Road Asset Management: Evolution and Trends

Clinic AC 6 Road Asset Management

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Center for Sustainable Transportation Infrastructure
Introduction

Evolution

Enabling Technologies/ Approaches

Success Factors

Look Ahead
Motivation

- Productive and competitive economies
- Sustainable economic growth
- Societal stability / equity

Physical Infrastructure

Economic System

Social System

Natural Environment
Transportation Infrastructure Challenges

- Deterioration
- Increasing Demands
- Shrinking Budgets
- Increasing Expectations
Challenge: Change in Expectations
(example: pavements)

Performance Measures
Multifunction Pavement
✓ Safety
✓ Comfort
✓ Mobility
✓ Access
✓ Travel time
✓ Operation costs
✓ Sustainability
✓ Energy harvesting
The Road “Enemies” (Caminos, CEPAL)

Heavy Vehicles

Water
What is the solution?

- Better & more sustainable materials
  - Material design
  - Construction quality
- More effective design methods
  - Mechanistic-based approaches
- Innovative financing
  - Balancing risk and responsibilities
- Systematic Asset Management
  - Maximum benefit for each dollar invested
Why Asset Management?

We want to have good roads

Not this!

After Bennett, 2009
Asset Management

Systematic process of:

- maintaining, upgrading, and operating physical assets *(pavements, bridges, etc.)*
- cost-effectively, efficiently, and comprehensively.

Integration
Asset Management Evolution

Pavement Management Systems (60’s) → Principles → Bridge Management Systems (80’s) → Integration → Infrastructure Management Systems (90’s)

Asset Management Systems → Business-like Objectives → Non-physical assets
Structure of a PMS (AASHTO, 1991)

DATABASE
- Physical Inventory
- Condition Evaluation

ANALYSIS
- Pavement Condition Analysis
- Priority Assessment Models
- Optimization Methods

FEEDBACK
PMS – BMS Common Features

(Hudson and Hudson, 1994)

DATABASE
Inventory Condition

ANALYSIS TOOLS
Performance Prediction
Needs / Life-cycle
Optimization / Programming

REPORTS

PERFORMANCE
MONITORING

GRAPHICAL
INTERFACES
Asset Management

- [http://downloads.transportation.org/amguide.pdf](http://downloads.transportation.org/amguide.pdf)
- [Transportation Asset Management Guide](http://downloads.transportation.org/amguide.pdf)

Prepared for
National Cooperative Highway Research Program (NCHRP) Project 20-24(11)
AMS Framework
Resource Allocation and Utilization Process (NCHRP 2001)

**Policy Goals and Objectives**
- System Performance
- Economic
- Social & Environmental

**Integrated Analysis of Options and Tradeoffs**
- **Asset Classes**
  - Highway
  - Bridge
  - Transit
  - Aviation
  - Rail
  - Bike & pedestrian
- **Goals**
  - Safety
  - Preservation
  - Availability
  - Mobility/Reliability
  - Accelerated Projects
- **Types of Investments**
  - Capital
  - Operating
  - Maintenance

**Decision Applying Resources, Investment Choices**
- Financial
- Human
- Information

**Implementation/ Delivery**
- Agency, Intergovernmental
- Public / Private Partnership
- Outsource - Privatize

**Systems Monitoring and Performance Results**
Key characteristics

1. Policy-driven, performance-based
2. Analysis of options and tradeoffs at each level of decision making
3. Long-term view
4. Decisions based on quality data/information
5. Monitoring to provide accountability and increase reliability

(CS 2002)
The Asset Management Process

**INFORMATION MANAGEMENT**

**DATABASE**
- Inventory
  - Condition
  - Usage
  - Maintenance Strategies
- Feedback
- Performance Monitoring

**NETWORK-LEVEL ANALYSIS TOOLS**
- Condition Assessment
- Performance Prediction
- Prioritization/Optimization
- Needs Analysis
- Programming Project Selection

**PROJECT LEVEL ANALYSIS**
(Design)

**STRATEGIC ANALYSIS**
- Goals & Policies
  - System Performance
  - Economic/Social/Environmental
- Budget Allocations

**PRODUCTS**
- Network-Level Reports
  - Performance Assessment
  - Network Needs
  - Facility Life-cycle Cost
  - Optimized M&R Program
  - Performance-based Budget

**GRAPHICAL DISPLAYS**

**CONSTRUCTION DOCUMENTS**

Virginia Tech Transportation Institute
Introduction

Evolution

Enabling Technologies/Approaches

Success Factors

Look Ahead
RMS Framework

DATA
- Linear Data
- Spatial Data

PROCESSES
- Bridge / Structures
- Pavement
- Roadway
- GIS
- Traffic – operation
- Safety: crashes
- Hazards
- Project Monitoring

DECISIONS & OUTPUTS

Expenditure Programs
Enabling Technologies (examples)

● Data Collection
  ➢ Location
  ➢ Sensing technologies

● Data Analysis / decision support
  ➢ Data management/ integration
  ➢ Economic-based decision-support tools
  ➢ Proactive approaches - Preservation
  ➢ Sustainability assessment (LCA, etc.)

● Innovative delivery
  ➢ Performance-based contracting
  ➢ Road Funds
Data Collection Degree of Detail/Quality

After Bennett & Paterson, 2000
Global Positioning System (GPS)

Source: Trimble Navigation Limited
# Pavement Evaluation Technologies

<table>
<thead>
<tr>
<th>Category</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service and User Perception</td>
<td>Serviceability (Roughness)</td>
</tr>
<tr>
<td>Physical Condition</td>
<td>Distress</td>
</tr>
<tr>
<td>Structural Integrity/Load-Carrying Capacity</td>
<td>Deflection</td>
</tr>
<tr>
<td>Safety and Sufficiency</td>
<td>Friction/Macrotecture</td>
</tr>
<tr>
<td>Environmental</td>
<td>Noise</td>
</tr>
</tbody>
</table>

[Image Credit: Virginia Tech Transportation Institute]
What pavement condition data does your agency collect?

- Structural Capacity: 16.1% (Network Level), 71.4% (Project Level), 94.6% (Total)
- Frictional Properties: 33.9% (Network Level), 55.4% (Project Level), 66.1% (Total)
- Smoothness: 98.2% (Total)
- Surface Distress: 58.9% (Total)

NCHRP Synthesis 401, Quality Management of Pavement Condition Data Collection
# Examples of Bridge Data Collection Technologies

<table>
<thead>
<tr>
<th>Equipment Class</th>
<th>Equipment Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bridge Access Technologies</td>
<td>Hydraulic lifts; Snooper-type trucks; Scaffolds; Diving equipment.</td>
</tr>
<tr>
<td>Non-destructive testing (NDT) technologies</td>
<td>Rebound hammer; Probe device; Cover meters/ Pachometers; Infrared thermography; Ground Penetrating Radar</td>
</tr>
<tr>
<td>Digital imaging</td>
<td>Digital Camera; Satellite Imagery.</td>
</tr>
</tbody>
</table>
Data Collection Technologies for Road Management

http://road-management.info/reports/user/6/07-02-12DataCollectionTechnologiesReport-v2.pdf
Data Integration

"Which roadway sections with drainage problems have culverts underneath them?"

Fused Data (Data Warehouse)

Pavement Condition View

Inventory Location View

Culvert Structures View

Maintenance History View

Interoperable Data (Federated Data)

Federated View

Pavement Database

Roadway Inventory

Structures Database

Other Databases

Single data server

Pavement Database

Roadway Inventory

Structures Database

Other Databases

Multiple, independent data servers

NCHRP Synthesis 335 – Pavement Management Applications Using Geographic Information Systems
We Must Manage Our Road Assets

Preservation

Financial Considerations

...but what about preservation?

Taxes collected from road users

Transportation Agency

Courtesy: NCPP
**When to Apply a Treatment?**

- **EXCLENT**: 75% of service life
- **VERY GOOD**: 40% quality loss
- **GOOD**: $1 not expended here...
- **FAIR**: Will cost $4 to $5 here
- **POOR**: 40% quality loss
New Approach Centered on the User

Performance Measures

- Safety
- Comfort
- Mobility
- Access
- Travel time
- Operation costs
- Sustainability
- Energy harvesting...
Output- and Performance-based Road Contracts (OPRC)

- Contractor has to ensure that road users get a certain Level of Service
- Level of Service defined in terms of:
  - usability, road surface conditions, safety features, roadside assistance, etc.
- Specifications included in Contract describe Level of Service expected for each road in the network.

After Schliessler, 2007
Types of OPRC Programs

1. Projects focused mainly on improving the service of the roads that also utilize small, medium, and large contractors

2. Projects with a significant social component in economically depressed areas that use mostly cooperative micro-enterprises
## Types of OPRCs (PBCs)

<table>
<thead>
<tr>
<th>Type of Program</th>
<th>National</th>
<th>Urban Local</th>
<th>Rural Local</th>
</tr>
</thead>
<tbody>
<tr>
<td>Types of roads</td>
<td>Mostly high-traffic routes Good geometrical standards</td>
<td>Paved and unpaved urban streets</td>
<td>Access roads (many built over ancient walking paths)</td>
</tr>
<tr>
<td>Main network function</td>
<td>Connectivity</td>
<td>Mobility</td>
<td>Access</td>
</tr>
<tr>
<td>Main program objective(s)</td>
<td>Reduce transportation costs Promote development</td>
<td>Improve service Enhance mobility Provide employment</td>
<td>Access to services/ markets Provide employment Promote development</td>
</tr>
<tr>
<td>Type of performance indicators</td>
<td>Objective, measurable performance parameters</td>
<td>Variable and dependent on the type of network</td>
<td>Subjective, fairly general road condition indicators (e.g., passable road, no potholes)</td>
</tr>
<tr>
<td>Type of contractors</td>
<td>Medium or large contractor</td>
<td>Small to large contractors</td>
<td>Micro- and small enterprises</td>
</tr>
<tr>
<td>Type of work included under the PBC</td>
<td>Routine and emergency maintenance (and often rehabilitation) using heavy construction equipment</td>
<td>Routine maintenance (and often rehabilitation) Labor-intensive &amp; equipment-based</td>
<td>Routine maintenance only using mostly labor-intensive methods</td>
</tr>
</tbody>
</table>
Road Funds

- Several success stories in Latin America
- Based on a fee-for-service concept
- Second generation (WB/IMF):
  - i. Minimizes any adverse impacts on the budget; and
  - ii. Strengthens financial discipline to ensure better value for money.
Success Factors for Road Management Systems
(The World Bank)

Successful projects properly address all three factors.
Processes

● Key Success Factor:
  - The RMS must have appropriate functionality and fit into the organization’s business processes.

● To Achieve This:
  - The RMS must be an integral part of the agency’s monitoring and planning process
  - Outputs should be used to prepare annual reports to ensure data are regularly collected and the system applied
# Two Approaches

<table>
<thead>
<tr>
<th>Correct Approach</th>
<th>Wrong (but typical) Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Business Process Analysis</strong></td>
<td><strong>Select software before project starts or write new software</strong></td>
</tr>
<tr>
<td>– Determine the function and role of the PMS in the agency, required features</td>
<td>– Fit the agency’s activities into the software</td>
</tr>
<tr>
<td><strong>System Design</strong></td>
<td><strong>Adopt too intensive data collection</strong></td>
</tr>
<tr>
<td>– Design the system around the institution’s capabilities</td>
<td><strong>Complex system and analyses</strong></td>
</tr>
<tr>
<td><strong>Select and Adapt/Customize Existing Software</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Simple analyses</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Implement and provide ongoing support</strong></td>
<td></td>
</tr>
</tbody>
</table>
Technology

• Key Success Factor:
  - The technology adopted must be appropriate for the institution given its capabilities and resources

• To Achieve This:
  - System predictions relevant
  - Need a strong IT division – or outsource
  - Need an IT strategy
  - RMS must fit into IT strategy
  - RMS must be properly supported from an IT perspective
Key RMS Components

Basic RMS
- Asset inventory
- Asset accounting
- Maintenance management
- Contract management
- Resource management
- Inventory control
- Condition monitoring

Advanced RMS
- Predictive modeling
- Risk assessment
- Treatment options and costs
- Lifecycle costing
- Works planning
- Optimized decision-making
- Interface data import/export

What most countries need
What most countries get
People

- **Key Success Factor:**
  - The RMS must be fully institutionalized and supported

- **To Achieve This:**
  - There must be an organizational unit to manage, monitor and continually improve the RMS
  - Unit must have appropriate staff, clear job responsibilities, sufficient budget, clear reporting lines to upper management
More automatic data collection
### Formal Quality Management Procedures for Pavement Condition Data Collection

<table>
<thead>
<tr>
<th>Before Data Collection</th>
<th>During Production (Data Collection &amp; Processing)</th>
<th>After Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality Management</td>
<td>Quality Control</td>
<td>Quality Assurance</td>
</tr>
</tbody>
</table>

#### Quality Management
- Personnel training/certification
- Equipment calibration/certification/inspections
- Initial Control Site Testing
- Review qualifications or certifications

#### Quality Control
- On-vehicle real-time data checks
- Periodic diagnostics checks
- Incoming data and video check

#### Quality Acceptance
- Complete database checks
- Control/verification site testing
- Sampling for quality acceptance

#### Independent Assurance
- Consistency checks
- Sampling and re-analyzing

#### After Production
- Distress rating data checks
- Final database checks
- Completeness checks
- Final database reviews
- GIS-based quality checks
- Time history comparisons
- Completeness checks
- Time History Comparisons
Corridor Level Health Indices

- Pavements
  - Cracking
  - IRI
  - Rutting
  - FWD Data, etc.
- Structural
- Functional
- Environmental
- Safety

- Pavement Rating

- Bridges
  - Primary Members
  - Abutments
  - Piers
  - Bridge Deck, etc.
- Structural
- Functional
- Environmental
- Safety

- Bridge Rating

- Facilities
  - Toll Plazas
  - Weigh Stations, etc.
- Structural
- Functional
- Environmental
- Safety

- Facilities Rating

- Safety Features
  - Pavement Markings
  - Signs, etc.
- Structural
- Functional
- Safety

- Safety Features Rating

- Others
- Serviceability
- Functional

- Others Rating
More Use of Simulation and Other Advanced Tools

- Evaluation of different "what if" scenarios.
- Life Cycle Cost Analysis (RealCosts)
- Benefit Cost Analysis
- Life Cycle Assessment
- …
Developed practical rule-based economic analysis (LCCA) tools to support transportation infrastructure asset management.
Multifunctional Pavements /Roads

- Safety
- Comfort
- Mobility
- Access
- Travel time
- Operation costs

Performance Measures

Multiple Objectives

- Minimize the agency’s cost
- Maximizing the network performance
- Increasing safety
- ...

Many Challenges/ Constraints
Multi-Objective Cross-Asset Optimization

Strategic Level
Resource Allocation

Across assets classes
Highway
Bridge
Culvert...

Across work categories
Preservation
New capacity
Safety...

Work Category
System Objectives
Asset Type
Allocation boundaries

Network Level
Resource Allocation + Utilization

Within a given asset and work category

Program development: short- and long-range plans (project selection)

Policies/Goals

Database

Condition
Asset Inventory
Usage
Maintenanc e strategies

Performance monitoring

Work program execution

Project level analysis (Design)
More use of output and performance-based approaches with a bigger role of the private sector

- Pavement Warranties
- Performance-based maintenance contracts
- Public-private partnerships
- Concessions / Toll roads
- ...

Center for Sustainable Transportation Infrastructure
Integrated “Networks” Approach to Infrastructure Asset Management

Uncovering Network Interdependencies and Synergies (UNIS)

Society → Network Science and Engineering → Ecology → Economy

Transportation Infrastructure, Water Infrastructure, Electric Power Infrastructure, Financial Infrastructure
Decision Support Tools that Incorporate Sustainability Goals

**Economy**
- Economic Analysis
  - Life-Cycle Cost Analysis (LCCA)
  - Benefit/Cost, etc.
  - HERS-ST
  - RealCost
- HDM 4

**Environment**
- Life-Cycle Assessment (LCA)
  - PaLATE
- Grading Systems
  - Greenroads

**Equity**
- Analysis of Social Impacts, etc.

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Dwight David Eisenhower Transportation Program Grant for Research Fellowship (GRF)
Sustainability Considerations

**INFORMATION MANAGEMENT**

**DATABASE**
- CONDITION
- USAGE
- MAINTENANCE STRATEGIES

**INVENTORY**

**FEEDBACK**

**PERFORMANCE MONITORING**

**WORK PROGRAM EXECUTION**

**NETWORK-LEVEL ANALYSIS TOOLS**
- CONDITION ASSESSMENT
- PERFORMANCE PREDICTION
- NEEDS ANALYSIS
- PRIORITIZATION / OPTIMIZATION
- PROGRAMMING PROJECT SELECTION

**PROJECT LEVEL ANALYSIS**
(*Design*)

**ECONOMIC, SOCIAL AND ENVIRONMENTAL IMPACTS**

**PRODUCTS**
- NETWORK-LEVEL REPORTS
  - Performance Assessment
  - Network Needs
  - Facility Life-cycle Cost
  - Optimized M&R Program
  - Performance-based Budget
- GRAPHICAL DISPLAYS
- CONSTRUCTION DOCUMENTS

**STRATEGIC ANALYSIS**
- Goals & Policies
  - System Performance
  - Economic / Social & Environmental
- Budget Allocations
Sustainability - FHWA Definition

- Sustainable Transportation means:
  - providing exceptional mobility and access
  - in a manner that meets development needs without compromising the quality of life of future generations.
  - A sustainable transportation system is safe, healthy, affordable, renewable, operates fairly and limits emissions and the use of new and nonrenewable resources.
Example of Simplified Index: Greenroads

Most existing approaches lack a sound scientific foundation

- Greenroads certified
- Greenroads certified (SILVER)

<table>
<thead>
<tr>
<th>Category</th>
<th>Points Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>32-42 points</td>
<td>PR + 30% VC</td>
</tr>
<tr>
<td>43-54 points</td>
<td>PR + 40% VC</td>
</tr>
<tr>
<td>55-64 points</td>
<td>PR + 50% VC</td>
</tr>
<tr>
<td>65-74 points</td>
<td>PR + 60% VC</td>
</tr>
<tr>
<td>75-84 points</td>
<td>PR + 70% VC</td>
</tr>
<tr>
<td>85-94 points</td>
<td>PR + 80% VC</td>
</tr>
<tr>
<td>95-104 points</td>
<td>PR + 90% VC</td>
</tr>
<tr>
<td>105+ points</td>
<td>PR + 100% VC</td>
</tr>
</tbody>
</table>

More Use of “Green” Materials

Asphalt rubber

Porous Pavements

Bio-Asphalts

Warm-Mix Technologies

Photocatalytic pavements

Center for Sustainable Transportation Infrastructure
Questions?

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