University of Illinois

“Commuter Railroad Engineering and the State of Good Repair"

November 4, 2011

Joseph Lorenzini, P.E.
Chief Engineering Officer

Metra
• 6 Counties
• Annual Budget $930 Million
• 704 Trains each weekday
• 86.8 Million riders in 2008
• Largest commuter railroad in North America in terms of trackage
TERRITORY

- Track Miles – 1,189
- Route Miles – 546
- Road Grade Crossings – 534
- RR Grade Crossings – 19
- Bridges – 821
- Stations – 240
- Parking Spaces – 92,995
Metra System Ridership
Reported w/ Free Trips
August, 1983-2010

Ridership in Millions

Ridership in Millions

Years
Responsible for Fixed Assets

- Stations and Parking Lots
- Track
- Maintenance Facilities
- Signal Systems
- Communications
- Electrical Propulsion
- Line Extensions and Expansions
- Bridges
Stations and Parking Lots

- 5 Downtown Stations
- 235 Outlying Stations
- 92,955 Parking Spaces
- 30 New Stations Since 1983
- 40,355 New Parking Spaces Since 1987
- 14,387 Parking Spaces Rehabilitated Since 1983
La Salle Street Station
Millennium Station (Randolph Street)
Midlothian
51st – 53rd Streets  Hyde Park
Track

- 1,155 Miles of Track
- 574 Grade Crossings
- 3,800,000 Track Ties
- 115,000 Switch Ties
Tie replacement
Track surfacing
Track Renewal
Maintenance Facilities
Facilities & Equipment

Western Avenue Yard
Signals & Communication
Signals, Electrical, & Communications

Interlocking Upgrades
Signals, Electrical, & Communications

Interlocking Upgrades
Signals, Electrical, & Communications
Signal Operation
Automatic Block Signal
Manual Interlocking
Positive Train Control (PTC)
PTC Benefits

Safety Related Benefits
- Train Collision Avoidance
- Switch Protection
- Over Speed Avoidance
PTC – How Does It Work?

- Before a train leaves its originating terminal all relevant information is downloaded.

- GPS works in conjunction with the geographic track data base.

- As the train moves the PTC onboard computer constantly calculates a warning and braking curve based on all downloaded information.

- As the train moves PTC pings wayside devices checking for broken rails, proper switch alignment, and signal aspects.
Phase 1 – Onboard & Wayside Integration

**PTC Wayside**
Route determined by:
- Switch Position interrogation
- Signal State interrogation

**PTC Onboard Package**
- Onboard Computer
- Engineer Display
- Data Communications
Railroad Communications
Passenger Communications

- TRACK 5
- NORTHWEST LINE
- 410

- TRACK 11
- BOARDING
- 9:30 AM
- MILWAUKEE WEST
- BIG TIMBER ROAD

- WESTERN AVE
- NATIONAL ST.
- GRAND/CICERO
- ELGIN
- GALEWOOD
- BIG TIMBER RD.
- MONT CLARE
- ELMWOOD PARK
- RIVER GROVE
- FRANKLIN PARK
- BENSENVILLE
- WOOD DALE
- ITASCA
- MEDINAH
- ROSELLE
- SCHAUMBURG
- HANOVER PARK
- BARTLETT

- 9:30 AM BIG TIMBER RD.
Passenger Communications
Passenger Communications

- GPS CENTER CAN SEND ON-BOARD ANNOUNCEMENTS TO TRAINS

- PROVIDES LOCATION AND STATUS OF TRAIN TO GPS CENTER FROM ON-BOARD EQUIPMENT

GPS CENTER
547 W.JACKSON

GPS SATELLITE

WIRELESS CONNECTION

GPS RADIO CONNECTION

PROVIDES LOCATION OF TRAIN TO ON-BOARD EQUIPMENT
Electric Propulsion
Electrical Facilities

- 11 Substations
- 5 Tie Stations
- 109 Miles of 1500 Volt D.C. Catenary
- 114 Miles of 4kV A.C. Transmission Wire
Electrical Upgrades

Incoming Commonwealth Edison 12kV AC Supply Line #1

12kV AC SWITCHGEAR

TRANSFORMER
TRANSFORMER
TRANSFORMER

12.470V AC In 1.167V AC Out
1.167V AC In 1.836V DC Out

RECTIFIER
RECTIFIER

NEGATIVE BUS

1,500V DC SWITCHGEAR

1,500V D.C. CATENARY SYSTEM

(+ -) 1500V D.C. CATENARY SYSTEM

RAILWAY NEGATIVE RETURN CABLE

(-) 1500V D.C. CATENARY SYSTEM

RAILWAY LIGHT & POWER TRANSFORMER

4.160V AC In 2.400V AC Out

4.160V AC In 2.400V AC Out

4.160V AC In 4.180V AC Out

4.160V AC In 4.180V AC Out

2.4KV AC SWITCHGEAR

4.180V AC In 480V AC Out

COMMUTER STATION

SWITCH HEATER POWER

SIGNAL SYSTEM POWER

2.400V AC In 120/240V AC Out
Electrical Upgrades
Electrical Upgrades
Electrical Upgrades
Electrical Upgrades
Electrical Upgrades
Electrical Upgrades
### MED

<table>
<thead>
<tr>
<th>PROJECT NAME</th>
<th>PROJ. NO.</th>
<th>COST</th>
<th>REMARKS</th>
</tr>
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<tbody>
<tr>
<td>MILLENNIUM STATION-VENTILATION IMPROV</td>
<td>3944 FY07</td>
<td>5624 K</td>
<td>99% completed</td>
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<tr>
<td>RECTIFIERS REPLACEMENT AT BROODALE SUBSTATION</td>
<td>42352</td>
<td>1234 K</td>
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<tr>
<td>RICHMOND/WATTESON YARD DE-HOME SYSTEM</td>
<td>3246</td>
<td>5555 K</td>
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<tr>
<td>VAN BUREN STA, GENERATOR ROOM HVAC IMPROV</td>
<td>OLD MONEY</td>
<td>1234</td>
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<tr>
<td>AC SWITCHGEAR, AT BROODALE SUBST.</td>
<td>4646 FY11</td>
<td>1234 K</td>
<td>Waiting for FY2011 funds</td>
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<tr>
<td>SUBSTATIONS BUILDING IMPROVEMENT PROJECT</td>
<td>3462 FY11</td>
<td>1234</td>
<td>Design by McDougal ongoing</td>
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<tr>
<td>GENERATOR SYSTEM IMPROVEMENT AT VAN BUREN STATION</td>
<td>3545</td>
<td>1234 K</td>
<td>Design completed. Out for bid</td>
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<tr>
<td>ELECTRICAL SYSTEM AUGMENTATION NEW SUBSTATION AT 31ST ST.</td>
<td>4245 FY11</td>
<td>1234</td>
<td>Design ongoing</td>
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<tr>
<td>ELECTRICAL SYSTEM AUGMENTATION NEW SUBSTATION AT 31ST ST.</td>
<td>4650 FY12</td>
<td>1234</td>
<td>In house Design complete</td>
</tr>
<tr>
<td>RECTIFIERS REPLACEMENT AT CHALTEMN SUBSTATION</td>
<td>4649 K FY14</td>
<td>1234</td>
<td>In house Design complete</td>
</tr>
<tr>
<td>DC SWITCHGEAR REPLACEMENT AND DC BUS TIE BREAKER ADDITION AT BROODALE SUBSTATION</td>
<td>4649 K FY14</td>
<td>1234</td>
<td>In house Design complete</td>
</tr>
</tbody>
</table>

**UN-FUNDED TOTAL** 48,573 K

### NOTES:
1. Table arranged per project priority, top to bottom.
2. Estimated costs include construction and construction management.
3. Construction ongoing or completed.
4. Design ongoing or complete. Shall be ready to bid.
5. FY2011 budget request.
6. FY2012 budget request.
7. FY2013 budget request.
8. FY2014 budget request.
9. High priority project

### PROJECT FUNDING CATEGORIES:
- **P - 035** Traction Power System Augmentation
- **P - 030** Electrical Equipment Improvements / Replacement
- **P - 031** Electrical Systems Improvements / Replacement
- **P - 039** Yard Improvements
- **P - 040** Building Improvements

### DC SWITCHGEAR REPLACEMENT Proj #4649

<table>
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<tr>
<th>SUBSTATIONS</th>
<th>PROJ. NO.</th>
<th>COST</th>
<th>DATE</th>
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<tbody>
<tr>
<td>BROOKDALE</td>
<td>1234 K</td>
<td>FY12</td>
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<tr>
<td>JORDAN</td>
<td>1234 K</td>
<td>FY13</td>
<td></td>
</tr>
<tr>
<td>CHALTEMN</td>
<td>777 K</td>
<td>FY15</td>
<td></td>
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<tr>
<td>FRONT</td>
<td>1234 K</td>
<td>FY15</td>
<td></td>
</tr>
<tr>
<td>5TH ST</td>
<td>1234 K</td>
<td>FY15</td>
<td></td>
</tr>
<tr>
<td>LAPLUM</td>
<td>1234 K</td>
<td>FY15</td>
<td></td>
</tr>
<tr>
<td>HARVEY</td>
<td>1234 K</td>
<td>FY15</td>
<td></td>
</tr>
<tr>
<td>VOLMER</td>
<td>777 K</td>
<td>FY15</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>1234 K</td>
<td>FY15</td>
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</table>

### RECTIFIER REPLACEMENT Proj #4950

<table>
<thead>
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<th>SUBSTATIONS</th>
<th>PROJ. NO.</th>
<th>COST</th>
<th>DATE</th>
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</thead>
<tbody>
<tr>
<td>CHALTEMN</td>
<td>1234 K</td>
<td>FY12</td>
<td></td>
</tr>
<tr>
<td>5TH ST</td>
<td>1234 K</td>
<td>FY13</td>
<td></td>
</tr>
<tr>
<td>LAPLUM</td>
<td>1234 K</td>
<td>FY15</td>
<td></td>
</tr>
<tr>
<td>HARVEY</td>
<td>1234 K</td>
<td>FY15</td>
<td></td>
</tr>
<tr>
<td>VOLMER</td>
<td>777 K</td>
<td>FY15</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>1234 K</td>
<td>FY15</td>
<td></td>
</tr>
</tbody>
</table>
Metra’s Recent Expansion Projects

- NCS Expansion
- UP West Extension
- SWS Expansion & Extension
Union Pacific West Line Extension

- Elburn Yard & Station
- La Fox
- Geneva
- West Chicago Yard (to be converted to freight use)
Union Pacific West Line New Start Project

- New Yard
- New 3rd Main Track
- Signal Improvements
- Improved Train Service
- Two New Station Facilities
SWS Extension & Expansion
Southwest Service New Start Project

• Additional Rush Hour and Mid-Day Trains
• Track Improvements
• New 2\textsuperscript{nd} Main Track
• Signal Improvements
• Three New Stations
• Upgraded Station & Parking Facilities
Future New Expansion Projects
Bridges & Structures

- 821 Bridges
- 903 Catenary Structures
- More Than 25 Miles of Retaining Walls
- Numerous Pipes and Culverts
<table>
<thead>
<tr>
<th>Decade</th>
<th>Number of Bridges</th>
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<tbody>
<tr>
<td>1890</td>
<td>123</td>
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<tr>
<td>1910</td>
<td>205</td>
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<tr>
<td>1930</td>
<td>89</td>
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<td>1950</td>
<td>51</td>
</tr>
<tr>
<td>1970</td>
<td>14</td>
</tr>
<tr>
<td>1990</td>
<td>44</td>
</tr>
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</table>
Bridge Replacement

- Union Pacific Northwest Line
- 14 Bridges Between Webster and Kostner
- $120 Million
Rock Island District

- 28 Bridges from 18th Street to 60th Street
- $125 Million
Golf Road Bridge Replacement

Project Cost: $8.1 Million
Union Pacific – North Line

- 22 Bridges from Fullerton Avenue to Balmoral Avenue
- $250 Million over 10 years
Fig. 451. Bridge at Montrose Ave., 80 ft. between abutments, posts on curb line.
LOOKING NORTH
LOOKING NORTH
LOOKING NORTH
LOOKING NORTH
# Table 15-1-1. Structural Steel (Note 1)

<table>
<thead>
<tr>
<th>ASTM Designation</th>
<th>$F_Y$ - Min Yield Point psi</th>
<th>$F_U$ - Ultimate Strength psi</th>
<th>Thickness Limitation</th>
<th>Applicable to Shapes</th>
</tr>
</thead>
<tbody>
<tr>
<td>A36</td>
<td>36,000</td>
<td>58,000 min 80,000 max</td>
<td>To 6 incl.</td>
<td>All</td>
</tr>
<tr>
<td>A709, Grade 36</td>
<td>36,000</td>
<td>58,000 min 80,000 max</td>
<td>To 4 incl.</td>
<td>All</td>
</tr>
<tr>
<td>A588 (Note 2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A709, Grade 50W (Note 2)</td>
<td>50,000</td>
<td>70,000 min</td>
<td>To 4 incl.</td>
<td>All</td>
</tr>
<tr>
<td>A709, Grade HPS 50W (Note 2)</td>
<td>50,000</td>
<td>65,000 min</td>
<td>None</td>
<td>All</td>
</tr>
<tr>
<td>A588 (Note 2)</td>
<td>46,000</td>
<td>67,000 min</td>
<td>Over 5 to 8 incl.</td>
<td>None</td>
</tr>
<tr>
<td>A588 (Note 2)</td>
<td>42,000</td>
<td>63,000 min</td>
<td>Over 5 to 8 incl.</td>
<td>None</td>
</tr>
<tr>
<td>A992</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A709, Grade 50S</td>
<td>50,000</td>
<td>65,000 min</td>
<td>None</td>
<td>All</td>
</tr>
<tr>
<td>A572, Grade 50</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A709, Grade 50</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A572, Grade 42</td>
<td>42,000</td>
<td>60,000 min</td>
<td>To 6 incl.</td>
<td>All</td>
</tr>
<tr>
<td>A709, Grade HPS 70W (Note 2)</td>
<td>70,000</td>
<td>85,000 min 110,000 max</td>
<td>To 4 incl.</td>
<td>None</td>
</tr>
</tbody>
</table>

Note 1: These data are current as of January 2002.

Note 2: A588 and A709, Grade 50W, Grade HPS 50W, and Grade HPS 70W have atmospheric corrosion resistance in most environments substantially better than that of carbon steels with or without copper addition. In many applications these steels can be used unpainted.
1.2.5 DEFLECTION (2001)\textsuperscript{1} R(2003)

a. The deflection of the structure shall be computed for the live loading plus impact loading condition producing the maximum bending moment at mid-span for simple spans. The computation of component stiffness shall be based on the following assumed behavior:

- For flexural members use the gross moment of inertia.

- For truss members without perforated cover plates use the gross area.

- For truss members with perforated cover plates use the effective area.

The effective area shall be the gross area reduced by the area determined by dividing the volume of a perforation by the distance center to center of perforations.

b. The structure shall be so designed that the computed deflection shall not exceed 1/640 of the span length center to center of bearings for simple spans.

c. Lateral deflection of spans shall be limited to 3/8 inch (10 mm) for tangent track as measured on a 62 foot (19 meter) chord. On curved track, lateral deflection shall be limited to 1/4 inch (6 mm) as measured on a 31 foot (9.5 meter) chord. Allowable lateral deflection for spans shall be calculated based on these limits taken in squared proportion to the span length under consideration.

The lateral deflection calculated is to be the maximum lateral deflection at track level due to all applicable lateral forces and loads specified in Section 1.3 excepting those due to earthquake (seismic) or wind on unloaded bridges. The maximum lateral deflection at track level shall be referenced to the point on a vertical plane below which lateral deflection is restrained (i.e. base of structure, span bearings, bottom flange of girder; depending on the lateral deflection being considered).
BEAM DIAGRAMS AND FORMULAS
For various static loading conditions

For meaning of symbols, see page 2 - 293

1. SIMPLE BEAM—UNIFORMLY DISTRIBUTED LOAD

Total Equiv. Uniform Load = \( w \frac{l}{2} \)

- \( R = V \)
- \( V_x = w \left( \frac{l}{2} - x \right) \)
- \( M_{\text{max. (at center)}} = \frac{w a^2}{8} \)
- \( M_x = \frac{w x}{2} \left( l - x \right) \)
- \( \Delta_{\text{max. (at center)}} = \frac{5 w x^4}{384 E I} \)
- \( \Delta_x = \frac{w x^2}{24 E I} \left( l^2 - 21x^2 + x^4 \right) \)

2. SIMPLE BEAM—LOAD INCREASING UNIFORMLY TO ONE END

Total Equiv. Uniform Load \( = \frac{16W}{9 \sqrt{3}} = 1.0256W \)

- \( R_1 = V_1 = \frac{W}{3} \)
- \( R_2 = V_2 \text{ max.} = \frac{2W}{3} \)
- \( V_x = \frac{W}{3} - \frac{W x^2}{\sqrt{3}} \)
- \( M_{\text{max. (at } x = \frac{l}{\sqrt{3}} = 0.5774l) \} = \frac{2W l}{9 \sqrt{3}} = 0.1283 W l \)
- \( M_x = \frac{W x}{2} \left( x^2 - x^3 \right) \)
- \( \Delta_{\text{max. (at } x = 0.5774l)} = \frac{W l^3}{180 E I} \left( 3x^4 - 10l^3x^2 + 7l^4 \right) \)
- \( \Delta_x = \frac{W x^2}{180 E I} \left( 3x^4 - 10l^3x^2 + 7l^4 \right) \)

3. SIMPLE BEAM—LOAD INCREASING UNIFORMLY TO CENTER

Total Equiv. Uniform Load \( = \frac{4W}{3} \)

- \( R = V \)
- \( V_x \text{ (when } x < \frac{l}{2} \} = \frac{W}{2l^2} \left( l^2 - 4x^2 \right) \)
- \( M_{\text{max. (at center)}} = \frac{W l}{6} \)
- \( M_x \text{ (when } x < \frac{l}{2} \} = \frac{W x}{2} \left( \frac{l}{2} - 2x^2 \frac{x}{3l} \right) \)
- \( \Delta_{\text{max. (at center)}} = \frac{W l^3}{60 E I} \)
- \( \Delta_x \text{ (when } x < \frac{l}{2} \} = \frac{W x^2}{480 E I} \left( 5l^2 - 6l x^2 \right) \)
Belmont Road Grade Separation
Temporary Run-around of Belmont Road
(July 2010 through September 2011)
Pedestrian Tunnel
CREATE P-1

Englewood Flyover

Grade separation of Metra
Rock Island District and NS
Main Line
CREATE Partners

Illinois Department of Transportation

CDOT

Metra

UNION PACIFIC

CSX

NORFOLK SOUTHERN

BNSF RAILWAY

CN

AMTRAK

INDIANA HARBOR BELT

DEPARTMENT OF TRANSPORTATION

UNITED STATES OF AMERICA

THE BELT RAILWAY CO & CHICAGO
Riverdale Bridge Fire
State of Good Repair

- State of Good Repair: SGR is the condition where all assets perform their assigned function without limitation

- Essential if public transportation systems are to provide safe and reliable service to millions of daily riders

- Includes sharing ideas on recapitalization and maintenance issues, asset management practices, and innovative financing strategies

- Includes issues related to measuring the condition of transit capital assets, prioritizing local transit re-investment decisions and preventive maintenance practices
# Metra Capital Investment History

## 1985 – Present *(in $Millions)*

<table>
<thead>
<tr>
<th>Assets</th>
<th>MED</th>
<th>RID</th>
<th>SWS</th>
<th>MHC</th>
<th>BNSF</th>
<th>UP-W</th>
<th>MWD-W</th>
<th>UP-NW</th>
<th>MWD-N</th>
<th>NCS</th>
<th>UP-N</th>
<th>Total</th>
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<tr>
<td>Rolling Stock</td>
<td>$850.0</td>
<td>$195.5</td>
<td>$57.5</td>
<td>$10.9</td>
<td>$307.1</td>
<td>$159.5</td>
<td>$163.5</td>
<td>$177.1</td>
<td>$142.5</td>
<td>$23.4</td>
<td>$145.2</td>
<td>$2,232.2</td>
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<td>Track &amp; Structure</td>
<td>72.4</td>
<td>264.8</td>
<td>25.6</td>
<td>9.9</td>
<td>113.3</td>
<td>56.5</td>
<td>90.6</td>
<td>159.1</td>
<td>63.0</td>
<td>32.1</td>
<td>106.8</td>
<td>994.2</td>
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<tr>
<td>Signal, Elec, &amp; Comm</td>
<td>105.8</td>
<td>48.6</td>
<td>18.1</td>
<td>3.5</td>
<td>103.3</td>
<td>54.0</td>
<td>58.0</td>
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<td>56.0</td>
<td>7.7</td>
<td>29.7</td>
<td>518.9</td>
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<td>Facilities &amp; Equipment</td>
<td>91.6</td>
<td>76.5</td>
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<td>9.1</td>
<td>63.3</td>
<td>17.8</td>
<td>56.5</td>
<td>35.1</td>
<td>54.6</td>
<td>18.0</td>
<td>21.8</td>
<td>461.6</td>
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<td>Stations &amp; Parking</td>
<td>188.0</td>
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<td>35.3</td>
<td>12.9</td>
<td>52.5</td>
<td>110.1</td>
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<td>60.2</td>
<td>12.9</td>
<td>99.4</td>
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<td>Acq, Ext, Expansions</td>
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<td>1.3</td>
<td>158.6</td>
<td>0.6</td>
<td>1.4</td>
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<td>1.2</td>
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<td>Support Activities</td>
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<td>28.4</td>
<td>22.4</td>
<td>21.5</td>
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<td>26.5</td>
<td>14.7</td>
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<td><strong>Total</strong></td>
<td><strong>$1,368.2</strong></td>
<td><strong>$746.8</strong></td>
<td><strong>$326.4</strong></td>
<td><strong>$58.3</strong></td>
<td><strong>$669.4</strong></td>
<td><strong>$543.4</strong></td>
<td><strong>$505.7</strong></td>
<td><strong>$590.5</strong></td>
<td><strong>$404.1</strong></td>
<td><strong>$342.9</strong></td>
<td><strong>$431.4</strong></td>
<td><strong>$5,986.9</strong></td>
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<tr>
<td><strong>Percentages</strong></td>
<td>22.9%</td>
<td>12.5%</td>
<td>5.5%</td>
<td>1.0%</td>
<td>11.2%</td>
<td>9.1%</td>
<td>8.4%</td>
<td>9.9%</td>
<td>6.7%</td>
<td>5.7%</td>
<td>7.2%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

*Excludes South Shore, Preventive Maintenance, and pending FY 2010 grants*
State of Good Repair – Capital Budget*

Funding needed to achieve a State of Good Repair

* 2012 – 2015 amounts are projected estimates
† Not inclusive of State of Illinois Bond funding
RTA Capital Asset Condition Assessment

- 18-month effort to identify and characterize the condition of all existing RTA, CTA, Metra, & Pace capital assets
- RTA Region needs $24.6B in Capital Investment over the next 10 years. **Metra needs 30% of this.**

<table>
<thead>
<tr>
<th>Metra 10-year Capital Needs</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Backlog</td>
<td>$3.70 B</td>
</tr>
<tr>
<td>Normal Replacement</td>
<td>$1.70 B</td>
</tr>
<tr>
<td>Capital Maintenance</td>
<td>$1.97 B</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$7.37 B</strong></td>
</tr>
</tbody>
</table>
It takes over 1,000 things done right for your train to run on time, but only one error to make it late.