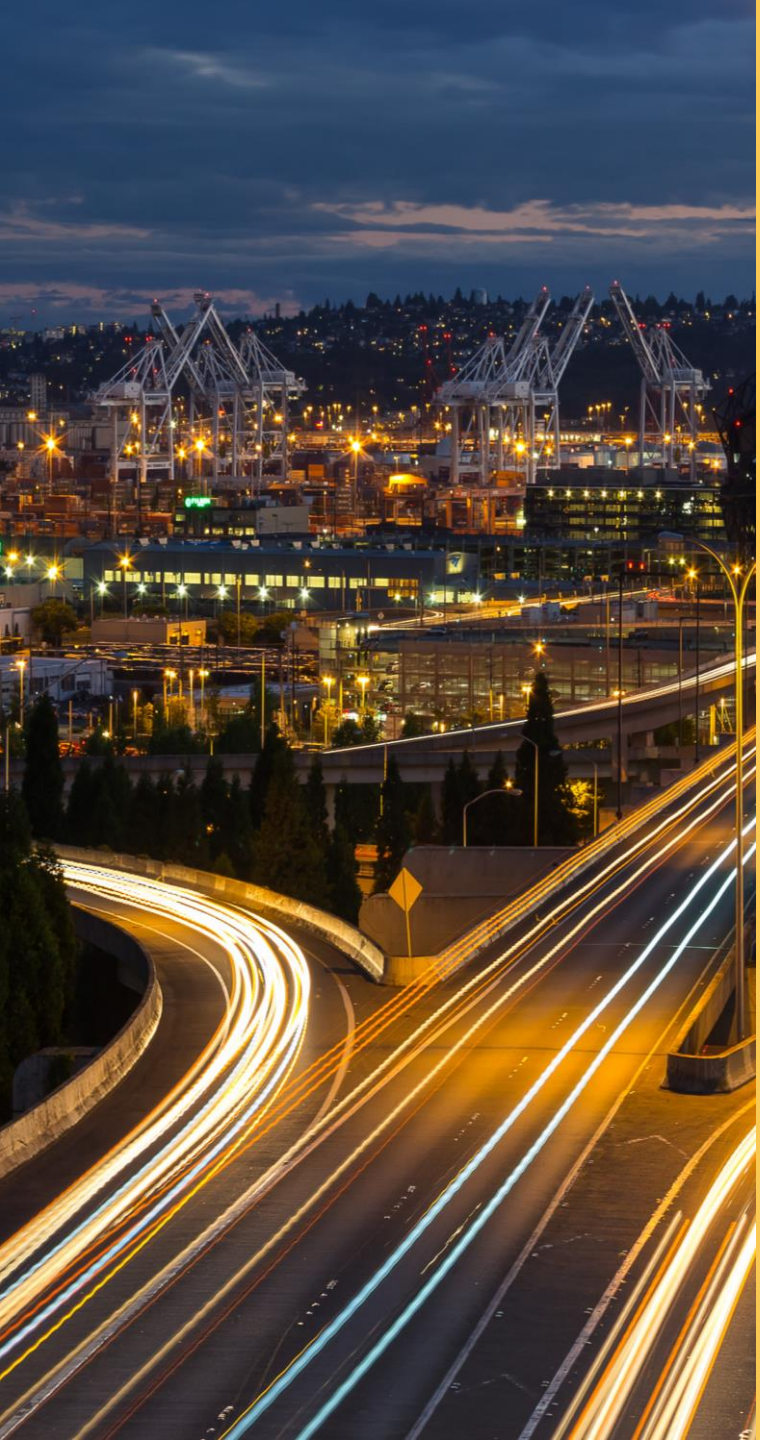


RUTGERS
Center for Advanced Infrastructure and Transportation

A U.S. Department of Transportation University Transportation Center

Transportation Infrastructure Asset Management & Resilience A U.S. Perspective

OMAINTEC-2019

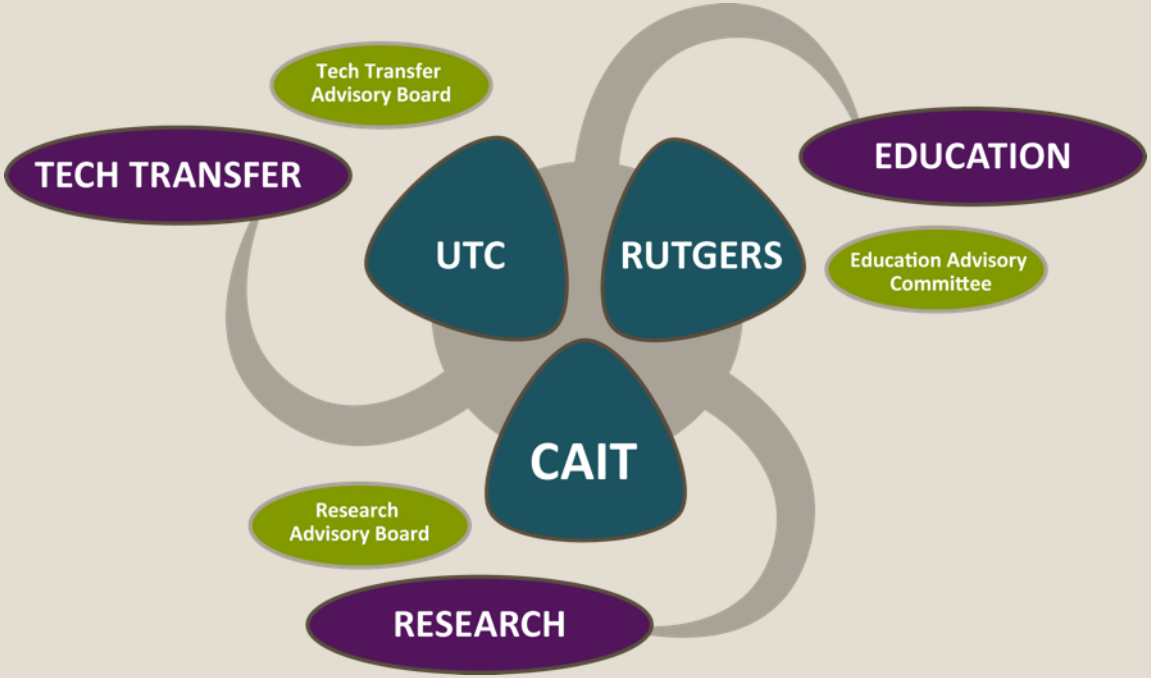
Ali Maher, PhD
Rutgers-CAIT

Eng. Hazim Abdulwahid
Hazim Consulting

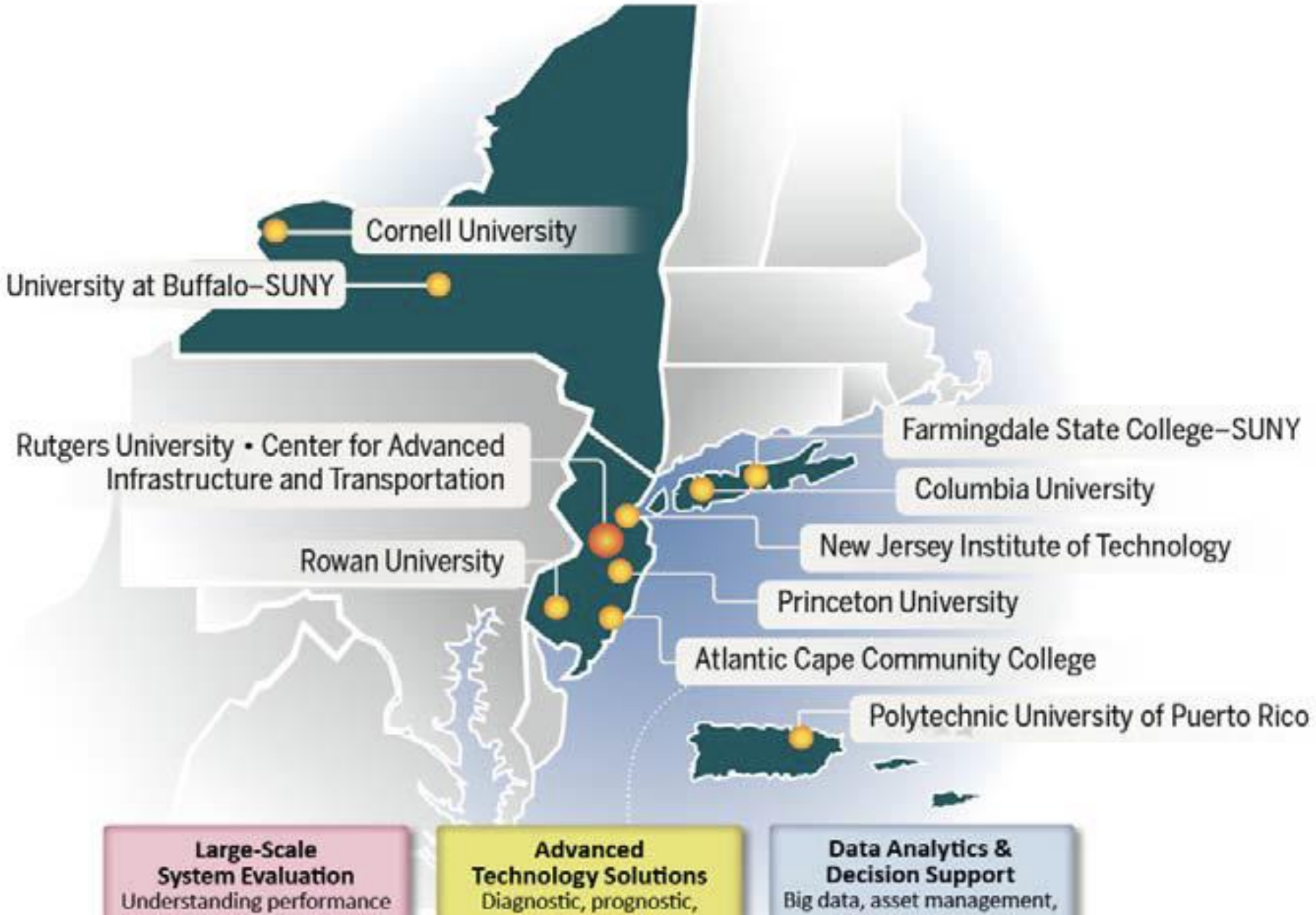
Moving Forward >>

CAIT's Mission

Solving complex, interrelated transportation and infrastructure problems, specifically in high-volume, multimodal corridor environments.



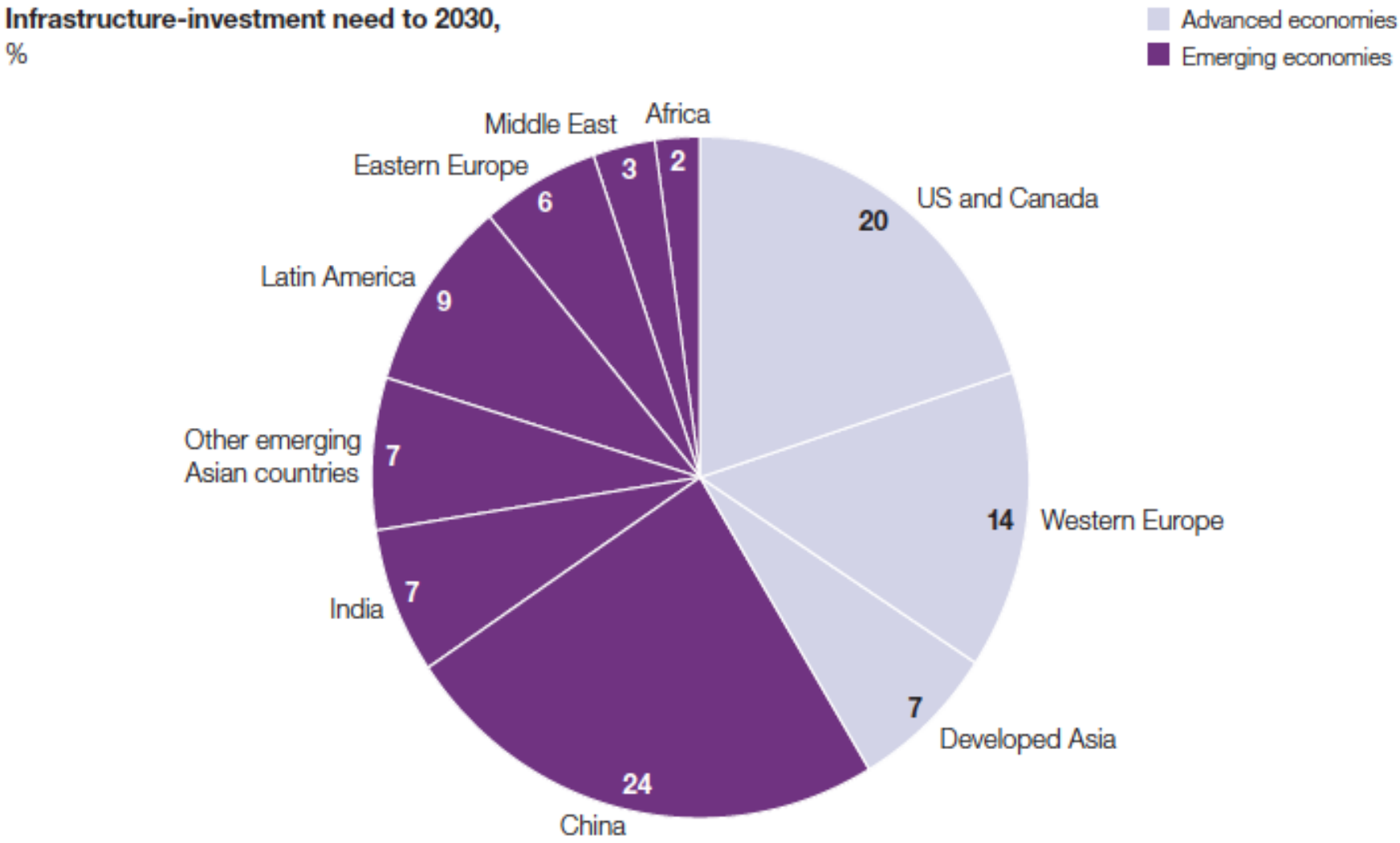
CAIT's Regional Partners >>



Infrastructure Asset Management & Resilience >>

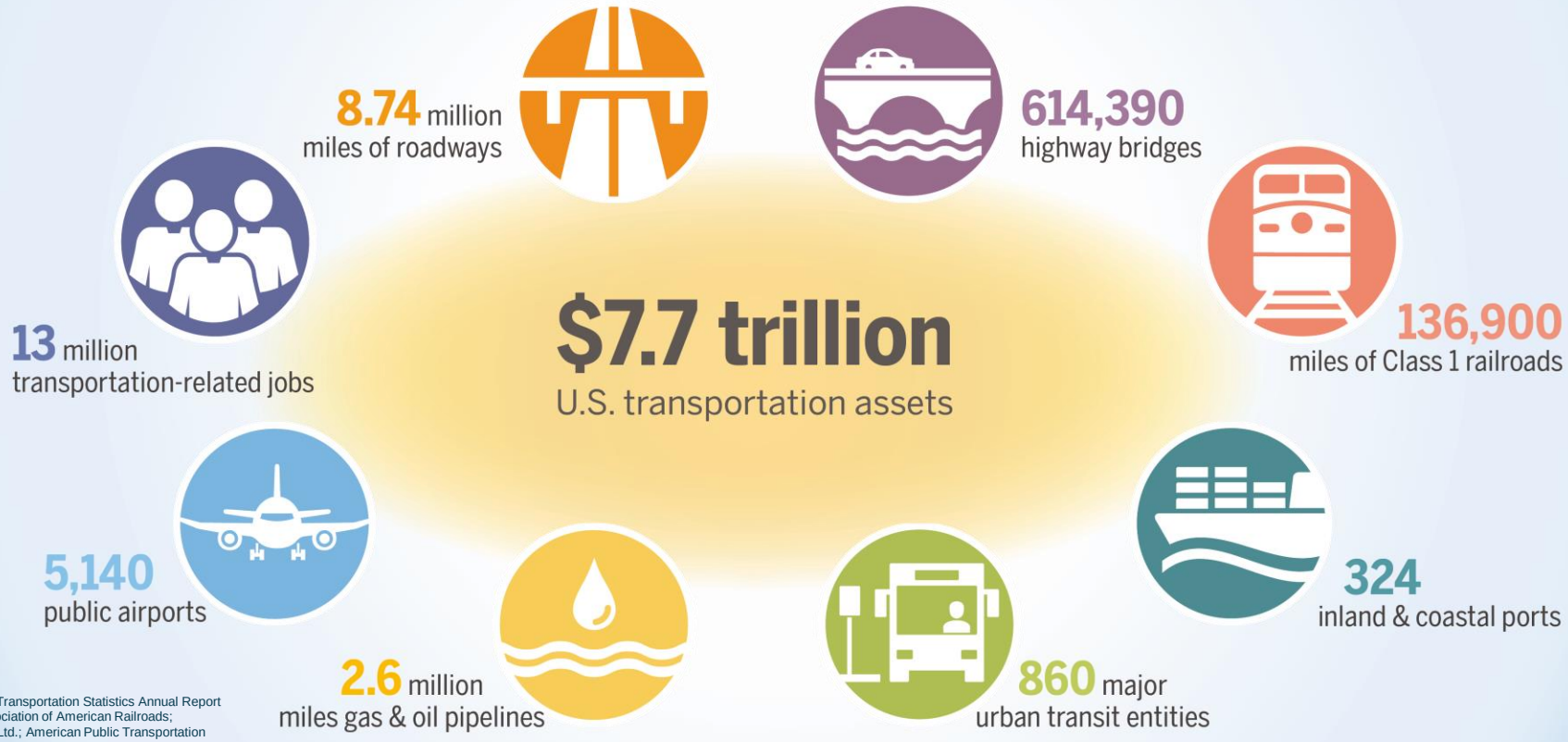
- Background
- Recent U.S. Legislation
- TAM Process
  - TAM Platforms
  - AI Utilization
- Condition Assessment
- Resilience

Global Outlook>>



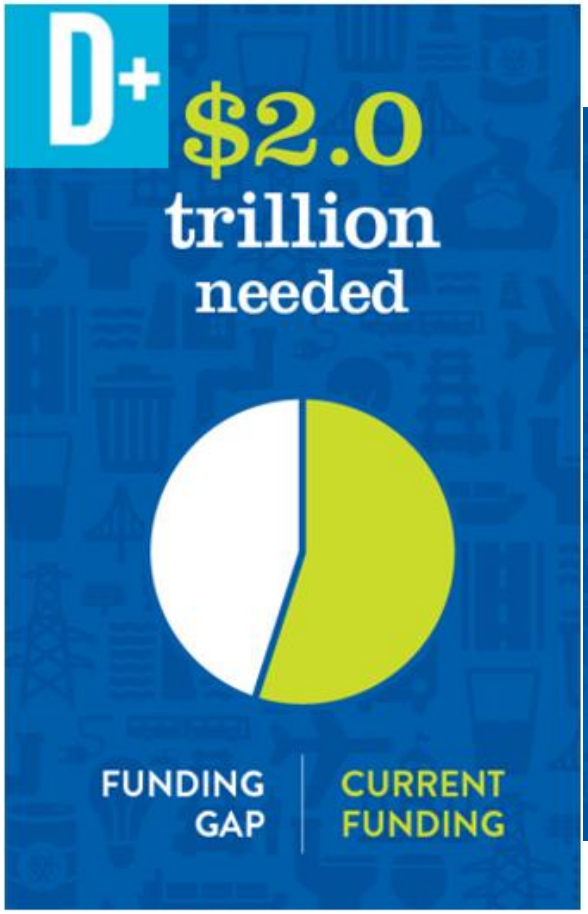
McKinsey & Co., 2015

U.S. Infrastructure Assets Inventory



Sources:
Bureau of Transportation Statistics Annual Report 2017; Association of American Railroads; SeaRates Ltd.; American Public Transportation Association

The State of Today's Infrastructure



2017 Infrastructure Grades

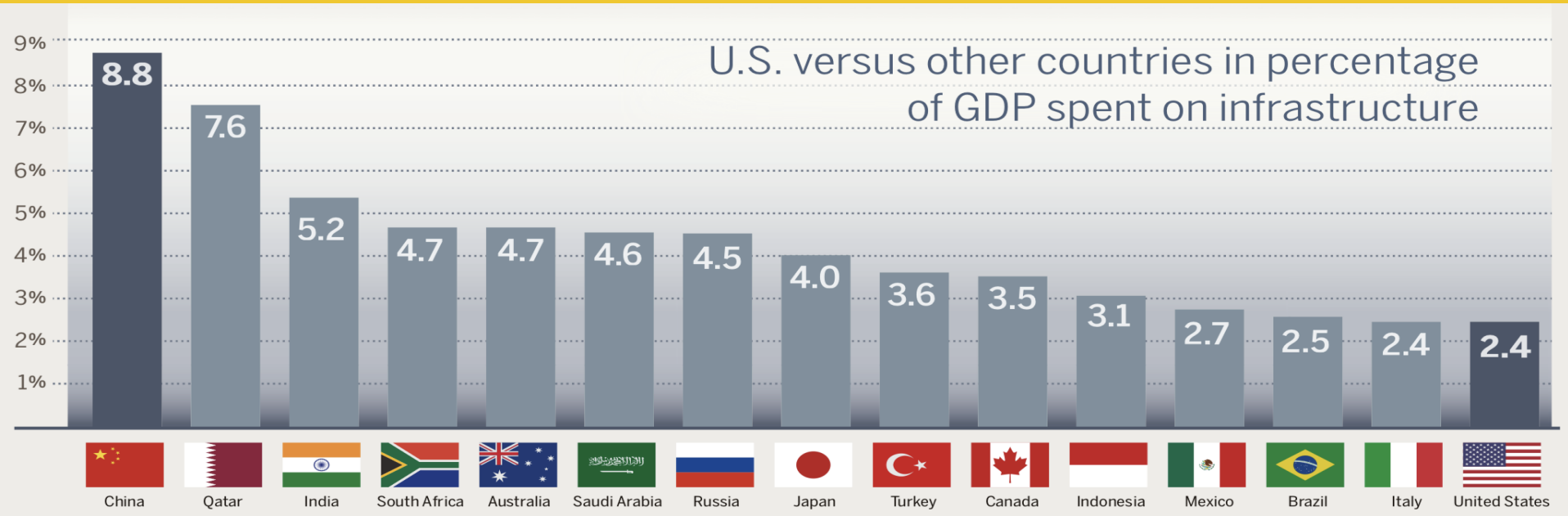
AVIATION	D	PARKS AND RECREATION	↓ D+
BRIDGES	C+	PORTS	↑ C+
DAMS	D	RAIL	↑ B
DRINKING WATER	D	ROADS	D
ENERGY	D+	SCHOOLS	↑ D+
HAZARDOUS WASTE	↑ D+	SOLID WASTE	↓ C+
INLAND WATERWAYS	↑ D	TRANSIT	↓ D-
LEVEES	↑ D	WASTEWATER	↑ D+

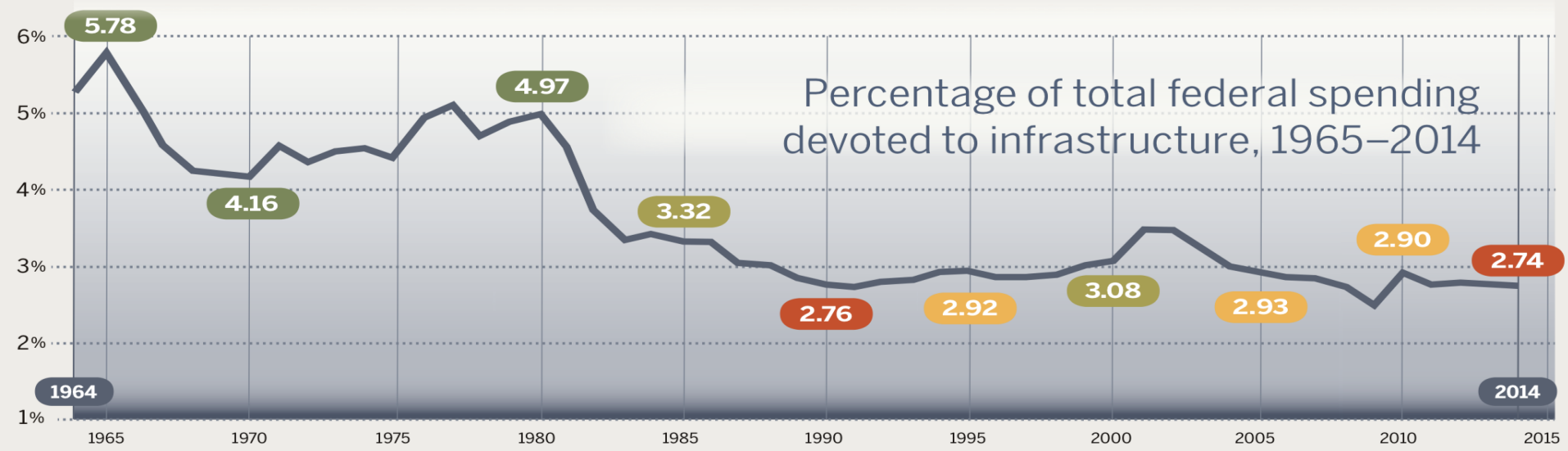
America's Cumulative Infrastructure Grade

D+

A	EXCEPTIONAL
B	GOOD
C	MEDIOCRE
D	POOR
F	FAILING

U.S. Expenditure in % of GDP>>





Source: Congressional Budget Office based on data from the Office of Management and Budget and the Census Bureau.

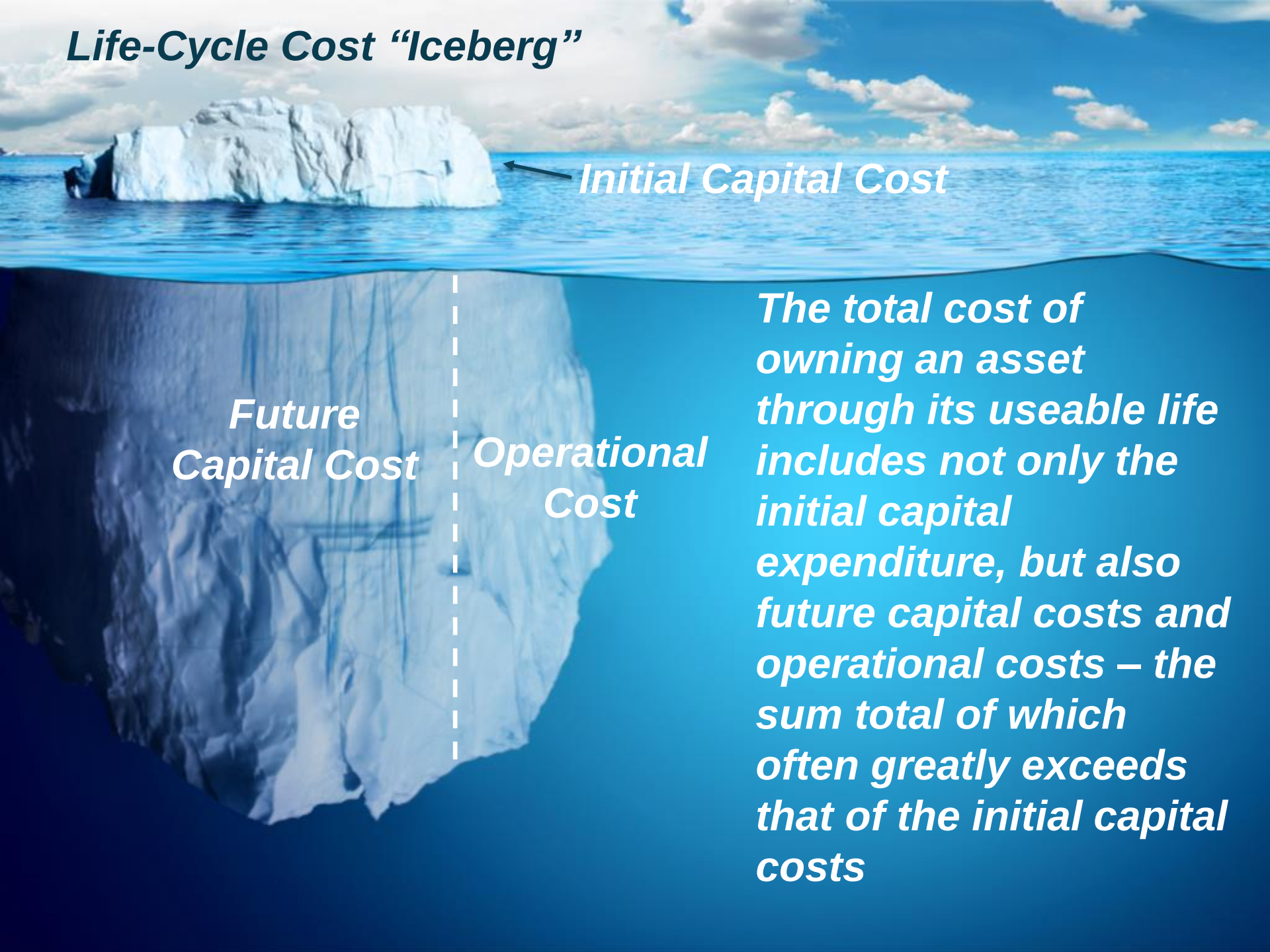
We have decisions to make

FAILURE TO ACT

CLOSING THE INFRASTRUCTURE
★ INVESTMENT GAP ★
FOR AMERICA'S ECONOMIC FUTURE

COST TO THE ECONOMY	COST TO BUSINESS	COST TO WORKERS	COST TO FAMILIES
$3.9 TRILLION	$7 TRILLION	2.5 MILLION JOBS	$3,400 PER YEAR

Life-Cycle Cost "Iceberg"

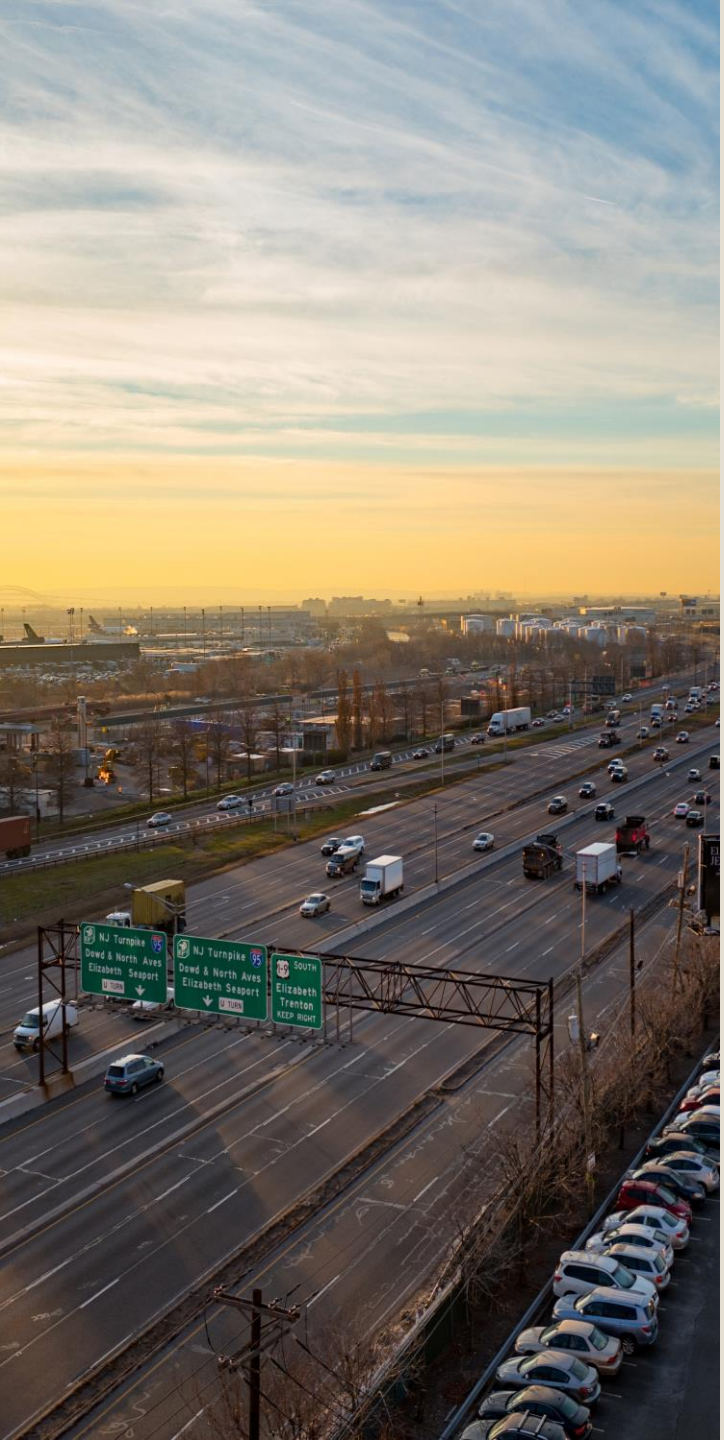


The total cost of owning an asset through its useable life includes not only the initial capital expenditure, but also future capital costs and operational costs – the sum total of which often greatly exceeds that of the initial capital costs


condition
NEW
treatment
DO NOTHING
condition
GOOD
treatment
PRESERVATION
cost per sq yard
$2.00
condition
FAIR
treatment
REHABILITATION
cost per sq yard
$20.00
condition
POOR
treatment
RECONSTRUCTION
cost per sq yard
$40–$80.00


WHAT
HOW
WHERE
SOLUTION
WHO
WHEN
WHY

What is Asset Management?
Data-Driven Decision Making



"Transportation Asset Management (TAM) is a strategic and systematic process of operating, maintaining, improving and expanding physical assets effectively throughout their lifecycle…"

USDOT

- Longer Life Expectancy of Assets
- More Efficient Decision Making
- Increased Service to Public
- Improved Accountability
- Increased Economic Development
- Reduced Failure Risk of Critical Assets

Infrastructure Asset Management

- Recent U.S. Legislation

Legislations>>

MAP-21

- Each State is required to develop a risk-based asset management plan for the National Highway System (NHS) to improve or preserve the condition of the assets and the performance of the system. (23 U.S.C. 119(e)(1), MAP-21 § 1106)

FAST ACT

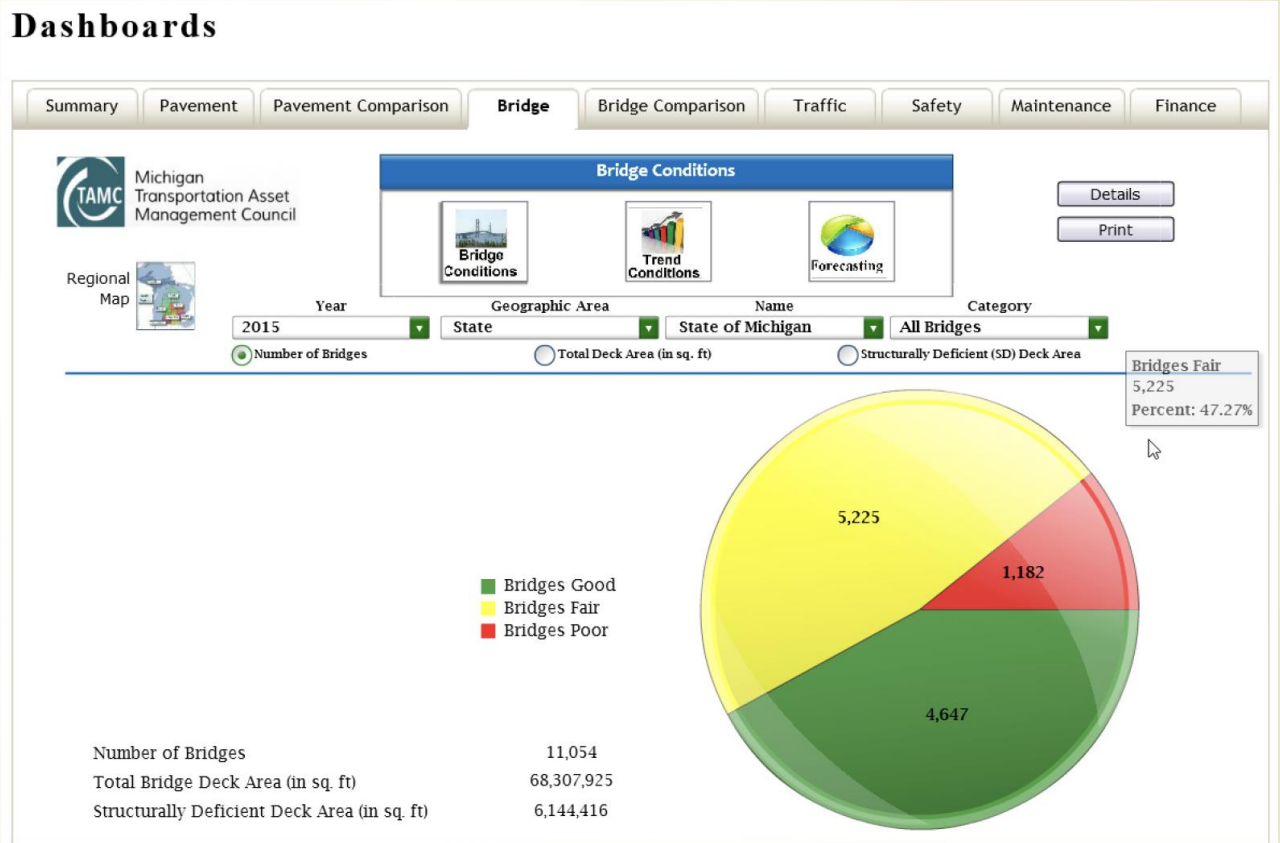
- The FAST Act provides an estimated average of $23.3 billion per year for the National Highway Performance Program (NHPP), which will support achieving performance targets established in a State's asset management plan for the National Highway System (NHS).

- **TAM Process**
  - TAM Platforms
  - AI Utilization

TAM Goals and Metric>>

State Defined Performance Measures

- Michigan Performance Measures
  - Take care of all critical needs
  - Freeway 95% Good or Fair
  - Non-Freeway 85% Good or Fair
  - Reduce the number of scour critical bridges carrying the interstate
  - **Reduce reactionary actions on our bridges**



Juntunen, 2018

TAM Primary Components>>

Inventory Management

Inspection & Condition Assessment

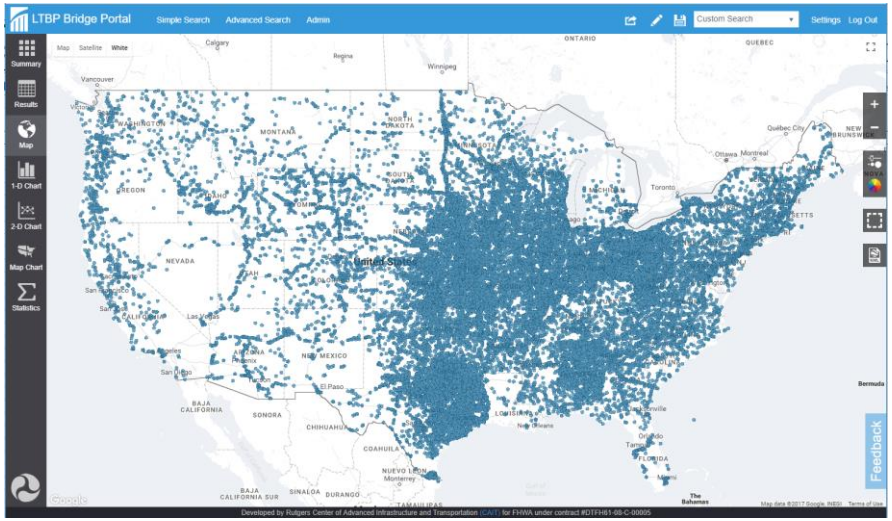
Deterioration & Life-cycle Cost Analysis

Maintenance Management

Capital Planning

Inventory Management
Example - Bridge Management System (BMS)

Inventory Management

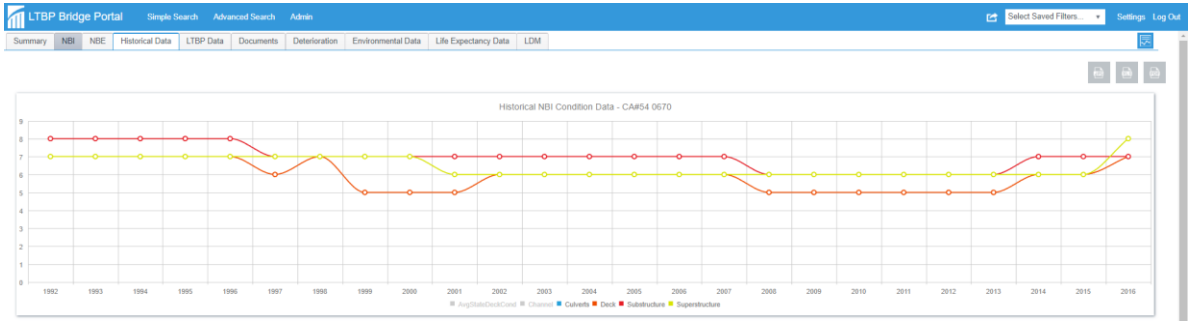


	Count	Deck Area(m²)	ADTT Vol.	Avg. Age	SD - Count	SD - Deck Area(m²)	Posted	Scour Critical
All	2,374	5,780,200	13,578,905	32.7	59	196,240	1	38
State	2,027 (85.4%)	4,617,624 (79.9%)	10,768,743 (79.3%)	32.6	57 (96.6%)	192,906 (98.3%)	1 (100%)	38 (100%)
Local	8 (0.3%)	124,066 (2.1%)	67,633 (0.5%)	41.5	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Interstate	2,295 (96.7%)	5,637,103 (97.5%)	13,331,379 (98.2%)	32.6	54 (91.5%)	188,819 (96.2%)	1 (100%)	38 (100%)
NHS	2,356 (99.2%)	5,755,826(99.6%)	13,552,914 (99.8%)	32.7	58 (98.3%)	194,522(99.1%)	1 (100%)	38 (100%)
Non NHS	18 (0.8%)	24,375 (0.4%)	25,991 (0.2%)	39.2	1 (1.7%)	1,718 (0.9%)	0 (0%)	0 (0%)

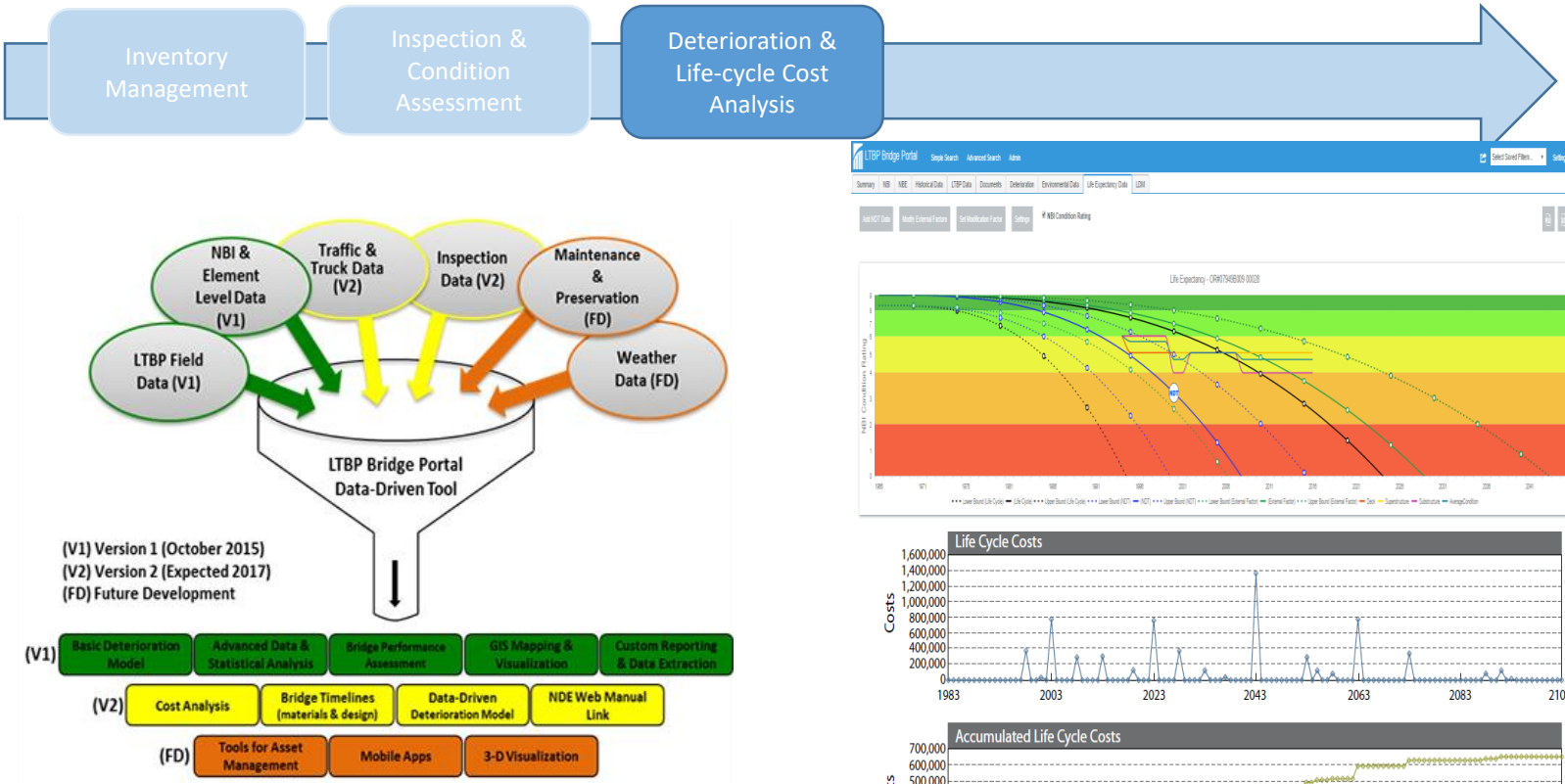
General	Age & Service	Structure Info	Load Rating	Inspection Summary
- State Name **- Structure Number** **- Highway Agency District** **- Owner** **- Functional Class of Inventory Route** **- Sufficiency Rating** **…**	- Year Built/Reconstructed - Lanes on/under Structure - Average Daily Truck Traffic - Type of Service on/under Bridge - Bypass/Detour Length …	- Type of Material/Design - Skew - Number of Spans - Total Length - Deck Width/Type - Type of Wearing Surface - Type of Deck Protection …	- Design Load - Structure Open/Posted/Closed - Operating Rating - Inventory Rating - Bridge Posting …	- Deck Condition Rating - Superstructure Condition Rating - Substructure Condition Rating - Inspection Date - Fracture Critical Details - Underwater Inspection …

Inspection and Condition Assessment
Example - Bridge Management System (BMS)

GENERAL CONDITION RATINGS (FHWA 1979)	
CODE	Description
N	Not Applicable
9	Excellent Condition
8	Very Good Condition- no problems noted.
7	Good Condition- some minor problems.
6	Satisfactory Condition – structural elements show some minor deterioration.
5	Fair Condition – all primary structural elements are sound but may have minor section loss, cracking, spalling or scour.
4	Poor Condition – advanced section loss, deterioration, spalling or scour.
3	Serious Condition – loss of section, deterioration, spalling or scour have seriously affected primary structural components. Local failures are possible. Fatigue cracks in steel or shear cracks in concrete may be present.
2	Critical Condition – advanced deterioration of primary structural elements. Fatigue cracks in steel or shear cracks in concrete may be present or scour may have removed substructure support. Unless closely monitored it may be necessary to close the bridge until corrective actions take place.
1	"Imminent" Failure Condition – major deterioration or section loss present in critical structural complements or obvious vertical or horizontal movement affecting structure stability. Bridge is closed to traffic but corrective action may put it back in light service.
0	Failed Condition – out of service – beyond corrective action.

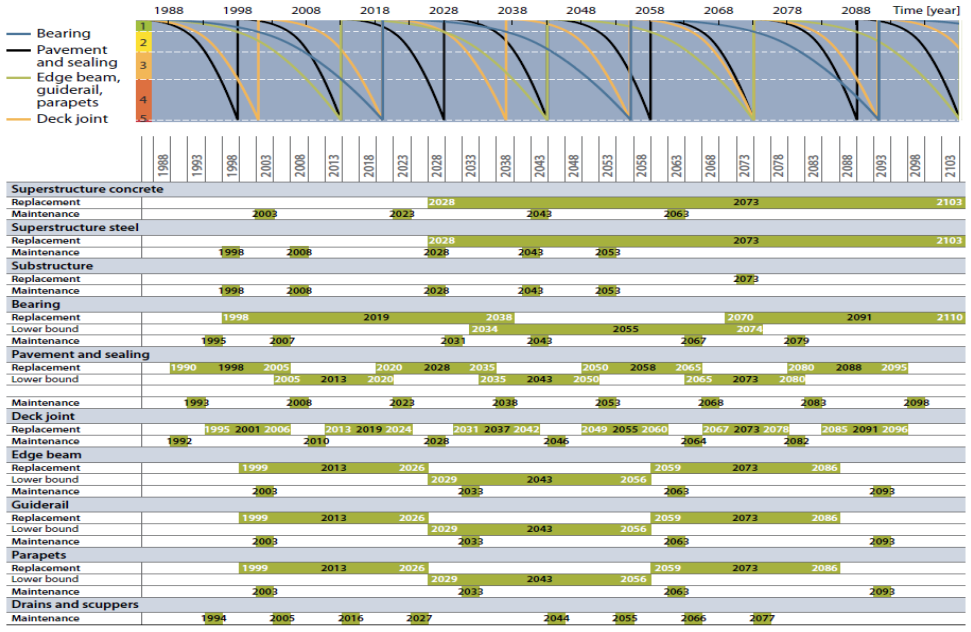


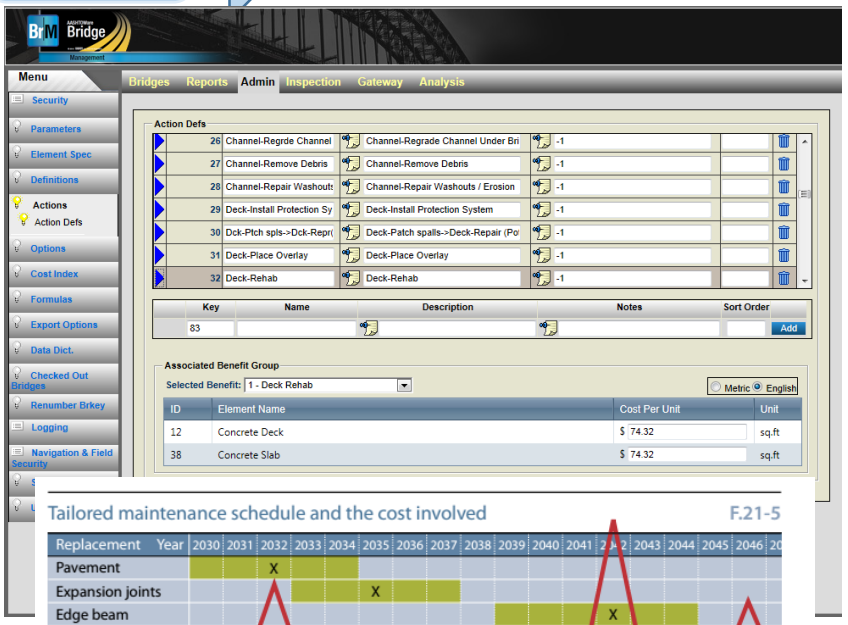
Deterioration and LCC Modeling
Example - Bridge Management System (BMS)



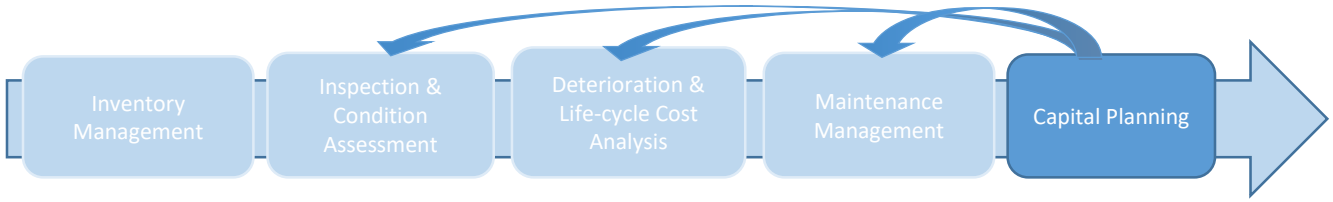
Maintenance Management
Example - Bridge Management System (BMS)

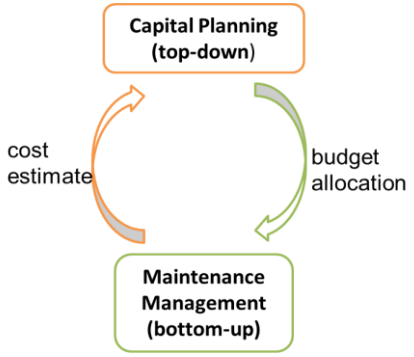
Inventory Management → Inspection & Condition Assessment → Deterioration & Life-cycle Cost Analysis → **Maintenance Management** → Capital Planning

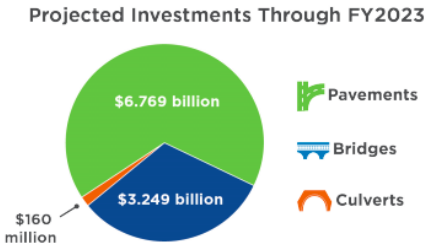


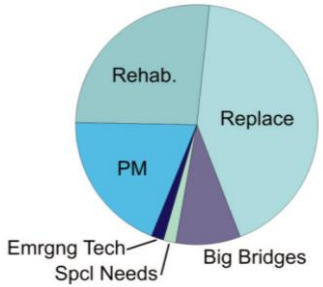


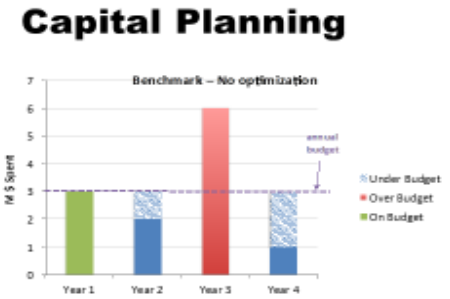
Capital Planning for Bridge Asset Management System

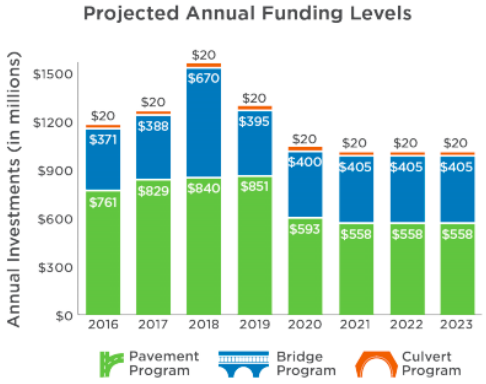




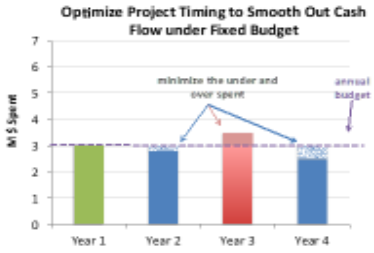


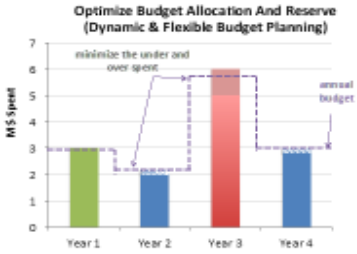






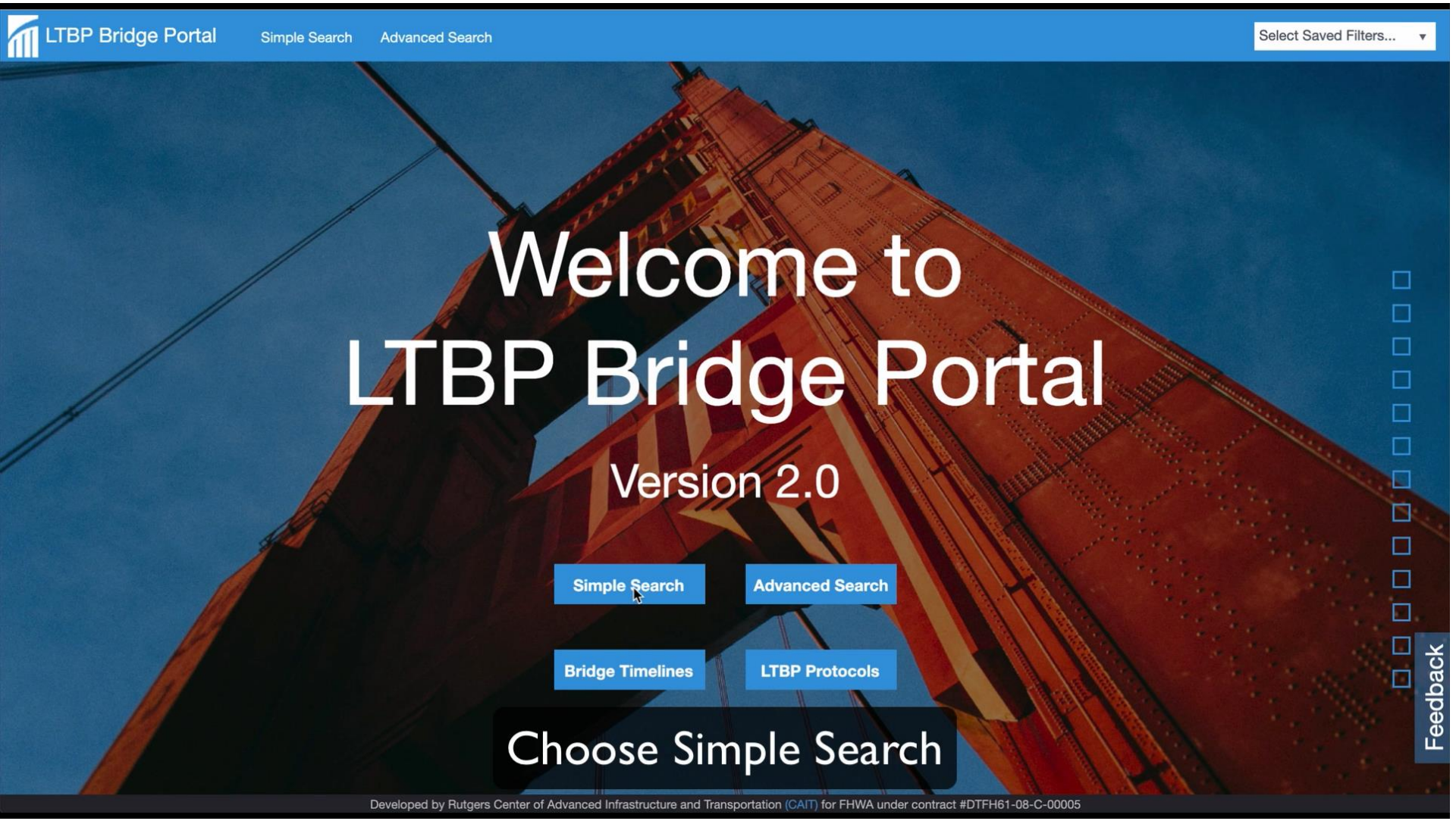
Bridge Program	Allocation Million $
Big Bridges	16.0
Special Needs	3.0
Emerging Technologies	3.0
Preventive Maintenance	35.9
Rehabilitation	48.9
Replacement	78.2





- TAM Process
  - **TAM Platforms**
  - AI Utilization

Bridge Portal



Major Commercial General TAM Systems/Platforms in the United States>>

TAM systems	Company	Asset Type/Products	Management/Analysis	Modeling	Pros	Cons
AASHTOware	AASHTOW	- Project - Bridge - Pavement - Safety	- Data management - LCCA and investment planning - Maintenance management - Safety Analysis - Bridge inspection	- Advanced 3D analysis and modeling - Multi-tool integration	- Simple user interface - Powerful software for both bridge and pavement - Easy access to data	- Does not include general or ancillary assets - Only assets are bridge and pavement
AssetWise	Bentley	- Rail and transit - Road and highways - Water and sewer	- Data management (Asset Lifecycle Information Management - ALIM) - Risk and reliability analysis - Operational analytics - Enterprise Interoperability	- Advanced parametric 3D modeling - Multi-discipline BIM models	- Mobile capabilities - Manage key asset data for all disciplines in a single unified environment - Modeling capabilities	- Not user friendly - System issues - Data debugging
Asset Optimizers (Asset Optimizer™, Bridget Optimizer™, etc.)	IDS (infrastructure data solutions Inc.)	- General asset - Bridge - Road - Water and sewer	- Asset management (risk based prioritization, budget planning) - Preservation planning - Project management	- Multi-variate deterioration modeling - Risk analysis - Multi-objective optimization	- Multi-Objective optimization - Custom software development to meet user's needs	- GIS software not included
AgileAssets	AgileAssets Inc.	- Pavement - Bridge - Safety - Data Visualization - Cross-Asset Tradeoff Analysis	- LCCA and investment planning - Maintenance management - Safety Analysis - Bridge inspection - Management operations (facility, fleet, sign, signal, ITS)	- Deterministic deterioration modeling - Multi-period and multi-constraint predictive analysis	- Flexible - Customizable - Easy to report/share data	- Limited GIS mapping abilities
dTIMS	Deighton	- Pavement - Bridge - Water and sewer - Ancillary Assets	- Risk Based Analysis - Cross Asset Analysis - Multi-Criteria Optimization - LCCA and investment planning	- Data-driven - Performance curves	- Versatile - Many asset types	- Expensive

Major Bridge AM Systems Current Practices in the United States>>

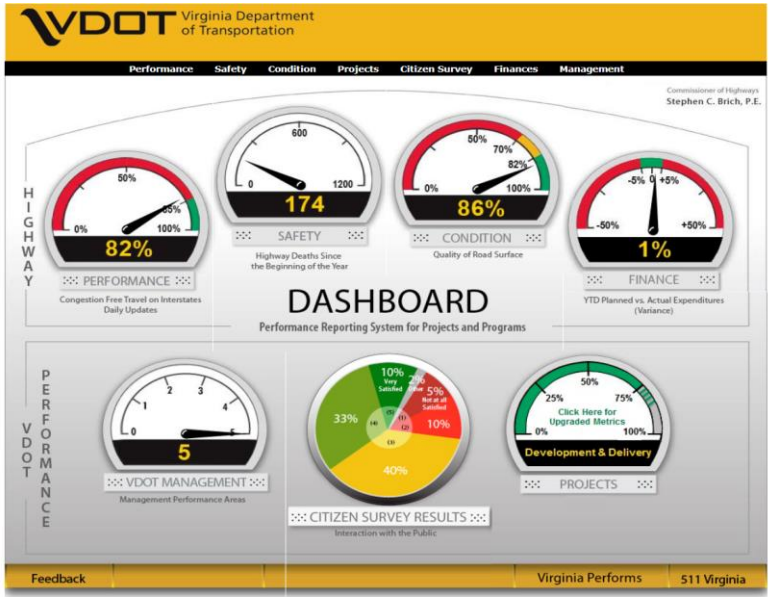
Bridge AM systems	Company/Agency	Data management	Deterioration Models	LCCA / Budget Allocation Optimization		Pros	Cons	Customers
				Individual	Network			
BrM (PONTIS, AASHTOware) V 5.2.3	**Bentley**	rating data Can create SI&A inspection report Performs as a data warehouse Slow and complex – not user friendly Supports NBI and AASHTO element level condition	- Not data-driven - Elicit-based (user defined) - Consider only four different environmental conditions	- Impact of one specific maintenance/replacement scenario - Requires cost data (user and agency)	- Only limited number of states using network level planning - Top-down optimization approach is used	- Designed to align with state DOT business practices - Aligned with other AASHTOWare products	- Slow and complex – not user friendly	- Washington DOT - New Jersey DOT - Oklahoma DOT
LTBP InfoBridge (formerly Bridge Portal)	**FHWA**	Acts as a data warehouse Mines data from other sources, such as NBI Manages and maintains massive amounts of data	- Not data-driven - Inaccurate deterioration forecasts	✗	✗	- Contains massive amount of quality data - Simple user interface	- Limited modelling capabilities - No LCCA/budget allocation optimization	- Virginia DOT
Bridge Analyst (& Bridge Inspect)	**AgileAssets**	Create and manage inspection report Performs as a data warehouse Supports NBI and AASHTO element level condition rating data Inspection workflow Load rating workflow Flag posting capability Vulnerability Assessment (damage from event) Post-event Inspections	- Data-driven	- Multi-period and multi-constraint analysis - Short-term work plans for deficient bridges	- Long-term planning - Create optimized work plans	- Mullti-year, Multi-constraint analysis - Generates interactive reports	- Expensive	- New York state DOT - North Carolina DOT - Georgia DOT
Bridge-optimizer	**IDS**	Supports NBI and AASHTO element level condition rating data Can create SI&A inspection report Automatic scheduling and tracking of inspections	- Supervised machine learning - Multi-variate inductive approach	- Evaluate different funding scenarios - Risk levels (multi objective optimization)	- Evaluate different funding scenarios on network level	- Unparalleled set of features - Advanced analytic capabilities - Customizable	- Deterioration modelling is not based on historical knowledge of trends	- Iowa DOT - Government of Canada
Scanprint (SMS)	**Advitam**	Supports NBI and element level condition rating data Provides access to see and put recommended repairs for certain elements Like Bridge Portal, acts as a data warehouse	✗	✗	✗	- Stores a large amount of data	- Undeveloped modelling and LCCA/budget allocation optimization	- Maryland DOT

Pavement AM Systems Current Practices in the United States

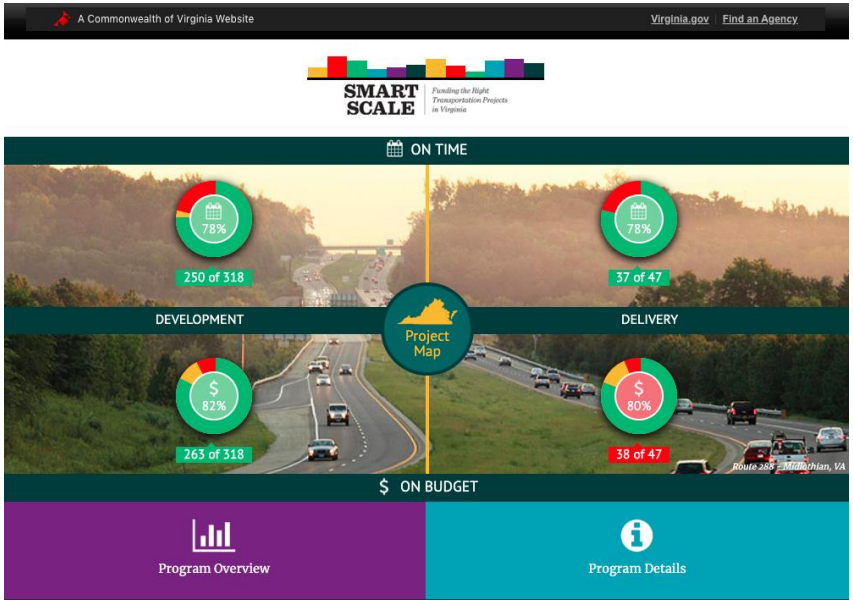
Pavement AM systems	Company/Agency	Data management	Deterioration Models	Pros	Cons	Customers
Roadsoft	Michigan Technological University	- Comes pre-populated with user's agency GIS map - Tracks data on physical features - Uses traffic and crash data for safety analysis - Schedule and plan future maintenance activity - Uses PASER rating data	- Data-driven - Used to predict how various treatment options will extend pavement life	- User friendly - Almost unlimited data handling capabilities	- Limited budget/investment Analysis - Limited customizability	- Michigan DOT
dTIMS	Deighton	- Multi-year prioritization - Built-in charts and reports - GIS map view	- Data-driven - Performance curves	- Accurate long-term planning - Versatile	- Expensive	- Maine DOT - Iowa DOT - NJ DOT - Indiana DOT
Pavement Analyst	AgileAssets	- GIS/LRS integration - Performs as a data warehouse - Spatial Analysis - Mobile capabilities	- Based on condition data - Flexible configuration - Multi-constraint Analysis - Long term modelling	- Flexible - User friendly - Easy to report/share data	- Limited GIS mapping abilities	- Texas DOT - Idaho DOT - Maryland DOT
MicroPAVER	US Army Corps of Engineers	- Uses PCI rating data - GIS/GPS capabilities - Variety of budget managing tools - Immediate mobile condition data entry - Advanced data collection methods	- Based on pavement "family" models - Emphasizes use of historical data	- Customizable - Optimized for large databases	- Cannot analyze other assets	- Illinois DOT
StreetSaver	Metropolitan Transportation Commission	- Uses PCI rating data - Bulk upload of changes - Data input can be difficult	- Project maintenance treatments and costs up to 30 years in the future.	- Extensive reporting tools - Long term analysis	- GIS integration requires additional software	- SFMTA - Oakland DOT - City of Patterson

In-house Developed TAM Systems

VDOT Dashboard v3.0



VDOT SMART SCALE program

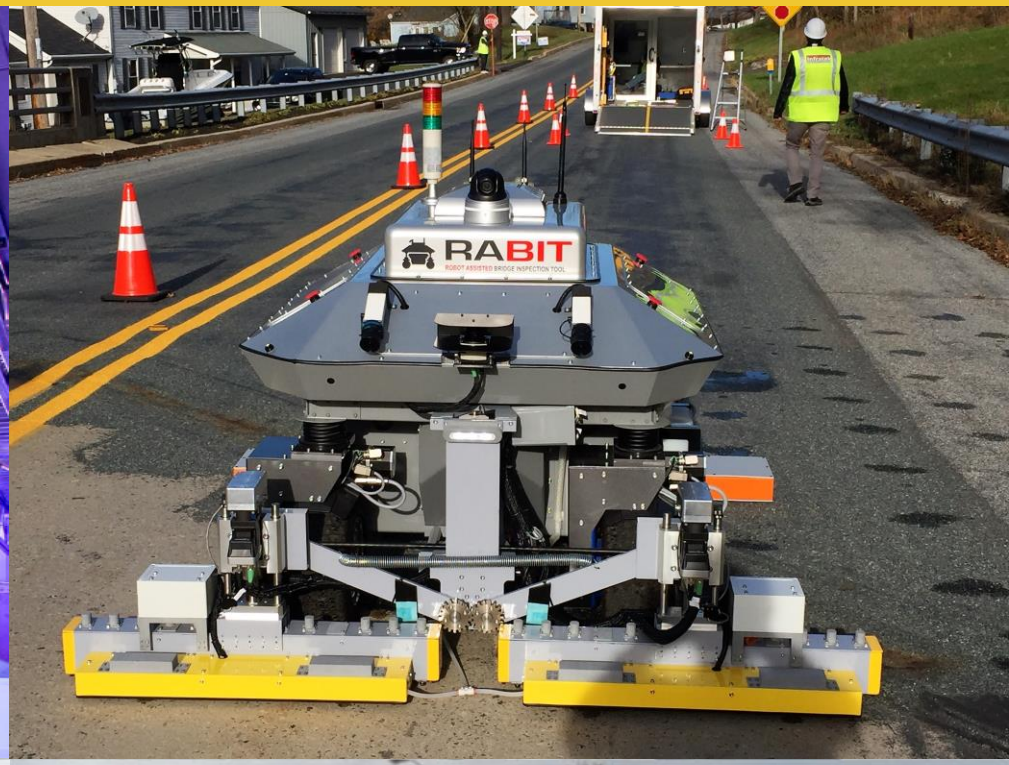


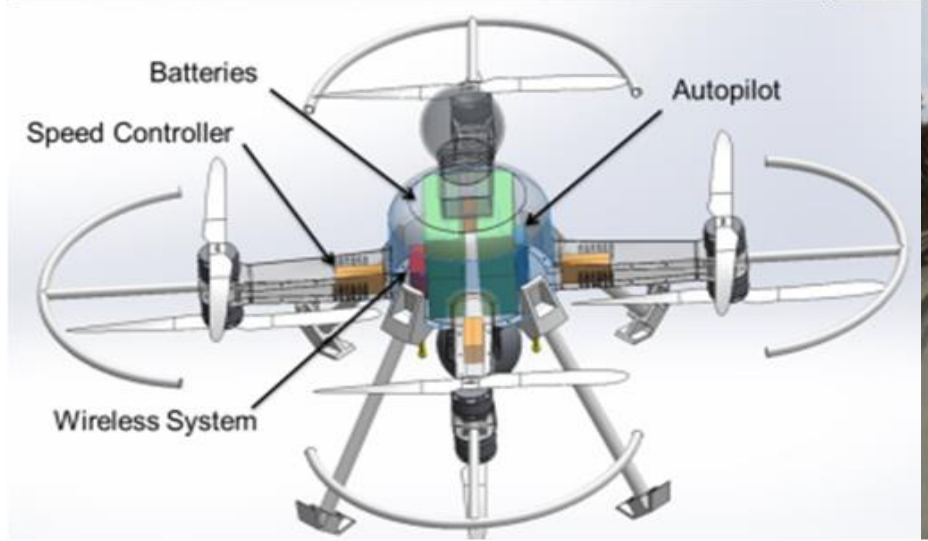
AI Application to TAM >>

- Utilize ”big data” for data-driven TAM
- AI for integration of context-specific domain knowledge and customized machine learning algorithms to discover new insights that are not possible to obtain via traditional methods.
- Utilize AI to predict track failure (Liu-2019)

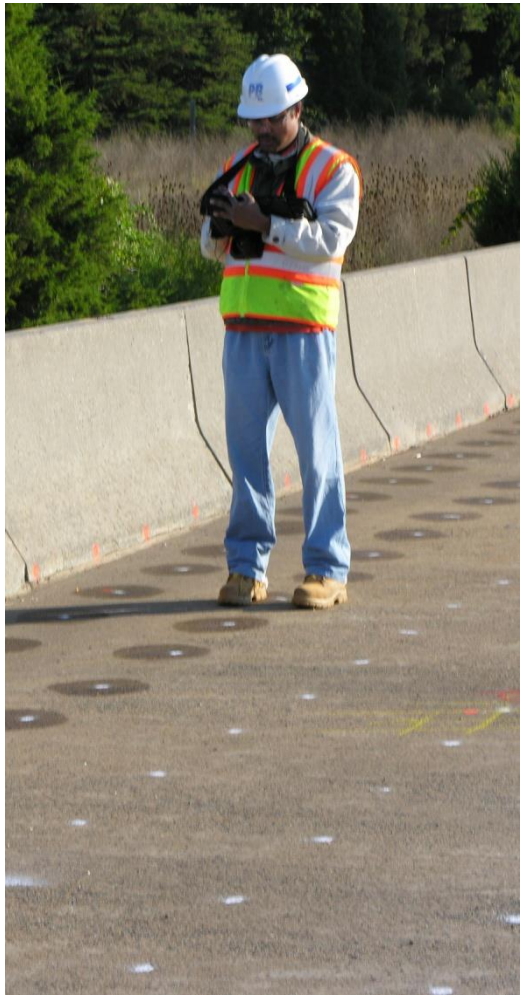
- Condition Assessment
  - **Advances in SHM & NDT**
  - **Automation & Robotics**
  - **Drones**
  - **Accelerated Testing Platforms**

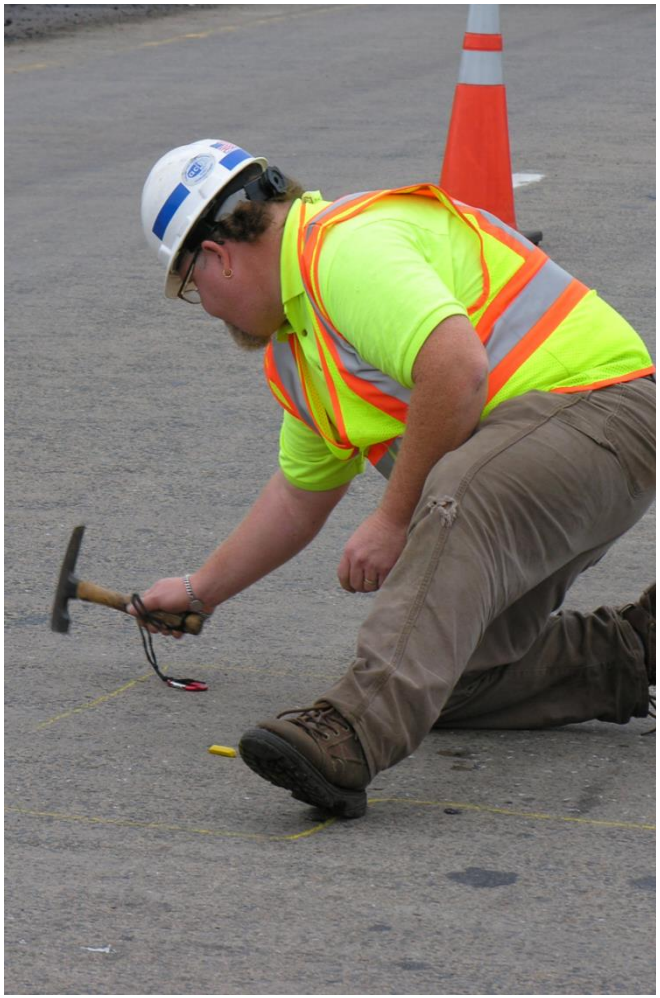
Recent Advances in Condition Assessment>>



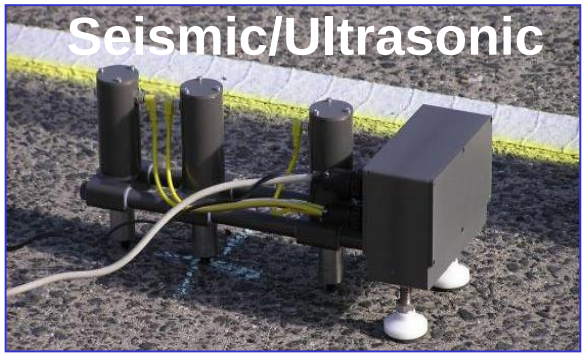


Deck Evaluation - State of Practice

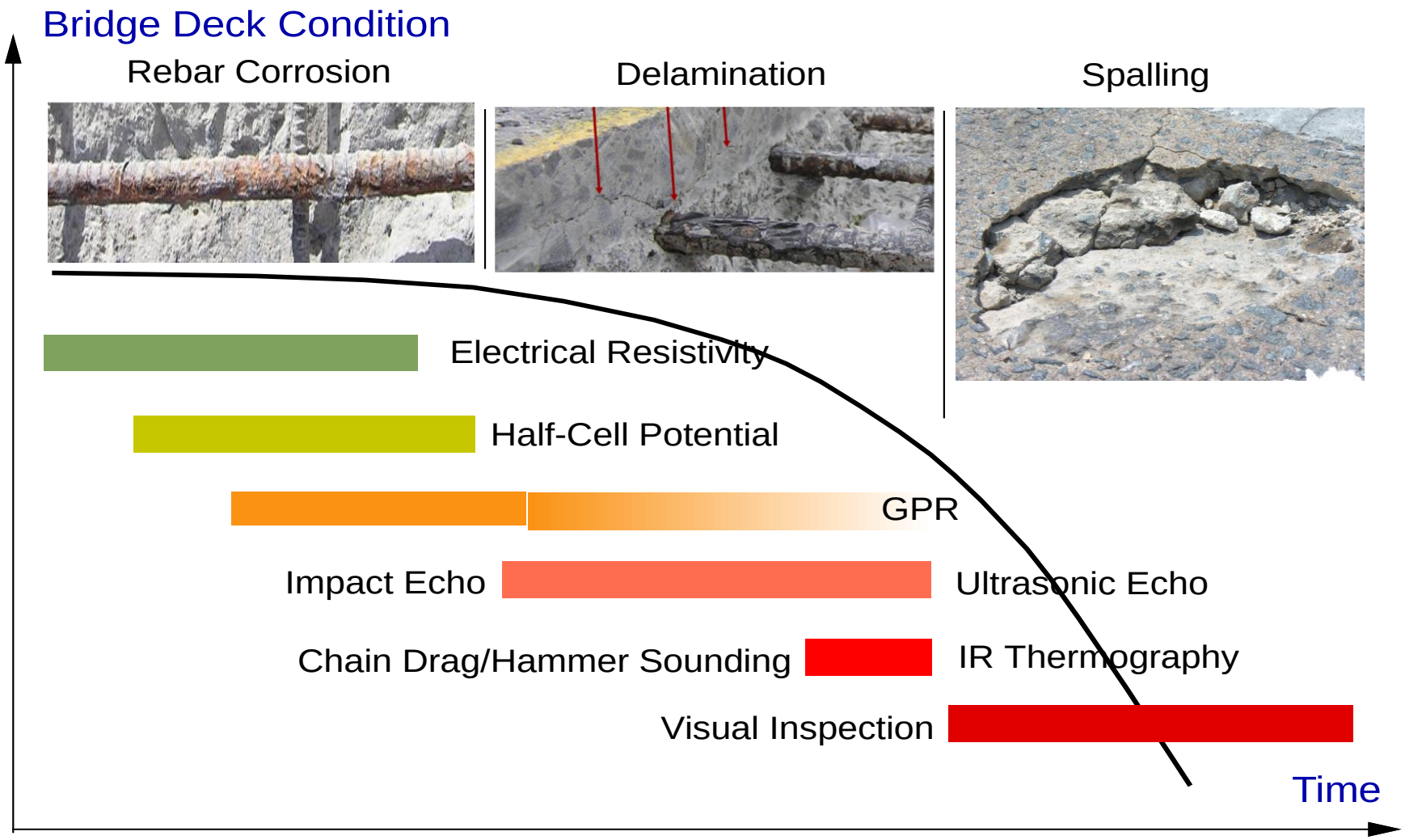




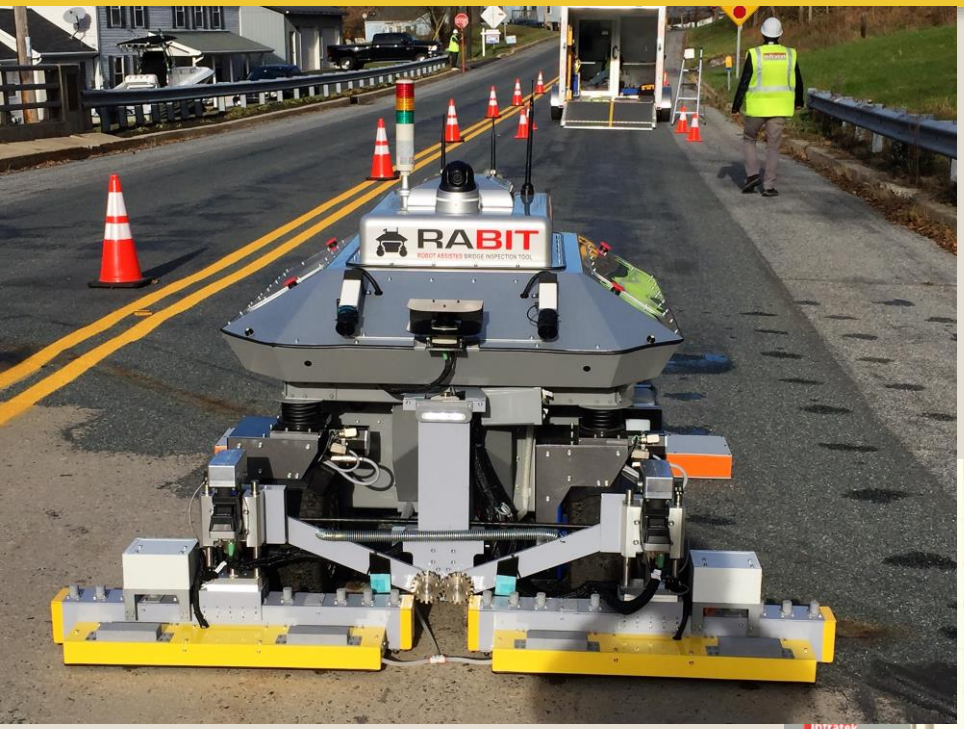
Bride Deck Evaluation – State of the Art



Deck Condition Assessment Vs. NDE Method



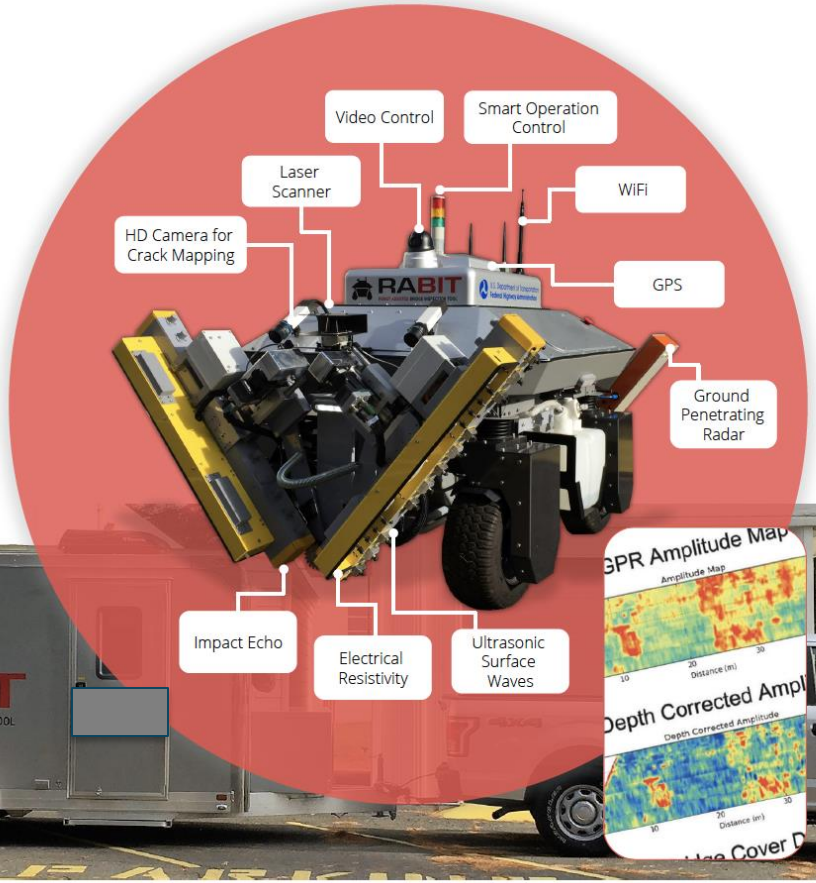
RABIT – Commercial Version

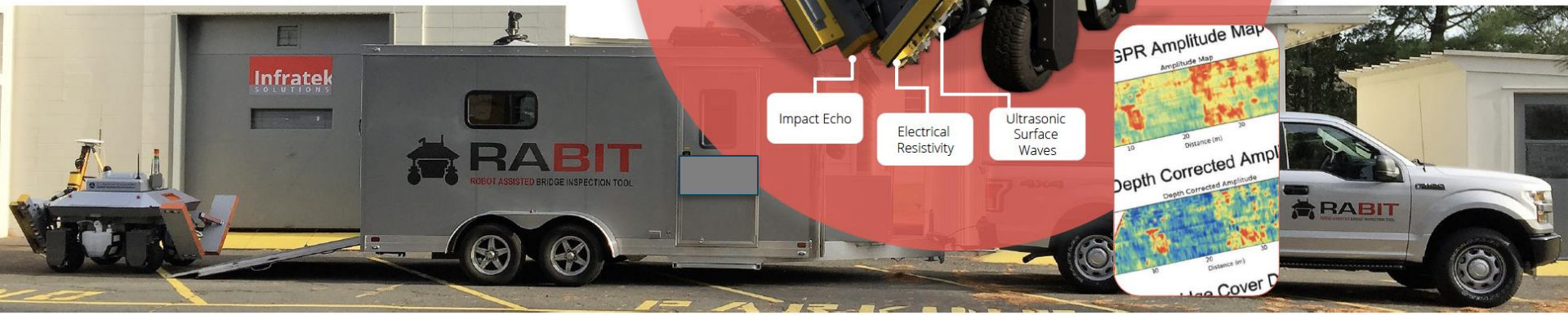


RABIT – Commercial Version

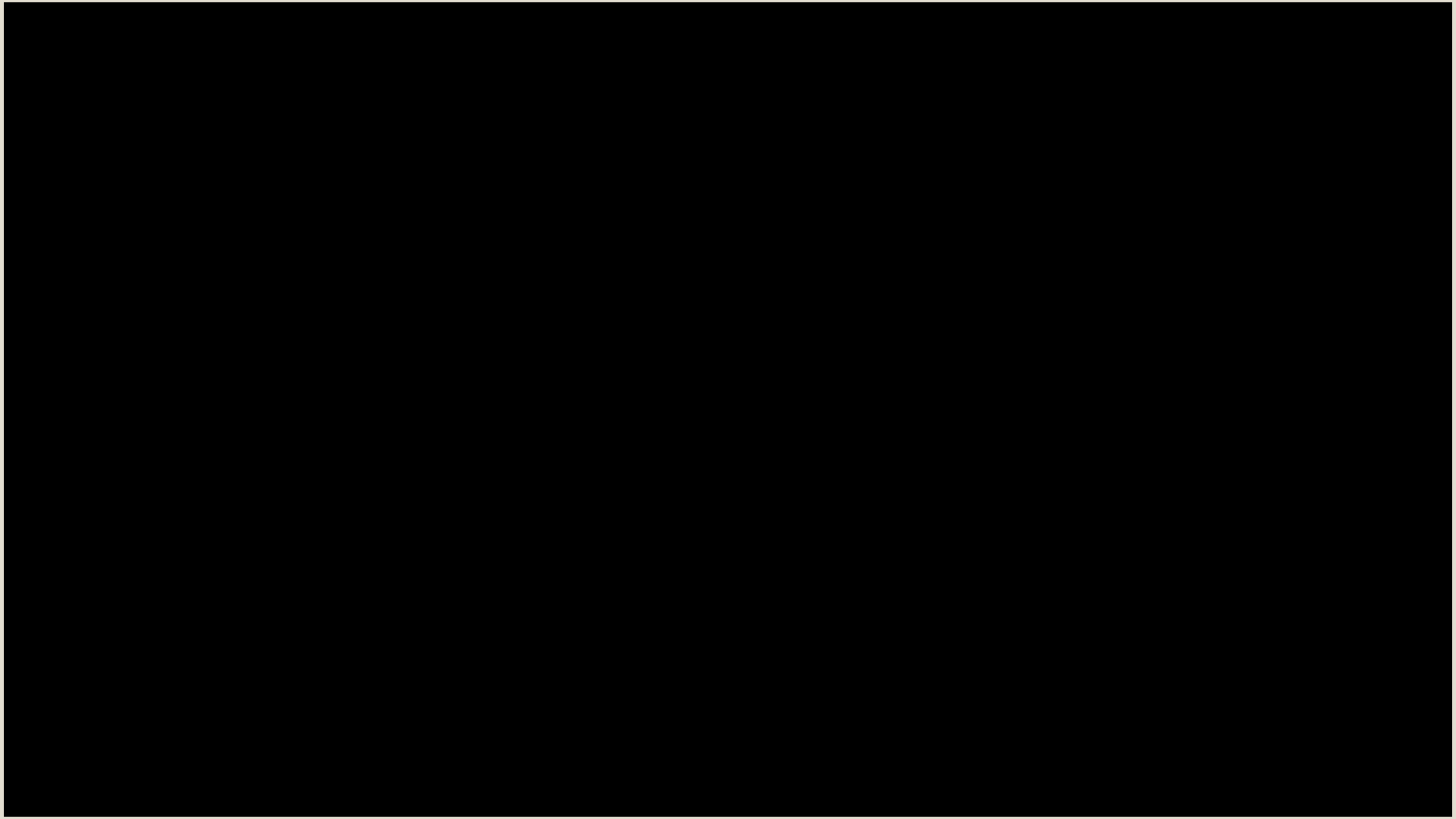
KEY FEATURES

- Multiple NDE technologies
- Smart error prevention
- Autonomous navigation
- Near real-time processing
- Subsurface corrosion and damage maps
- Two-man operation
- Accurate location coordinates





Robotic Assisted Bridge Inspection Tool



Winner of 2013 ASCE Charles Pankow Award for Innovation
&
USDOT Secretary Award

THMPR (Targeted Hits to Measure Performance Responses)

Step 1
Rapid modal impact testing using a self-contained mobile device

Step 2
Semi-Automated pre- and post-processing to obtain global frequencies and mode shapes

Step 3
Automated FE modeling using NBI data and on-site assessment

Step 4
Automated FE model calibration and load rating

Step 5
Reporting

Winner of 2016 ASCE Charles Pankow Award for Innovation

Rapid Evaluation of Bridge Integrity -THMPR

Targeted Hits for Modal Parameter Estimation and Rating (THMPER)

awarded the

Charles Pankow Award for Innovation at the 2017 ASCE OPAL Ceremony.

Research Collaborators:

Rutgers University, Drexel University, Federal Highway Administration, Pennoni Associates Inc., Intelligent Infrastructure Systems

Recent Advances in Condition Assessment>>

Another beast comes to Rutgers

Meet T-Rex. This awesome, unique piece of equipment is a high-force triaxial shaker used to simulate earthquakes and to do structural forced-vibration testing. It came to CAIT as part of an NSF project that is examining dynamic soil interaction as it pertains to our entire built environment.

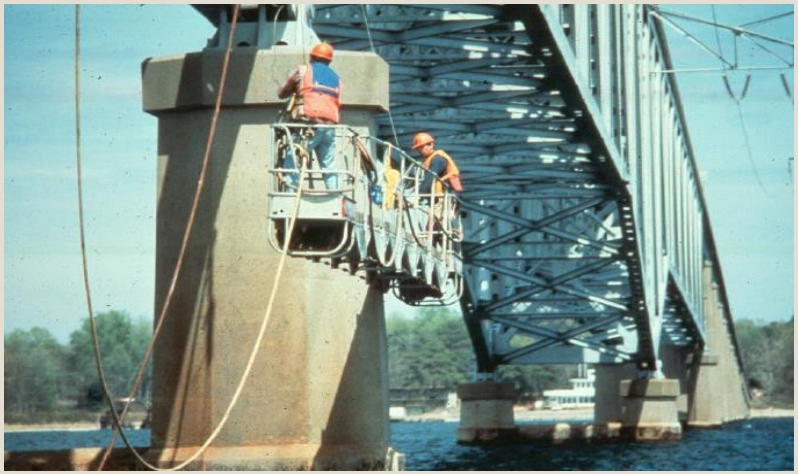
The **Natural Hazards Engineering Research Infrastructure program at the University of Texas at Austin** (NHERI@UTexas) brought T-Rex to Rutgers for a two-day structural testing workshop it cohosted with CAIT. The program included a field demonstration of T-Rex on a bridge in Hamilton, New Jersey.

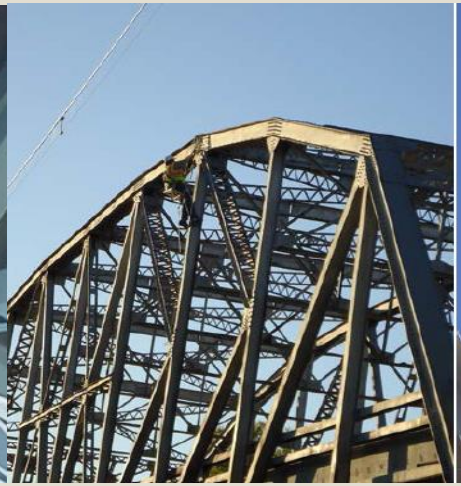
CAIT thanks the whole **NHERI@UTexas** team for bringing this "ground-breaking" technology to New Jersey for the workshop. We also thank **New Jersey Department of Transportation** for helping us identify a bridge and for facilitating the day's field testing.

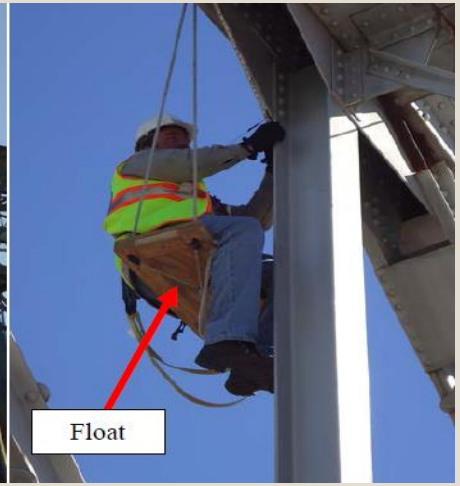
Look for a full article on the project in the next issue of *Transportation Today*.

Photo: ©Drew Noel Photography/Rutgers CAIT.

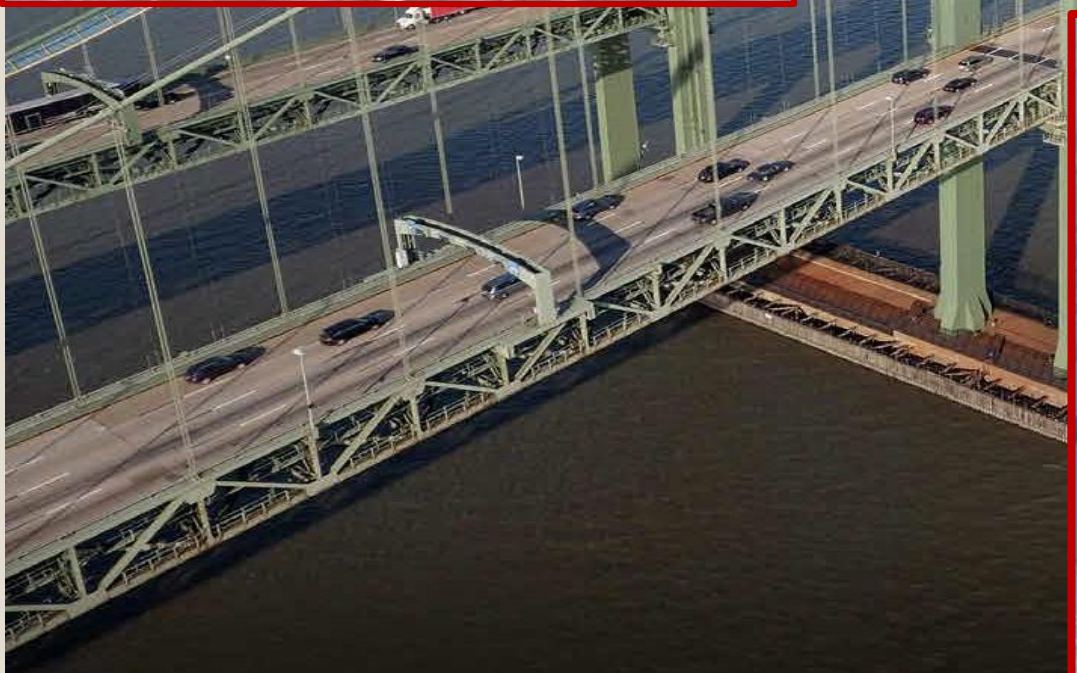
Recent Advances in Condition Assessment - UAS>>



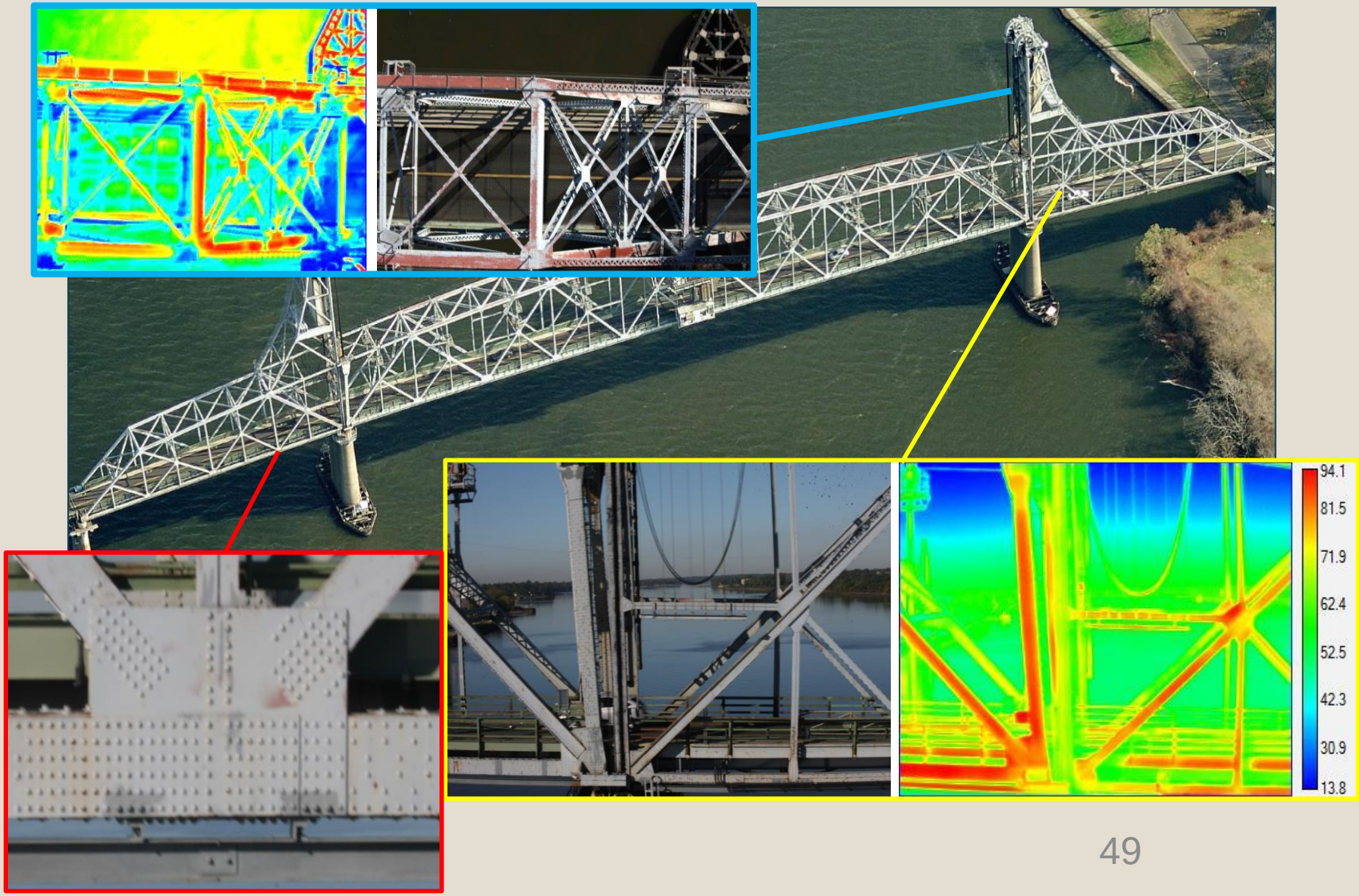




Recent Advances in Condition Assessment>>



Bridge Assessment Using Unmanned Arial Systems

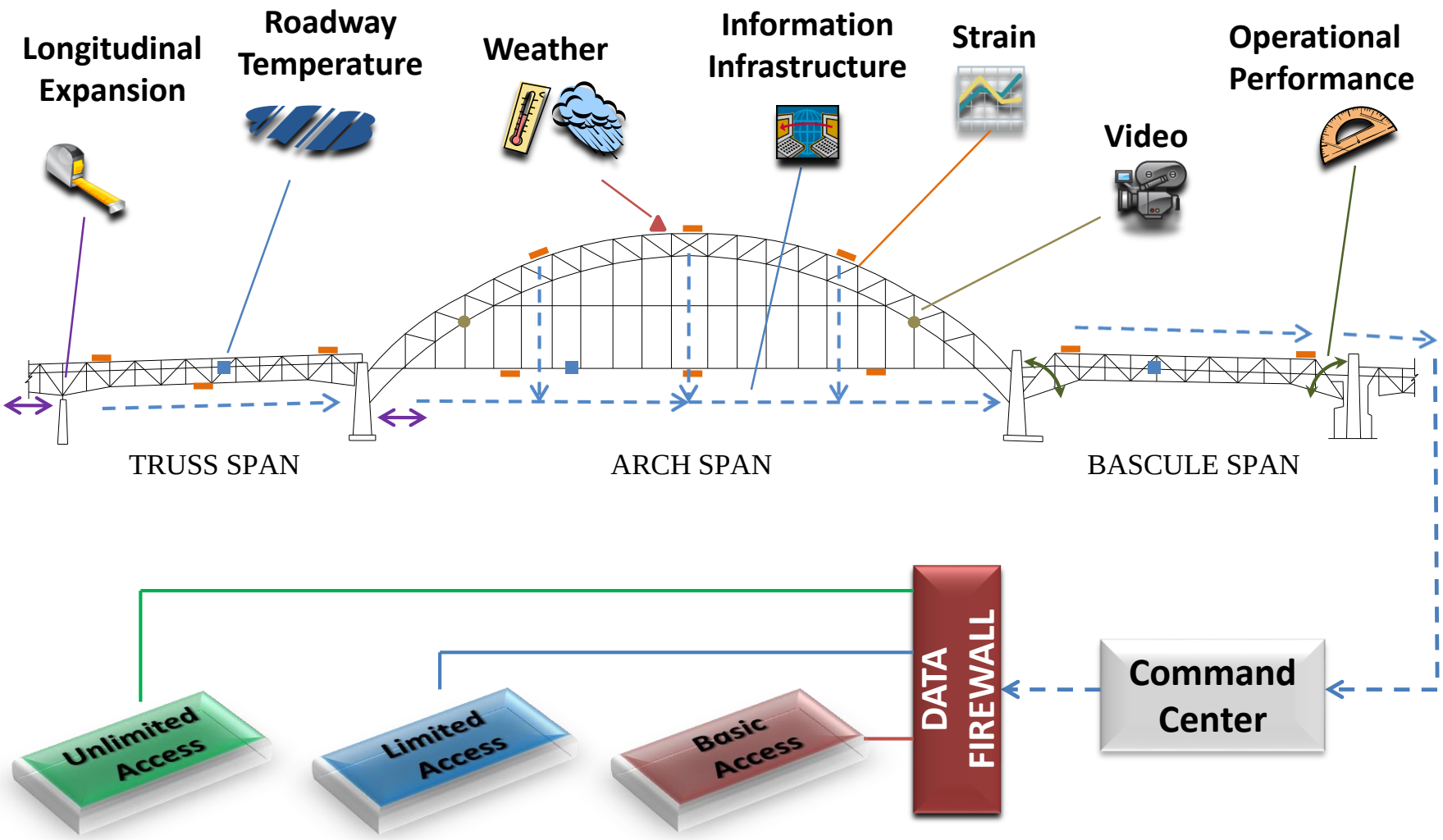


Structural Health Monitoring System - SHM>>

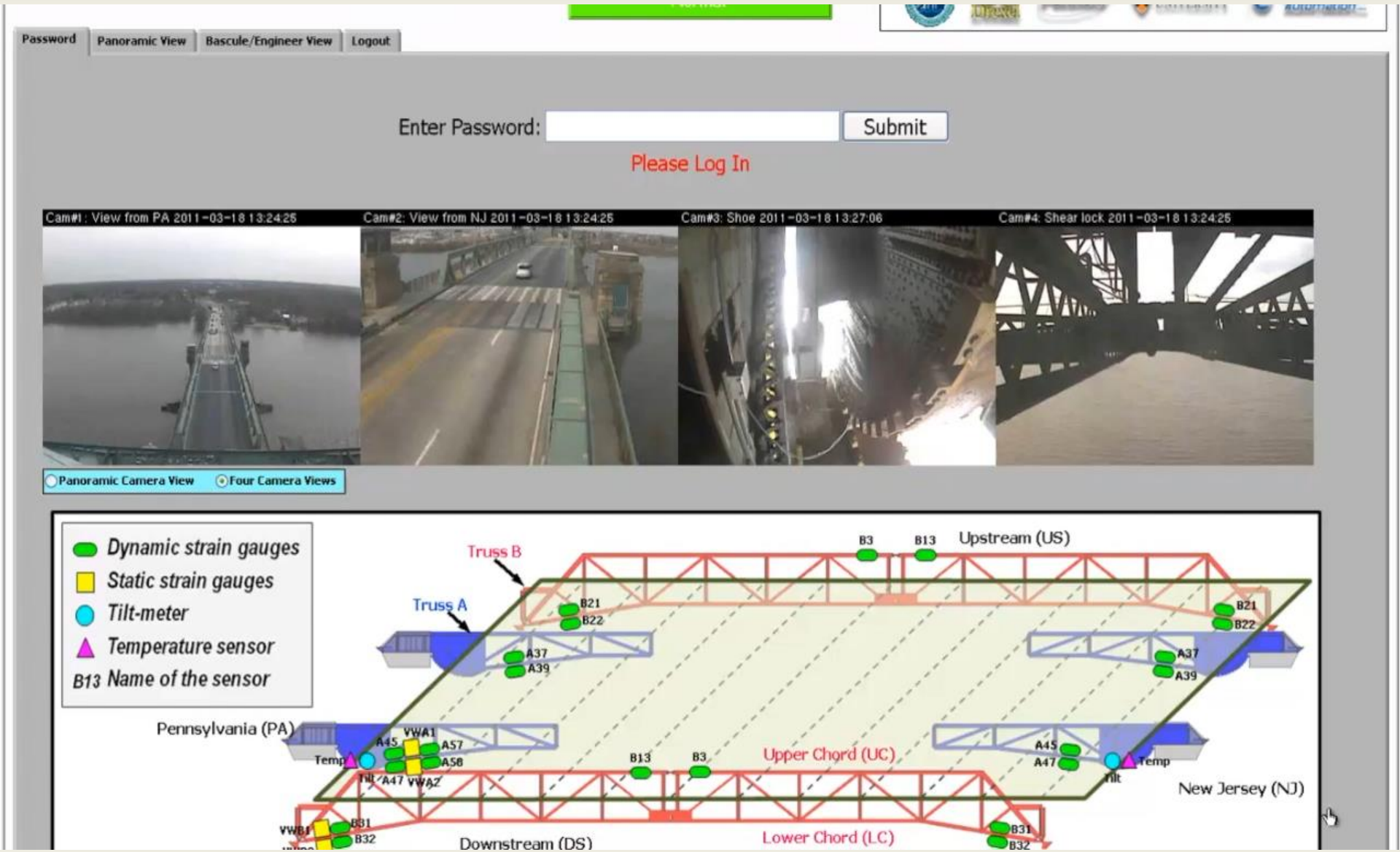
Monitoring the Health and Performance of Infrastructure

Using sensing, simulation and information technologies to augment qualitative, subjective inspections with quantitative, objective information

Structural Health Monitoring System - SHM>>



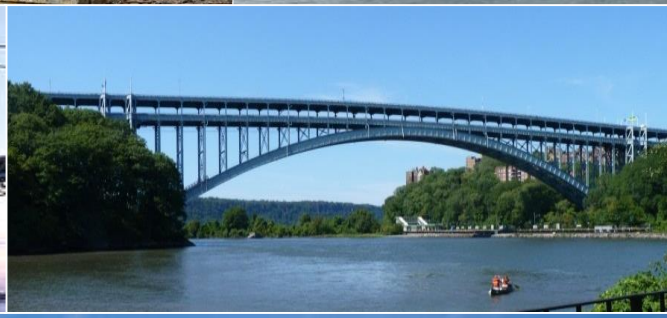
SHM Visualization Portal - Tacony Palmyra Bridge>>



Structural Health Monitoring System - SHM>>





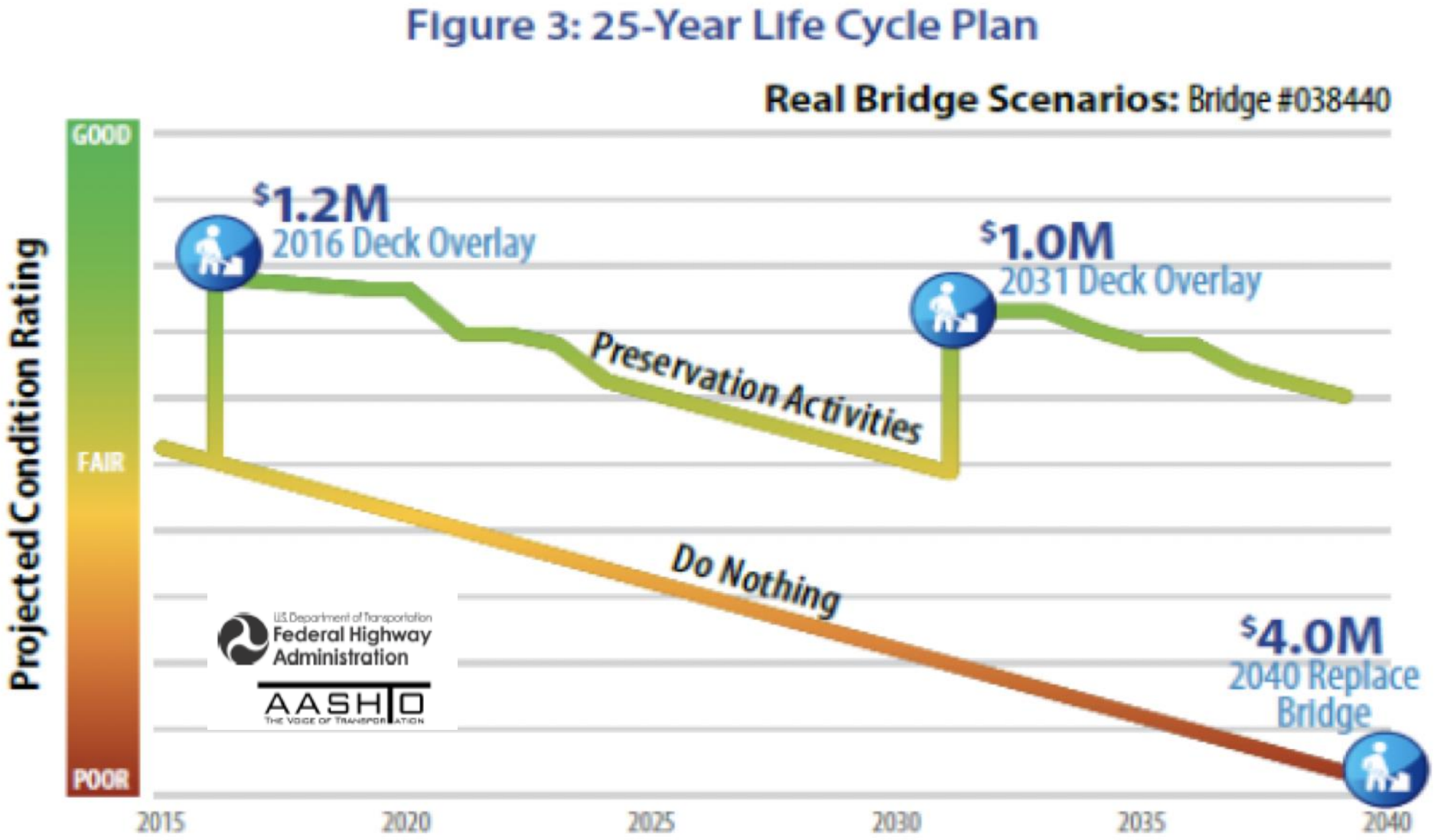



Highlight: The BEAST >>

Specifications

- Test spans up to 50 feet long by 28 feet wide
- Traffic loading cycles with 20 to 60 kips continuous at 20 mph; 48,000 cycles per day
- Rapid-cycling temperature fluctuation 0 to 104F degrees
- Salt brine application, 1 to 15 percent soluble solution
- Capable of testing concrete design, decking systems, rebar, coatings/sealants, superstructure frames, joints, bearings, and more

LCA through BEAST!>>



Pavement Condition Survey Equipment >>

Falling Weight Deflectometer (FWD)
Measures structural capacity • Relates to service/durability

Skid Trailer
Measures pavement friction • Relates to safety

Profiler
Measures roughness, distress, rutting, noise, cracking • Relates to quality/performance

Ground Penetrating Radar (GPR)
Measures layer thickness • Relates to performance/wear

Earth Radar

TSD d_0 (coloured bars)

(Continuous measurement of pavement surface deflection response under a rolling wheel load)

FWD d_0 (white dots ●)

(Conventional point-by-point measurement of pavement deflection under load)

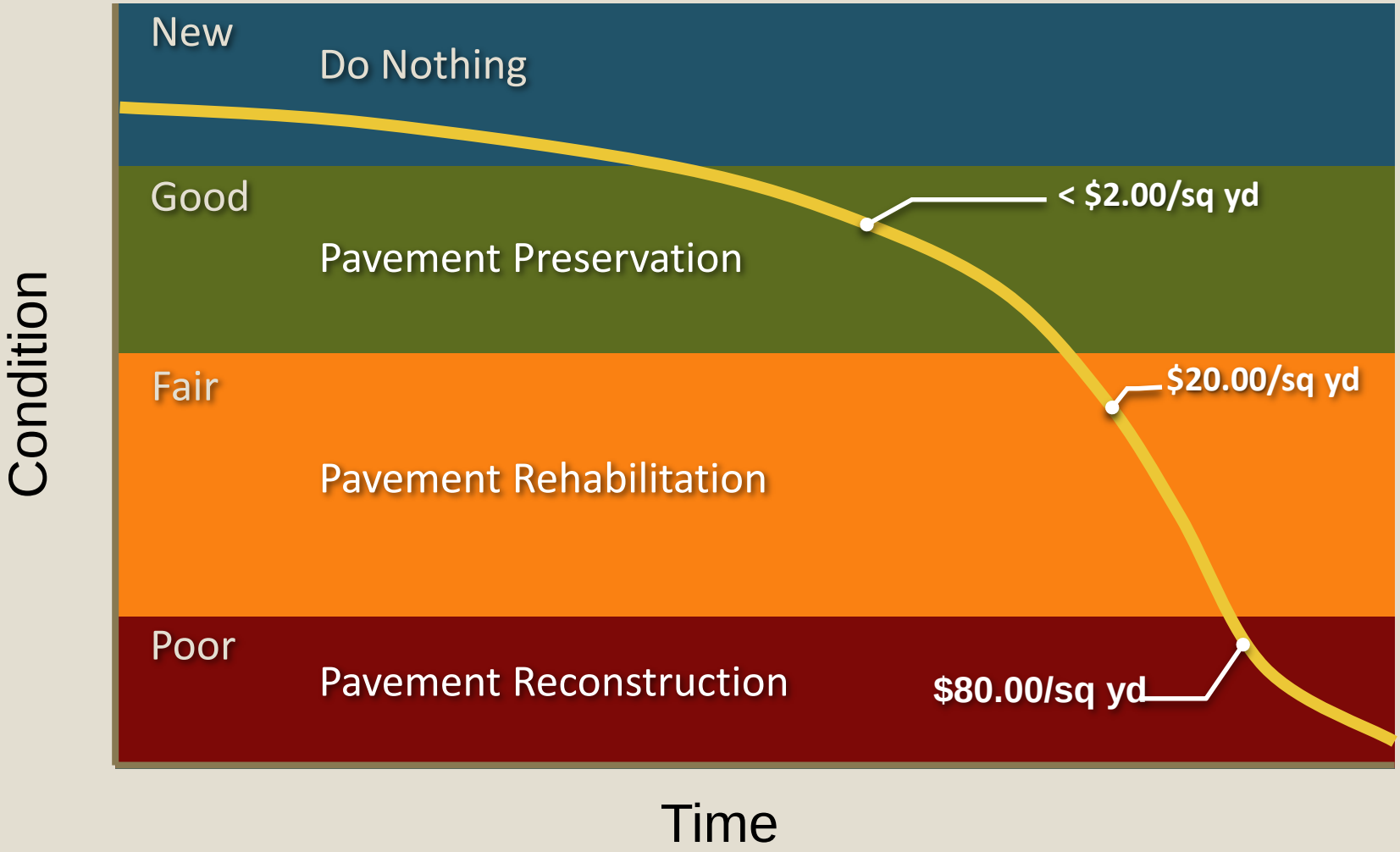
Mount Cotton
Redland Bay
Victoria Point
Coochiemudlo Island
Moreton Bay
Ch. 3.00km
Alberton
Ch. 4.00km
Ch. 5.00km
Ch.
Gilberton

NM-GPR (greyscale)

(Continuous measurement of pavement layer interfaces & other subsurface features)

Effect of Treatment Timing on Costs >>

Deterioration over time and cost to repair



- Build TAM as the basis for capital planning and decision-making process
- Build toward an enterprise model
- Deploy technology-based solutions for condition assessment
- Data → Information → knowledge
- Maintain TAM through work-force training

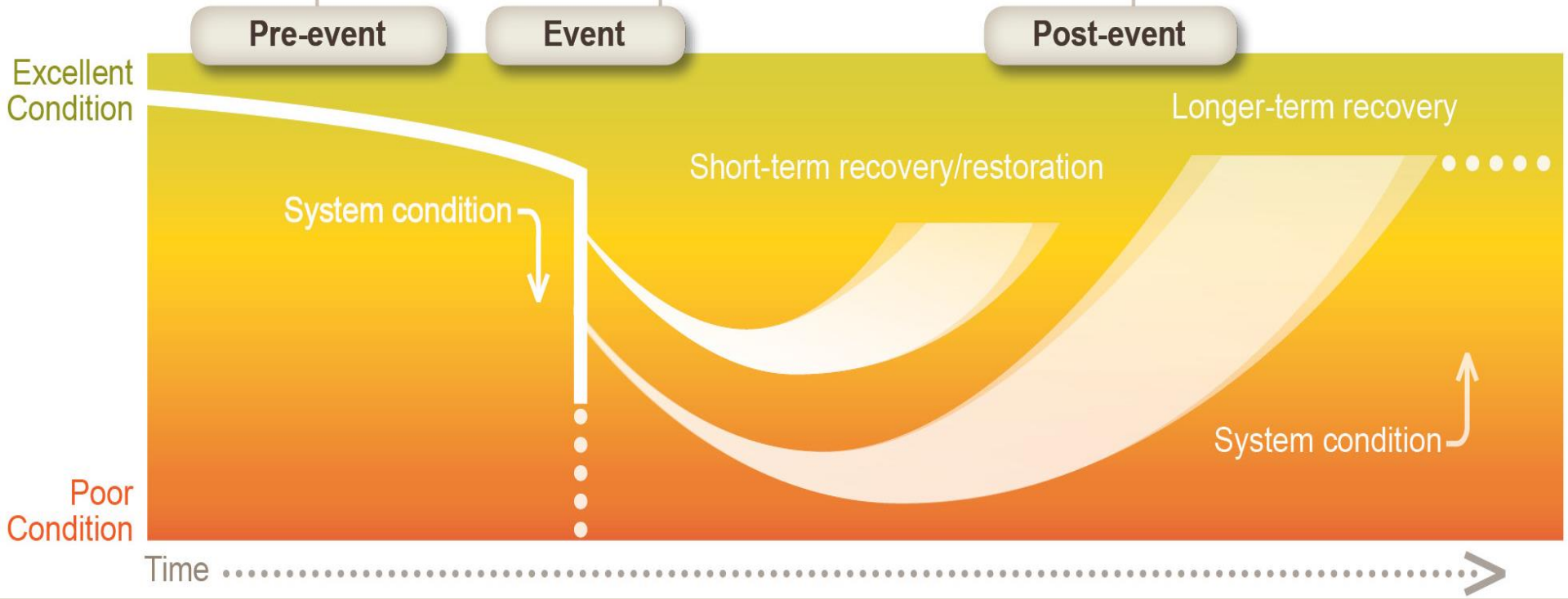

resilience
concept
motivate
optimism
strong
vitality
stability
mental
flexibility
steadiness
resistance
connection
optimistic
influence
action
protection
response
stamina
impact
personality
growth
education
compliance
conceptual
natural
success
elasticity
security
triumph
symbol
grow
improvement
industry
achievement
equipment
process
financial
resilient
adjustability
growing
determination
information
reaction
pressure
business
resist
defense
positive
path
immunity
type
leadership
adaptability
marketing
inspirational
endurance
travel
idea
persist
destination
way
sky
direction

Infrastructure Resilience>>

- Systems interdependency and cascading impacts
- Accurate baseline condition of assets
- Quantitative asset performance metrics
- Monitor asset performance and measure against expectations

- Real-time big data analytics (IoT)
- Performance modeling of expected failure rates
- Predictive event modeling
- Elevating/hardening infrastructure systems against flooding

- Large-scale system simulation
- Recovery objectives for critical assets to establish priorities
- Simple, quantitative resilience measurements for individual assets
- First response and liabilities training for engineers



Data Collection Tools>>

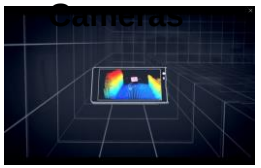
UAV-borne Sensing

Mobile Lidar

Gong, 2018

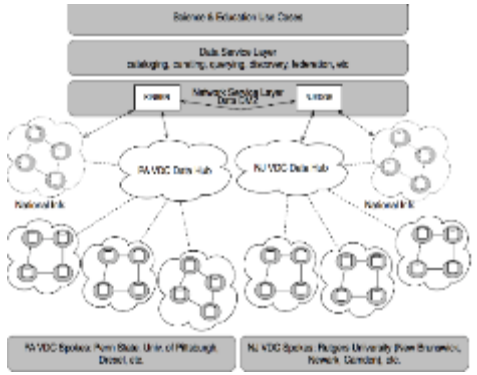
Static Lidar

Mobile Phones with 2D/3D Cameras



Hololens for Augmented Reality

GPU Cluster for Machine Learning



Cloud Computing Virtual Data Collaboratory

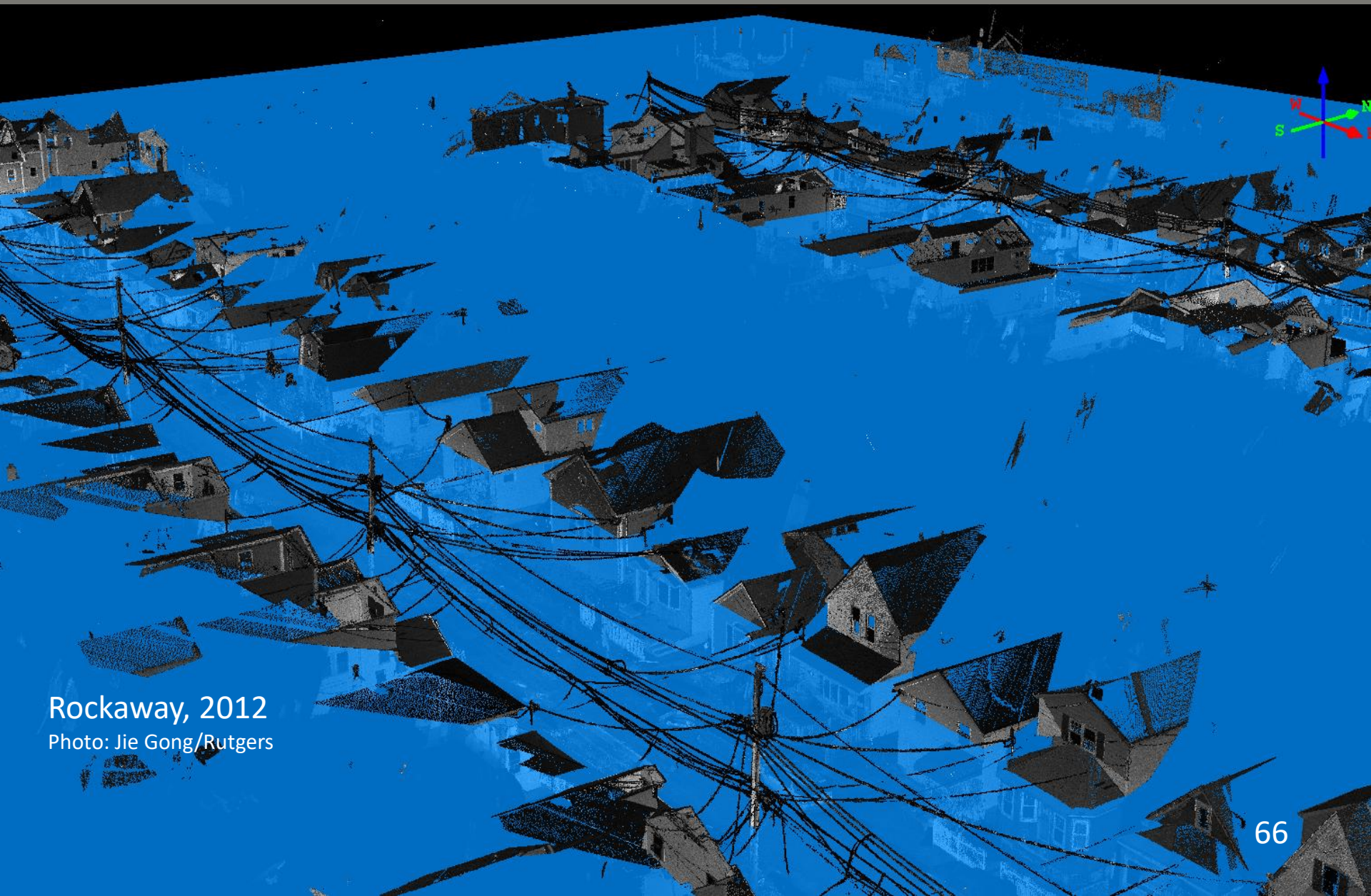
Data Collection Projects>>

Large-Scale Deployment of Mobile LiDAR during Hurricane Sandy

Highlight: Post-Sandy Mobile Lidar Pilot >>

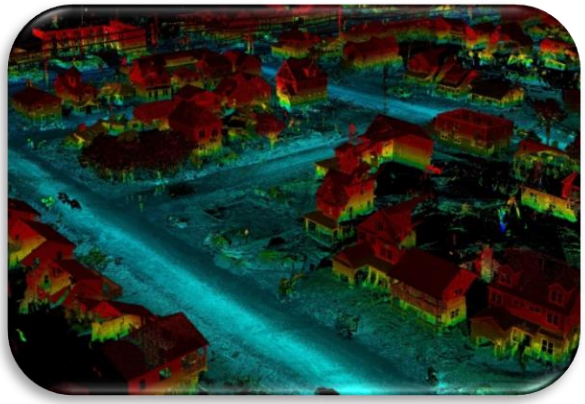
>> Data enables highly-accurate risk and predictive models that help planners, developers, and government agencies like FEMA assess future risk

Crossbay Avenue: 1% EL 16 Feet

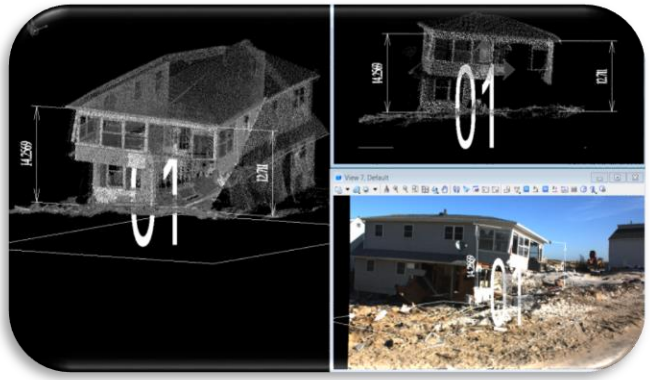


Rockaway, 2012
Photo: Jie Gong/Rutgers

Tools for Improving Coastal Infrastructure Resilience

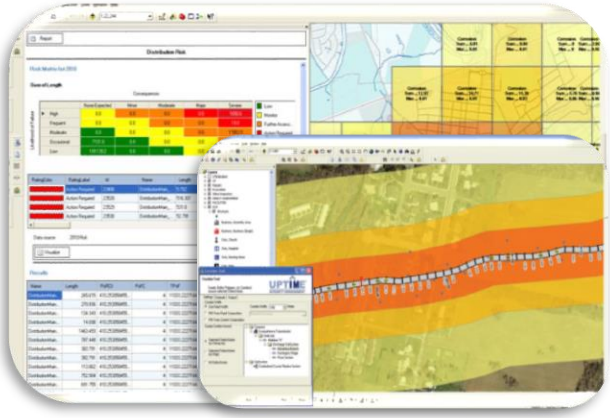


Big 3D Disaster Data

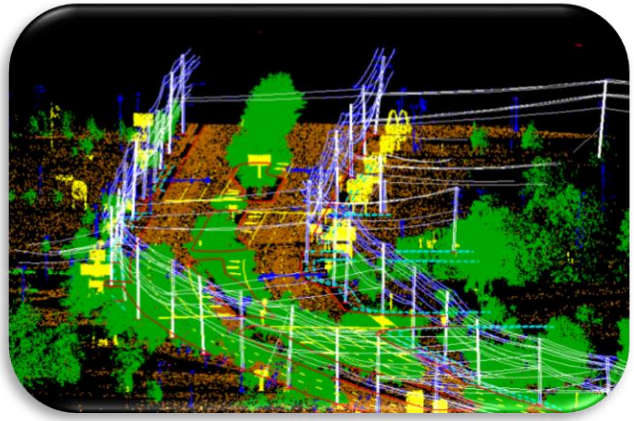


Hurricane Damage Modeling and Prediction

Risk Communication and Resilience Visualization

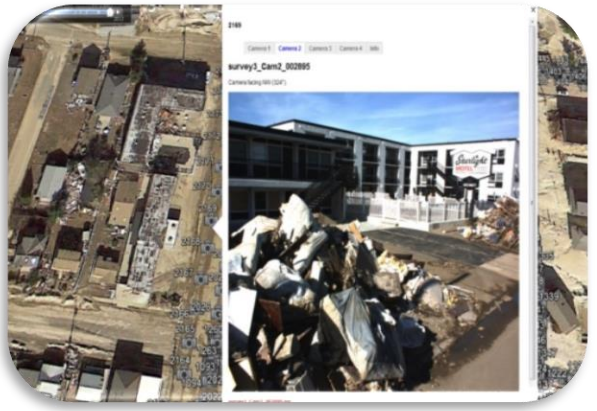


Data-Driven Threat Detection and Risk Analysis for Critical Infrastructure



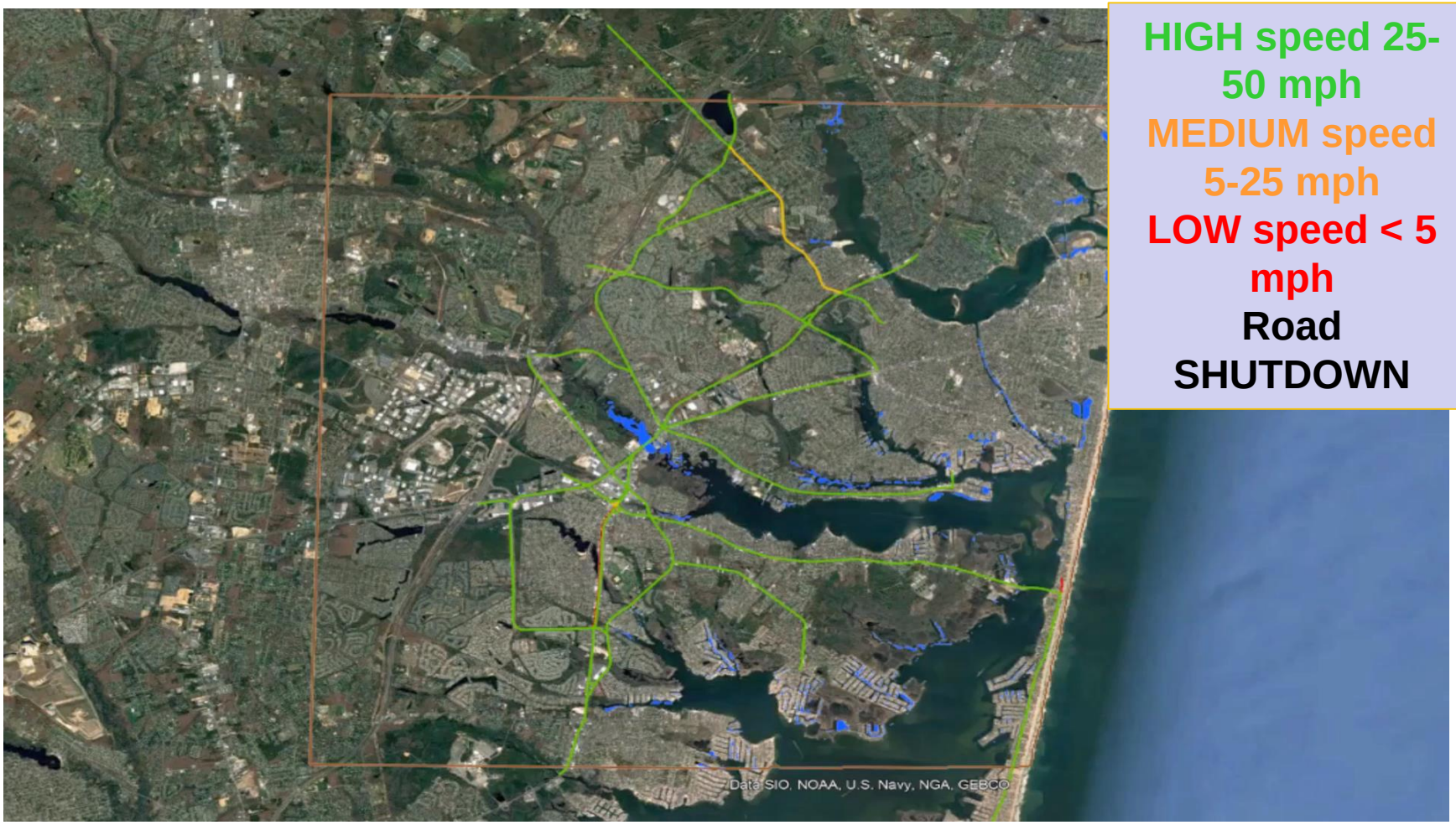
Resilient Electricity Grid: Outage and Recovery Modeling and Prediction

Gong, 2018



Computational Disaster Debris and Waste Management

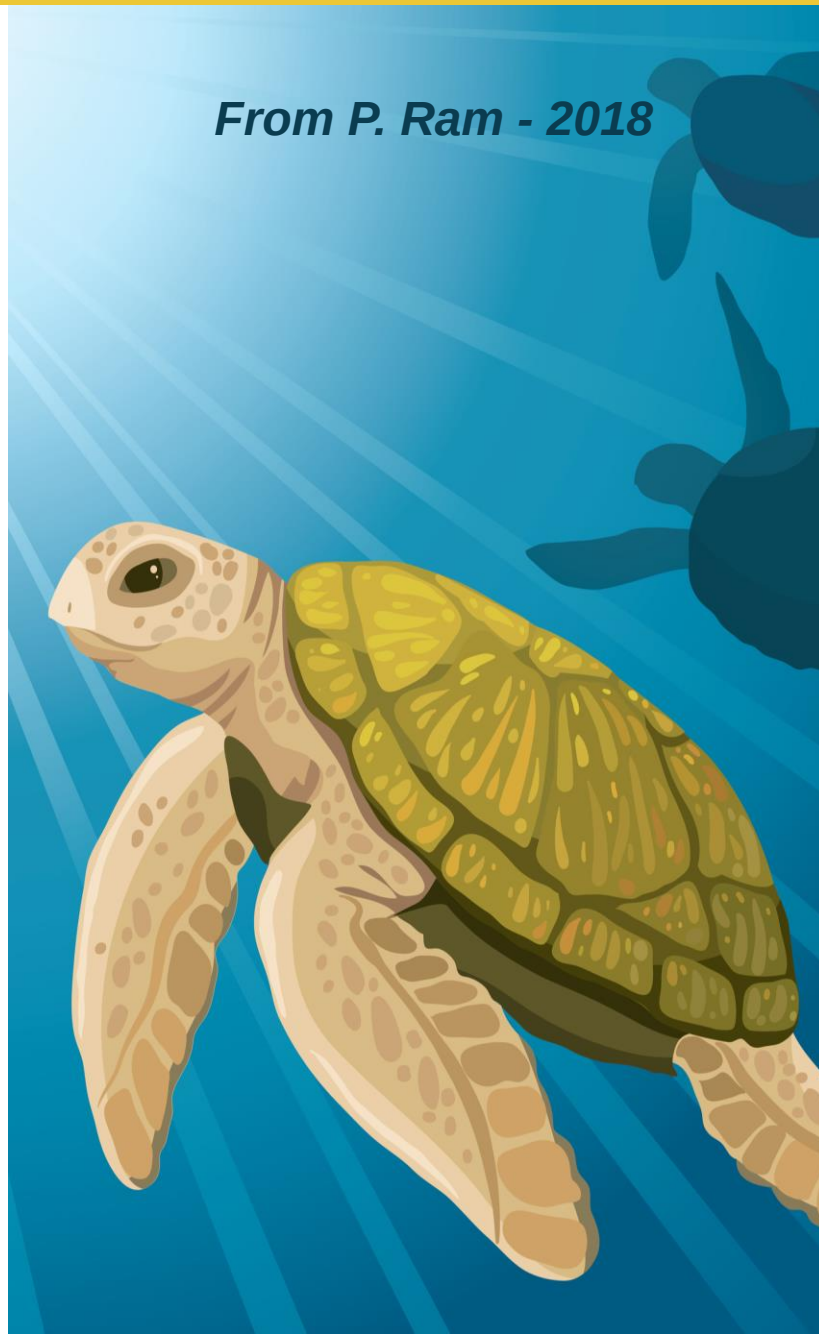
Prototype Extreme Event Visualization



Nazari, 2019

Turtles are Resilient
Be like them

"It is not the strongest that survive, nor the most intelligent, but the ones most responsive to change"
– Charles Darwin



>> cait.rutgers.edu

facebook.com/RutgersCAIT
Instagram user @rutgerscait

Thank you!

TODAY…

Pavement Engineering

Pavement Materials	Classification, quality assurance testing (specifications), material design
Pavement Design	Design of Structural layers for New Pavements and Pavement Rehabilitation Assess in-situ pavement material properties and layer thickness
Pavement Construction	Construction practices of New Pavements and Pavement Rehabilitation including specification development and quality assurance
Pavement Management	**Monitoring Post-construction condition, timing preventive preservation and rehabilitation treatments, and economic analysis of alternatives**
Pavement Research	Research to improve all of the above

The Basic Questions

- Where ?

Where to maintain my road network

- When ?

When should be maintained

- How ?

How it should be maintained

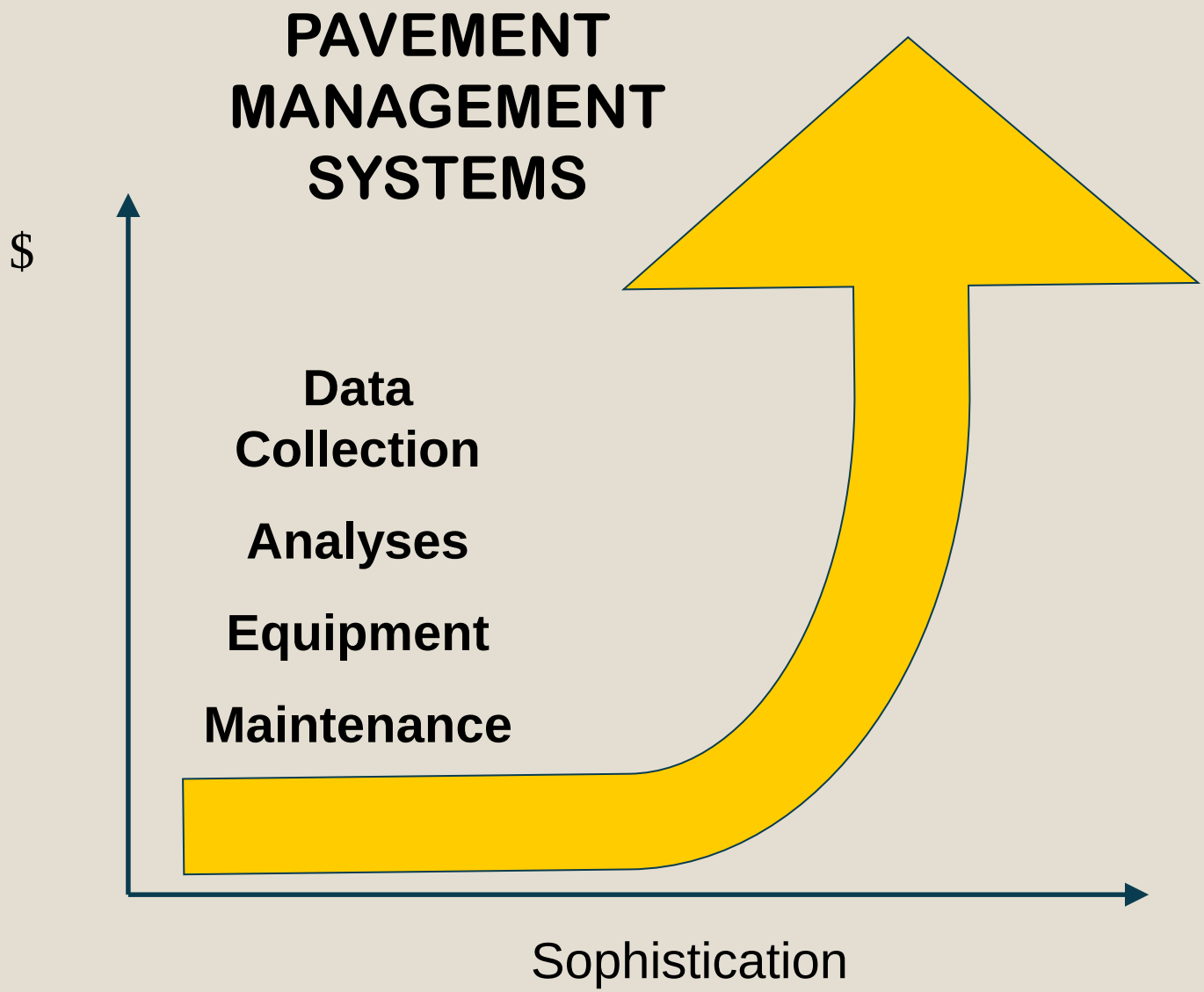
PAVEMENT MANAGEMENT SYSTEM Understanding

A Pavement Management System (PMS) is designed to *provide objective information* and *useful data* for *analysis* so that road managers *can make more consistent, cost-effective, and defensible decisions related to the preservation of a pavement network*.

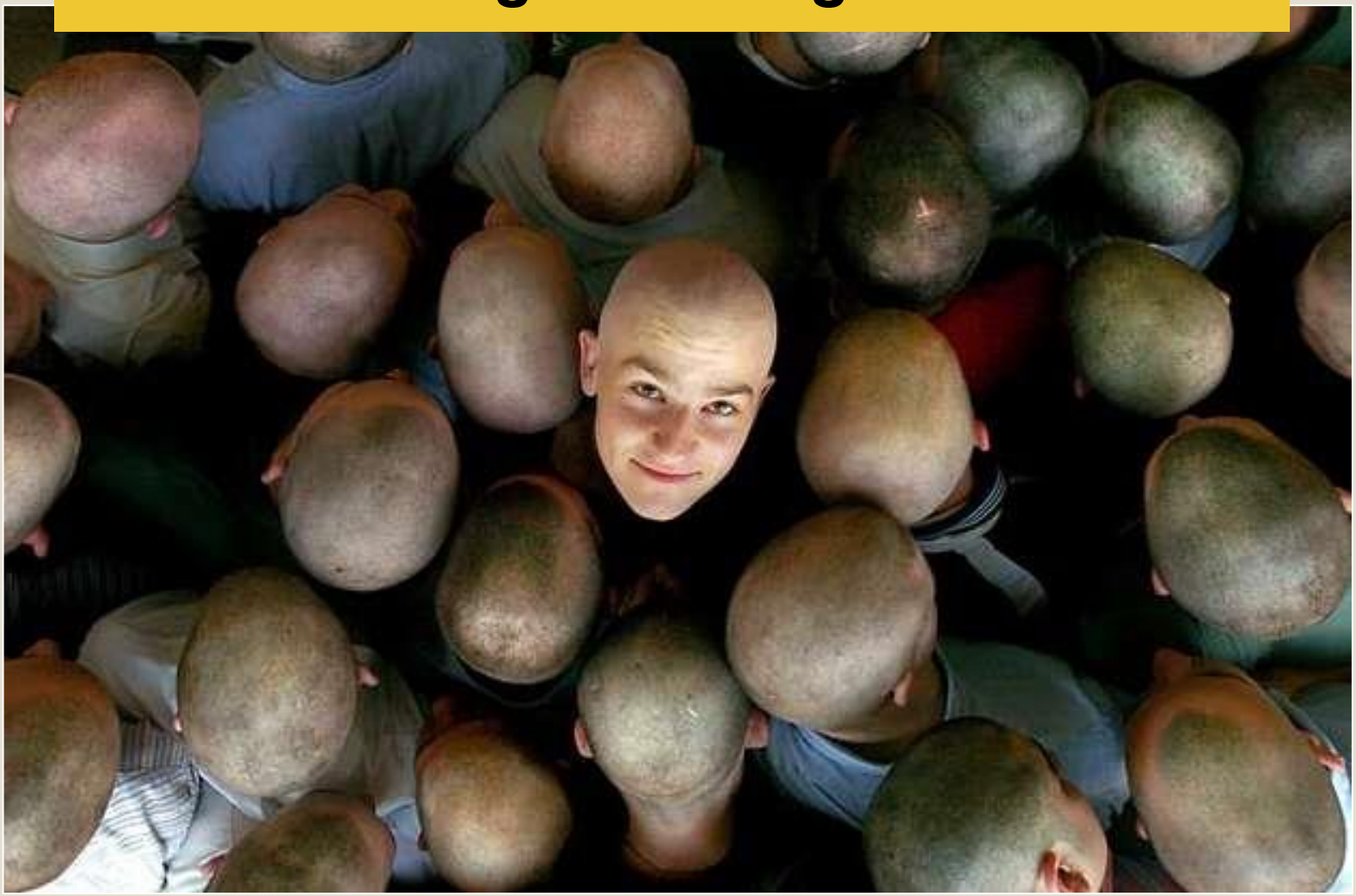
While a PMS cannot make final decisions, it can provide the basis for an informed understanding of the possible consequences of alternative decisions.

"A PMS does NOT make decisions, Managers DO!"

Pavement Management System Overview



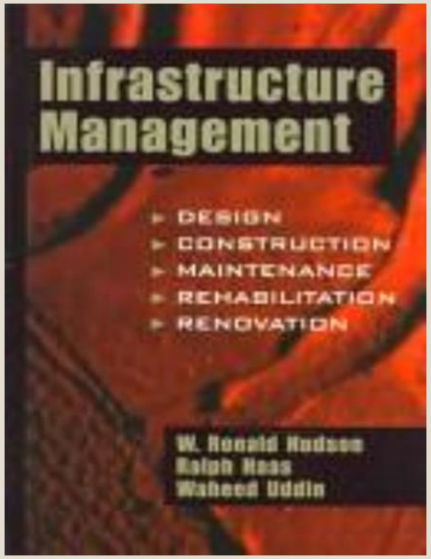
Choosing What's Right for YOU



Definitions

PAVEMENT MANAGEMENT

"Pavement Management is a program for improving the quality and performance of pavements and minimizing costs through good management practices"



Importance of Pavement Management

- Pavements deteriorate over time due to traffic/use, environment, and aging
- Poor road conditions **increase vehicle owner costs $325–$700 annually** (vehicle damage, tire wear, etc.)
  - National average is $333 per motorist totaling $67 billion per year
- Poor road conditions are a **contributing factor in many roadway accidents**
  - According to some studies as much as 30% of crashes each year)
- **Good roads cost less**…
  - If maintained at a reasonable level of service
  - If they receive proper preventative maintenance

Preserving roads in good condition is key to maintaining the health of the National Pavement Network.

November 2019 -Dubai

Implementing an Effective Road Pavement Management System

Hazim M Abdulwahid , MSC, MBA

Importance of Pavement Management

- To preserve our infrastructure value
  - ✓ Key component of the asset Management
- To develop “optimum” pavement preservation and renewal programs
  - ✓ Better Use of Available Resources
- To provide a **level of service** that the user considers appropriate
  - ✓ State of Good Repair

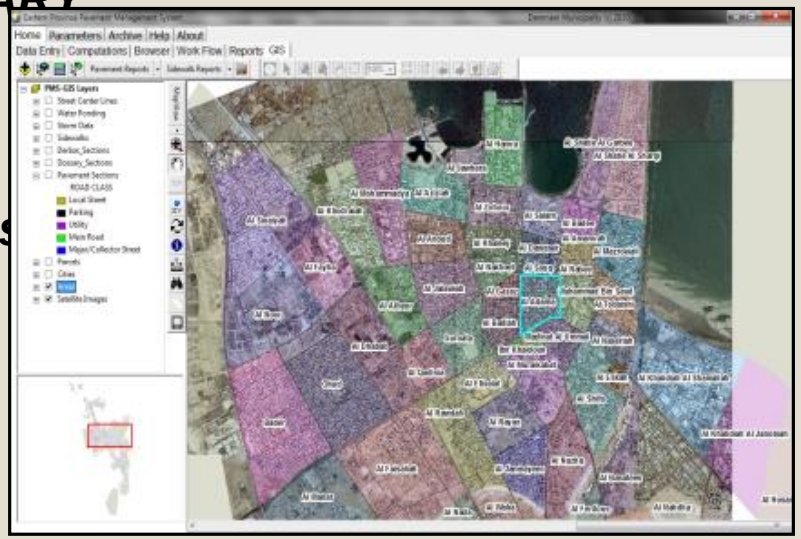
PMS Levels

NETWORK

BIRD'S EYE VIEW OF NETWORK PAVEMENTS AS A WHOLE.

- ***CITYWIDE PAVEMENT CONDITION SUMMARY***
- ***BUDGET ESTIMATE***
- ***PERFORMANCE PREDICTION***

  - ***Establish network budget requirements***
  - ***Allocate funds to network priorities***
  - ***Schedule MR&R actions***

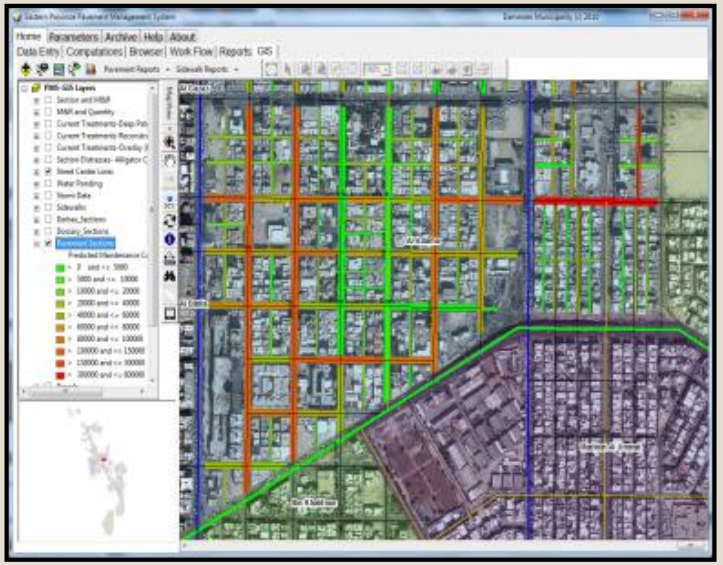


PMS Levels

PROJECT

ASSIST DESIGNERS IN CONSTRUCTING, MAINTAINING, OR REHABILITATING A SECTION OF ROADWAY

- ***PAVEMENT PRESERVATION***
- ***RESURFACING OR RECONSTRUCTION***
- ***TREATMENTS OPTIONS ALONG THE PROJECT***

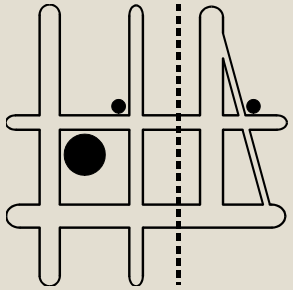


Primary objective is to provide information for <u>specific</u> pavement segments:

- **Preferred Maintenance Rehabilitation & Reconstruction MR&R for each project**
- **MR&R costs**
- **Expected MR&R performance.**

Sophistication

Maps



St Info

Cards

St	Nodes	Age
Main	Birch Oak	8
Jones	Main	3

Spreadsheets

Computer Databases

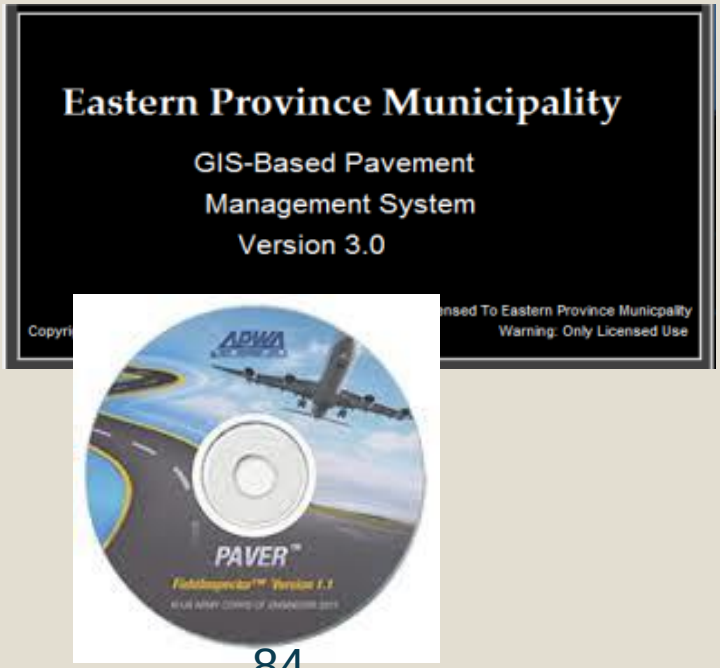
PMS Subsystems

- ***PMS DATA***

  - ***Inventory***
  - ***Condition - Pavement Evaluation***
  - ***History – Initial, Pavement Preservation, Routine Maintenance, Rehabilitation, and Reconstruction***
  - ***Traffic***
  - ***Costs***

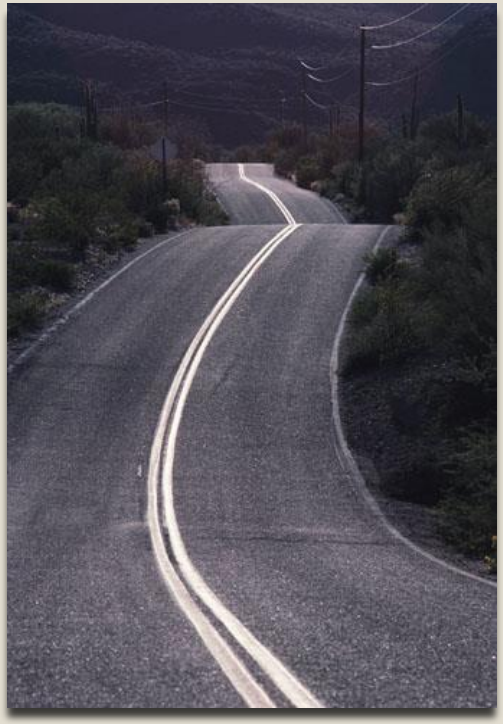
- ***MODELING – ANALYSIS***

  - ***Condition Survey***
  - ***Performance Predictions***
  - ***Performance and Economic Analyses***
    - ***-Budgeting***
    - ***-Programming***



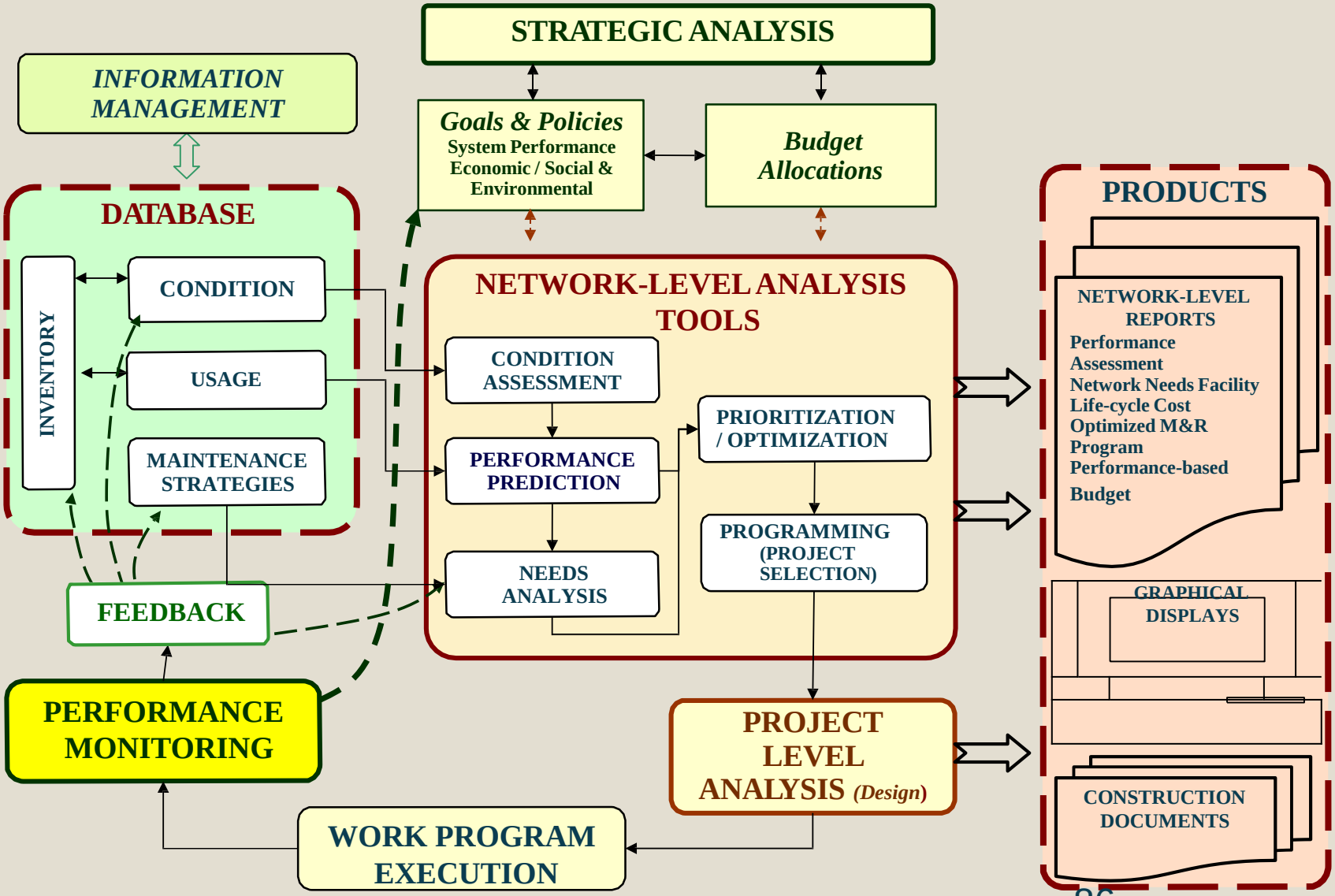
Content

- Introduction
- Pavement Management System Overview
- Inventory & Location Referencing System
- Pavement Condition Survey
- PMS Performance and Economic Analysis
- PMS Implementation
- Case Study
- Conclusion

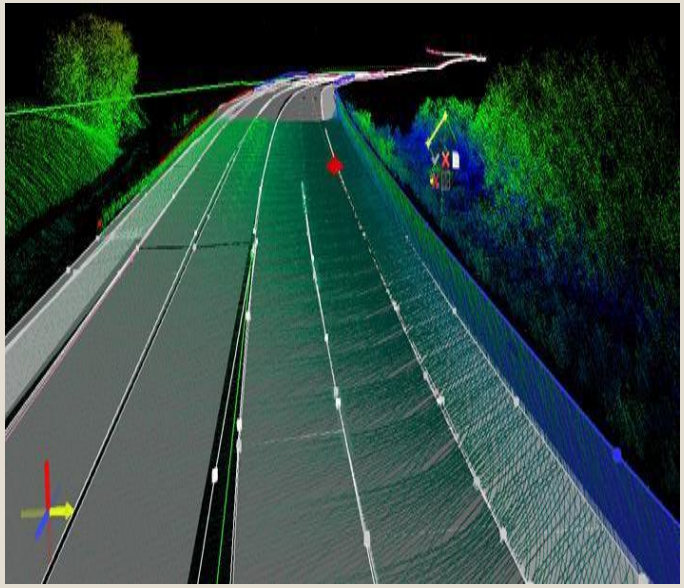


Pavement Management System Overview

Pavement Management as an Asset Management Business Process



3- Inventory & Location Referencing System



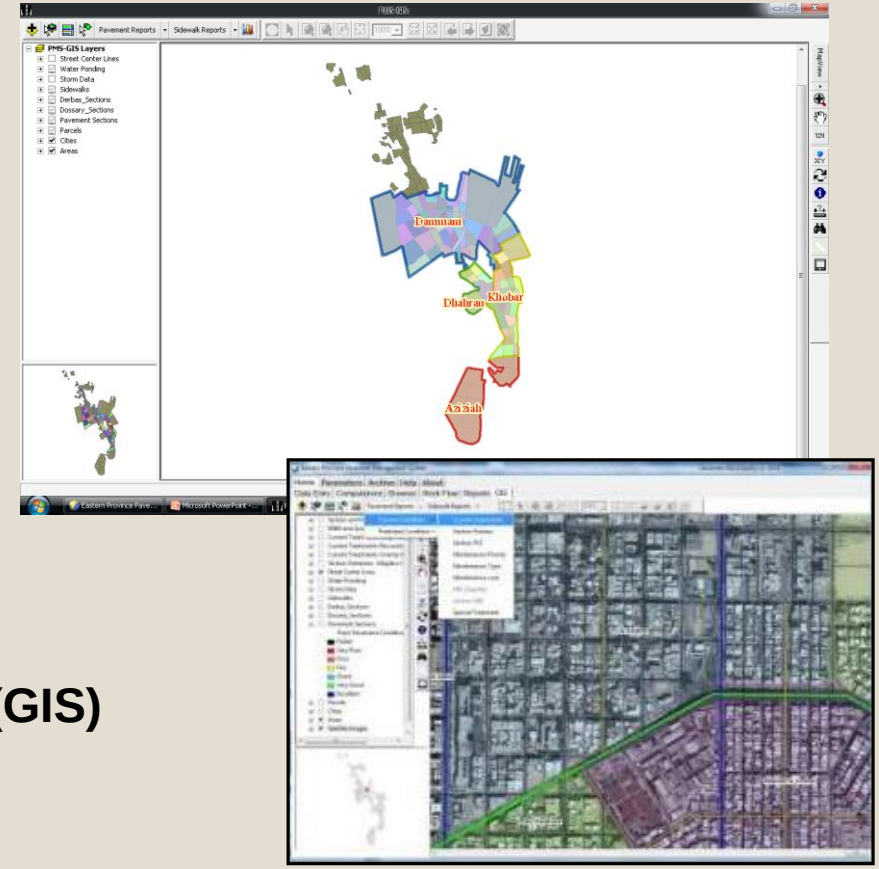
Reference System

Location Referencing Systems

- Mile Point/Mile Post
- Reference Point/Reference Post
- Link Node

Spatial Reference

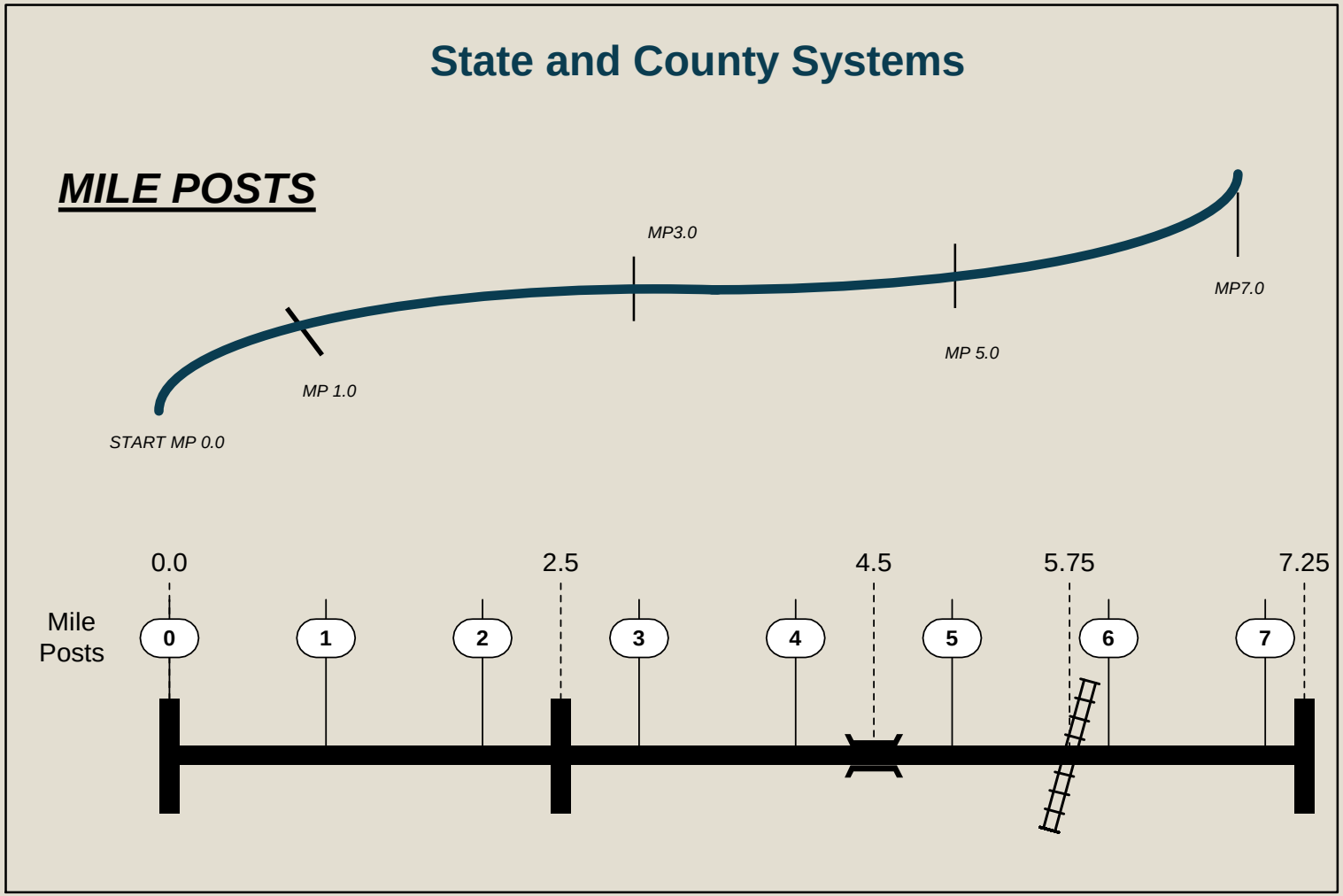
- Global Positioning System (GPS)
- Geographical Information Systems (GIS)



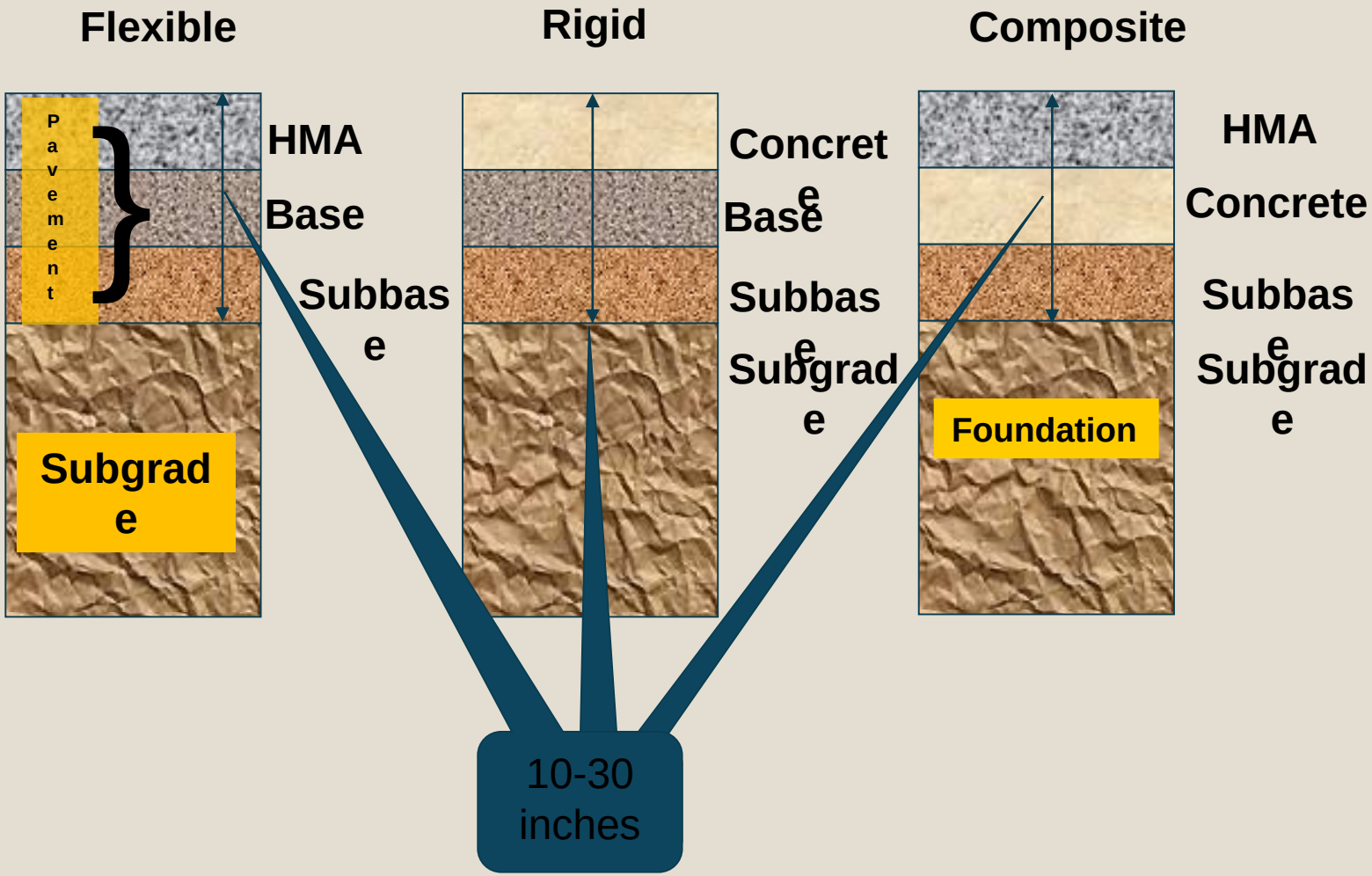
1- Introduction

Linear Referencing Systems

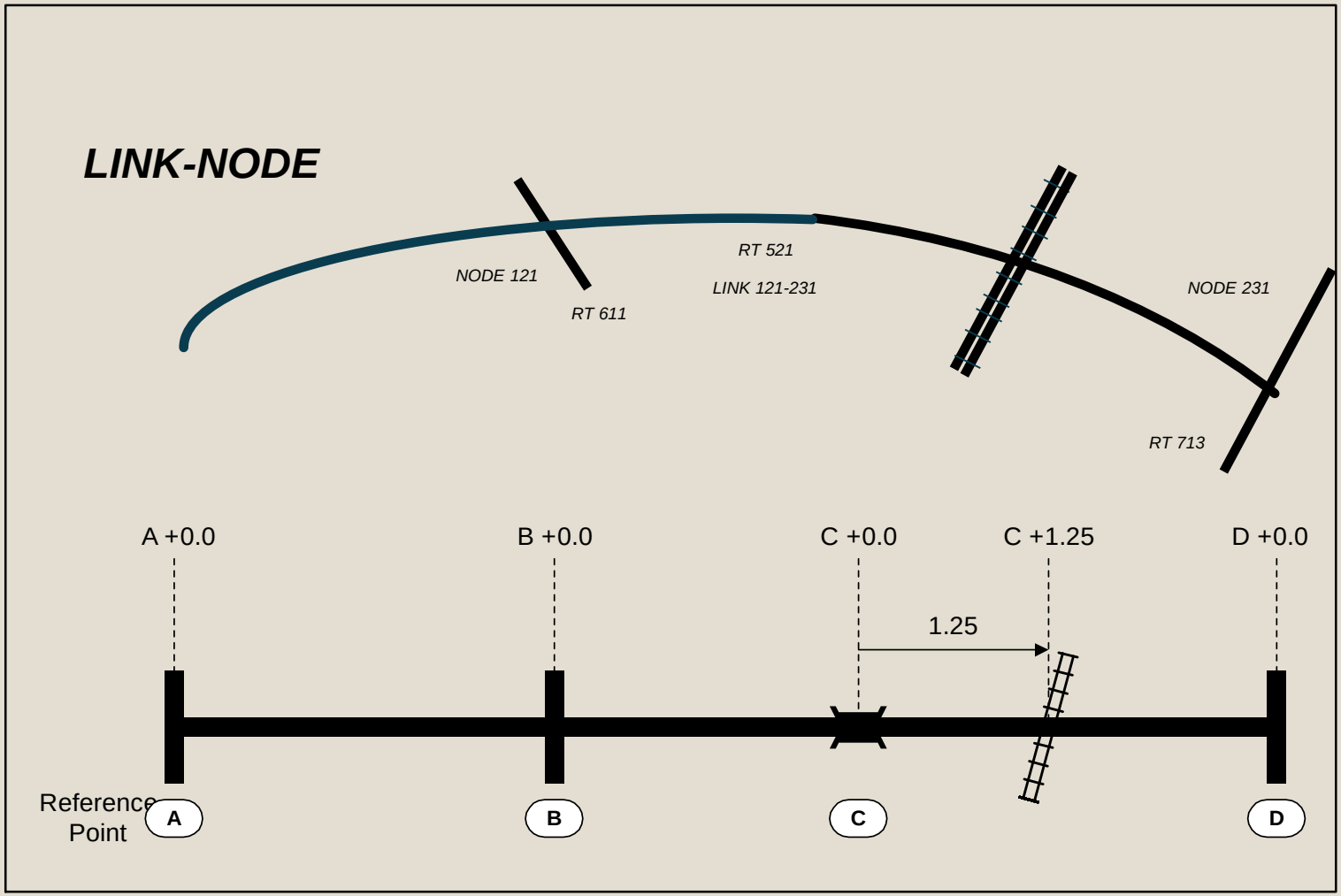
State and County Systems



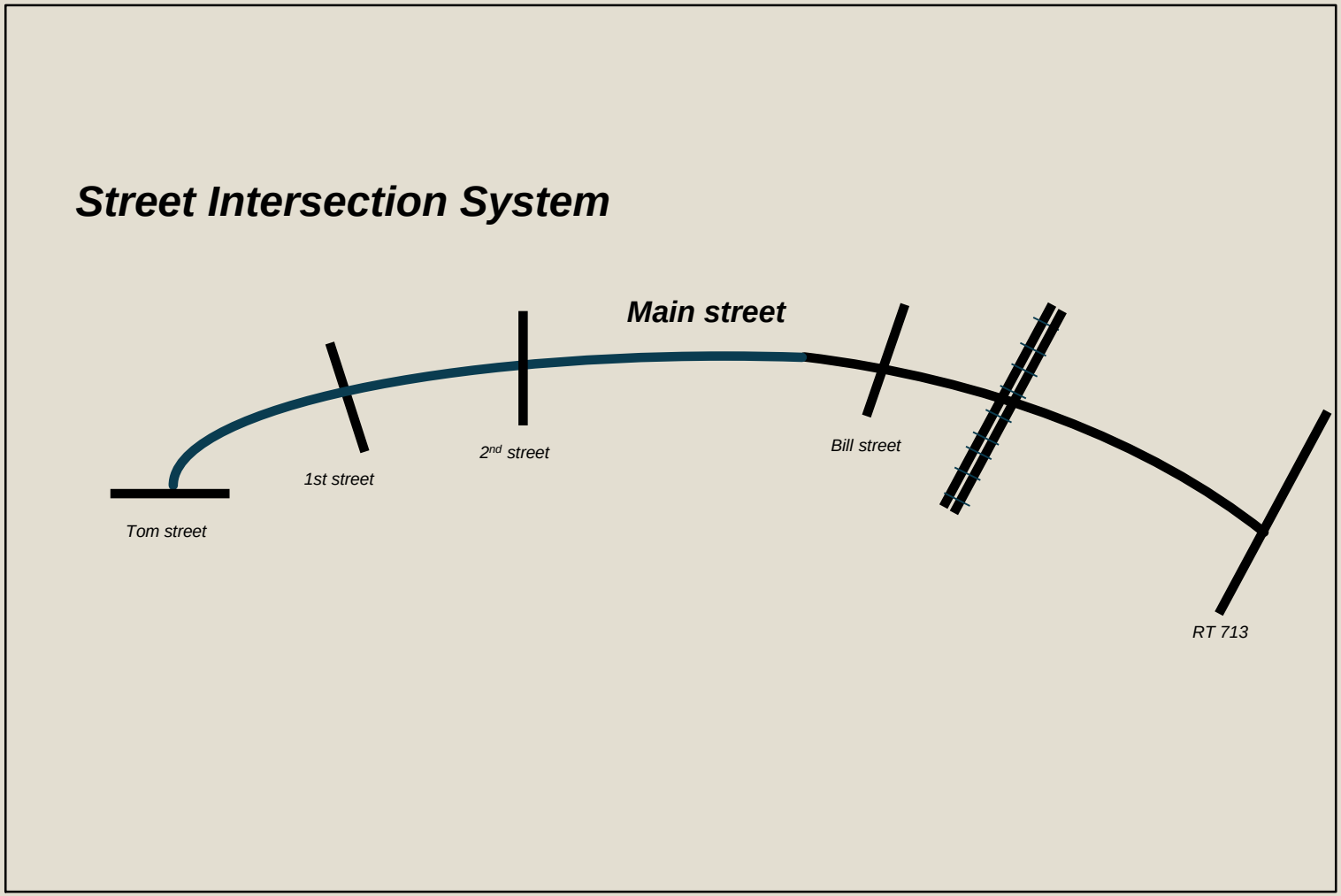
Pavement Structures



Linear Referencing Systems



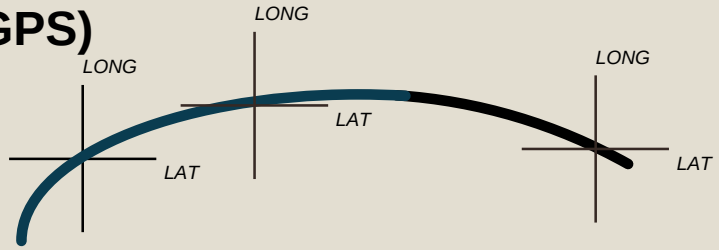
Linear Referencing Systems

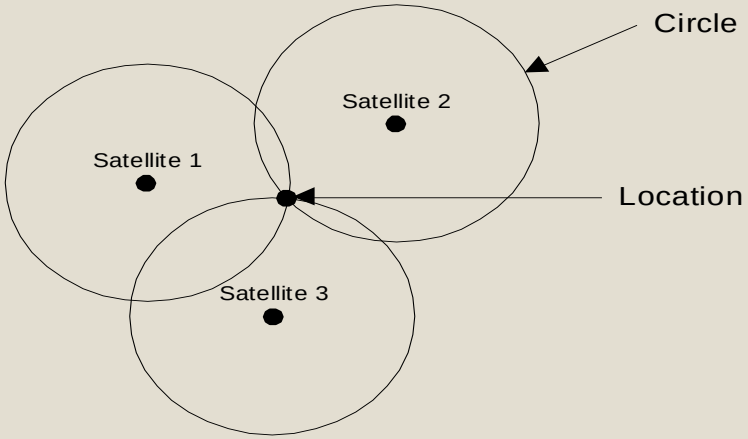


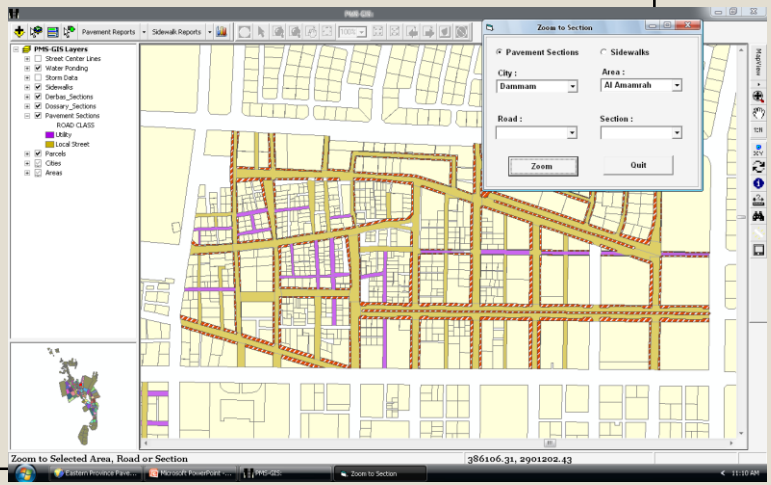
Linear Referencing Systems

Global Positioning System (GPS)

CITY COORDINATE SYSTEM - (GPS/GIS)



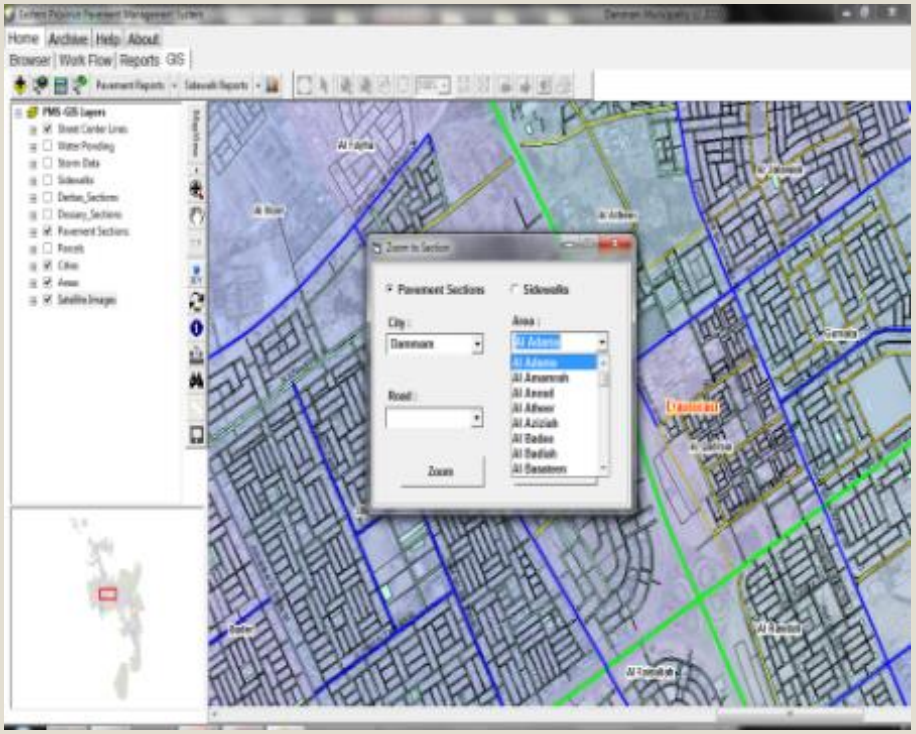




INVENTORY

The Network inventory is used to create a database of all local, collector, and arterial streets under the jurisdiction of the government agency.

This listing provides a basis for contracting, budget development, and annual paving program.



PMS Inventory Data Collection

DATA TYPES :

- INVENTORY,

- TRAFFIC/LOADS,

- COSTS - *Construction, Pavement Preservation, Routine Maintenance, Rehabilitation, Reconstruction*

- HISTORY – *Initial Construction, Pavement Preservation, Routine Maintenance, Rehabilitation and Reconstruction, (Last Treatment)*

PMS Inventory Data Collection

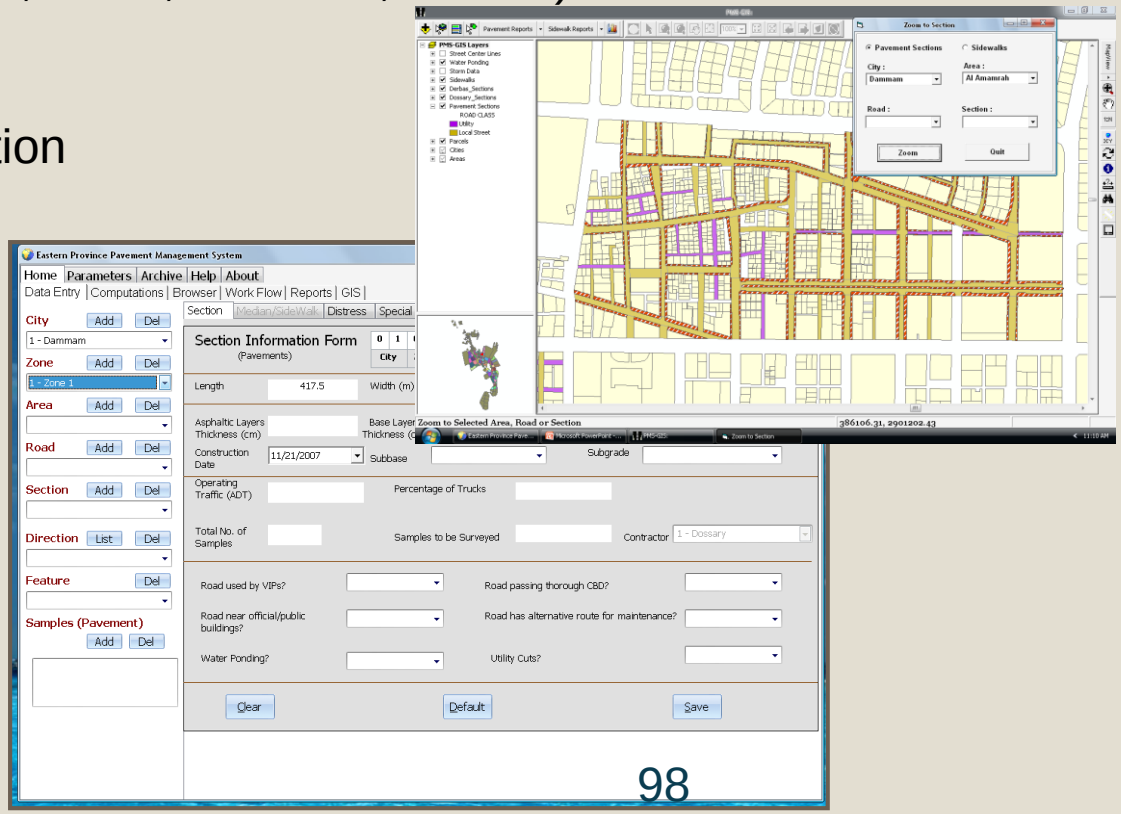
Inventory data is collected by reviewing agency hard-copy files, maps, and databases.

This data should be validated by an agency-wide field review.

Inventory data is more stable than pavement condition data and therefore once determined requires minimal changes in the future.

Example Inventory Data

- Region , City , District
- Route Number
- Route Type (Interstate, US, NJ)
- Functional Class (Urban, Rural, Local, Collector, Arterial)
- Length (from-to)
- Divided/Undivided Route Section
- Pavement Type
- Number of Lanes and Widths
- Shoulder Type and Width



Pavement Analysis Section

Divides the pavement network into sections that can be used for pavement condition survey, performance and economic analysis, and GIS map summaries.

Many GIS for local agencies were developed based on the “block to block” (intersection to intersection) limits. These sections are too short for PMS Analysis Sections.

In most situations, the entire length of the street is used. Where streets are longer than those typically used for a single construction project, the street can be subdivided into two or more shorter sections; each assigned its own PMS Analysis Section number.

Pavement Analysis Section

2. Section Numbering

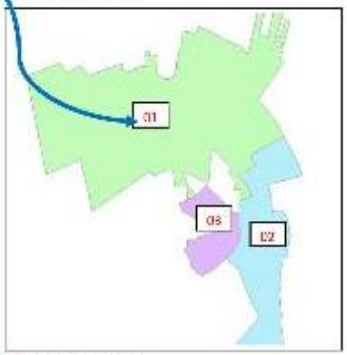
Table 1: Field Description

City		Zone		Area			Road			Section			Direction		Feature	
0	1	0	2	0	1	4	0	2	6	0	0	1	0	1	0	1
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

Example: Section No – **01020140260010101**

- This Section No. represent a section part of road #026 located in area #014 which is loc inside zone #02 of City #01 as shown in details by the following figures

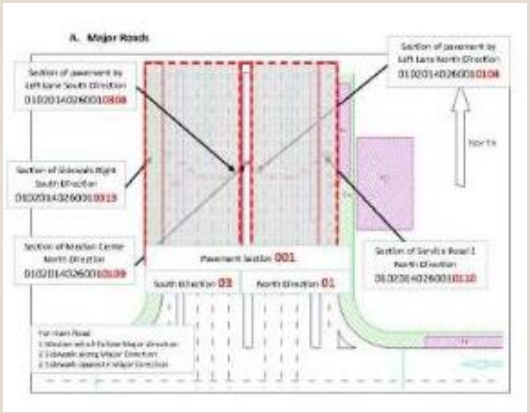
City = 01020140260010101

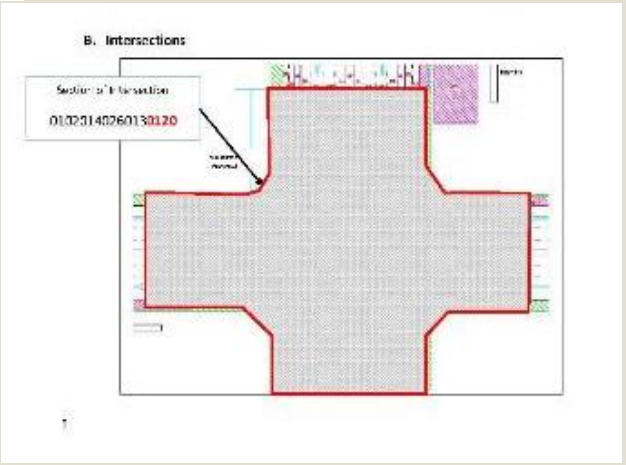


Zone = 01020140260010101

Areas = 01020140260010101

Features and Direction = 01020140260010101



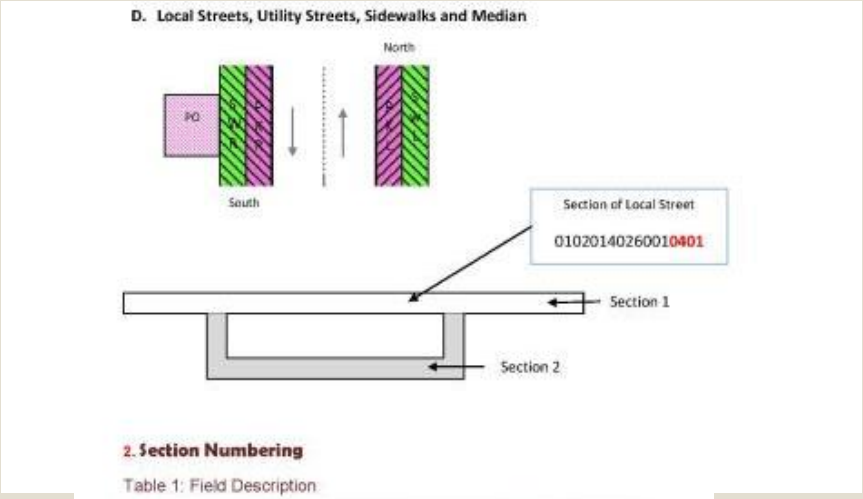


Example Inventory Data

Defining ANALYSIS Sections/Segments

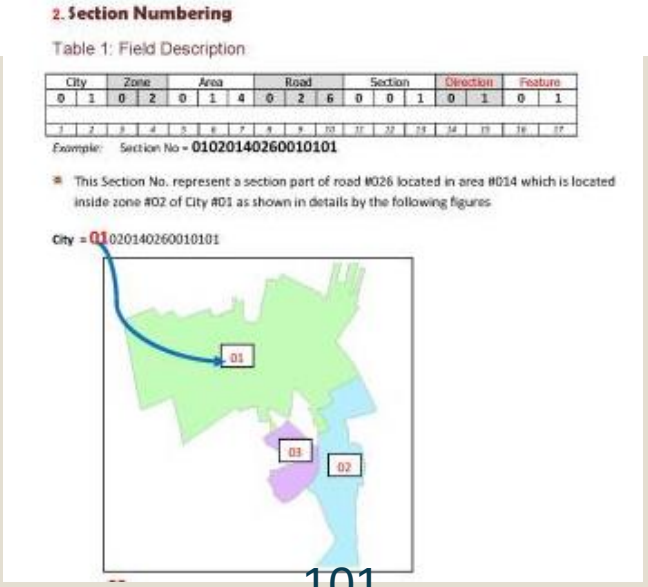
Homogeneous Sections

- Change in pavement type
- Change in pavement structure
- Change in traffic
- Geographical of political boundaries
- Change in pavement condition

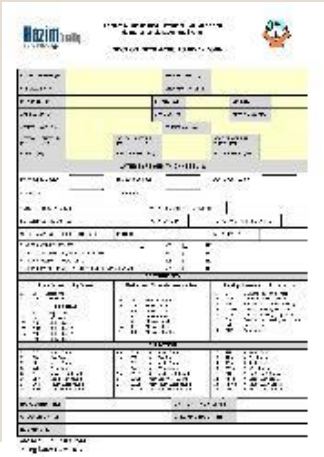


Geographic or man-made boundaries may offer or force section limits:

- Rivers or streams
- City or township limits
- County lines
- Railroad grade crossings
- District, ward, or parish lines



Collecting Inventory Data

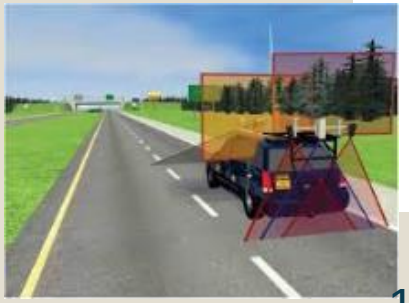


Office: collected on data forms or tabular formats so that a field verification of the inventory can be performed efficiently.

Field: VIDEO OR PHOTOGRAPHIC LOGGING

FIELD SURVEYS

- **Sections in the network**
- **Inventory data collection format**
- **Definition of sections and identification procedures**
- **Structure of inventory database**
- **Prioritized list of data to collect**
- **Prioritized list of roads to be verified**

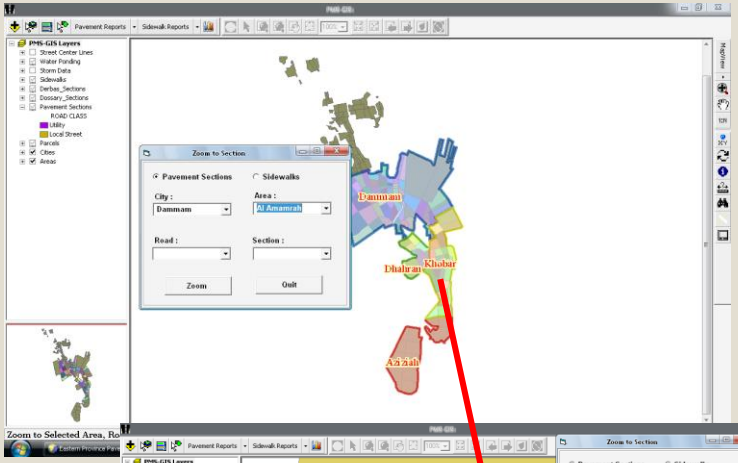


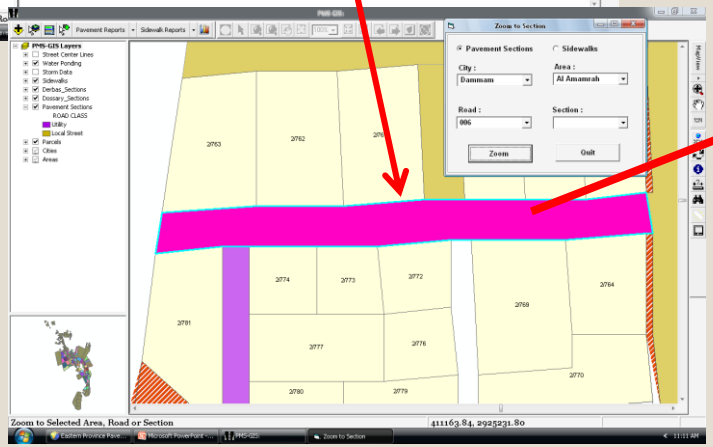
Collecting Inventory Data

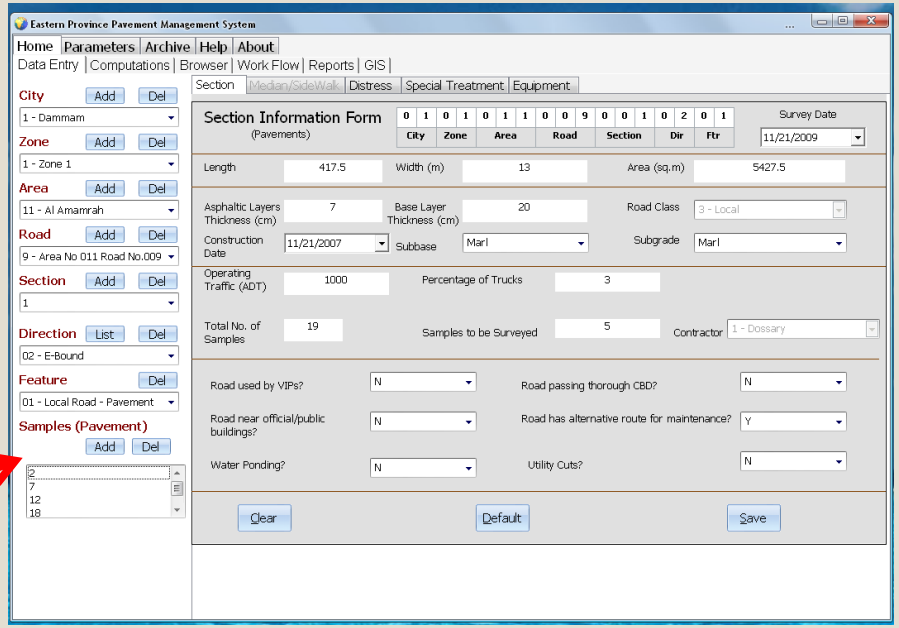
Quality Control

- **Integrity** - whenever two different pieces of data profess to represent the same fact, they must be equal.
- **Accuracy** - the data values represent as close as possible the actual situation at the indicated location and time.
- **Validity** - the given value is correct.
- **Security** - involves two things .
  - ✓ confidential
  - ✓ backups

Collecting Inventory Data



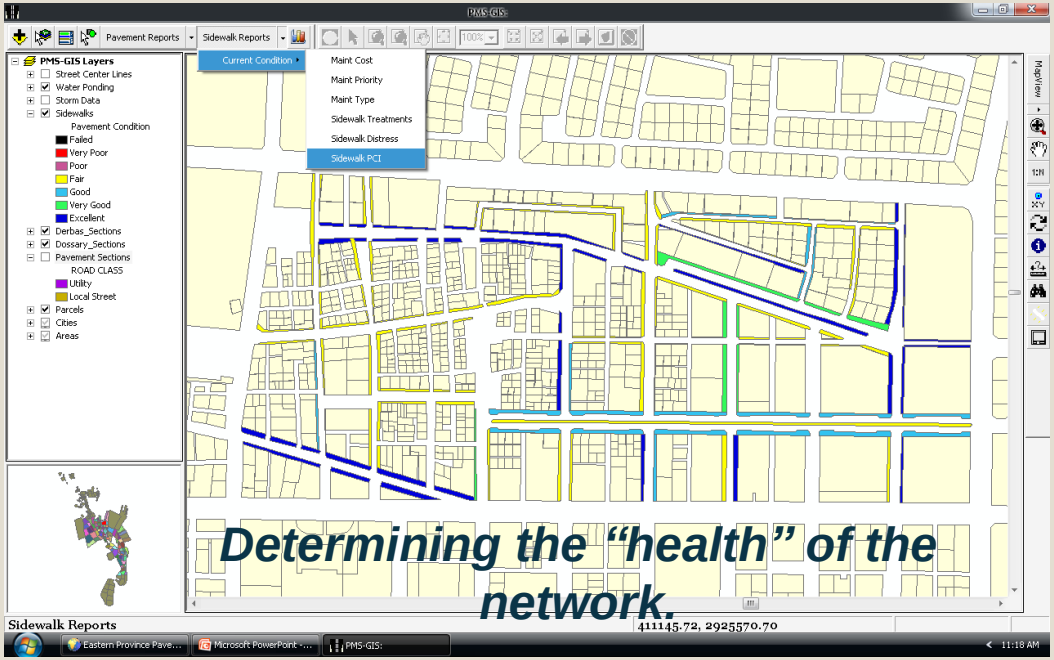




4-Pavement Condition Survey

Condition Data Collection

The Pavement Condition Survey provides a *means of assessing the current pavement condition* of the PMS Analysis Sections and which are in need of pavement preservation, rehabilitation, or reconstruction treatments.



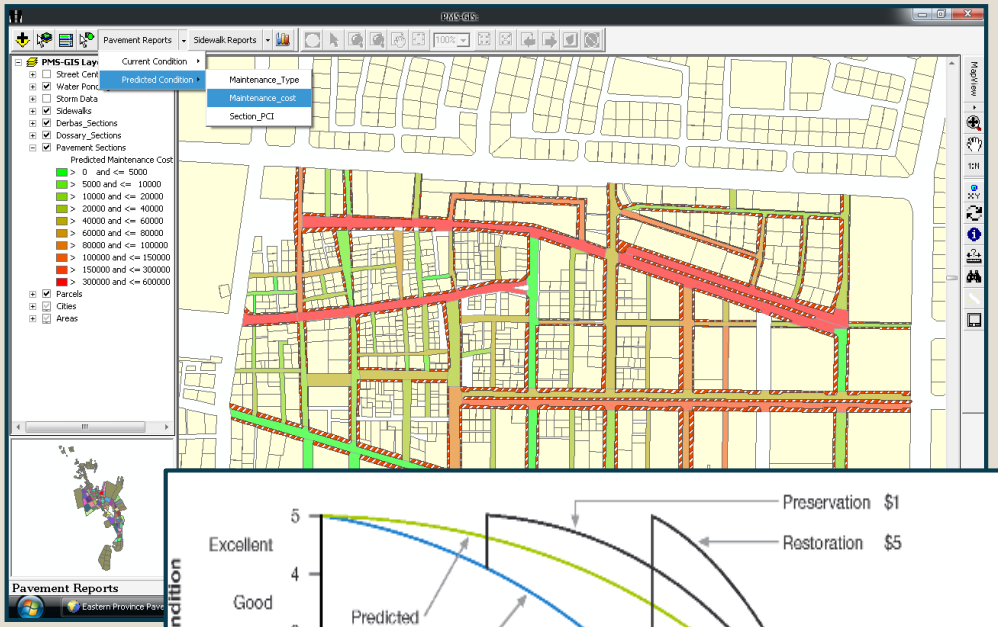
Determining the "health" of the network.

Condition Data Collection

This survey forms the *basis for the performance and economic analysis* which follows.

Pavement Condition surveys provide a rational and consistent method of allocating limited financial resources.

Pavement Condition Surveys are used to assess or describe the state of being, or readiness for use, of those elements being managed.



Condition Data Collection

By Monitoring the Pavement Condition an Agency should be able to:

- Evaluate the current condition of the network.
- Determine the rates of deterioration.
- Project future conditions.
- Determine maintenance and rehabilitation needs.
- Determine the costs of repair.
- Prepare plans for repairs.
- Determine the effects of budget reductions and deferred maintenance.
- Schedule future pavement maintenance activities.
- Track performance of various pavement designs and materials.

Condition Data Collection

- ***SURFACE DISTRESS***
- ***PAVEMENT ROUGHNESS or RIDE QUALITY***
- ***SKID RESISTANCE***
- ***STRUCTURAL CAPACITY***

Pavement Condition Survey Equipment

Profiler

roughness, distress, rutting, noise, pavement cracking

Skid Trailer

Pavement friction

GPR

Layer Thickness

FWD

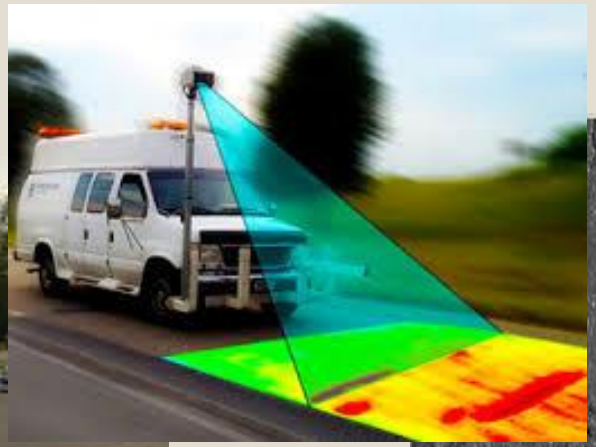
Structural Capacity

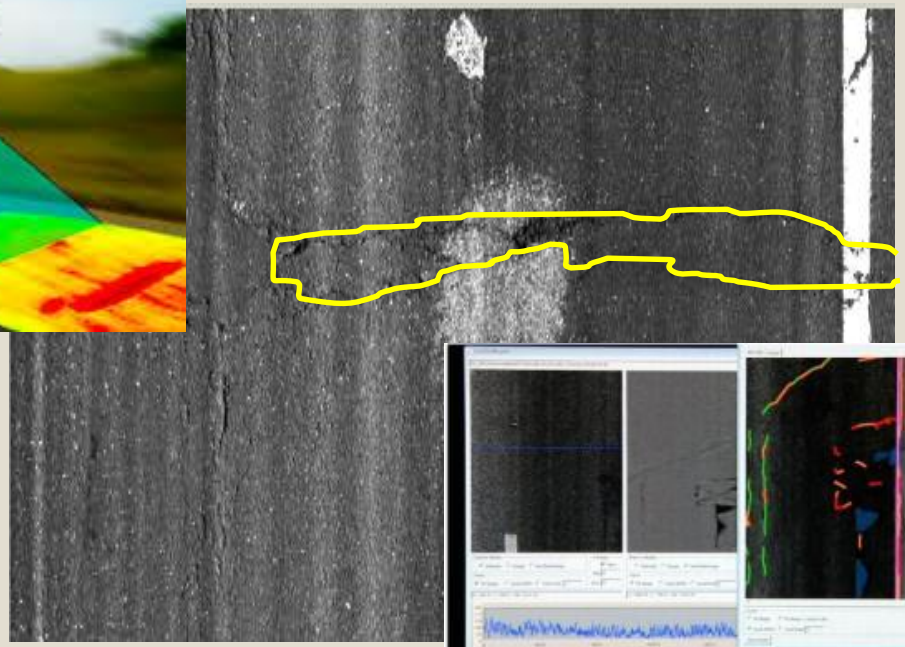
Pavement Condition Evaluation

Surface Distresses

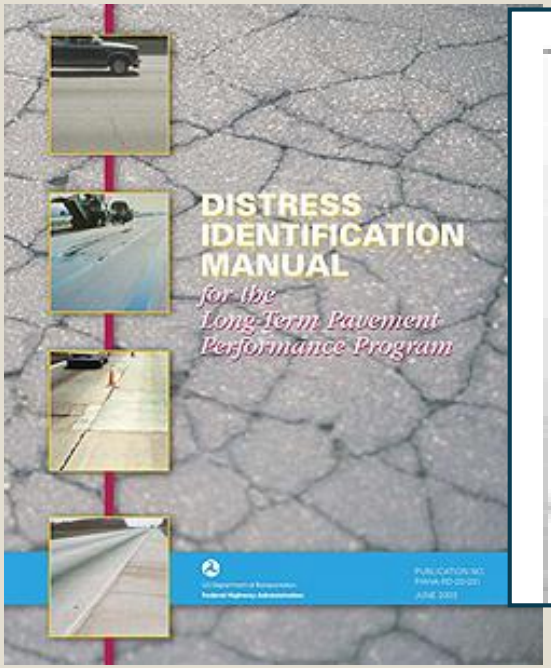
Data Collection

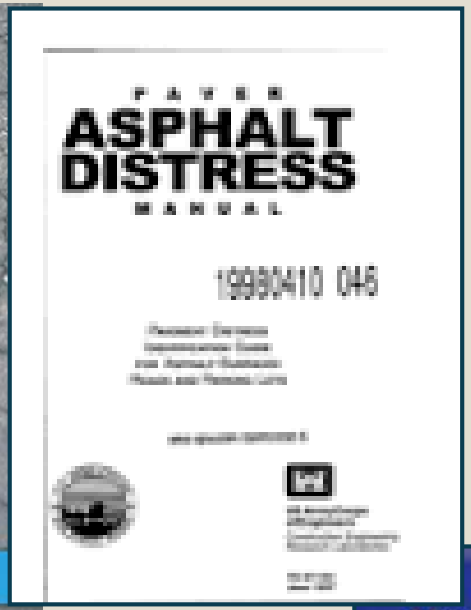
CONTINUOUS – VISUAL INESPECTION SURVEY (COMPUTER RATER KEYBOARD, and CRACK VIDEO)

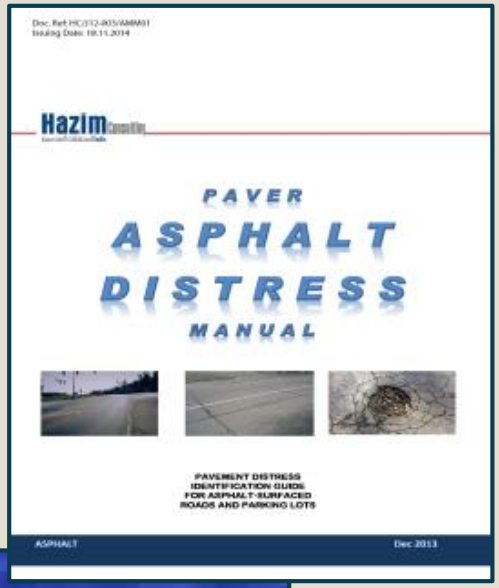


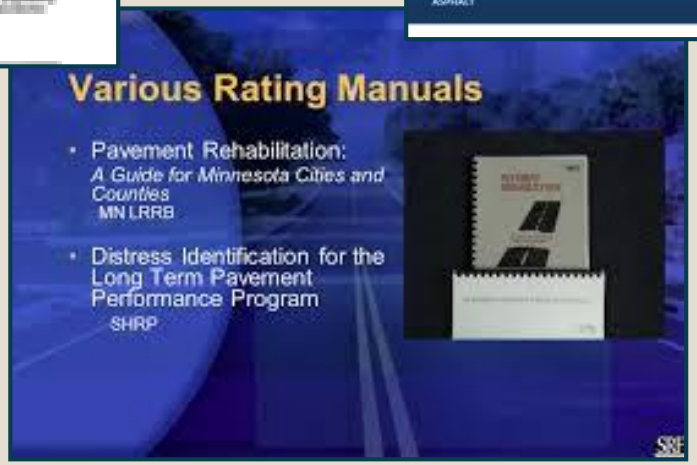


Distress Identification Manual for the Long-Term Pavement Performance Program









Surface Distresses Identification Manual

PCI Distress Classification for Roads and Parking Areas

Code	Distress	Cause
01	Alligator or Fatigue Cracking	Load
02	Bleeding	Other
03	Block Cracking	Climate
04	Bumps and Sags	Other
05	Corrugation	Other
06	Depression	Load
07	Edge Cracking	Climate
08	Joint Reflection	Other
09	Lane/Shoulder Drop-off	Other
10	Longitudinal and Transverse Cracking	Load
11	Patching and Utility Cut Patch	Other
12	Polished Aggregate	Other
13	Potholes	Load
14	Railroad Crossing	Other
15	Rutting	Load
16	Shoving	Load
17	Slippage Cracking	Other
18	Swell	Other
19	Ravelling and Weathering	Climate

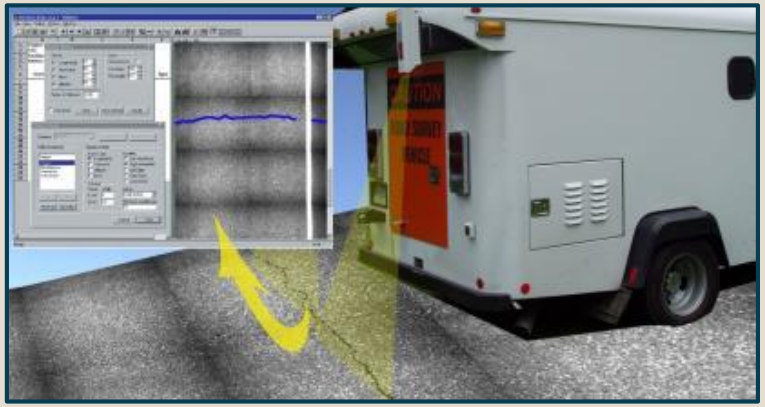
ASTM D6433 - 11

Pavement Condition Evaluations

Surface of the pavement is evaluated manually, or automated equipment to identify:

- ❑ Type of distress
- ❑ Severity.
- ❑ Quantity or extent of distress present on the pavement surface.

- *Type of distress tells us the type of damage*
- *Severity tells how bad the damage is*
- *Quantity gives us the extent of the type and severity of damage that is present.*



Pavement Condition Evaluations

Surface Distress

Bituminous / Composite Pavement

Longitudinal Cracking

Transverse Cracking

Alligator Cracking

Patch Condition

Rutting

Pothole

Pavement Condition Evaluations

Alligator (Fatigue) Cracking Example

Description:

A series of interconnected cracks caused by failure of the base or subgrade to support the HMA layer(s) and fatigue failure of the HMA surface under repeated traffic loading.

Severity Levels:

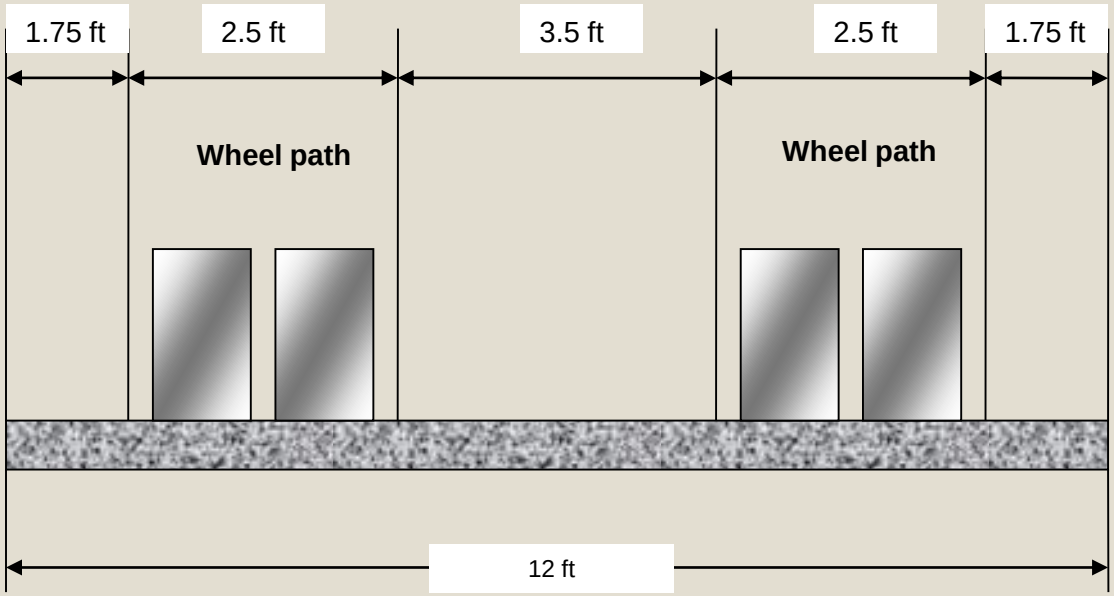
L—Fine, longitudinal hairline cracks running parallel to each other The cracks are not spalled

M—Further development of light alligator cracks into a pattern or network of cracks that may be lightly spalled

H—Network or pattern cracking has progressed so that the pieces are well defined and spalled at the edges.

Pavement Condition Evaluations

SURFACE DISTRESS



LOAD ASSOCIATED vs. Non-LOAD ASSOCIATED LOCATION

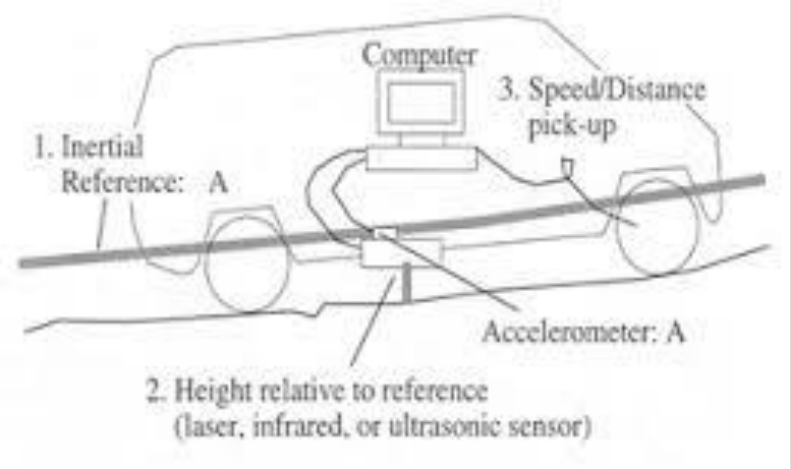
Pavement Condition Evaluations

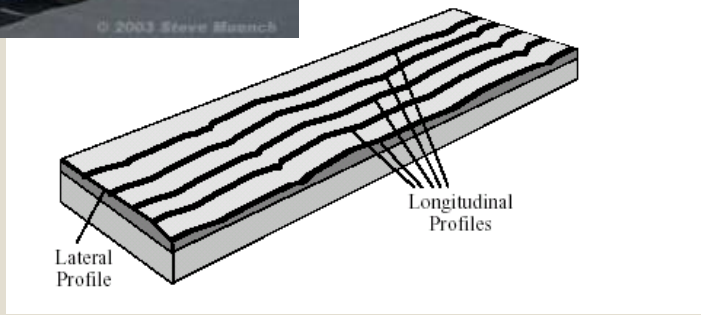
ROAD ROUGHNESS

"ROAD ROUGHNESS IS THE IRREGULARITIES IN THE PAVEMENT SURFACE AFFECTING USER COMFORT AND SAFETY"

DUE TO VARIATIONS IN HORIZONTAL, VERITICAL, AND TRANSVERSE PROFILES

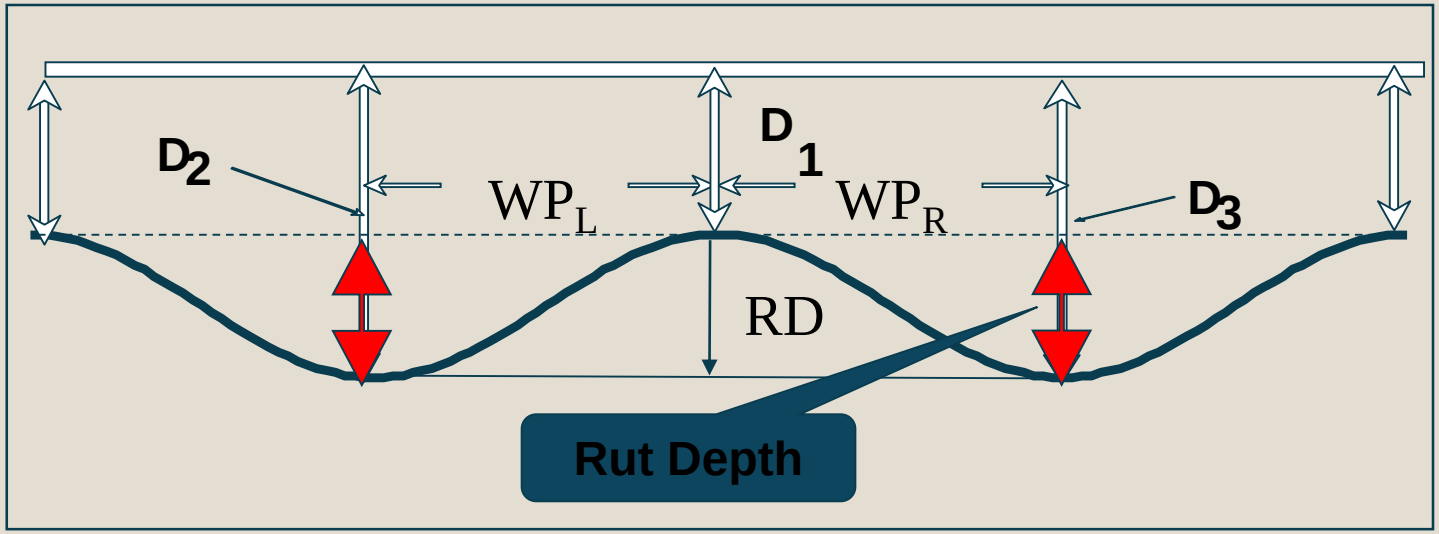
RIDE QUALITY - USER PERCEPTION OF PAVEMENT ROUGHNESS





Pavement Condition Evaluations

Rut Depth Measurement



Severity Levels (Mean Rut Depth):

L—6 to 13 mm (0.2 to 0.5 in.).
M—>13 to 25 mm 0.5 to 1 in.)
H—>25 mm (>1 in.)

Pavement Condition Evaluations

SKID RESISTANCE

SAFETY

DESCRIPTION

ASSESSMENT OF THE COEFFICIENT OF FRICTION OF THE WET PAVEMENT SURFACE (BASED ON SPEED)

DATA COLLECTION

CONTINUOUS - ASTM E274 (LOCK WHEEL) SKID TRAILER

Pavement Condition Evaluations

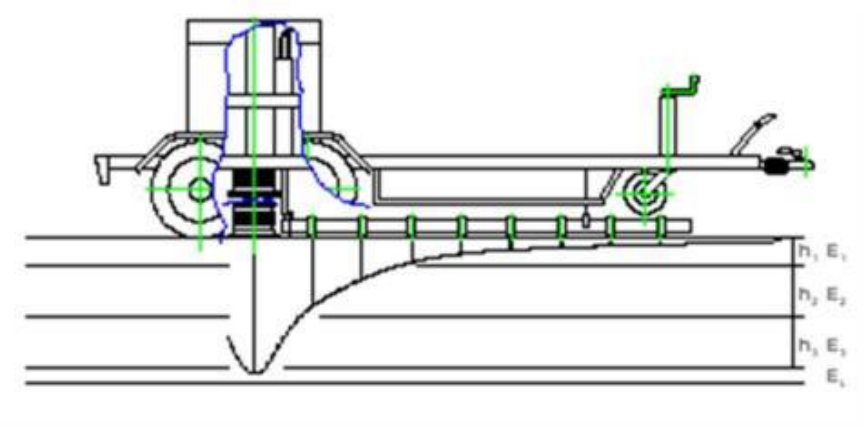
Structural Integrity

DESCRIPTION

ASSESSMENT OF THE THE LOAD CARRYING CAPACITY

DATA COLLECTION

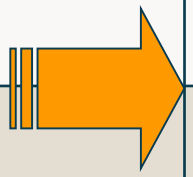
Deflection Data – Falling Weight Deflect meter



Condition Surveys
Ride Quality, Surface Distress, Rutting

Pavement Indices

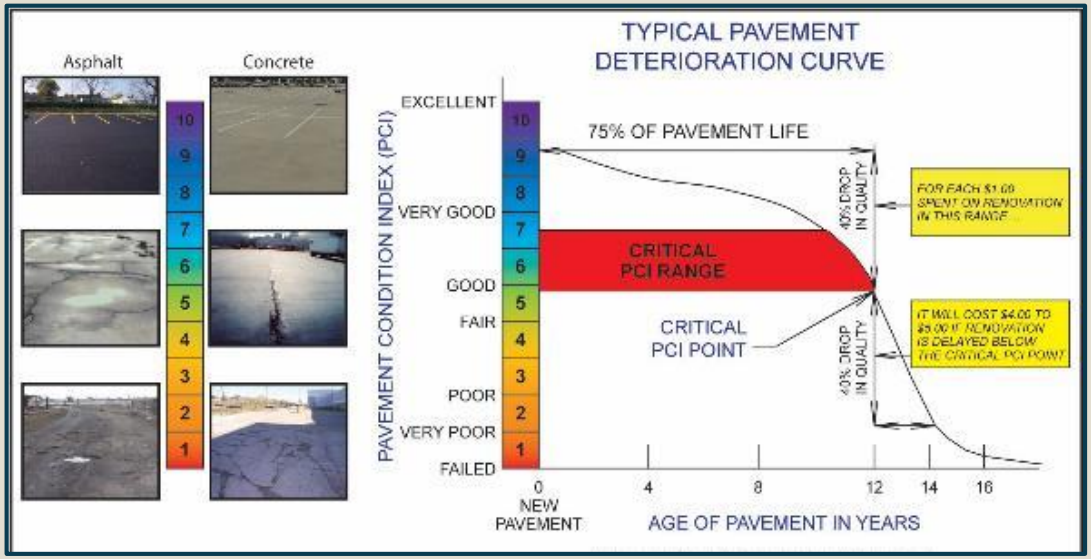
Pavement Wheel Path Profile	Ride Quality Index IRI
Pavement Surface Distresses	Surface Distress Index
Skid Resistance	Skid Number
Structural Capacity Deflections	Structural Capacity Index



Converts collected data to single value

Pavement Condition Index

The Pavement Condition Index (PCI) is a numerical index between 0 and 100 which is used to indicate the general condition of a pavement.



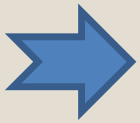
ASTM Standardized:

- *ASTM D6433 - 11: Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys*

- *ASTM D5340 - 11: Standard Test Method for Airport Pavement Condition Index Surveys*

Pavement Condition Index

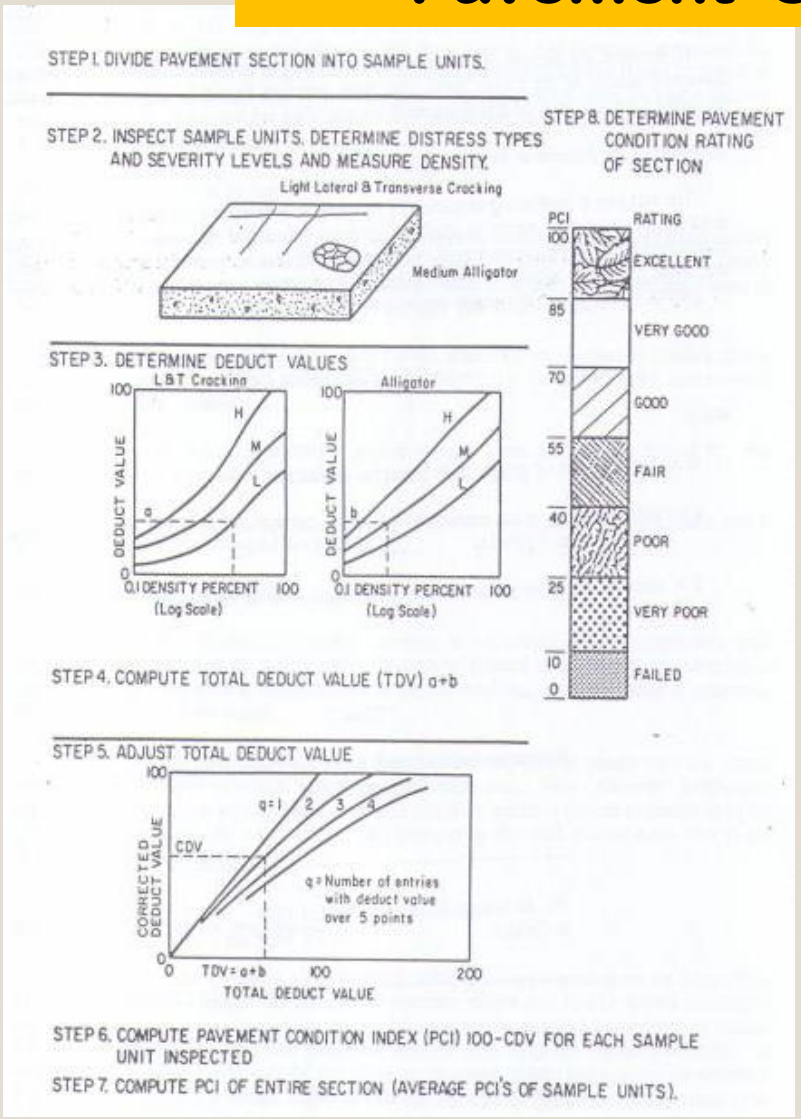
Main Street		
Distress	Severity	Extent
Long/Transverse Crack	Mod	20%
Fatigue Crack	Slight	10%
Raveling	Slight	80%
Patching	Severe	2%
Rutting	None	

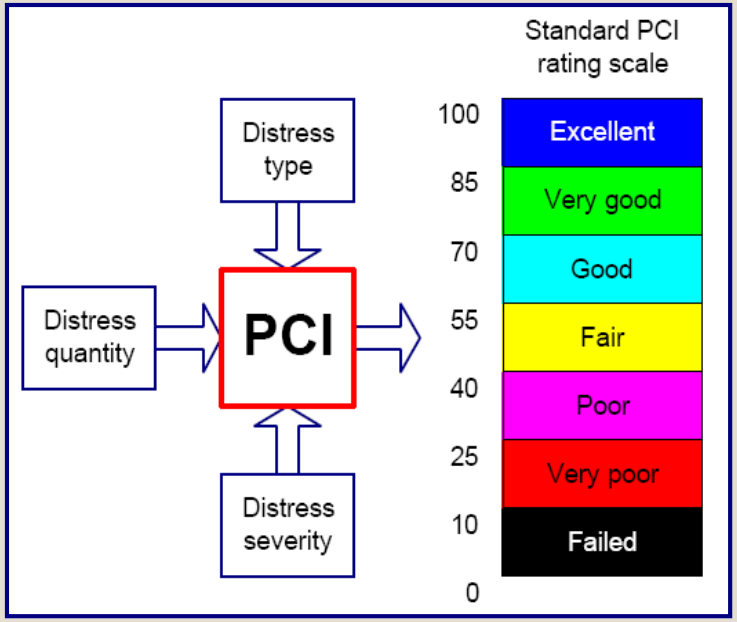


Section PCI Value

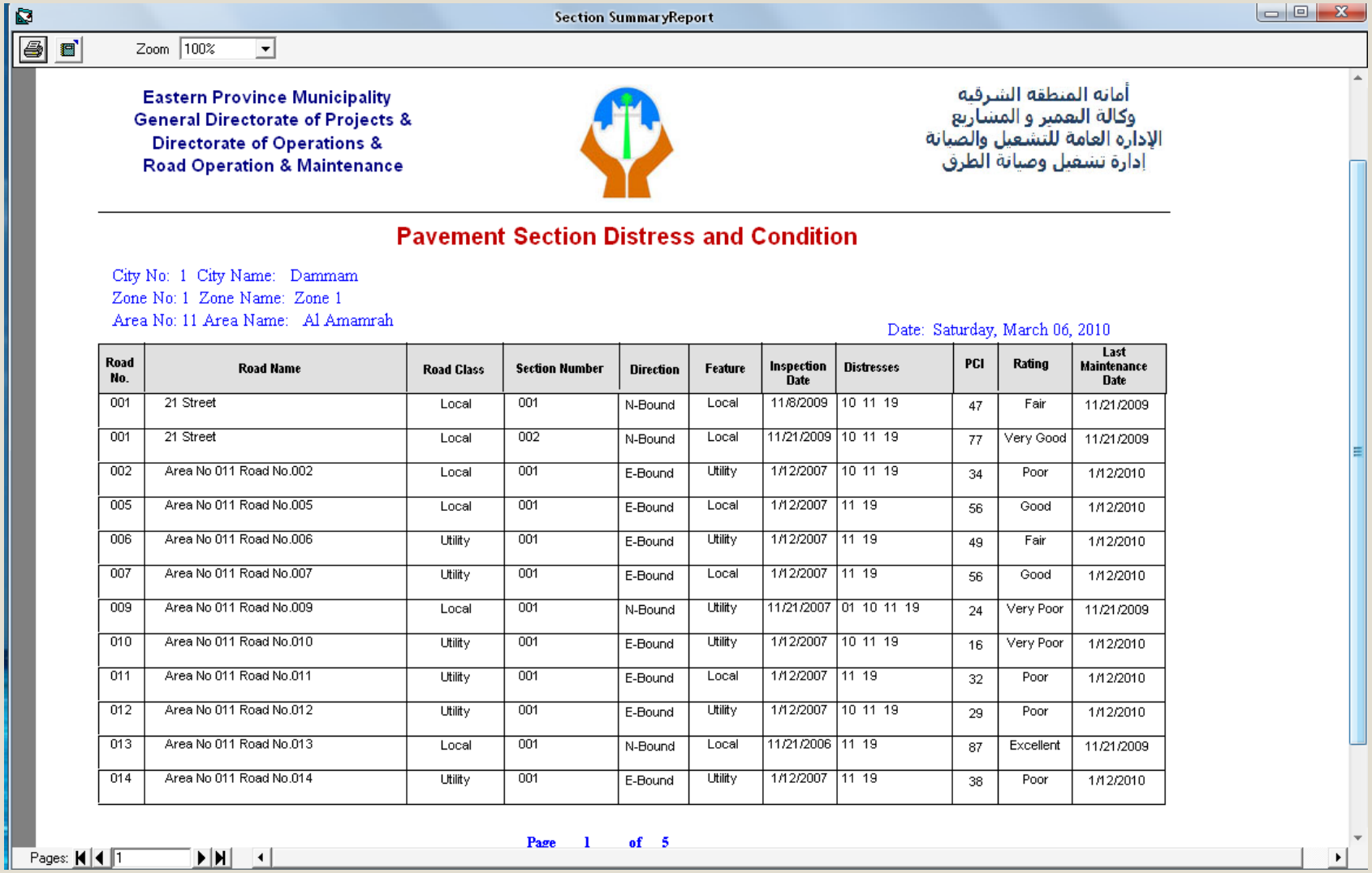
Pavement Condition Index Converts multiple distresses into a single value for the pavement segment /section

Pavement Condition Index





Pavement Condition Index



Section SummaryReport

Zoom 100%

Eastern Province Municipality
General Directorate of Projects &
Directorate of Operations &
Road Operation & Maintenance

أمانه المنطقه الشرقيه
وكالة التعمير و المشاريع
الإداره العامة للتشغيل والصيانة
إدارة تشغيل وصيانة الطرق

Pavement Section Distress and Condition

City No: 1 City Name: Dammam
Zone No: 1 Zone Name: Zone 1
Area No: 11 Area Name: Al Amamrah

Date: Saturday, March 06, 2010

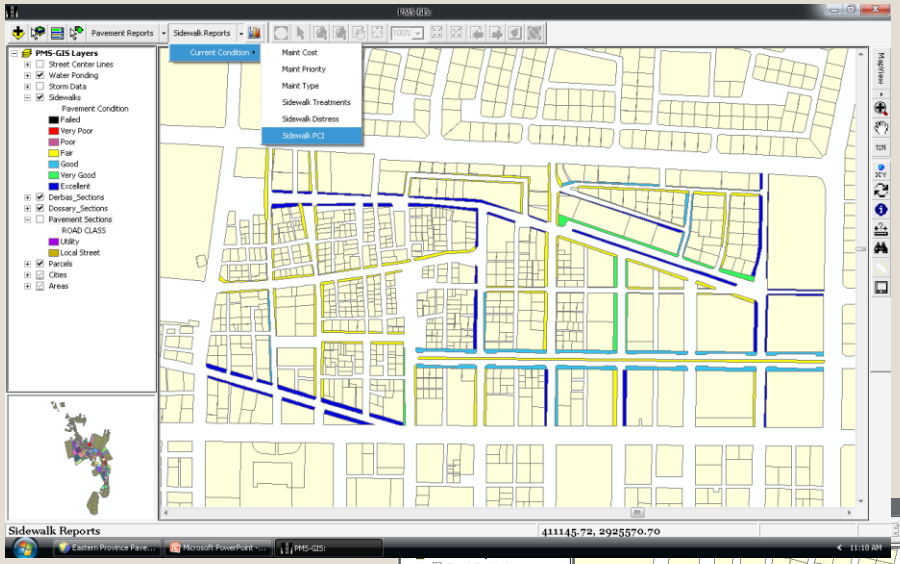
Road No.	Road Name	Road Class	Section Number	Direction	Feature	Inspection Date	Distresses	PCI	Rating	Last Maintenance Date
001	21 Street	Local	001	N-Bound	Local	11/8/2009	10 11 19	47	Fair	11/21/2009
001	21 Street	Local	002	N-Bound	Local	11/21/2009	10 11 19	77	Very Good	11/21/2009
002	Area No 011 Road No.002	Local	001	E-Bound	Utility	1/12/2007	10 11 19	34	Poor	1/12/2010
005	Area No 011 Road No.005	Local	001	E-Bound	Local	1/12/2007	11 19	56	Good	1/12/2010
006	Area No 011 Road No.006	Utility	001	E-Bound	Utility	1/12/2007	11 19	49	Fair	1/12/2010
007	Area No 011 Road No.007	Utility	001	E-Bound	Local	1/12/2007	11 19	56	Good	1/12/2010
009	Area No 011 Road No.009	Local	001	N-Bound	Utility	11/21/2007	01 10 11 19	24	Very Poor	11/21/2009
010	Area No 011 Road No.010	Utility	001	E-Bound	Utility	1/12/2007	10 11 19	16	Very Poor	1/12/2010
011	Area No 011 Road No.011	Utility	001	E-Bound	Local	1/12/2007	11 19	32	Poor	1/12/2010
012	Area No 011 Road No.012	Utility	001	E-Bound	Utility	1/12/2007	10 11 19	29	Poor	1/12/2010
013	Area No 011 Road No.013	Local	001	N-Bound	Local	11/21/2006	11 19	87	Excellent	11/21/2009
014	Area No 011 Road No.014	Utility	001	E-Bound	Utility	1/12/2007	11 19	38	Poor	1/12/2010

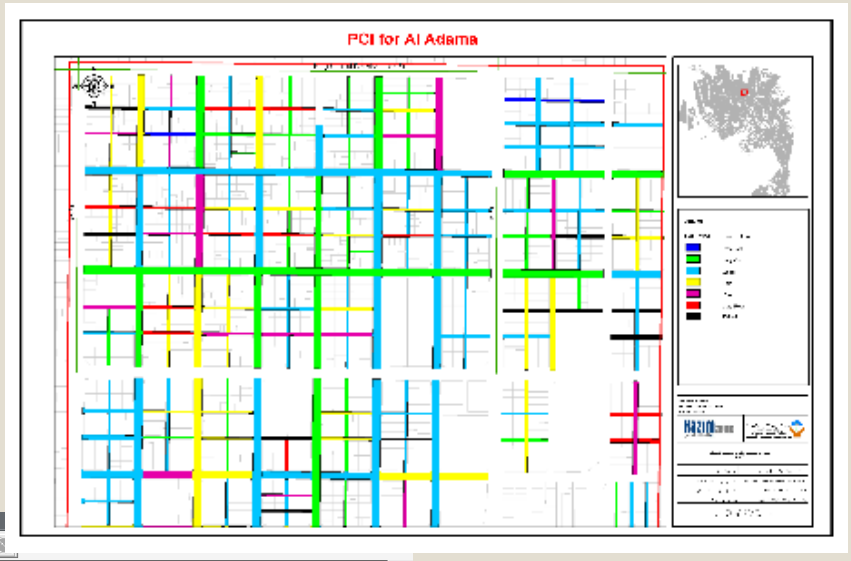
Page 1 of 5

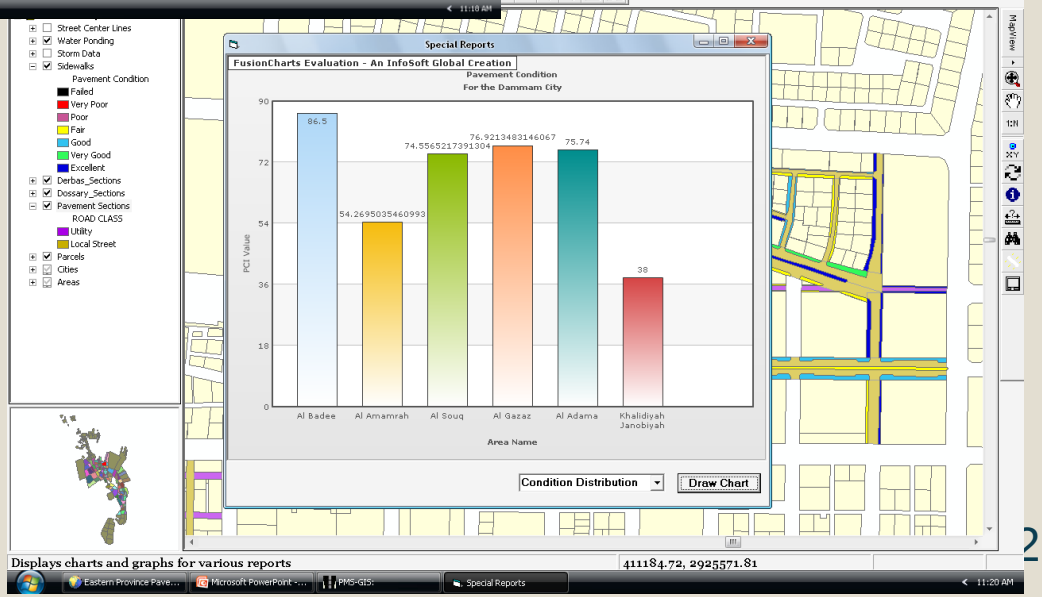
Pages: 1

Pavement Condition Survey

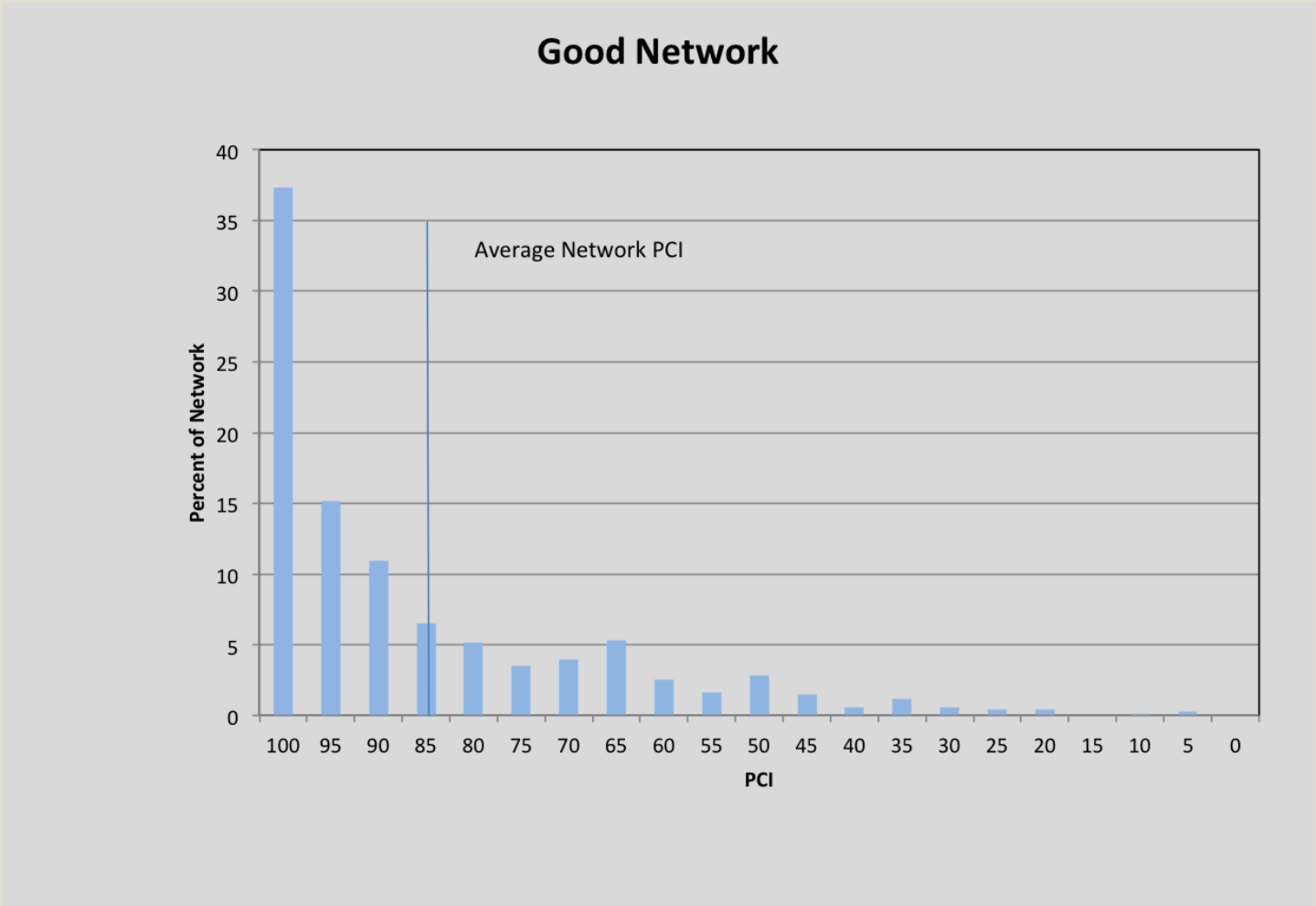
Pavement Condition Index



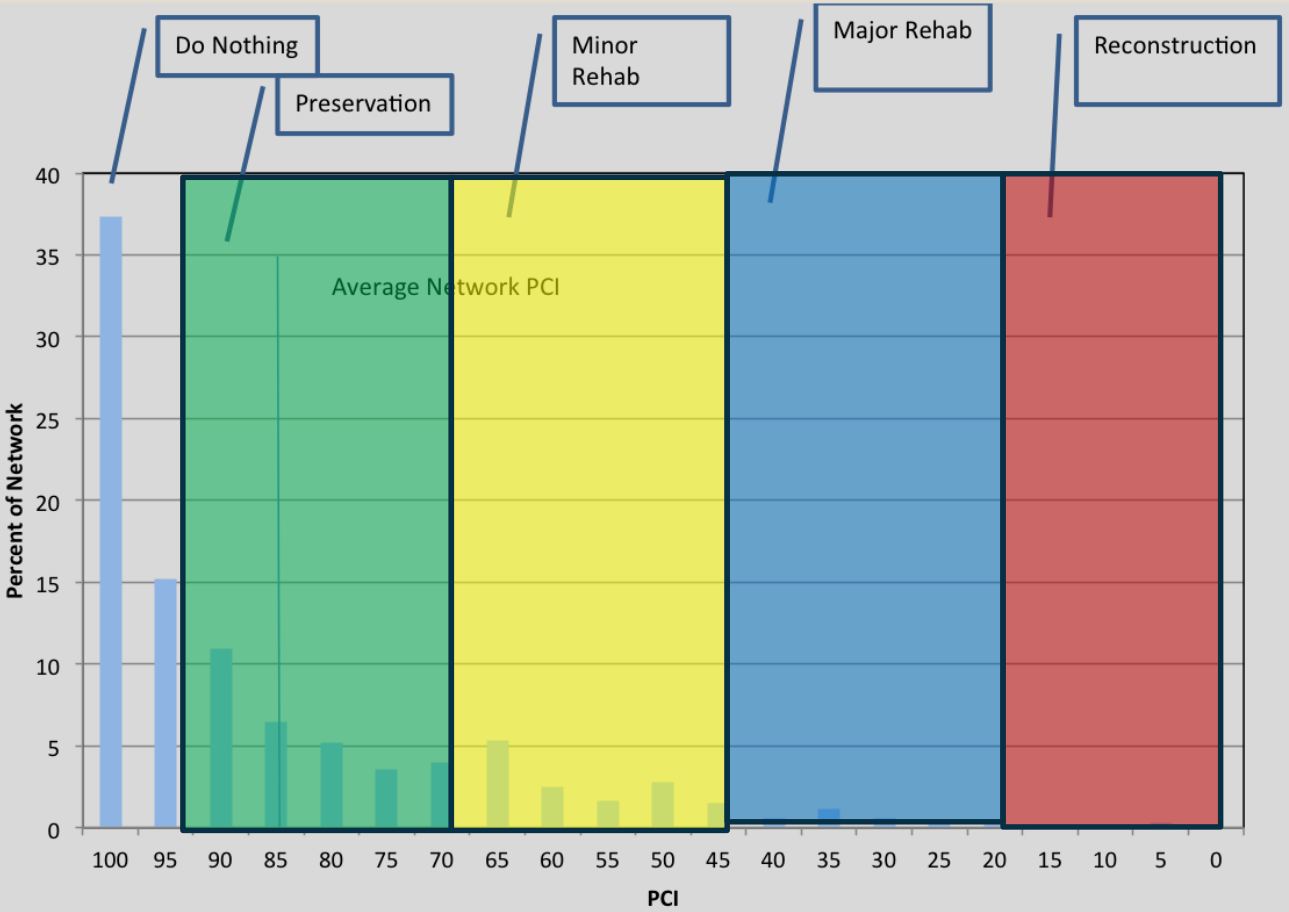




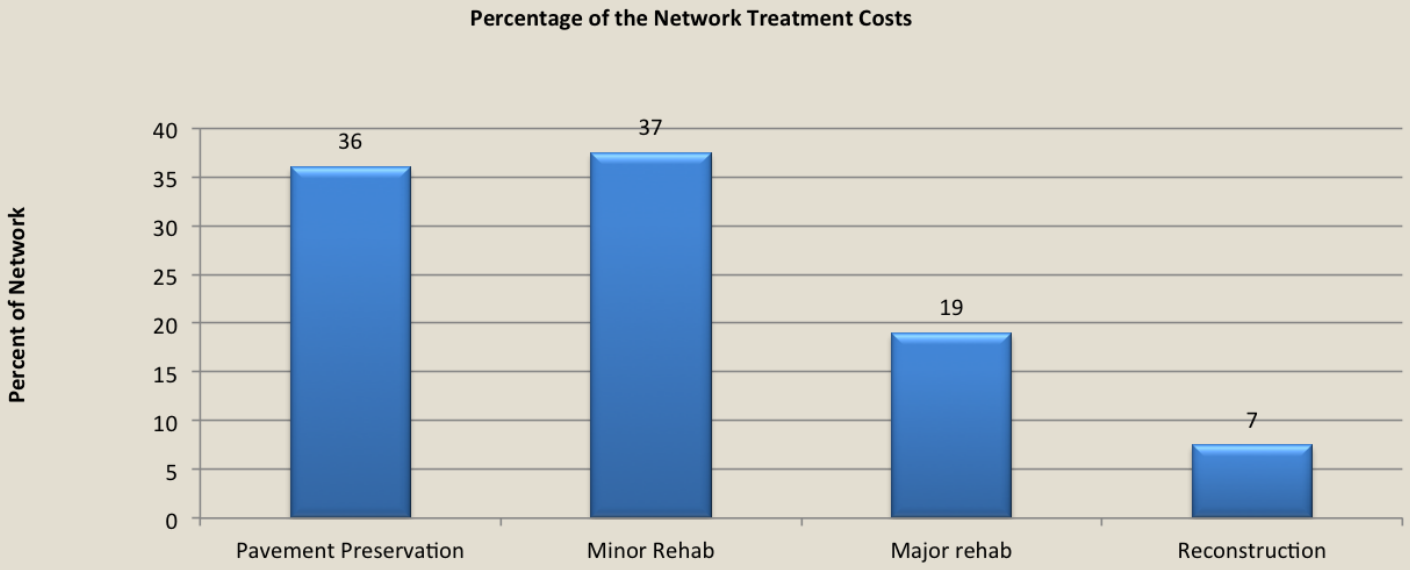
Pavement Condition Survey Summary



Pavement Condition Survey Summary

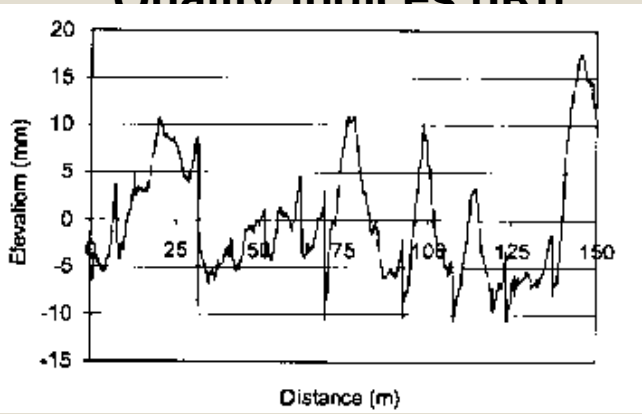


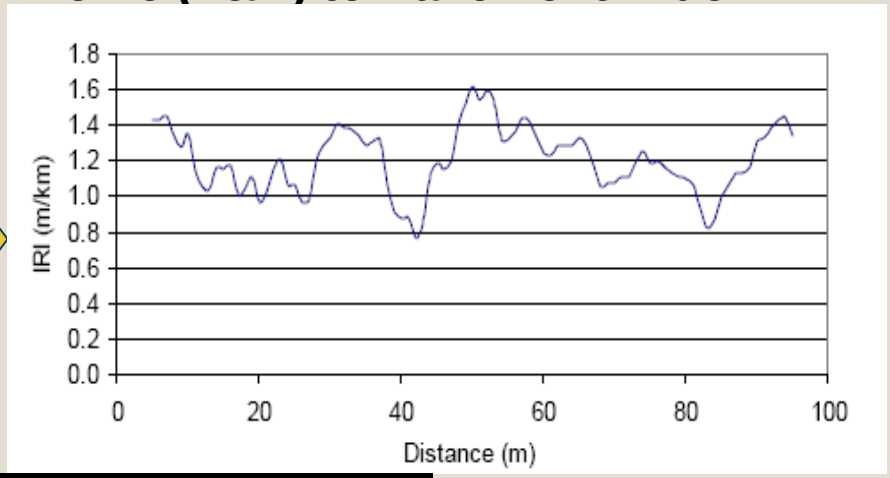
Pavement Condition Survey Summary



Pavement Index
Ride Quality Index

- Measure Pavement Wheel Path Profile(s) to assess Pavement Ride Quality
- Convert Pavement Wheel Path Profile (L&R) to Pavement Ride Quality Indices (IRI)

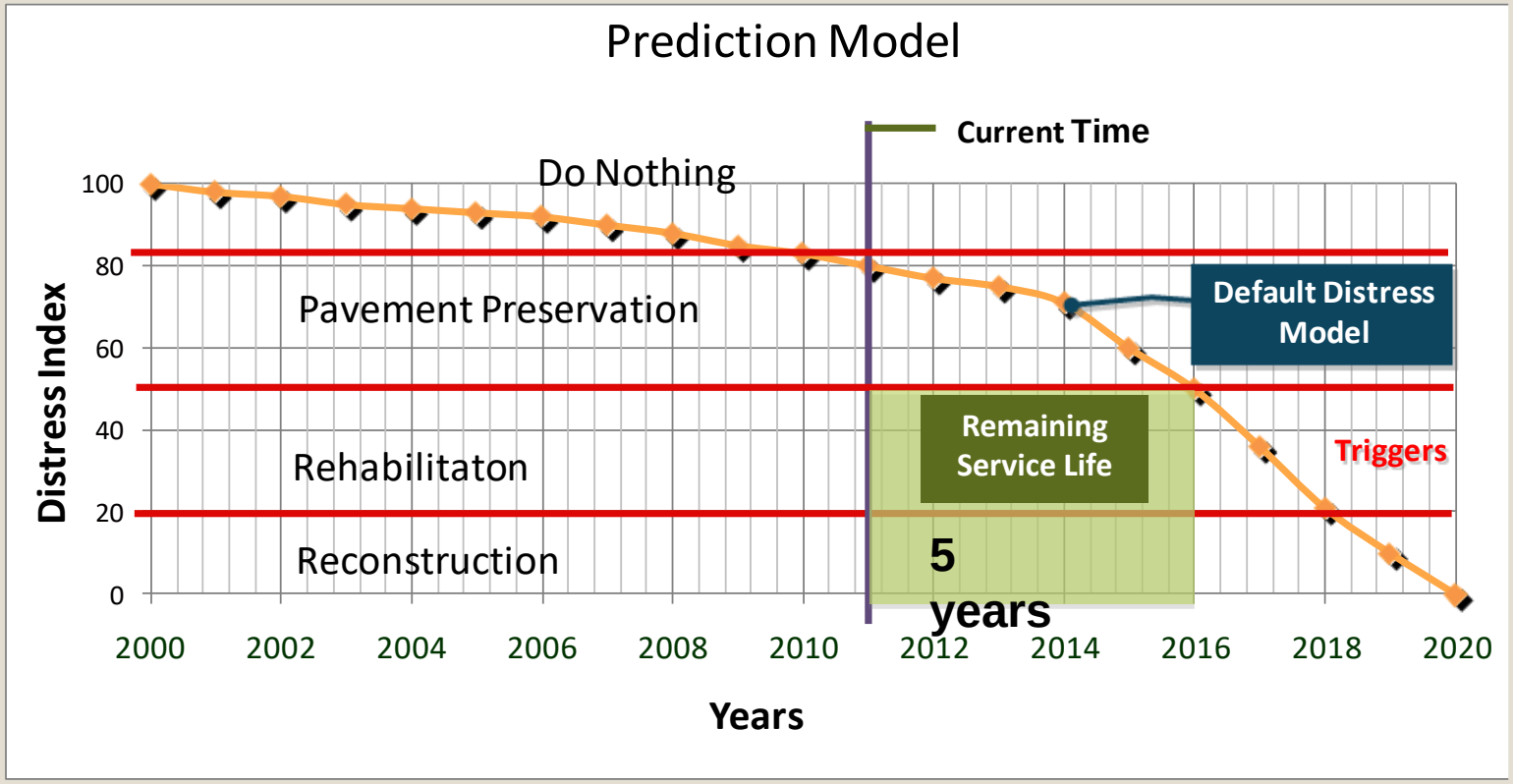




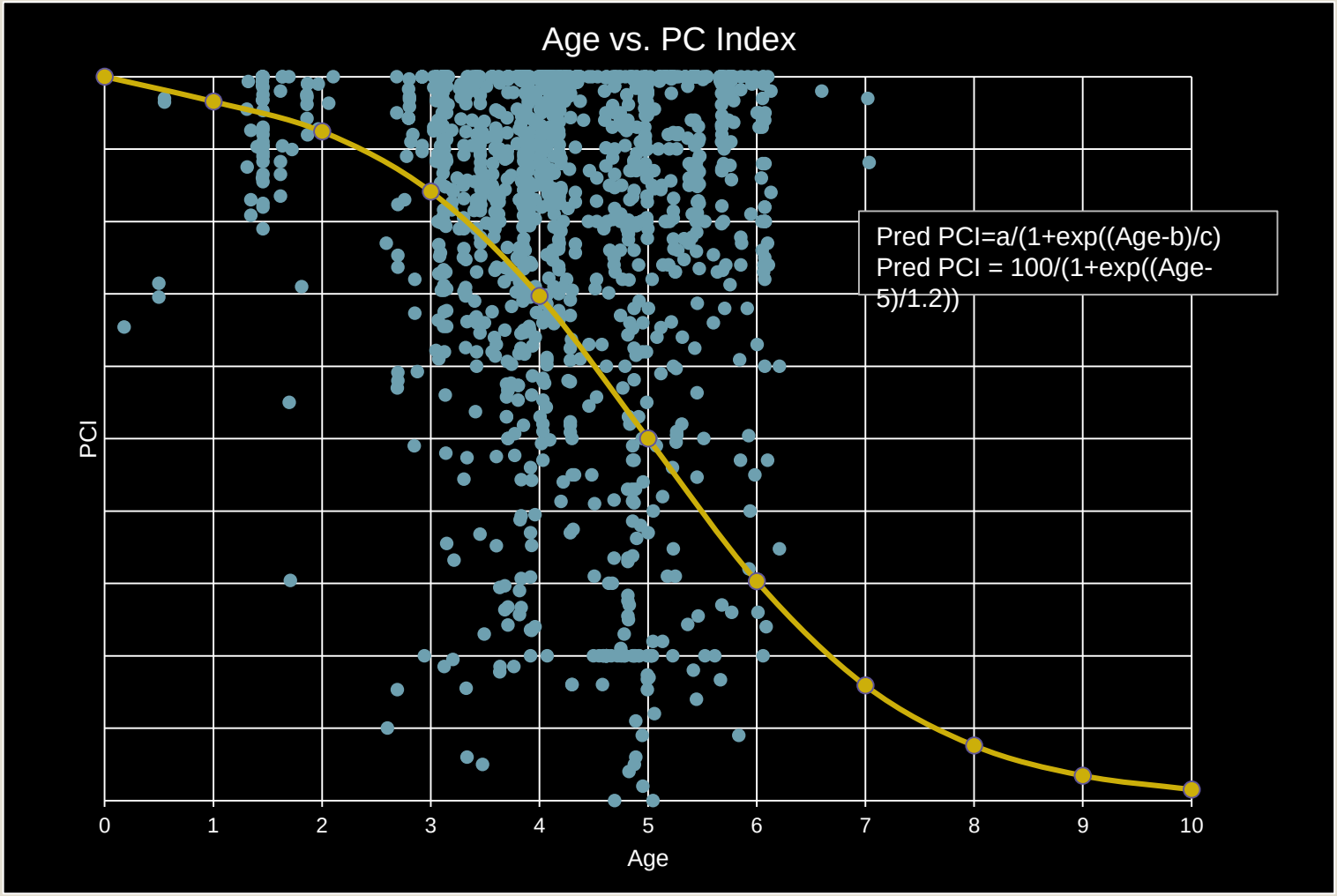
IRI Categories	Interstate Routes	NHS Non-Interstate Routes	Non-NHS Routes with ADT ≥ 2000	Non-NHS Routes with ADT < 2000
≤ 70	Excellent	Excellent	Excellent	Excellent
71-75	Good	Good	Good	Good
76-100	Fair	Fair	Fair	Fair
101-120	Poor	Poor	Poor	Poor
121-150				
151-170				
171-195				
196-220				
> 220				

5- PMS Performance and Economic Analysis

Pavement Performance Model



Pavement Performance Model



Analysis

PERFORMANCE AND ECONOMIC ANALYSES

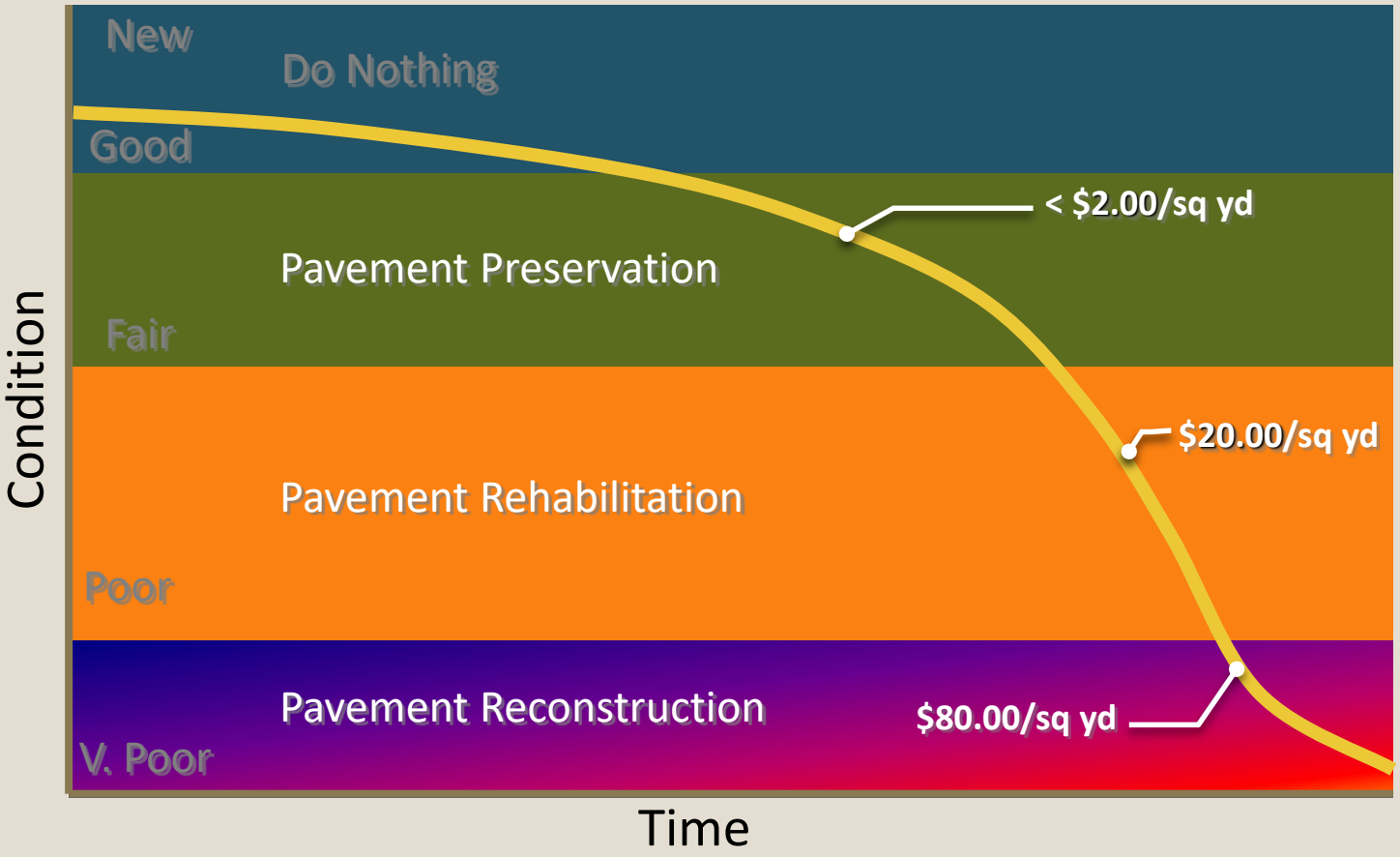
- ***RANKING -*** *SINGLE YEAR COST SUMMARY*
- ***MULTI YEAR PROGRAMMING*** **-** *COST PROJECTIONS*
- ***LIFE CYCLE COST ANALYSIS:***

  - *P&E, CONST, ANNUAL MAINT, REHAB, SALVAGE*
  - *NET PRESENT WORTH OR EQUIVALENT UNIFORM ANNUAL COSTS*
  - *DISCOUNT RATE = INTEREST - INFLATION RATE*

Sophistication

Effect of Treatment Timing on Costs

Deterioration over time and cost to repair



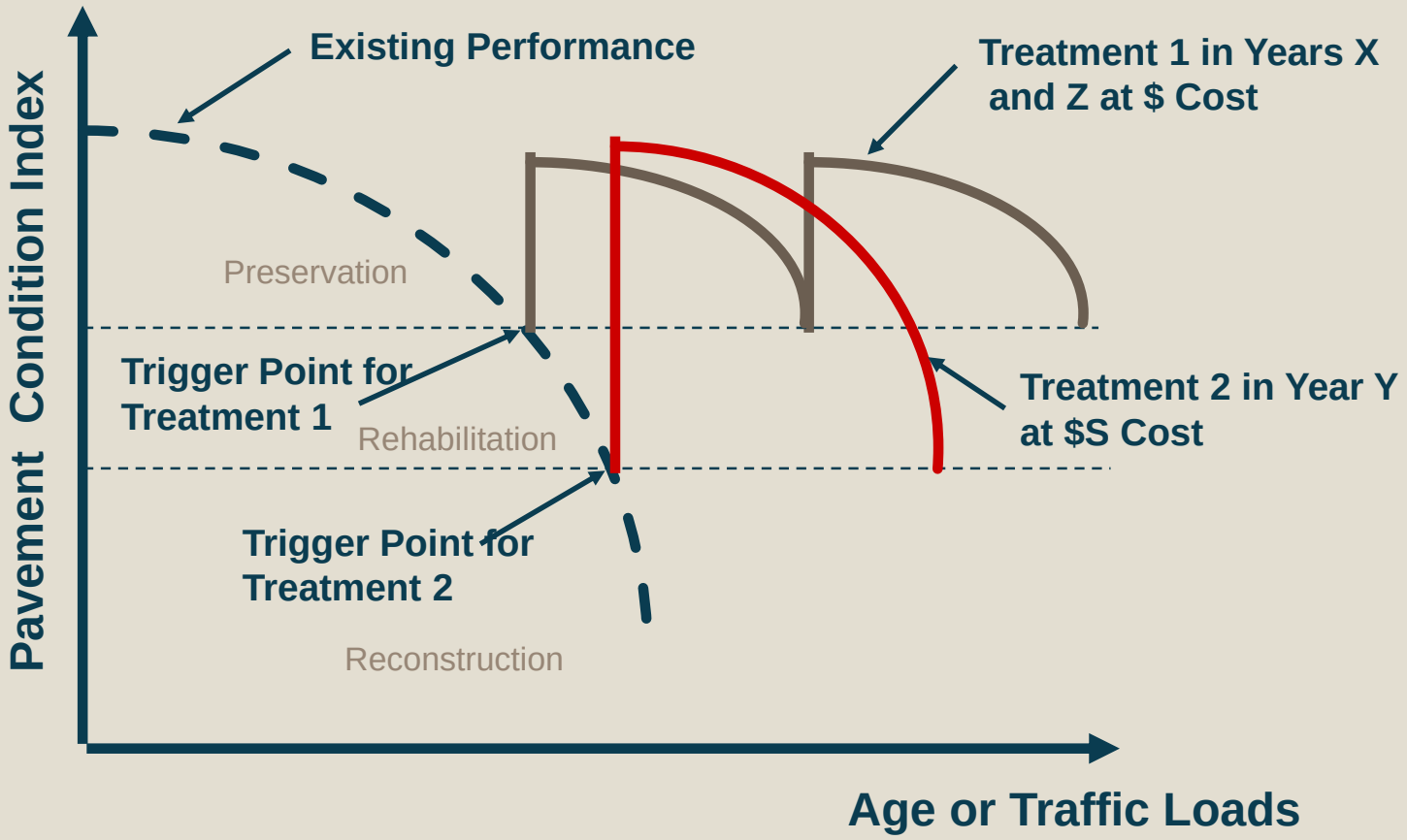
Treatment Types and Costs

Preservation Treatments	Cost Per Lane Mile
Slurry seals	**$14,080**
Micro surfacing	**$17,600**
High-performance thin overlays	**$45,760**

Rehabilitation Treatments	Cost Per Lane Mile
Minor (functional): mill 2 in. and overlay 2 in.	**$107,430**
Major (structural rehab): mill 2 in. and overlay >2 in.	**$154,106**

Reconstruction	Cost Per Lane Mile
Partial	**$422,400**
Full	**$689,920**

Treatment Choices



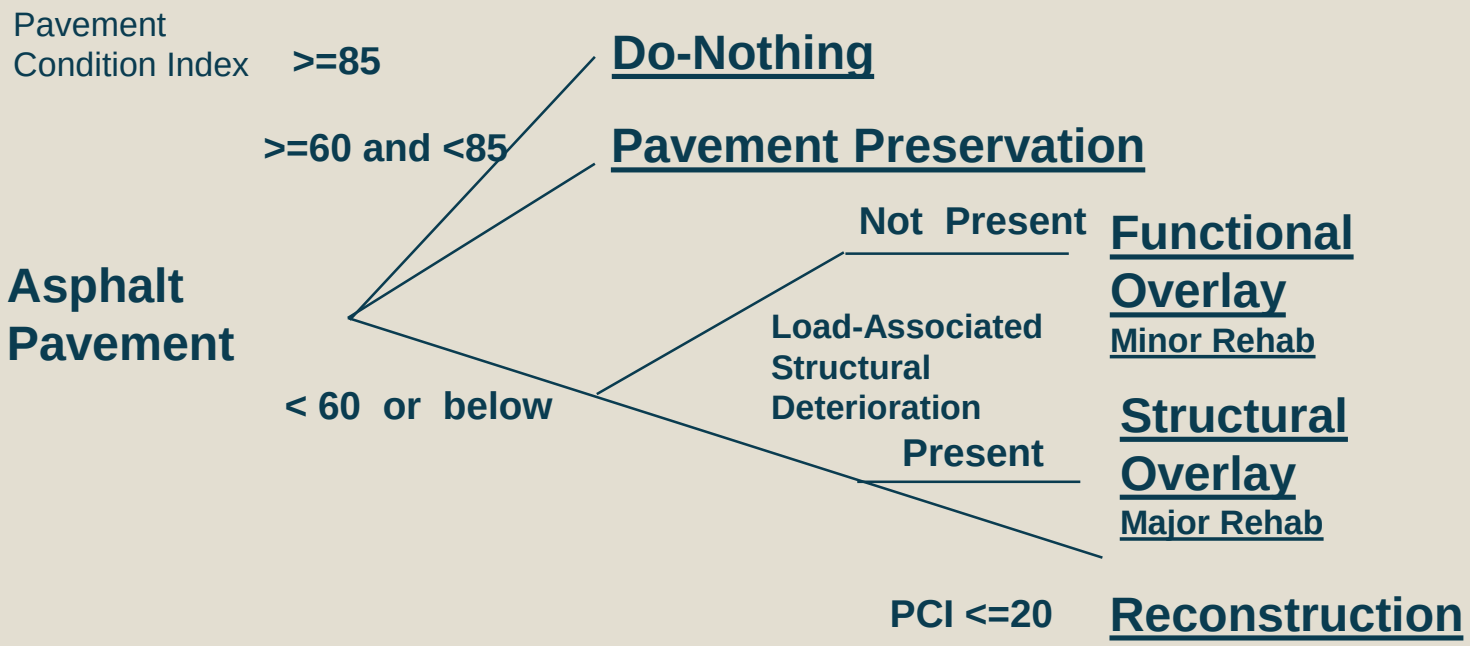
You never have enough fish!

Treatment Strategy Triggers

Treatment Type	Trigger Range
Do Nothing	PCI > 90
Pavement Preservation	60 > PCI ≤ 90
Minor Rehabilitation	40 > PCI ≤ 60
Major Rehabilitation	20 > PCI ≤ 40
Reconstruction	PCI ≤ 20

Treatment Selection

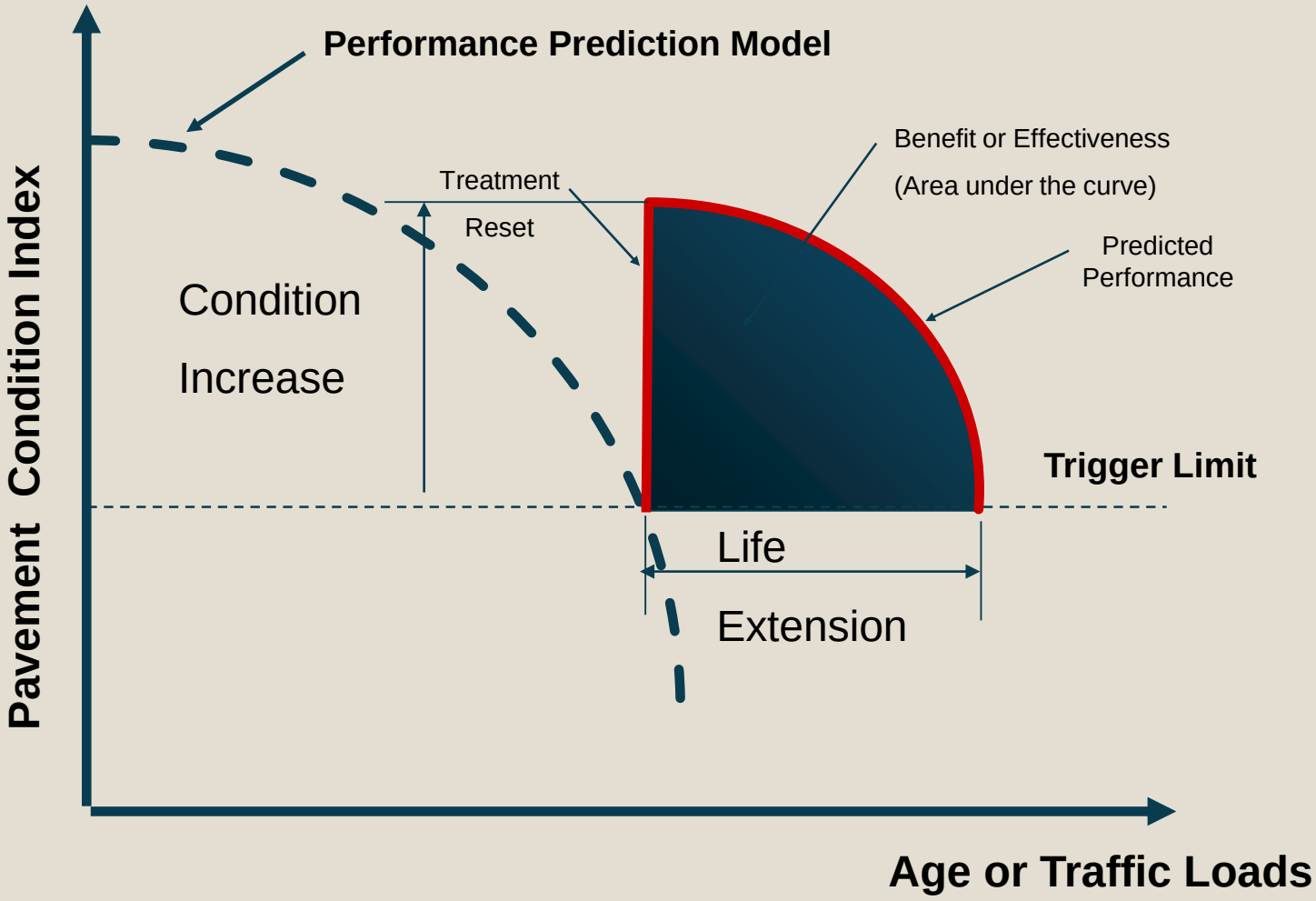
Decision Trees/Treatment Rules



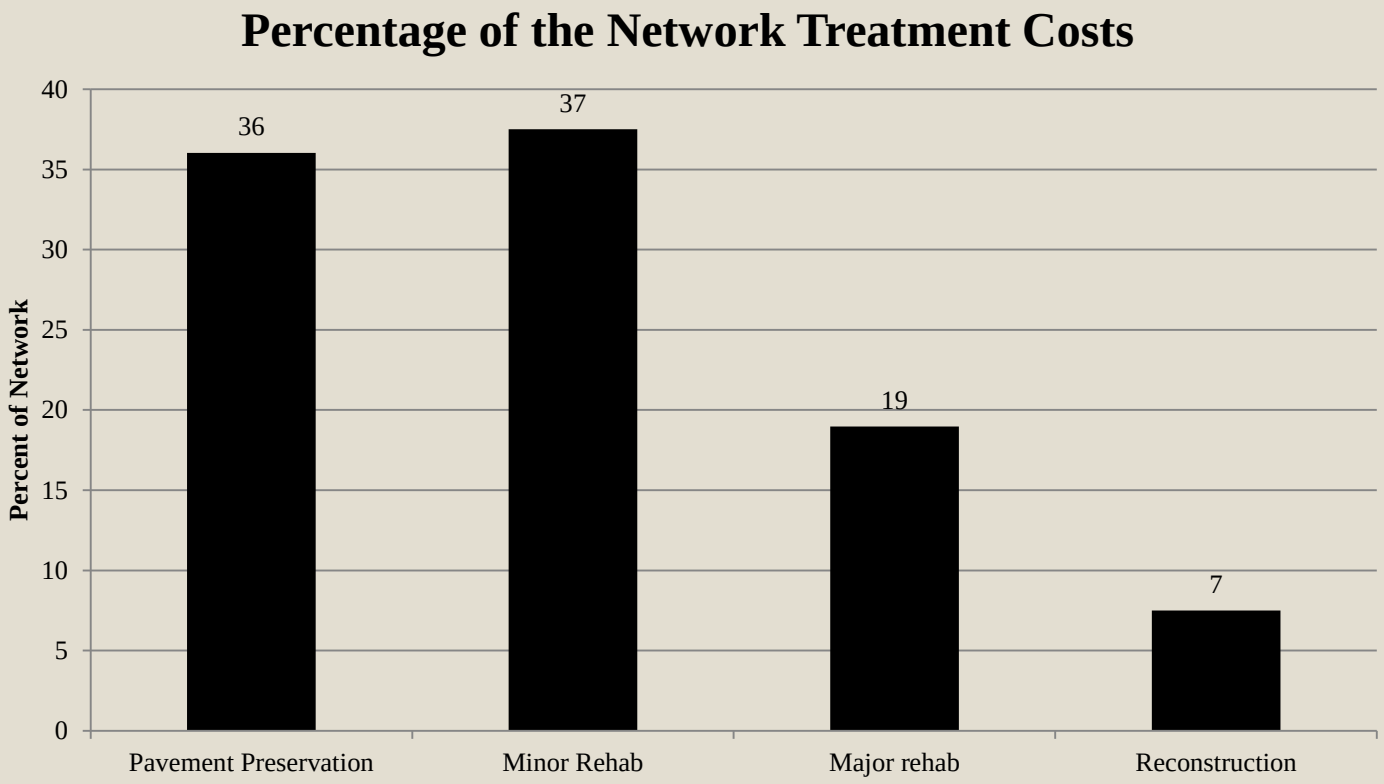
Recommended Treatment Class

…Managers make the final decision

Multi-Year Prioritization



Network Needs Treatment Cost Distribution – Good Network

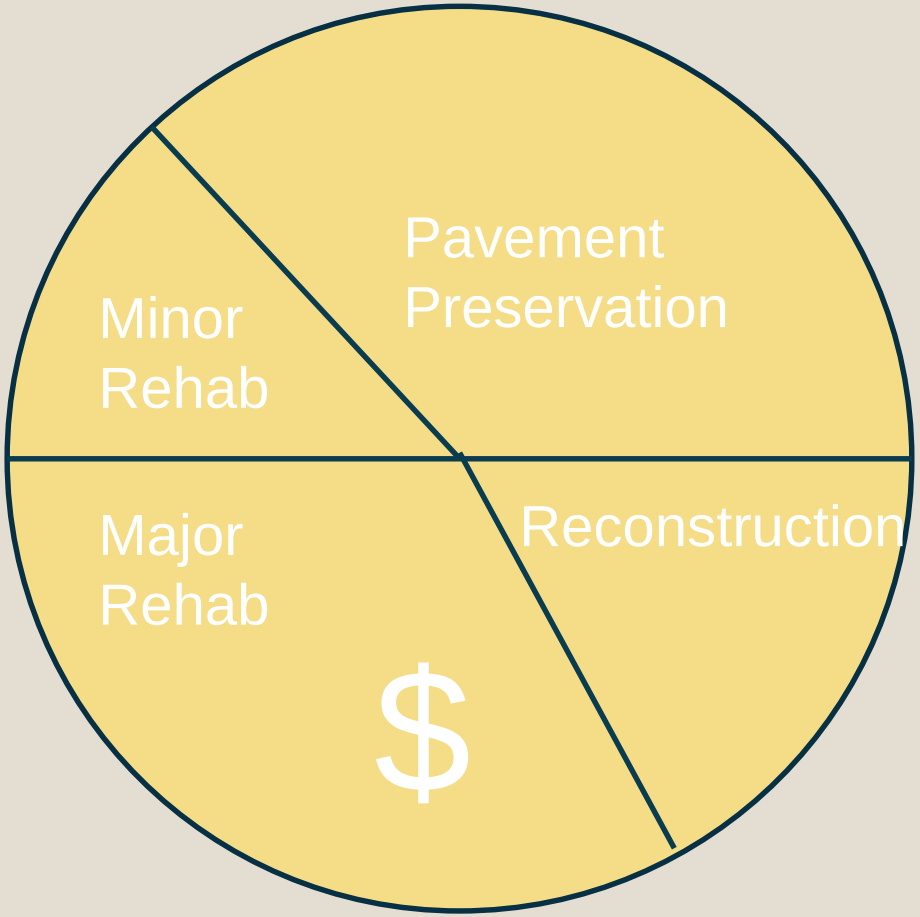


Budget Style

Incremental

A “mix of fixes” is applied

Distribution based on Network Needs Analysis



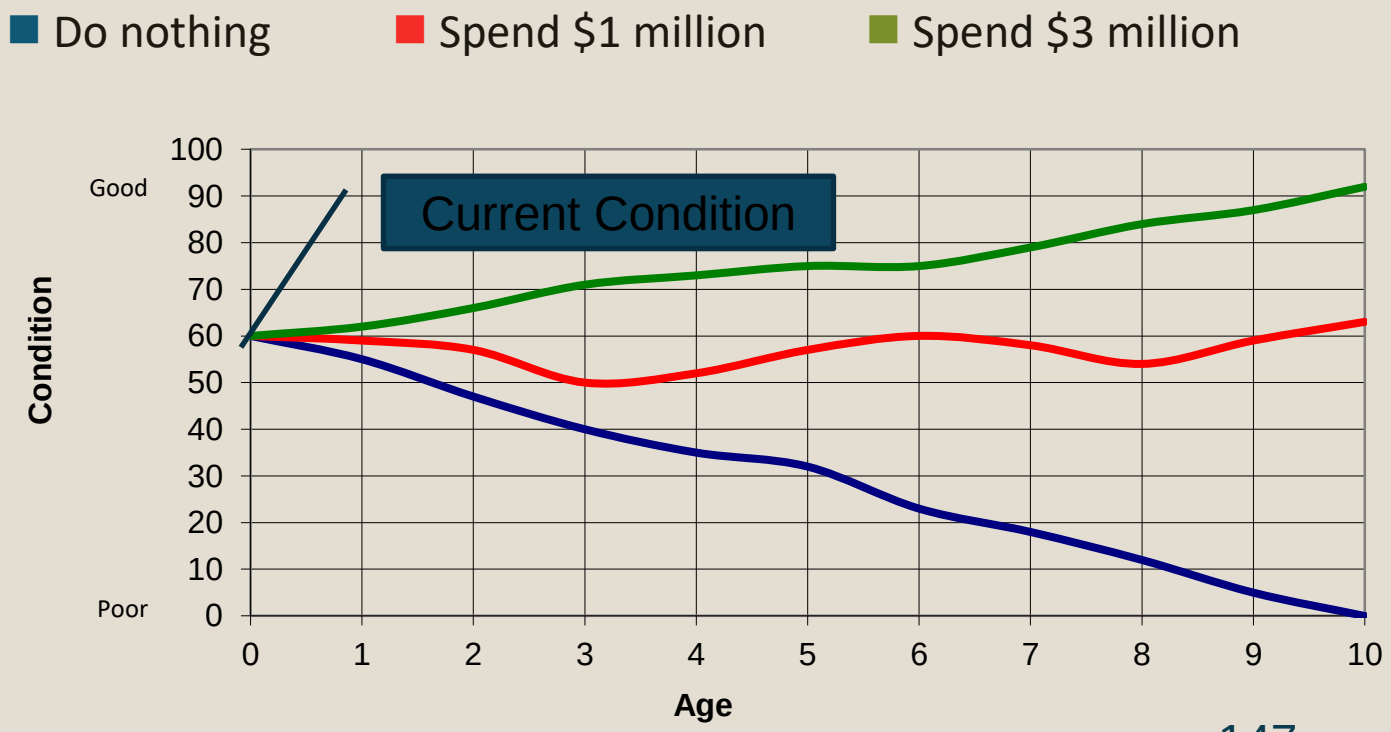
Budget Pie

Budget Amounts

- No funds
- $1,000,000 - Less
- $1,500,000 - **Current**
- $3,000,000 - More
- Unlimited

Example Network Performance Scenario

Policy Decisions can be based on the **average projected condition** at given budget levels for a single asset or for the entire network



Example 1 – Two Objectives (Goals)

- Secondary pavement network of 8000 km
- Goals:
  - ✓ Maximize performance (service life extension E)
  - ✓ Minimize cost
- Initial conditions:
  - ✓ Excellent (R_1)=34%
  - ✓ Good (R_2) =30%
  - ✓ Fair (R_3) =12%
  - ✓ Poor (R_4) = 24%
- Planning horizon of 10 years;
- Maintenance policies:
  - ✓ $(R_1+R_2)_{min}$ = 65%
  - ✓ $R_{4,t\ max}$ = 26%
    $R_{4,10\ max}$ = 22%
  - ✓ L_{2max} = 20% L
- Average yearly budget
  - ✓ Mean = $18 million
  - ✓ CL = 95%, C.o.v. = 5%

Example 1 – Model Formulation

$$\text{Max } Z_1 = \sum_{t=1}^{10}\sum_{i=1}^{4} R_{i(t-1)} x_{it} E_i L$$

Max. Maintenance Effectiveness
(extension is service life)

$$\text{Min } Z_2 = \sum_{t=1}^{10}\sum_{i=1}^{4} R_{i(t-1)} x_{it} C_i L$$

Min. Total Maintenance Cost

$$\begin{cases} R_{it} = (1-x_{it})R_{i(t-1)}P_{ii} + \sum_{j=1}^{4} x_{jt}R_{j(t-1)}T_{ji} & i = 1, \forall t \\ R_{it} = (1-x_{it})R_{i(t-1)}P_{ii} + (1-x_{(i-1)t})R_{(i-1)(t-1)}P_{(i-1)i} + \sum_{j=1}^{4} x_{jt}R_{j(t-1)}T_{ji} & i = others, \forall t \end{cases}$$

(performance prediction)

$$\sum_{k=1}^{4}\sum_{i=1}^{4} R_{i(t-1)} x_{itk} C_k L \le \mu_{B_t} + \Phi^{-1}(1-\alpha_t)\sigma_{B_t} \quad \forall t$$

(stochastic budget constraint)

$$\sum_{i=1}^{2} R_{it} \ge (R_1 + R_2)_{\min} \quad \forall t \qquad R_{4t} \le R_{4\max} \quad \forall t$$

(performance targets)

$$R_{2(t-1)} x_{2t} \le \frac{L_{2\max}}{L} \quad \forall t$$

(resource constraints)

$$\sum_{i=1}^{4} R_{it} = 1 \quad \forall t$$

(sum of percentage in all states = 1

$$0 \le x_{it} \le 1.0 \quad \forall i, t$$

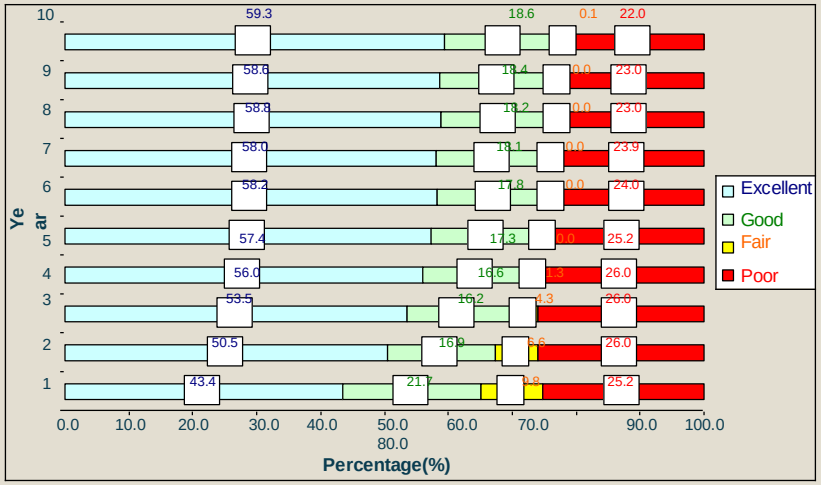
(non-negativity constraint)

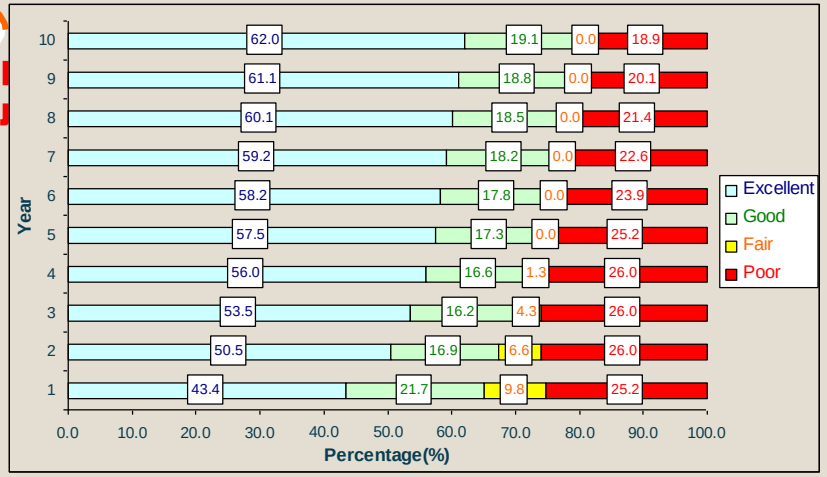
PMS Performance and Economic Analysis

Max. Life (Z_1): Average Annual Budget ~ $165 M

Total Effective Life 72,676 yr-ln-km

15% ↑ Budget → 6% ↑ performance





Max.Z_1 & Min.Z_2:

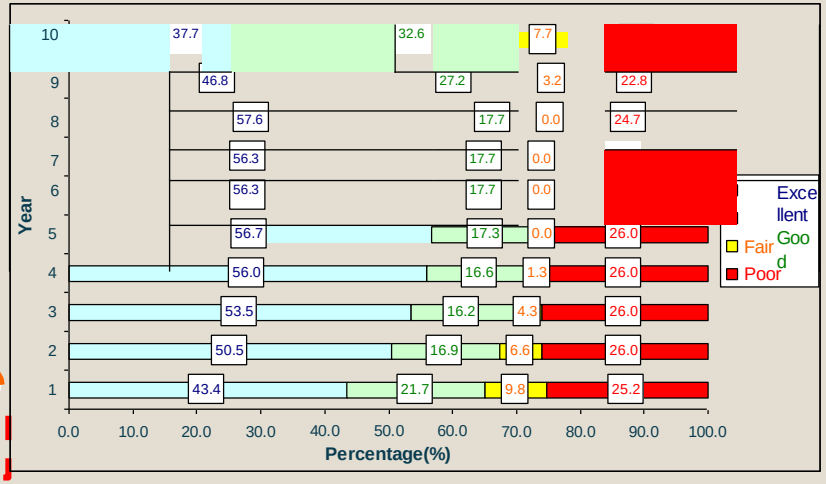
Average Annual Budget ~ $140 M,

Total Effective Life 68,622 yr-ln-km

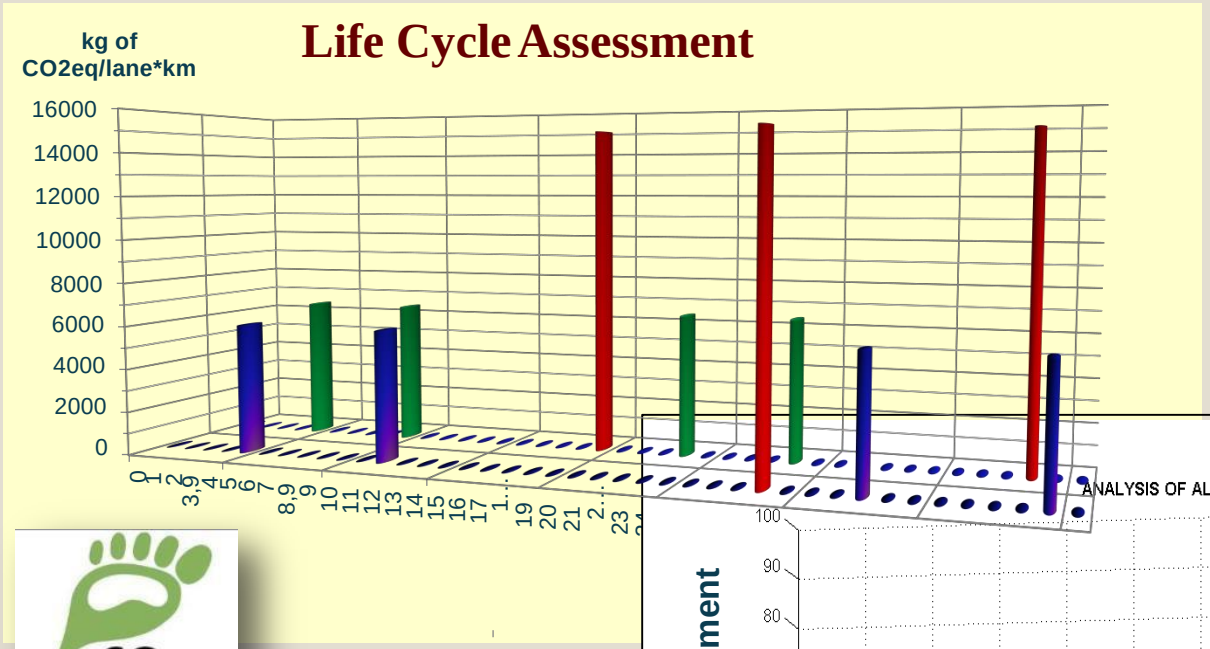
8% ↑ Budget → 29% ↑ performance

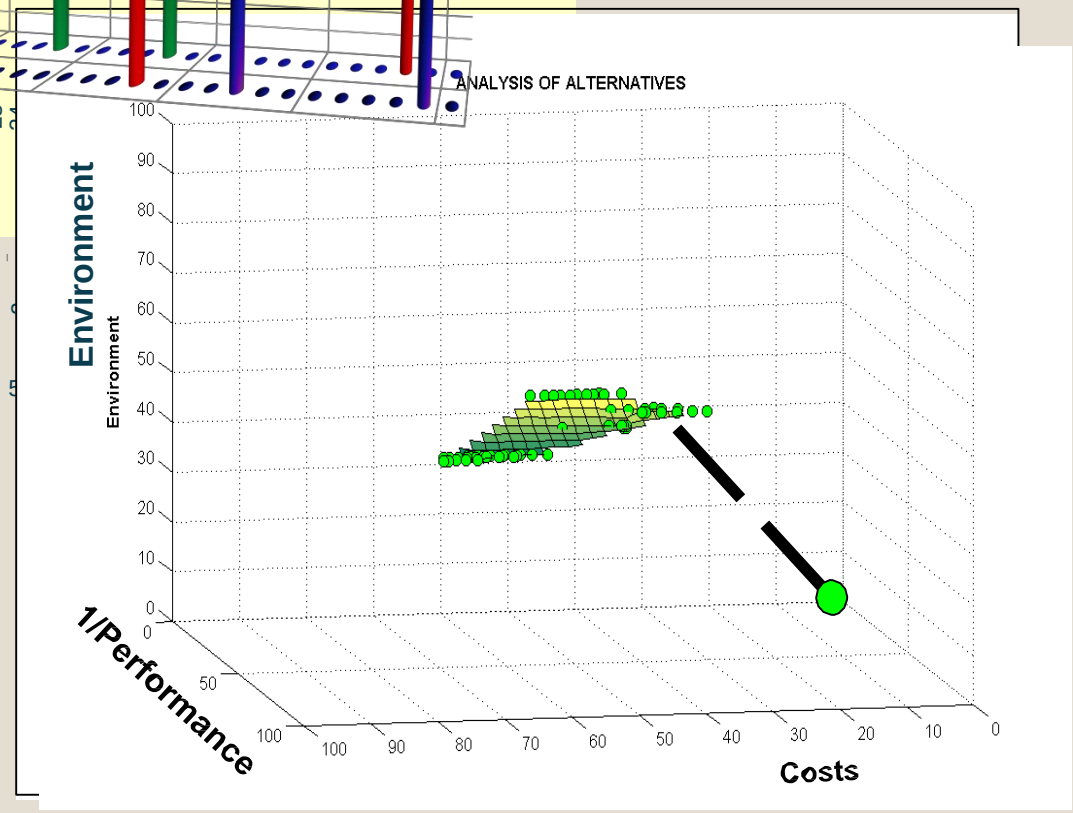
Min. Cost (Z_2): Average Annual Budget ~ $130 M

Total Effective Life 53,289 yr-ln-km



PMS Performance and Economic Analysis

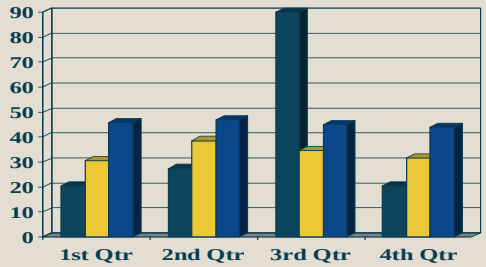




PMS Reporting Tools

Tables

Section	Year	Cost
32	2013	$100,000
47	2015	$237,999



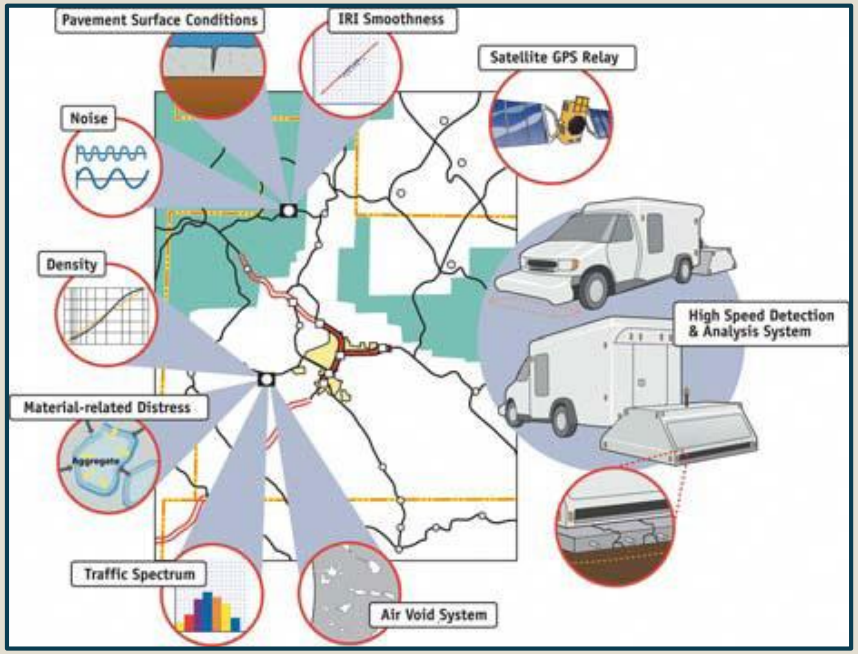
Graphs

GIS Maps

Annual Maintenance Program

Overall Network Condition

6- PMS Implementation



IMPLEMENTATION

ROLE OF MANAGEMENT :

STRATEGIC PLANNING OR DECISION TOOL FOR UPPER MANAGEMENT

ENGINEERING TOOL FOR TECHNICAL DECISION-MAKERS

DEVELOPMENT STEPS :

1- BEGIN COORDINATION THROUGH components of the agency

2- ORGANIZE TASK FORCE

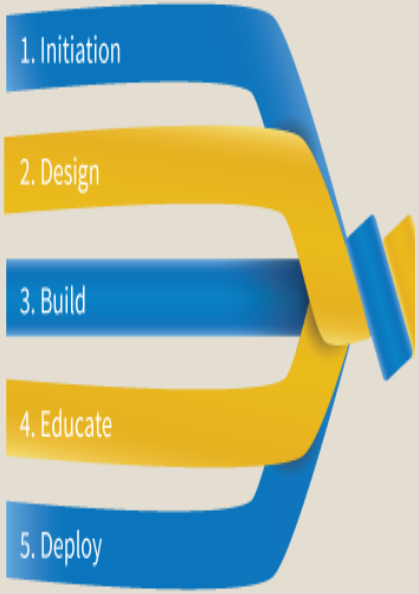
3- APPOINT PMS STAFF

4- PMS SYSTEM SELECTION OR DEVELOPMENT

5- DEMONSTRATION OF PILOT PMS

6- FULL SCALE IMPLEMENTATION, DOCUMENTATION, AND TRAINING

7- FOLLOW UP - FEEDBACK, IMPROVEMENTS, MODIFICATIONS



Barriers to Implementation

Issues and Barriers

The institutional issues and barriers can be loosely grouped into three classes; barriers related to:

- **People**
- **Organization**
- **Development & implementation of PMS**

People Issues and Barriers

- Personalities and interpersonal relationships
- Turf protection
- Fear of exposure to past or current practices
- Place of development (planning, engineering, maintenance, etc.)
- Resista

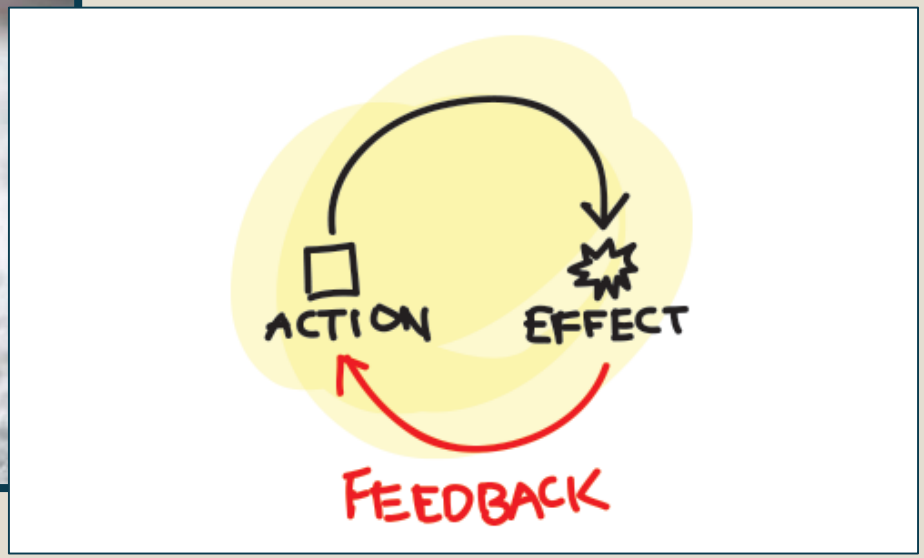
Organizational Issues and Barriers

- Size of organization
- Organizational structure
- Organizational level
- Past management and decision-making practices
- Stabilit

PMS Design Development & Selection

- Matched to agency needs
- Complexity – Need for adequate documentation
- "Black box" – Details of the analysis could not be seen

FEEDBACK LOOP



Feedback

- Review treatments and trigger levels with actual data
- Use actual case studies and output from several PMS optimization runs
- Confirm modifications

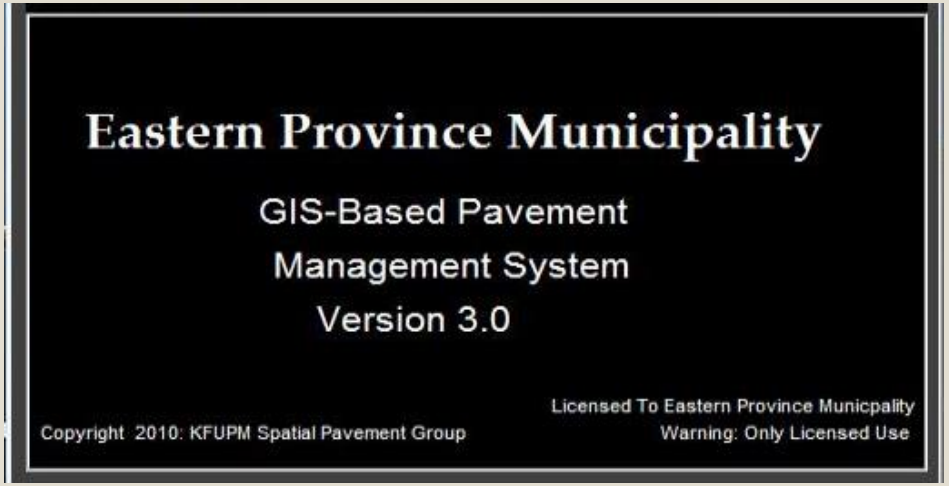
Feedback

- **Pavement Performance Models**
- **Treatments**
- **Treatment Trigger Levels**
- **Treatment Costs**
- **User Cost Models**
- **Data Quality Use Cost**

Feedback

- **Quality control of inventory/condition data essential**
- **Feedback loop on data quality regular part of PMS process**
- **Periodically raise and answer questions of cost, quantity, and use of data**

7- Case Study " EPM-PMS "



Development of Eastern Province PMS

EPM- Pavement Maintenance Management
"the Start & History"

Before 1997 : Depend on the Engineer Experience and Judgment

↓

1997-2000 : Documentation of Pavement Maintenance Procedures and development of a management procedures .

↓

2000-2006 :Establishment and implementation of a Pavement Management System , GIS Integration .

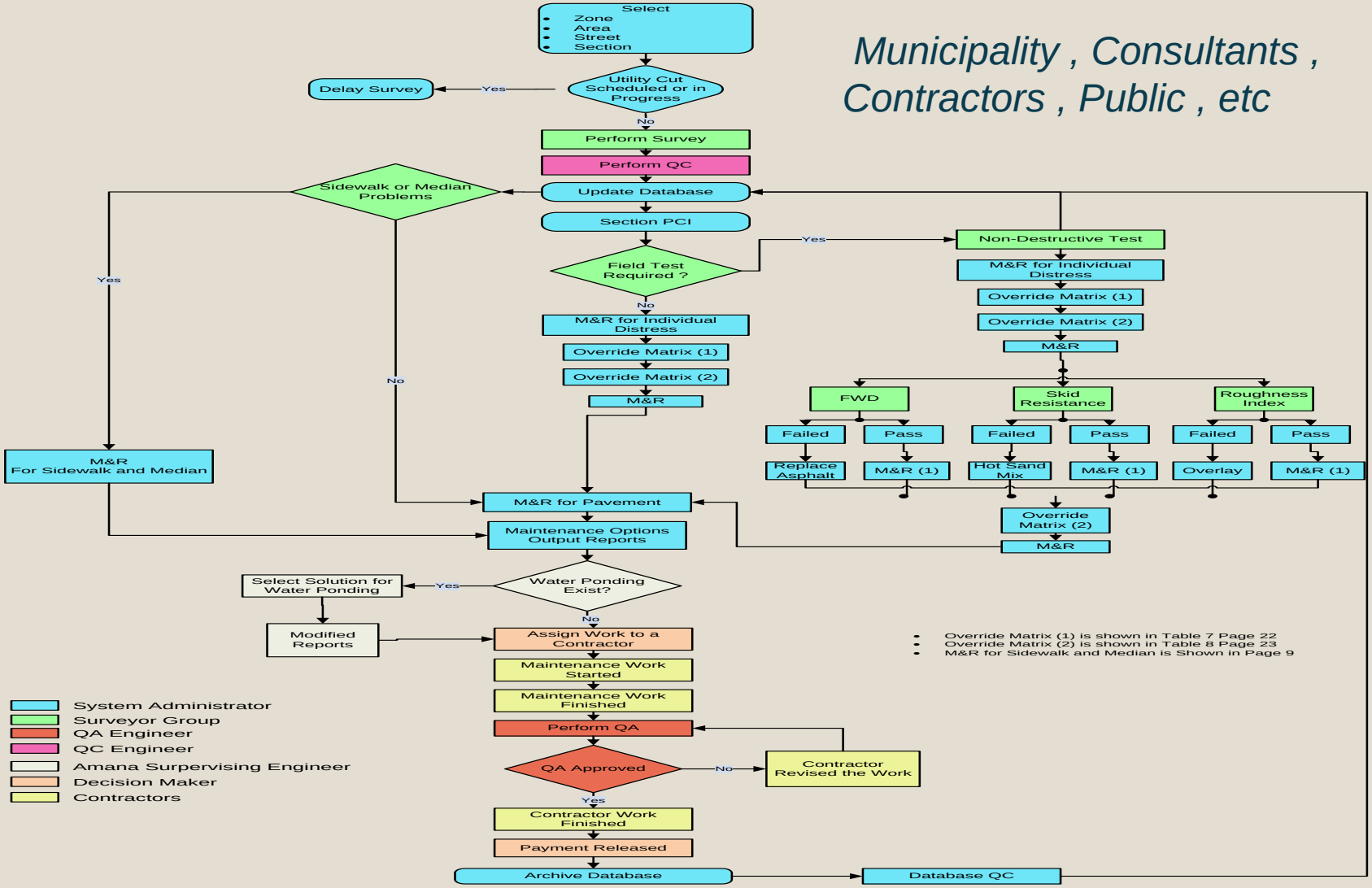
↓

2006- 2009 : Enhancement of the PMS , adding more functions , Manuals(Pavement Evaluation , Maintenance Activities , System Manual) , Training .

↓

2009 – 2012 : Introduce more changes

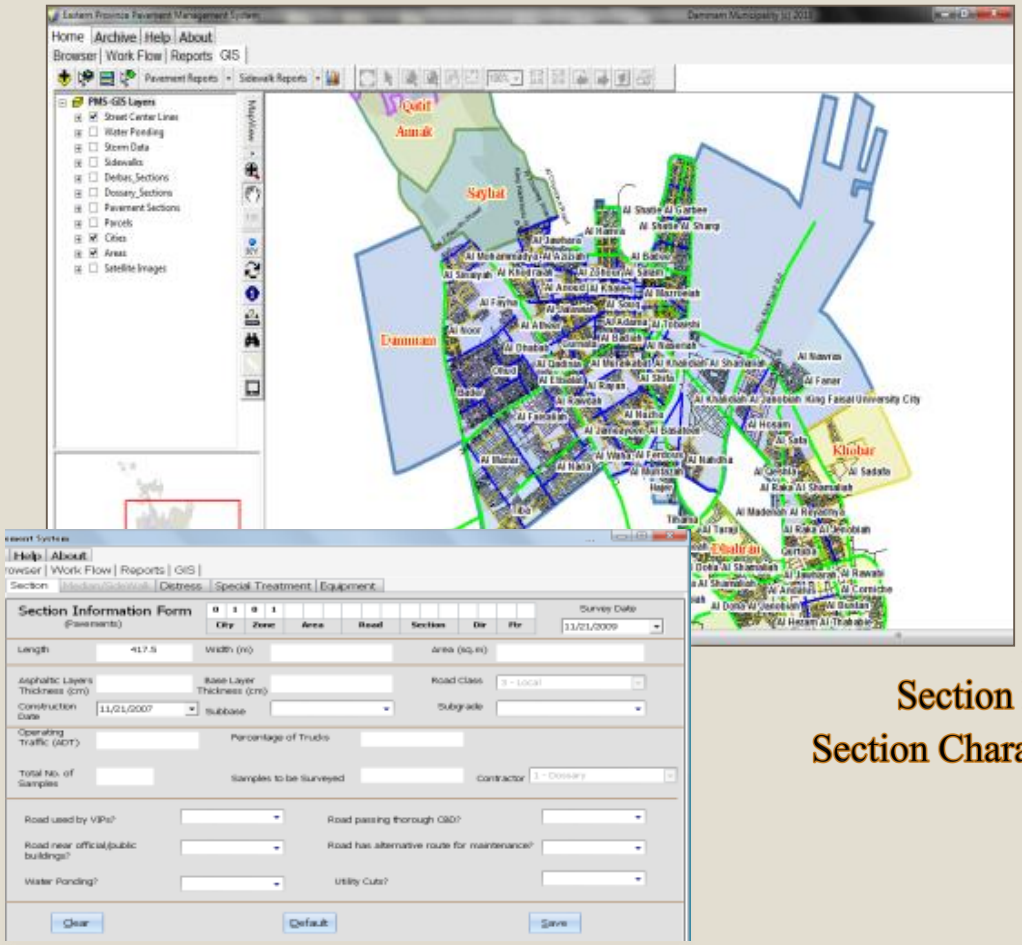
EPM-Pavement Management System Process

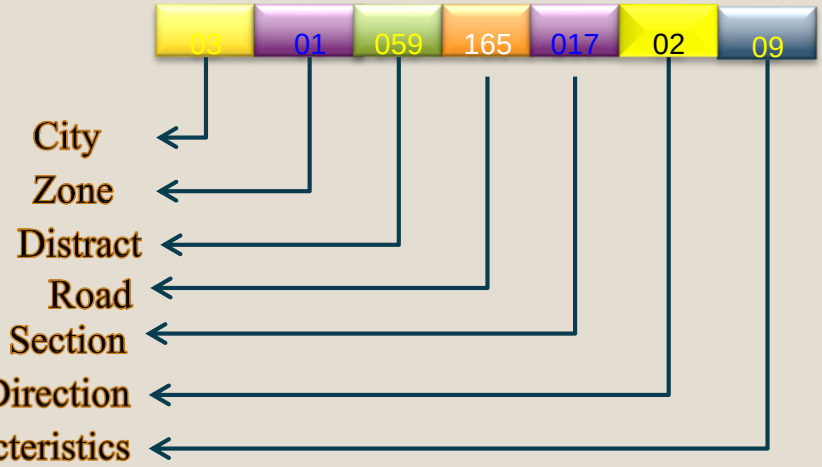


Municipality , Consultants , Contractors , Public , etc

Road Network Definition

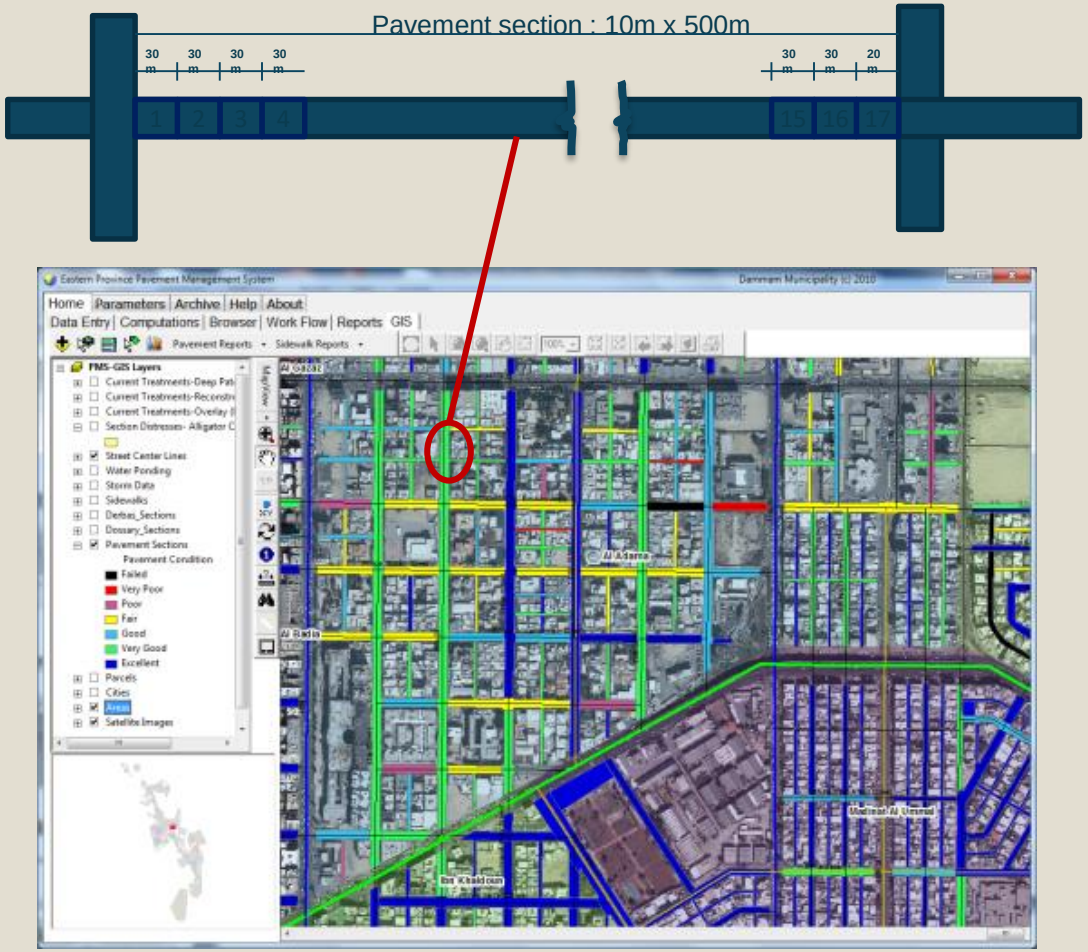
Road Network was divided by : City - Zone - District - Road - Section .





Pavement Condition Evaluation

- Using ASTM D6433 for condition evaluation
- Collect distresses “type , quantity and severity for each section “
- Calculating the PCI for each section in the network
- Rating for each section in the PCI scale of 0-100



Pavement Structural , Roughness and Skid Evaluation

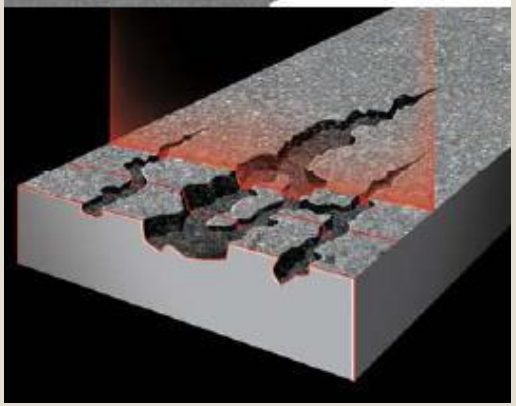
- Structural Evaluation **for limited sections** using Falling Weight Deflectometer (FWD)

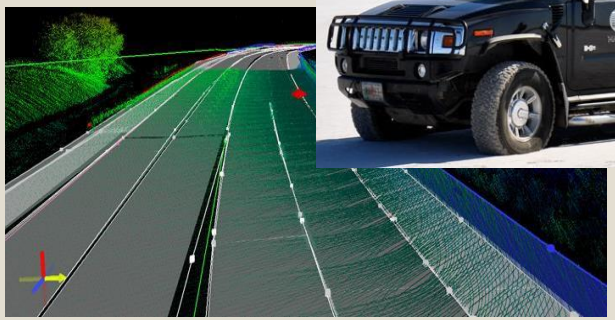
- Roughness Evaluation , Calculating the IRI . **Selecting locations Based on the road design speed .**

- Skid Resistance Test . **At intersections and selected locations**

Exploring New Data Collection Technologies

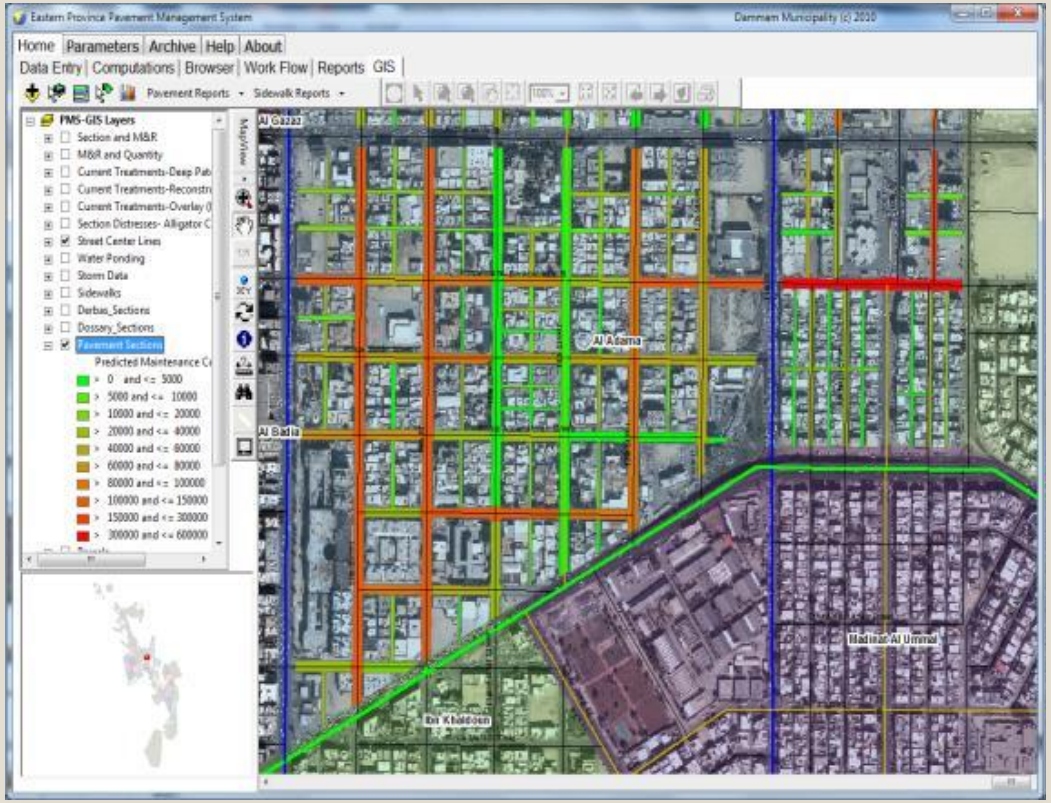
- Laser Line Scan for distresses survey with 3D Technology , **will be used soon**
- Assets Data Collection using mounted Cameras , **used for main roads**
- Mobile LIDAR Technology , **not used yet but understudy**





Pavement Performance Prediction Models

- Predict the future condition of the pavement network .
- Analyze different Maintenance Scenarios .
- Budget Planning.



Maintenance Programs

- Groups of *flexible parameters* can be modified when needed for practical and effective system output :

  - Maintenance Cost
  - Maintenance Type
  - Maintenance Priority
  - Maintenance programs planning
  - Maintenance Budget Planning

Maintenance Types

M&R Type	Description
1	Do Nothing
2	Apply Hot Sand and Roll
3	Crack Sealing
4	Surface Leveling
5	Surface Patching
6	Deep Patching
7	Micro Surfacing
8	Hot Sand Mix
9	Rubberized Friction Course Surfacing
10	Overlay
11	Overlay + Geo-textile Fabric
12	Mill and Repave
13	Mill + Geo-textile Fabric + Repave
14	Replace Asphalt
15	Reconstruction

cking

Maintenance Types Matrix - Fatigue

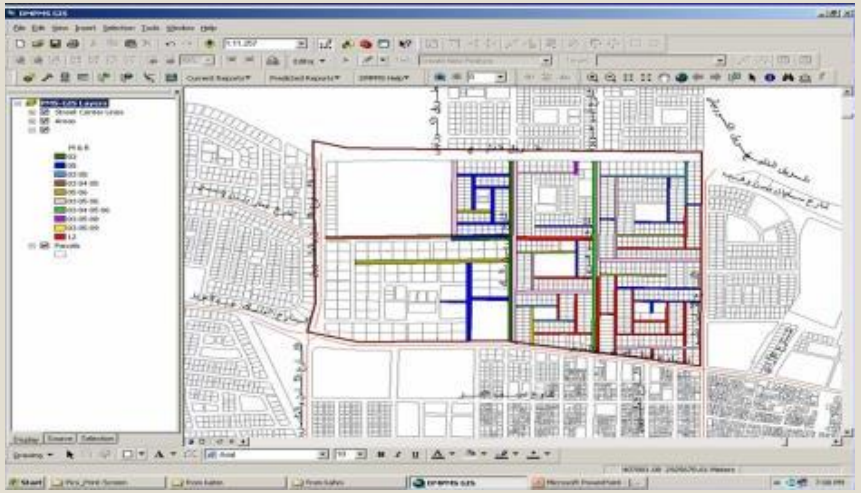
Severity Level	Density Level (%)			
	≤ 10	10 - 30	31 - 60	≥ 61
Low	1	5	5	14
Medium	6	6	14	15
High	6	6	14	15

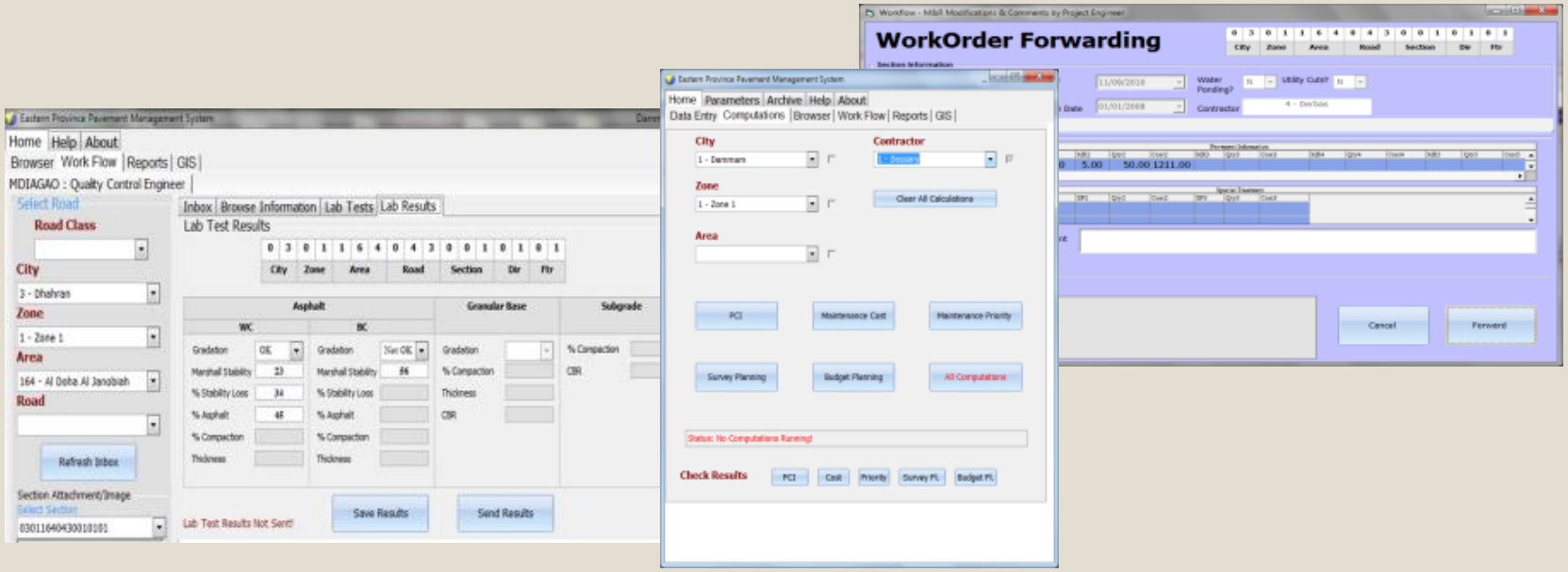
Priorities Factors

No.	Factor	Weight
1	Road Class	0.135
2	Pavement Condition	0.196
3	Operating Traffic	0.132
4	Riding Quality	0.124
5	Safety Condition	0.155
6	Maintenance Cost	0.106
7	Importance to Community	0.152

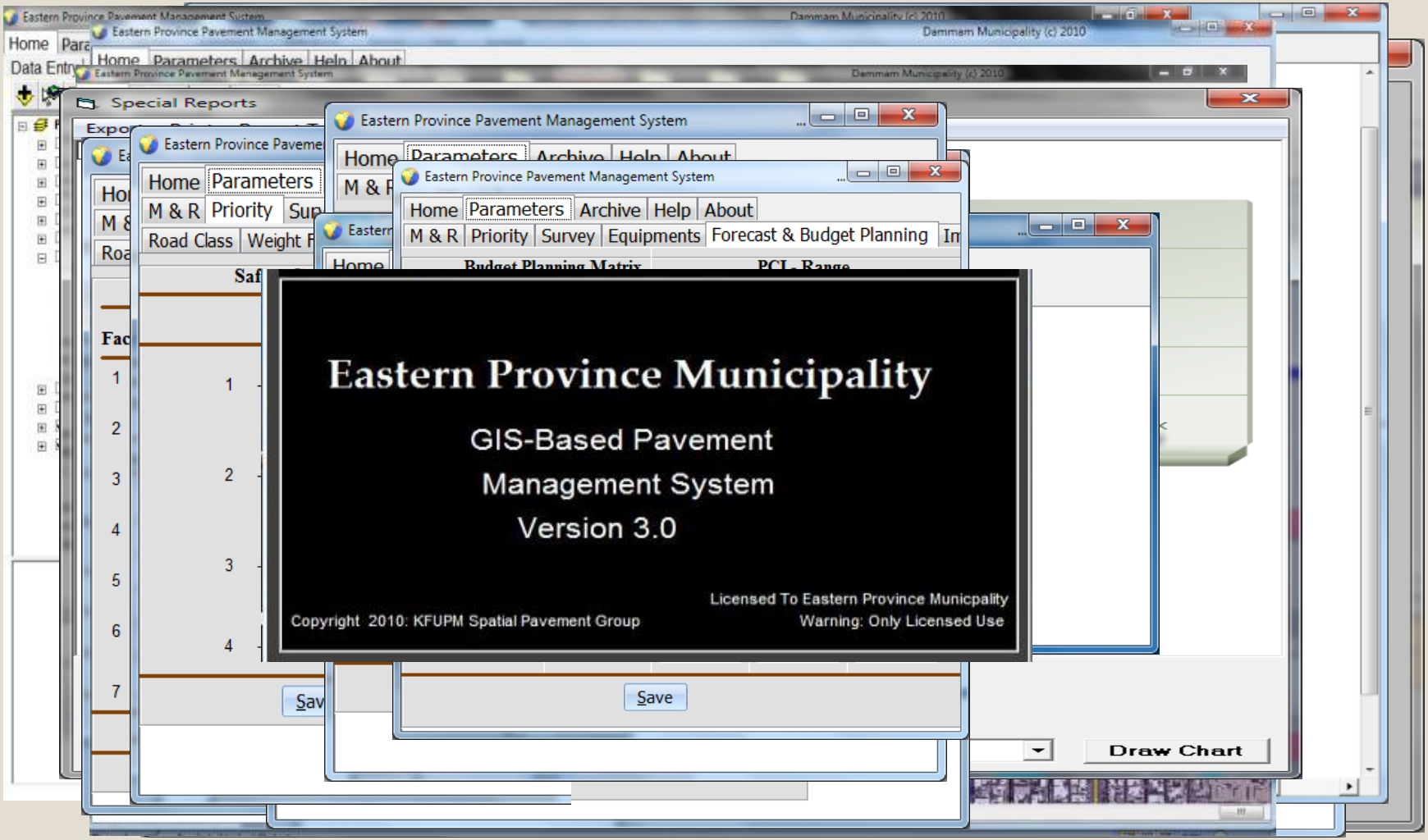
Maintenance Programs

- 3 years Maintenance Plans
- Maintenance Budget Planning
- Maintenance work orders
- Maintenance quality control
- Involving stake holders
- Contractors Performance Evaluation

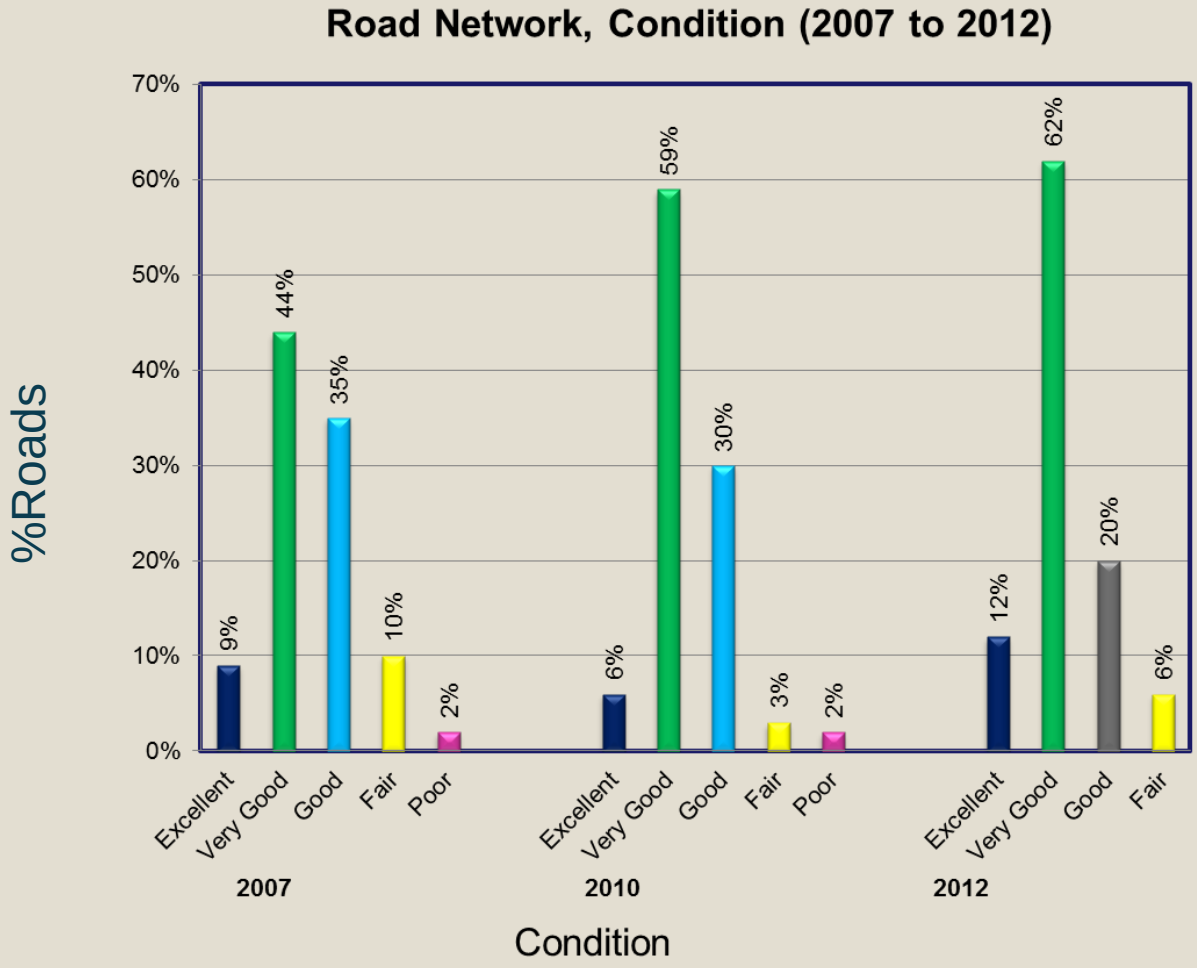




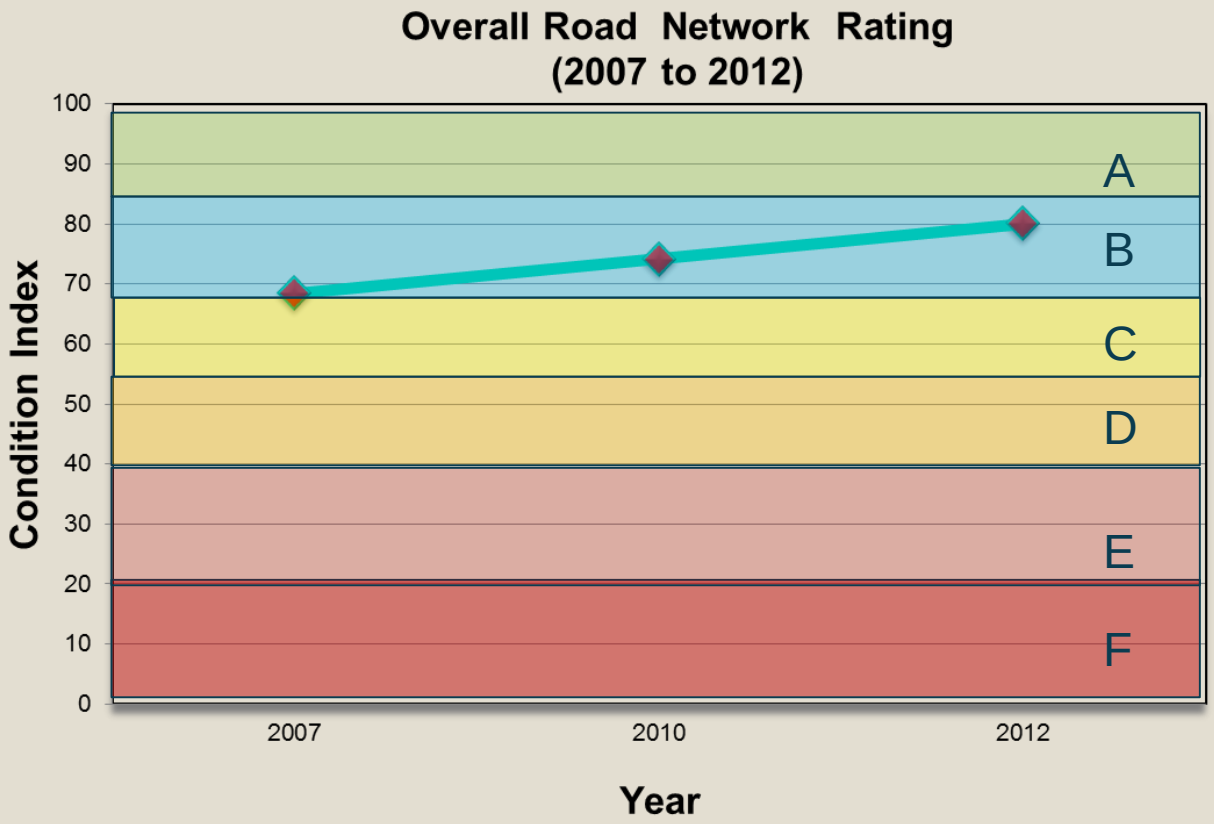
PMS SCREENS


Eastern Province Pavement Management System
Dammam Municipality (c) 2010
Home
Parameters
Archive
Help
About
M & R
Priority
Survey
Equipments
Forecast & Budget Planning
Special Reports
Save
Draw Chart
Eastern Province Municipality
GIS-Based Pavement
Management System
Version 3.0
Licensed To Eastern Province Municipality
Copyright 2010: KFUPM Spatial Pavement Group
Warning: Only Licensed Use

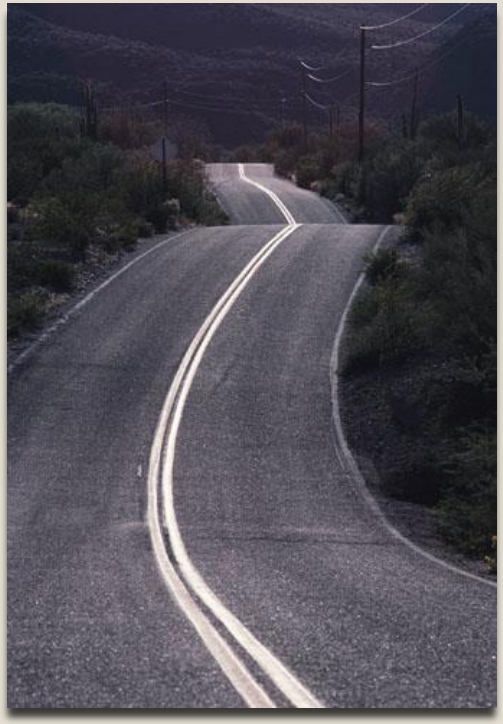
Pavement Performance Improvement



Pavement Performance Improvement



- **Conclusion**



Conclusion

- There is a need to preserve our road network assets
- Asset Management System is a tool for better assets preservation
- There is no system that can fit all , each organization should choose the system that meets its needs and challenges
- Agencies can develop its own PMS , with continues improvement
- The PMS helped the agencies to improve the road network condition and better utilize the available funds .
- It is important to realize that it is not a software but a complete integrated system
- Involving all stakeholders (Agency Engineers , Consultants , Contractors , etc) is important for success and continues improvement .
- Feed back and continues improvement

Thank you