on Investment

Step 3

- Required increased investment ~ $1.85B
- Annual fuel savings $900M
- Realized Benefit over GOOD Life (~9 yrs) ~ $8B (fuel savings)
Potential Return on Investment
Step 4

• Total Return on Investment over 9 yrs ~ 440%

• Pretty cool, but...
Yes, this is two separate pockets of money...

$1.85B increase Highway Funding

$8B Public Savings Fuel

$1.85B ~ $0.009 ↑ / gallon user fee
From $0.1844 to $0.1936... 5%↑
Where are the greatest potentials, **within** our control, for reducing environmental impacts???
THANK YOU
References

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