Road Management System

THAILAND EXPERIENCE

PATTHARIN SARUTIPAND

Department of Highways

Evolution of road maintenance planning

- **Past:** Responsive (Corrective) System
- **Present:** Systematic Procedure
  - Routine Maintenance
  - Periodic Maintenance
  - Special Maintenance & Rehabilitation
  - Emergency Maintenance

Preventive

Corrective

- **Future:** Centralized DB + WA
  - Database (DB)
  - Web-based Applications (WA)

Road Maintenance Management Tools

DEVELOPING HOLISTIC, SYSTEMATIC APPROACH FOR MAINTENANCE MANAGEMENT

Goals – Make the right decision

- Developing systematic approach for maintenance management
- Achieving the highest cost effectiveness of maintenance strategies and the highest efficiency of the management processes in the organization

Objectives

- Adapting the **I**nformation **T**echnologies to support the maintenance management processes in the organization

  → Correctness, Quickness, Standardized

- **Centralized** the data relevant to the maintenance management process

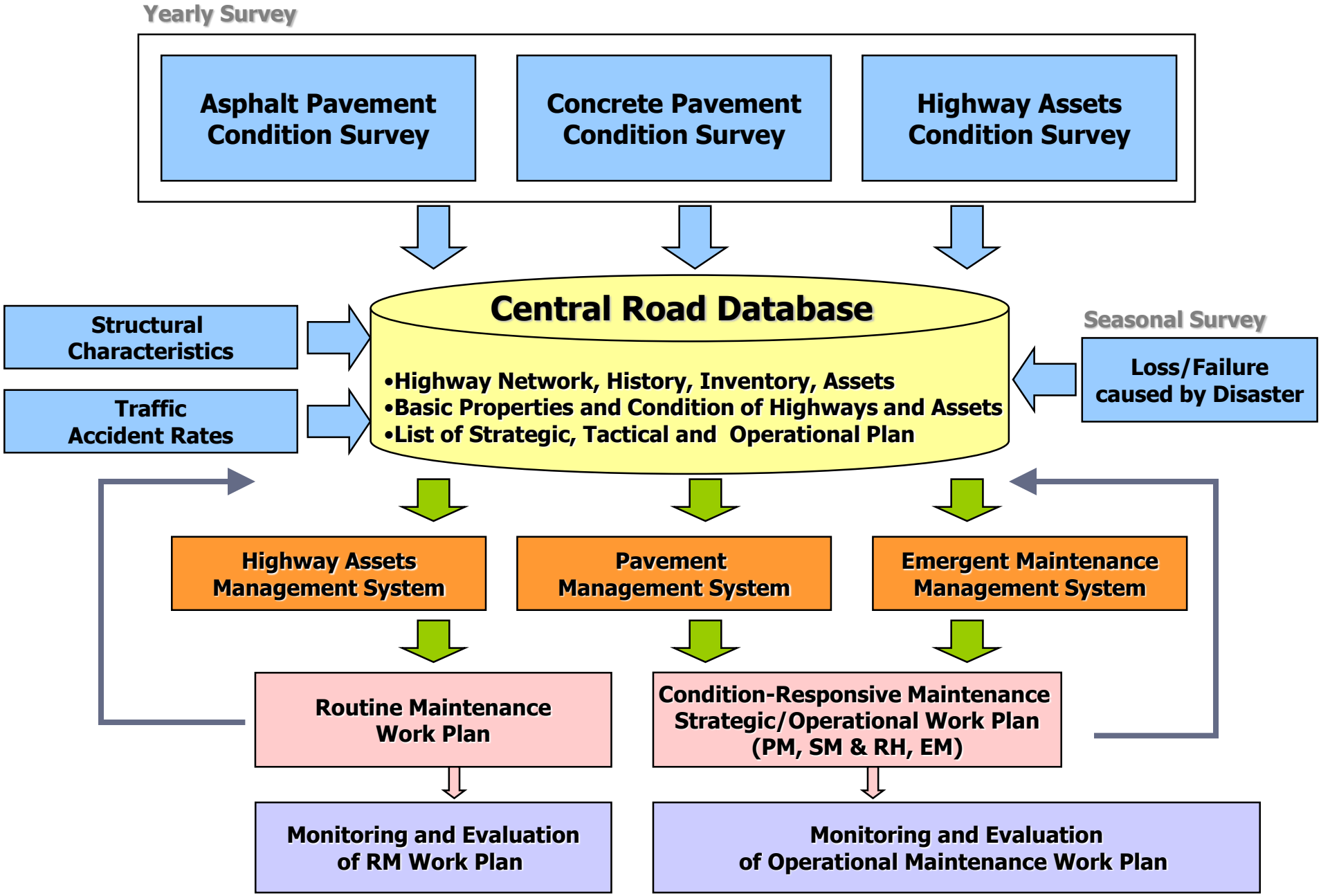
  → Reducing redundancy, error, diversity of data

- Representing the data and the analysis results on the **web-based** application using **G**eographic **I**nformation **S**ystem (GIS)

Centralized Database with Web-based Applications

- Pavement Condition Survey (3-yr survey cycle)
- Central Road Database (ROADNET)
- Pavement Management System (TPMS)
- Maintenance Plan Information System (PLANNET)
- Emergency Management System (EMS)
- Asset Management System (ASSET)

Holistic and Systematic Highway Maintenance System



Centralized Database with Web-based Applications

- **Pavement Condition Survey**
- Central Road Database
- Pavement Management System
- Maintenance Information System
- Emergency Management System
- Asset Management System

Pavement Condition Survey

Past:

- Manual/Visual Inspection
- Simple Instrument
- Data is summarized in spreadsheet forms

Present & Future

- Automated Survey Vehicle
- Data is presented on Graphical Information System (GIS) Map

Adopting new technology for condition survey

Past manually collected by state officials using simple instruments

Visual Inspection

แผ่นที่ 10

วันที่ 19-4-49 เวลา 13:25 สภาพอากาศ Fine

ลำดับที่ 36 ทางหลวงหมายเลข 4 กม. 622+600

พื้นที่สำรวจ 620+000 - 623+000

สาเหตุของความเสียหาย โครงสร้าง วัสดุ การก่อสร้าง เก่าขาดการบำรุง ระบบระบายน้ำ

การทดสอบเพิ่มเติม กม. - FWD Borescope GPR Coring

ข้อมูลเพิ่มเติม สภาพถนนเป็นทางยืนที่เป็น 4 LANE

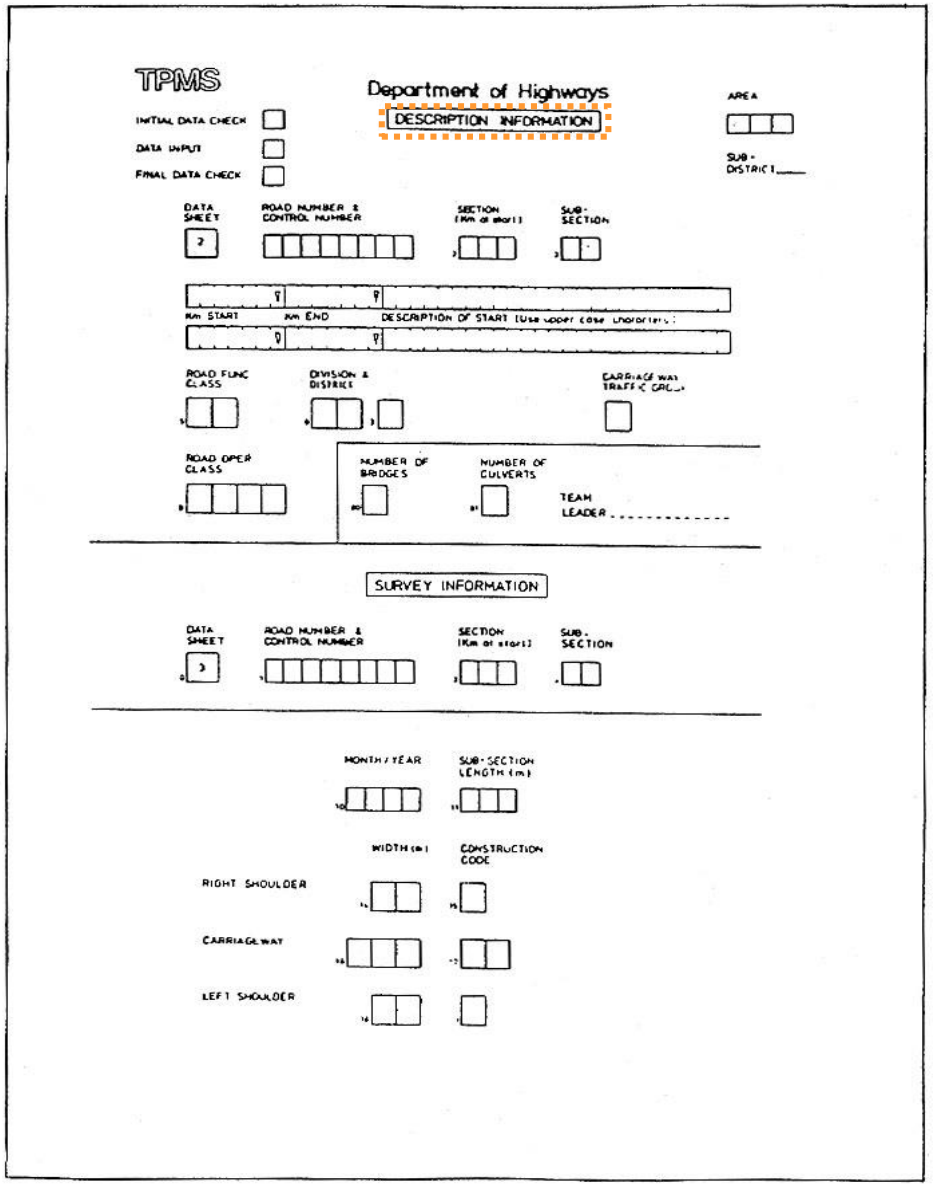
สภาพโดยรวมของถนน	ไม่มีความเสียหาย พบ Segregation เล็กน้อย - ปานกลาง [illegible]
รูปถ่ายลำดับที่	1400-1404 1404 - 1405
Drainage	ความเสียหายแนม
621+100- สภาพของจุดที่สำรวจโดยละเอียด	พบ Segregation น้อย แต่มีระยะทางของความเสียหาย [illegible] 60% [illegible] (LANE ซ้าย), พบ Segregation บริเวณ (LANE ขวา) [illegible] 200 ม. | GPS E 0459188 N 1092601
รูปถ่ายลำดับที่	1400, 1403 1400 - 1403

ความเสียหาย		มาก	กลาง	น้อย	ไม่มี	หมายเหตุ/ รูปถ่ายลำดับที่
รอยแตกตามยาว/ Alligator cracking	ความเสียหาย				✓	
	ความยาว					
ผิวแตก หลุดร่อน/ Block cracking and ravelling	ความเสียหาย				✓	
	พื้นที่					
หลุมบ่อ/ Potholes	ความเสียหาย				✓	
	ความถี่					
Segregation	ความเสียหาย			✓		
	ความถี่					
Bleeding	ยางที่ผิวทาง				✓	
	ความถี่					
การทรุดตัว / Rolling	ความเสียหาย				✓	
	ความถี่					
ร่องล้อซ้าย + ขวา	ความลึก	ร่องลึกประมาณ 1-2 มม.				(เลนซ้าย)
	ความยาว	[illegible] ประมาณ 200 ม.				
ร่องล้อขวา	ความลึก					
	ความยาว					

Rut Depth Measurement

Data Collection Method: Spread Sheet Format

Figure 8.1
TPMS Data Collection Form


TPMS

Department of Highways

DESCRIPTION INFORMATION

INITIAL DATA CHECK

DATA INPUT

FINAL DATA CHECK

AREA

SUB-DISTRICT

DATA SHEET

ROAD NUMBER & CONTROL NUMBER

SECTION (Km at start)

SUB-SECTION

Km START

Km END

DESCRIPTION OF START (Use upper case characters)

ROAD FUNC CLASS

DIVISION & DISTRICT

CARRIAGE WAY TRAFFIC GROUP

ROAD OPER CLASS

NUMBER OF BRIDGES

NUMBER OF CULVERTS

TEAM LEADER

SURVEY INFORMATION

DATA SHEET

ROAD NUMBER & CONTROL NUMBER

SECTION (Km at start)

SUB-SECTION

MONTH / YEAR

SUB-SECTION LENGTH (m)

WIDTH (m)

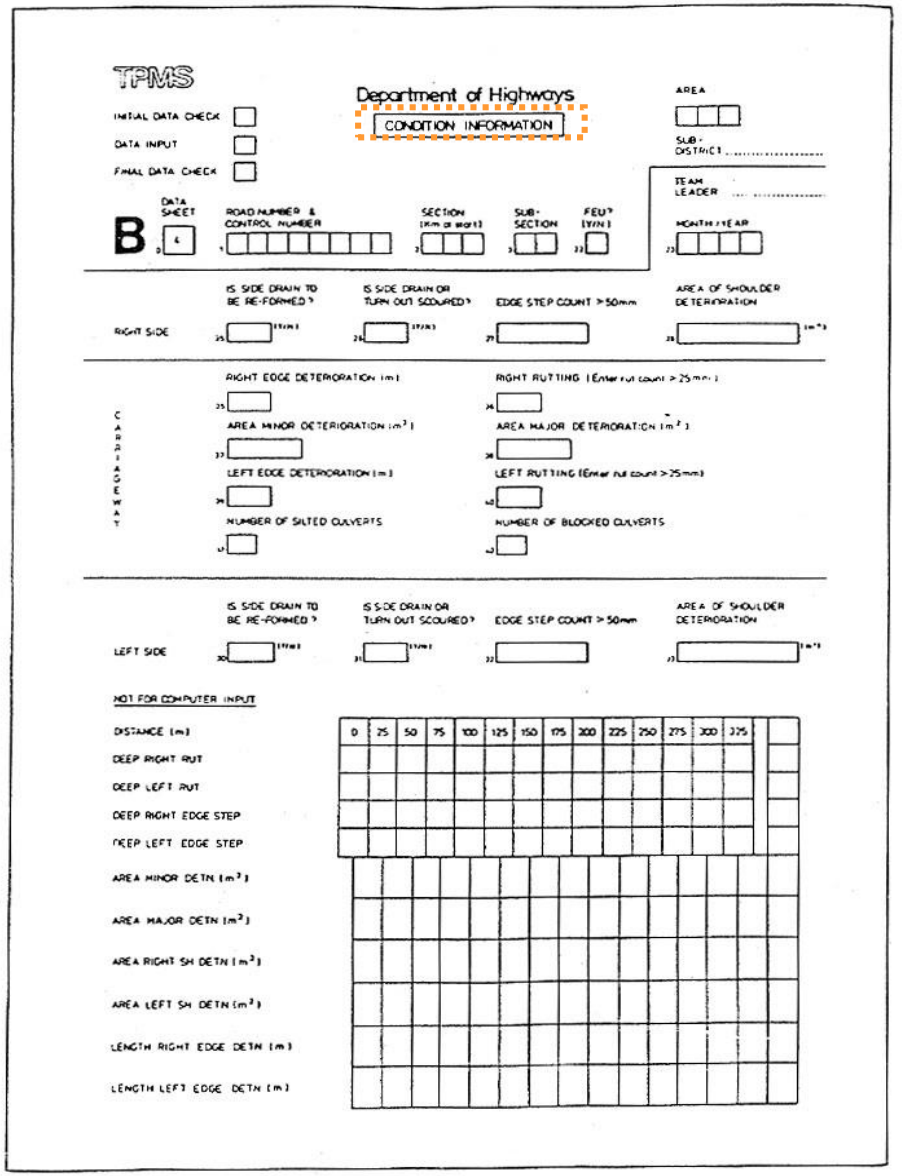
CONSTRUCTION CODE

RIGHT SHOULDER

CARRIAGEWAY

LEFT SHOULDER

Figure 8.1 (continued)
TPMS Data Collection Form


TPMS

Department of Highways

CONDITION INFORMATION

INITIAL DATA CHECK

DATA INPUT

FINAL DATA CHECK

AREA

SUB-DISTRICT

TEAM LEADER

MONTH / YEAR

B

DATA SHEET

ROAD NUMBER & CONTROL NUMBER

SECTION (Km at start)

SUB-SECTION

FEU? (Y/N)

RIGHT SIDE

IS SIDE DRAIN TO BE RE-FORMED?

IS SIDE DRAIN OR TURN OUT SCOURED?

EDGE STEP COUNT > 50mm

AREA OF SHOULDER DETERIORATION

CARRIAGEWAY

RIGHT EDGE DETERIORATION (m)

RIGHT RUTTING (Enter rut count > 25mm)

AREA MINOR DETERIORATION (m²)

AREA MAJOR DETERIORATION (m²)

LEFT EDGE DETERIORATION (m)

LEFT RUTTING (Enter rut count > 25mm)

NUMBER OF SILTED CULVERTS

NUMBER OF BLOCKED CULVERTS

LEFT SIDE

IS SIDE DRAIN TO BE RE-FORMED?

IS SIDE DRAIN OR TURN OUT SCOURED?

EDGE STEP COUNT > 50mm

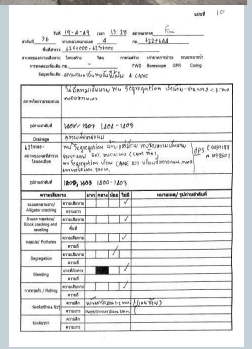
AREA OF SHOULDER DETERIORATION

NOT FOR COMPUTER INPUT

	0	25	50	75	100	125	150	175	200	225	250	275	300	325	
DISTANCE (m)															
DEEP RIGHT RUT															
DEEP LEFT RUT															
DEEP RIGHT EDGE STEP															
DEEP LEFT EDGE STEP															
AREA MINOR DETN (m²)															
AREA MAJOR DETN (m²)															
AREA RIGHT SH DETN (m²)															
AREA LEFT SH DETN (m²)															
LENGTH RIGHT EDGE DETN (m)															
LENGTH LEFT EDGE DETN (m)															

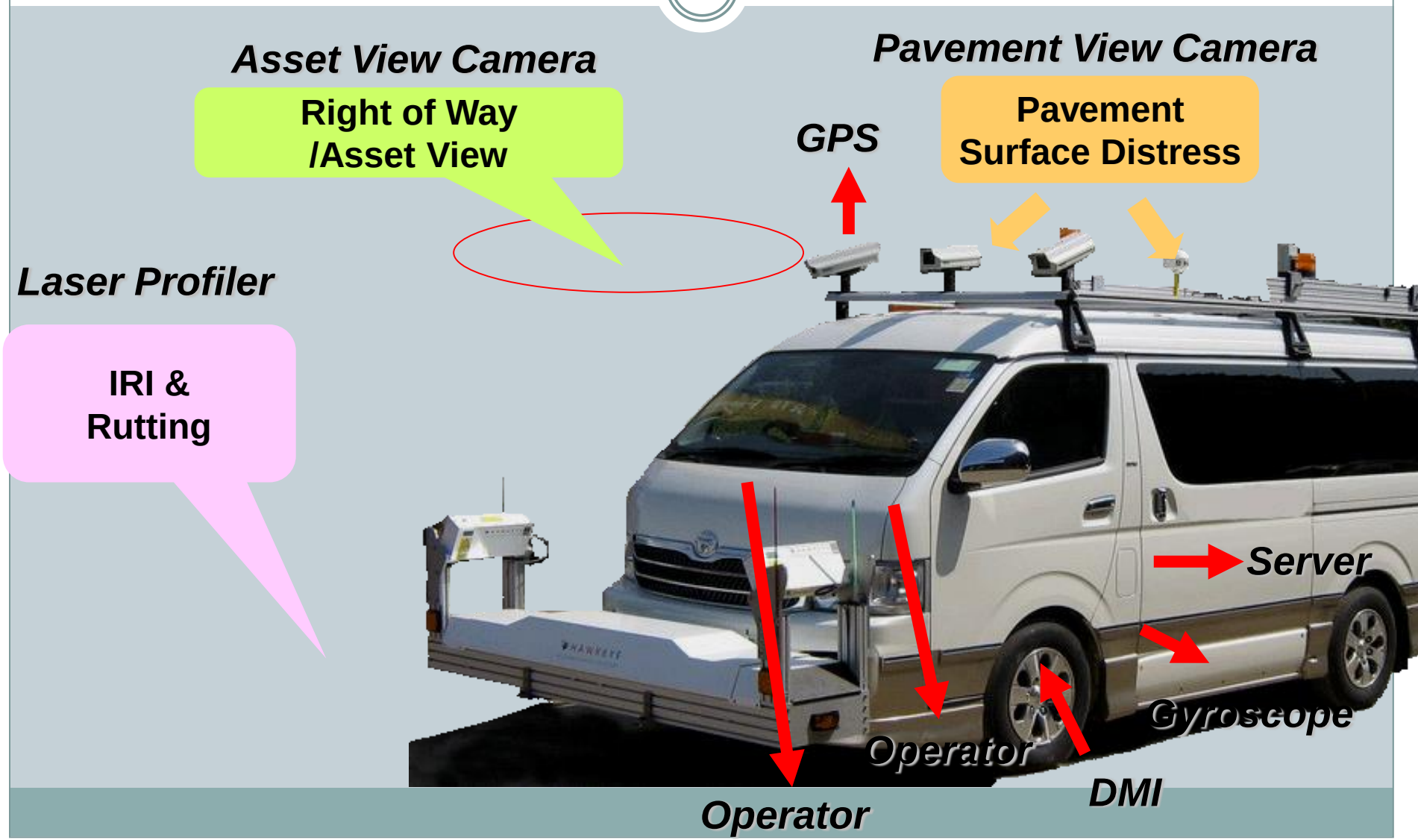
Pavement Condition Survey

- Past: Simple tools
  - Costly
    - Human resources
    - Survey Time
    - Data post-processing
    - Bias
  - Surface Distress
    - Visual Inspection
  - Deformation Distress
    - Structural Strength: FWD
    - Roughness: Bump Indicator (Mechanically)

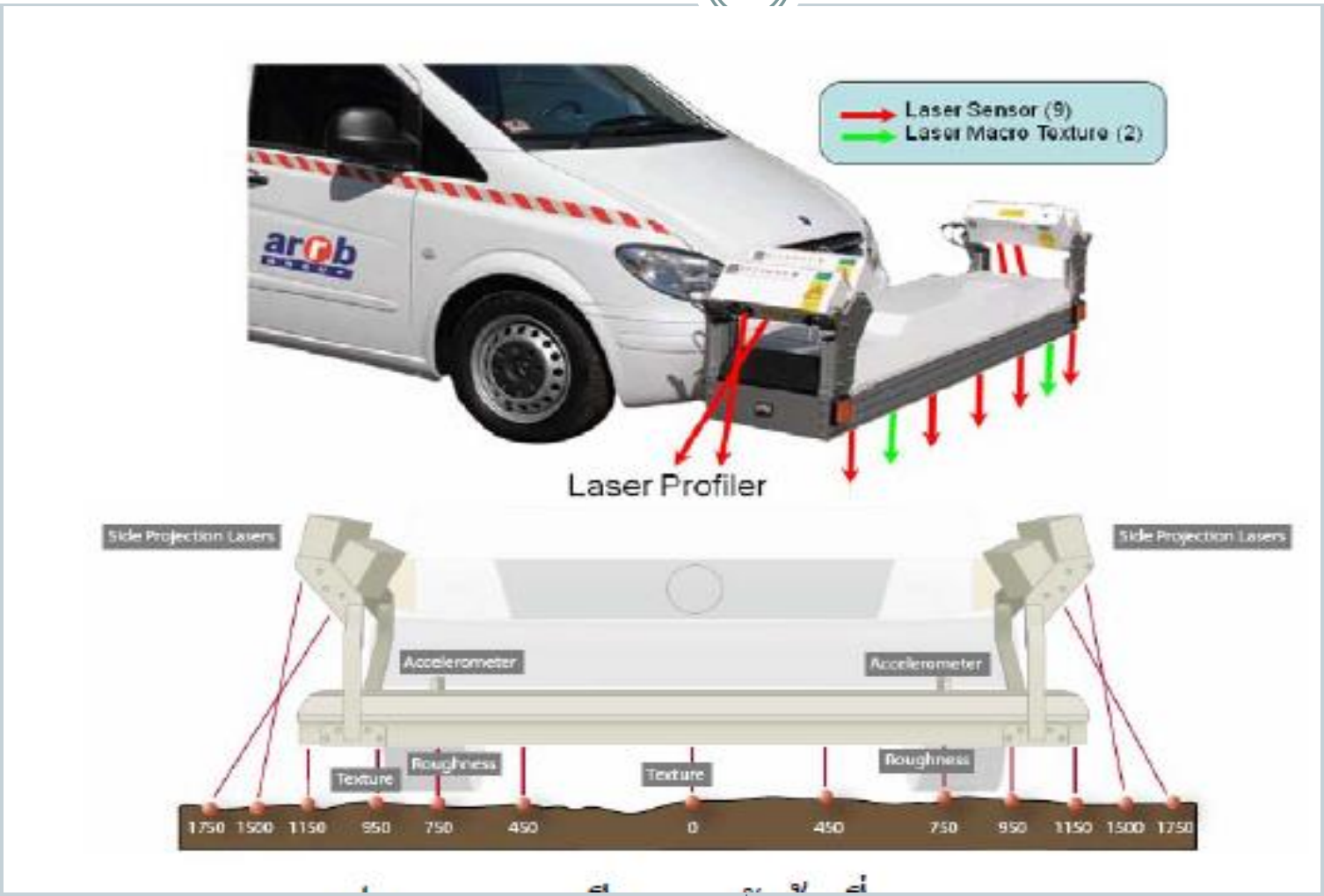


- Present: Sophisticated tools
  - Fast & Highly Accurate
    - 1 Driver +1 Operator/vehicle
    - Running speed 60 kph
    - Positioning by GPS
    - Systematic data post-processing
  - Surface Distress
    - Captured by software from videos
  - Deformation Distress
    - Structural Strength: FWD
    - Roughness: Laser Profiler (Electronically)

Automated Vehicle for PCS

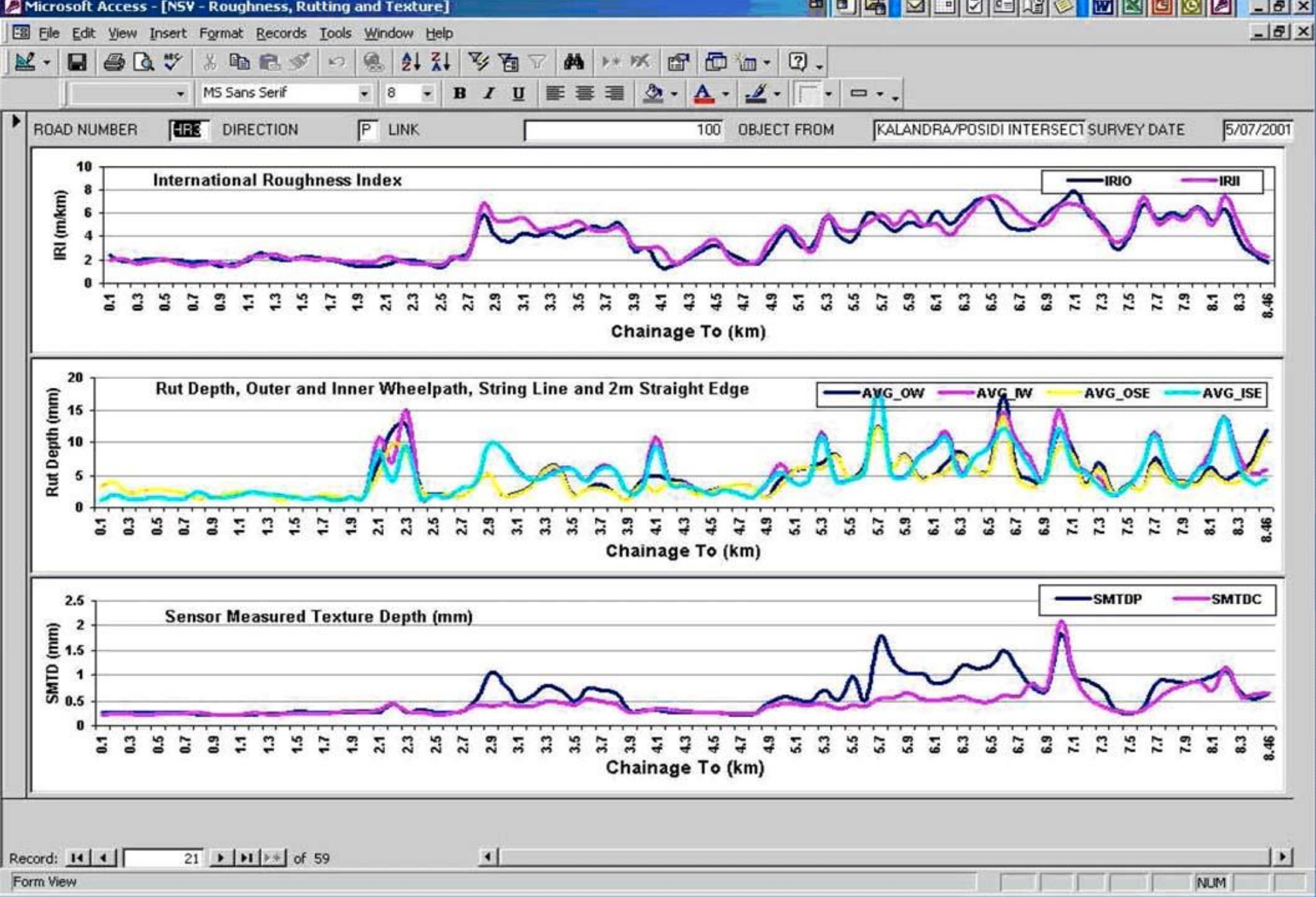


Laser profiler

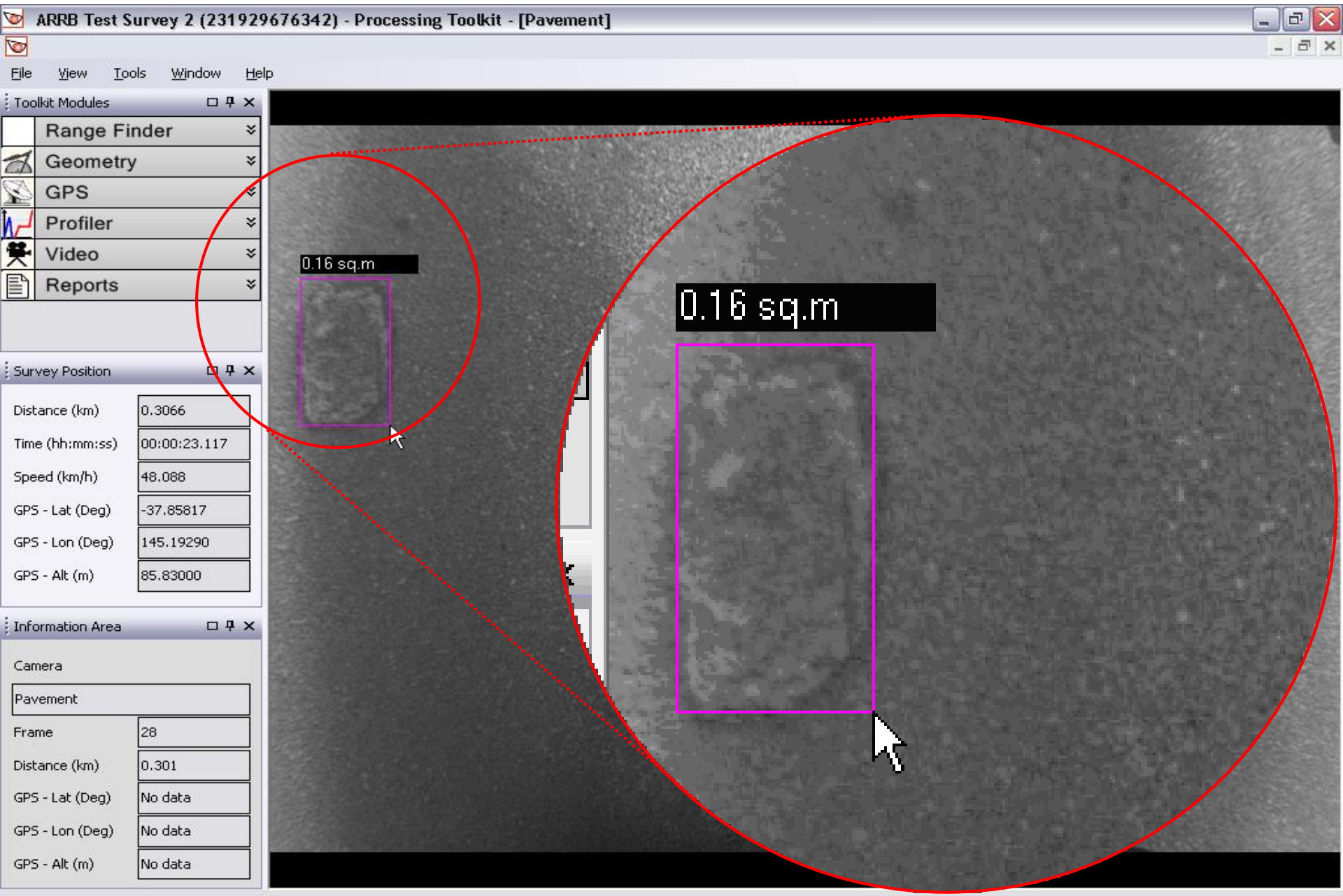


MEASUREMENT EQUIPMENT

PROCESSING TOOLS



PROFILE OF IRI, RUT DEPTH, TEXTURE DEPTH



DISTRESS AREA MEASUREMENT TOOLS

CENTRALIZED DATABASE

OGC Standard
SQL-Simple Feature
(SQL Script *.sql)

Condition data with GPS information

rutting | roughtness | rgeometry | gps | image | event | distress

GIS Map

km | link

CONVERT POINT DATA TO LINE

LINK TABLE DATA TO LINE

Centralized Database with Web-based Applications

- Pavement Condition Survey
- **Central Road Database**
- Pavement Management System
- Maintenance Information System
- Emergency Management System
- Asset Management System

Database design

- Road Inventory *from Bureau of Highway Planning*
  (No., Name, Start/End , #Lanes, District, Road Class, Construction Year)

from Automated Survey Vehicle

- GPS Data
- Road Geometry
  (Width, Slope, Grade, V/H Curve)
- Surfacing Distress
  (Crack, Pothole, Patching, Bleeding, Raveling)
- Deformation Distress
  (Roughness, Rutting)
- Asset Image

- Traffic Volume & Mix *from Bureau of Traffic and Safety*

Central Road Database

Road Database

- Road Inventory
- Geographic Information positioning by GPS

Maintenance Related Database

- Road Condition
  - Surface Distress

    (Crack, Pothole, Patching, Bleeding, Raveling)
  - Deformation Distress

    (Roughness, Rutting)
- Road Traffic (volume & mix)
- Asset Image

Road Database

Road Inventory

- Section Identification
- Attribute
- Physical Properties
- Engineering Properties
- Administration Unit
- History

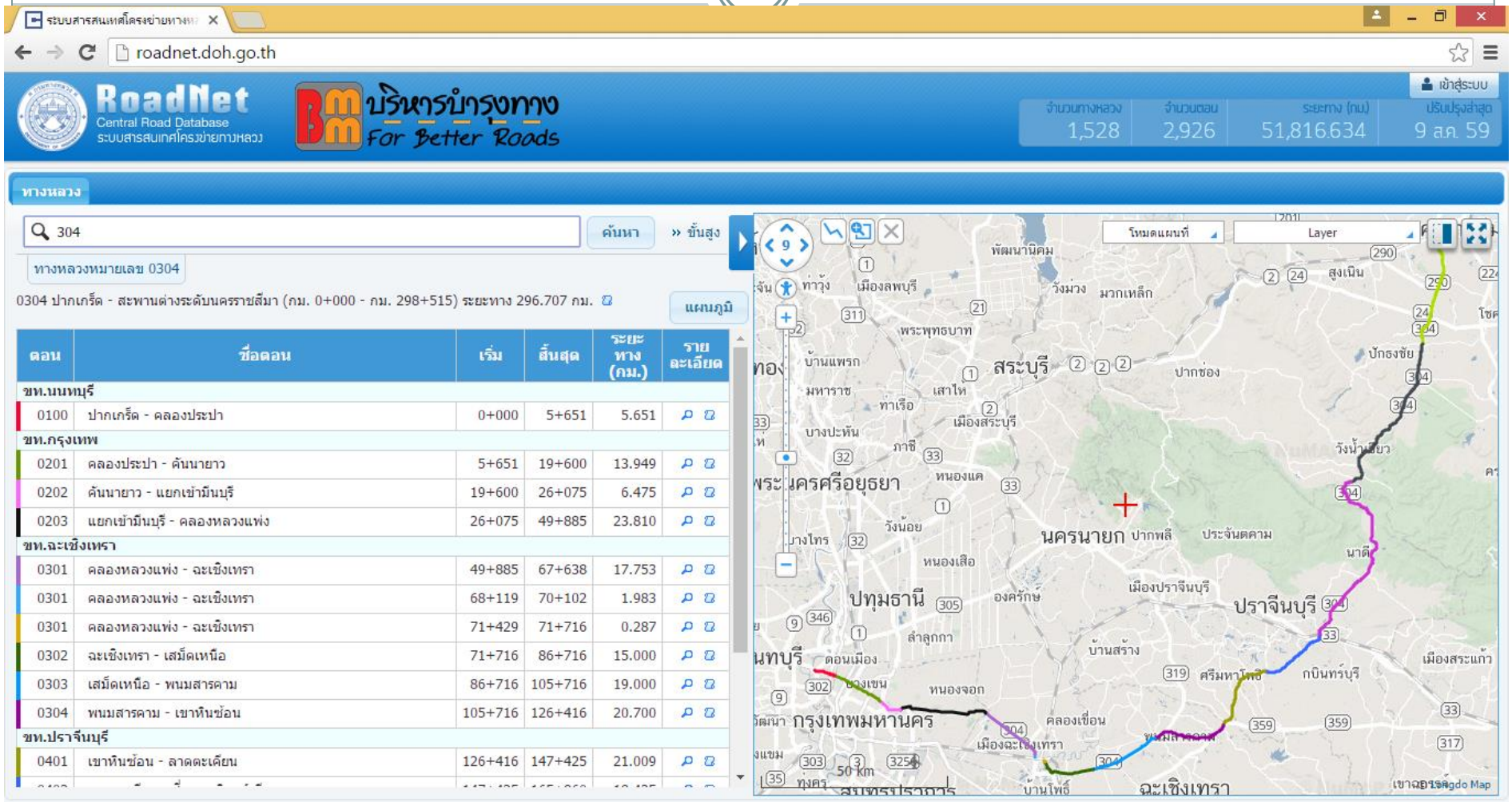
Survey

GIS Map

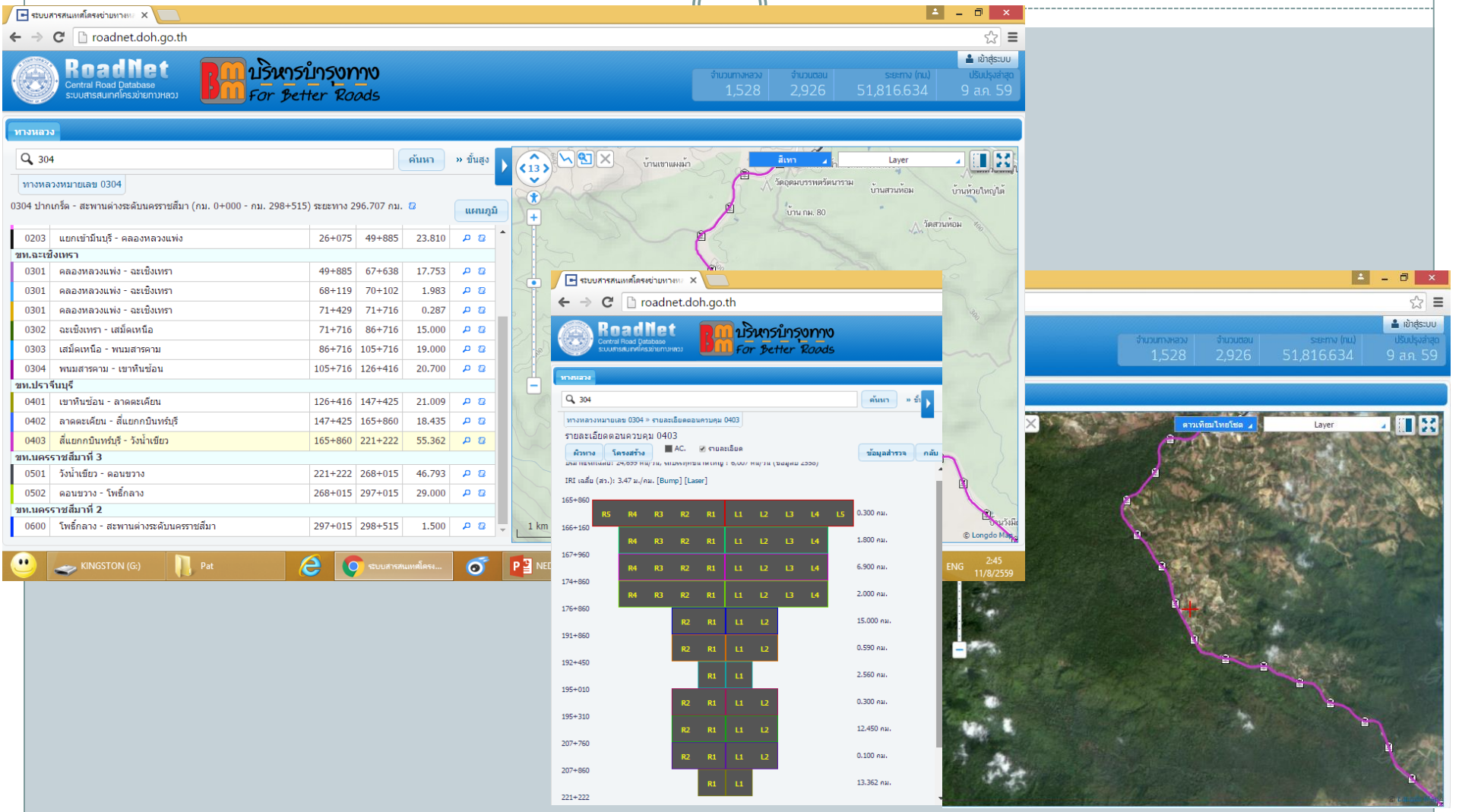
- Section geometry
- Referencing system post-kilometers
- Position by GPS

District	Route	Section	Start	End
511	1147	100	0+000	10+000
511	12	200	10+000	20+000
511	1061	101	5+000	10+050
511	1281	100	1+850	12+385

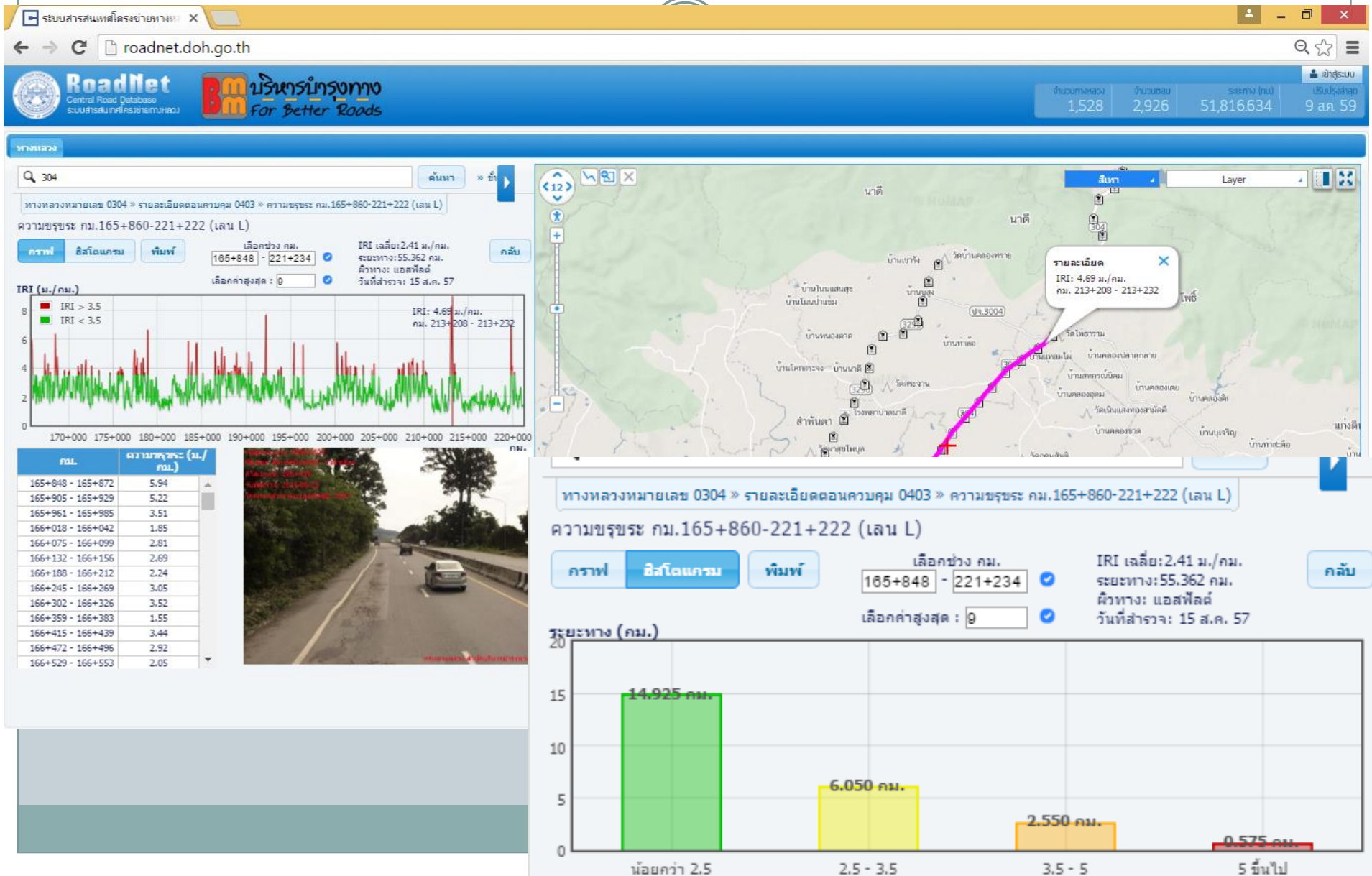
ROADNET (roadnet.doh.go.th)



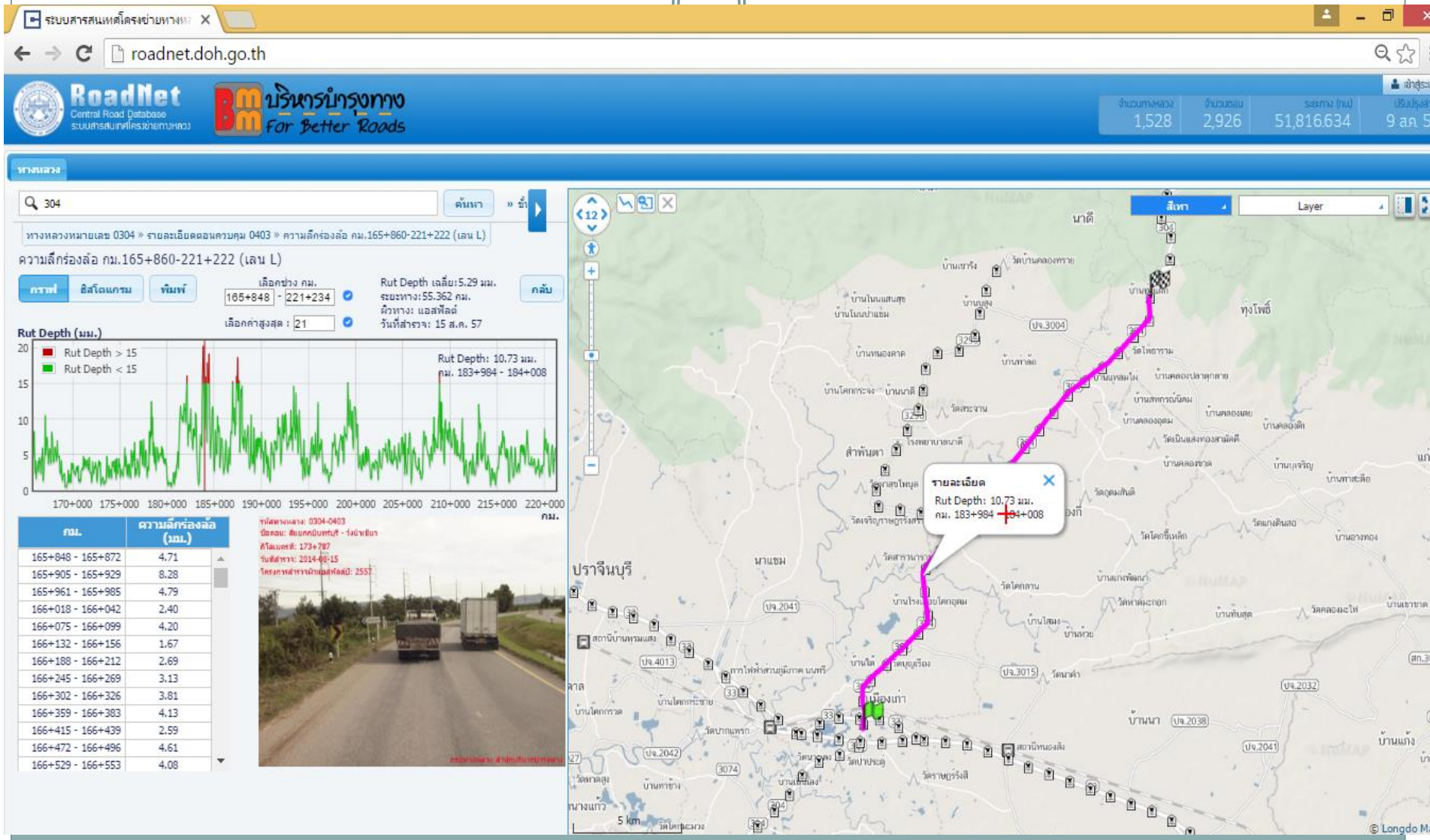
Route Info. (Length/ADT) + No. of Lanes + Geography



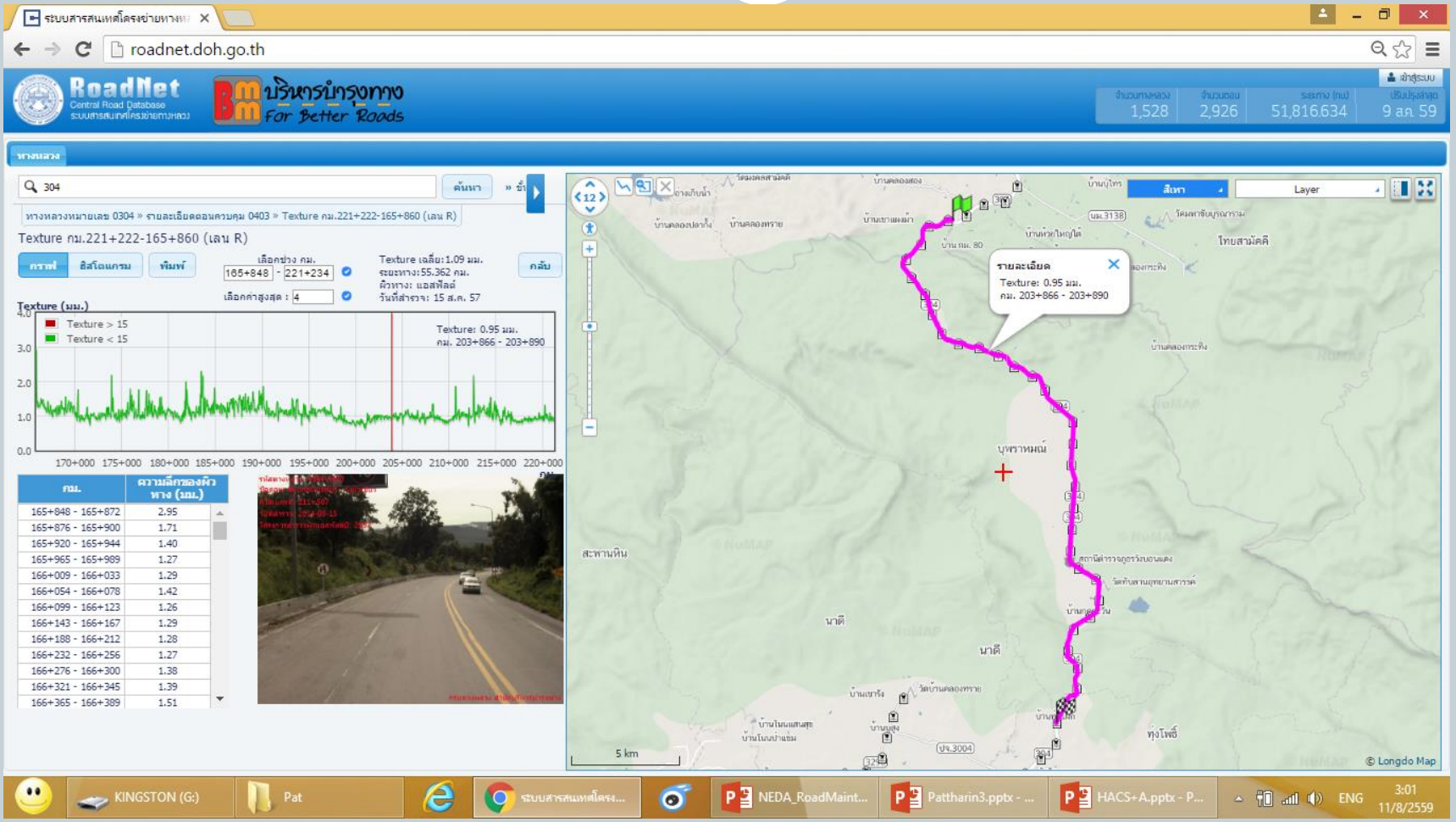
IRI (Profile/Histogram)+PICTURE+ LOCATION



Rutting Data



Texture Depth



What is the appropriate treatment ????

ADT 3,000 – 8,000 vehicle/day

Crack area 30 %

Rut Depth: Very Deep

Current Surface: AC 10 cm

What is the appropriate treatment ????

ADT < 3,000 vehicle/day

Crack area 15 %

No. of Pot Holes: Several

Current Surface: DBS

What is the appropriate treatment ????

ADT < 3,000 vehicle/day

Crack area 15 %

Current Surface: AC 5 cm

Pavement Management System

Making the right decision

- Engineering Analysis **Must be considered !**
  - Determine appropriate maintenance actions in corresponding to functional and structural characteristics
- Economic Analysis
  - Determine appropriate maintenance actions in corresponding to cost-effectiveness
- Network Analysis
  - Road users and Non-road users Impacts during Maintenance Period
  - Network Connectivity/Network Reliability
- Social Factors
  - Environmental Issues
  - Emissions/Pollutions

DOH Maintenance Policy

Routine Maintenance

- apply regularly

Periodic Maintenance

- maintain surface smoothness
- strengthen the pavement structure
- defer the pavement damages

Special Maintenance & Rehabilitation

- recover damages

Project Prioritization

Economic Benefit (Highways with high traffic volume)

Economic Analysis (Benefit/Cost Ratio)

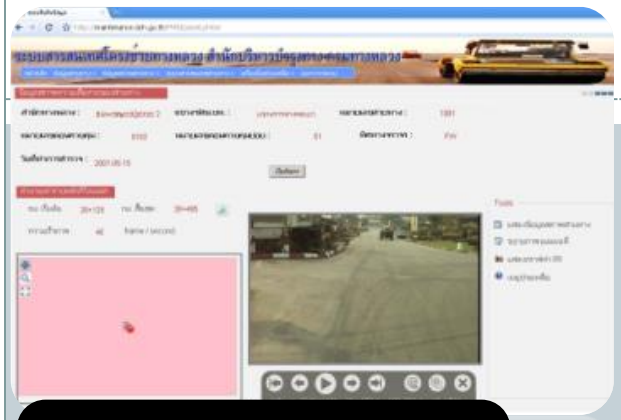
Community Connectivity (Collector roads)

Acceptable Serviceability Level / Maximum Allowable IRI

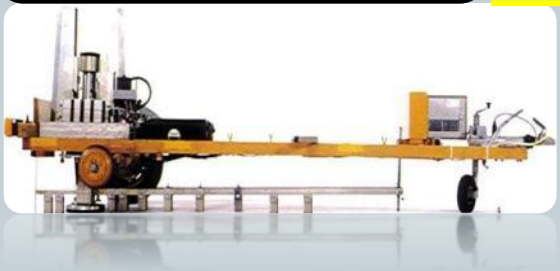
Respond to request/complaint from locals/regionals

Activities in the areas (Tourist Attractions, Urban Area, Conservative Area) Respond to governmental policy

Analysis Procedure



Functional and Structural Test



Road Condition Survey and Maintenance History

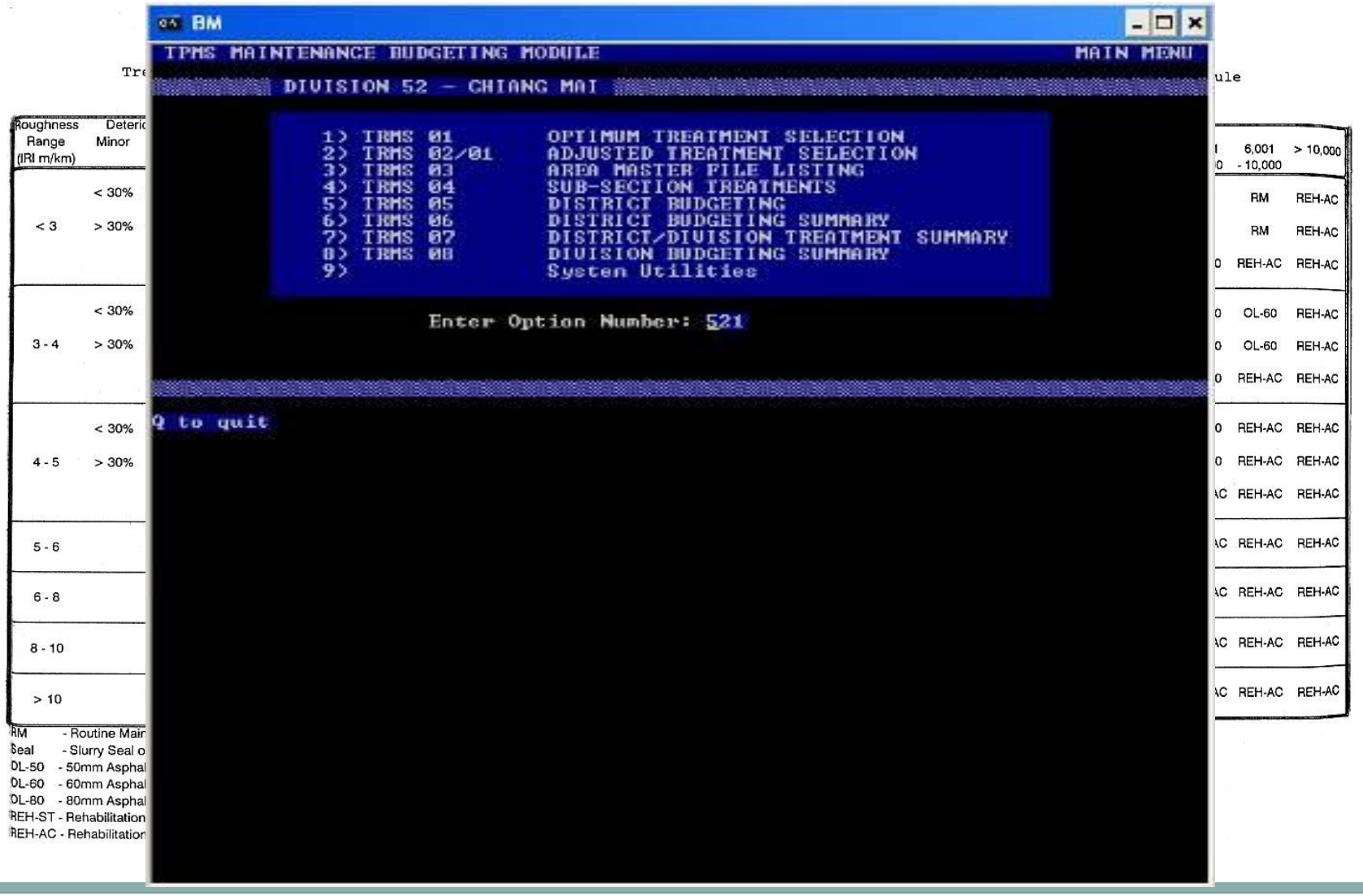
Road Condition Assessment

Appropriate Maintenance Options

Select the most cost-effective maintenance actions

Developing Pavement Management System

Past TPMS operating on Dos system + limitations



TPMS Maintenance Action Decision Matrix

Road Condition

Traffic

Table 8.1

Treatment Matrix for the TPMS Budgeting Module
AC Surface - Medium Strength

Roughness Range (IRI m/km)	Deterioration Minor	Deterioration Major	Traffic Range - AADT < 200	201 - 500	501 - 1,000	1,001 - 2,000	2,001 - 4,000	4,001 - 6,000	6,001 - 10,000	> 10,000
< 3	< 30%	< 10%	RM	RM	RM	RM	RM	RM	RM	RM
	> 30%	< 10%	Seal	Seal	Seal	Seal	RM	RM	RM	RM
		> 10%	Seal	Seal	Seal	Seal	OL-50	OL-50	OL-50	OL-50
3 - 4	< 30%	< 10%	RM	RM	RM	RM	OL-50	OL-50	OL-50	OL-60
	> 30%	< 10%	Seal	Seal	Seal	Seal	OL-50	OL-50	OL-50	OL-60
		> 10%	Seal	Seal	Seal	Seal	OL-50	OL-50	OL-50	REH-AC
4 - 5	< 30%	< 10%	RM	RM	OL-50	OL-60	OL-60	OL-60	OL-60	REH-AC
	> 30%	< 10%	Seal	Seal	OL-50	OL-60	OL-60	OL-60	OL-60	REH-AC
		> 10%	Seal	Seal	OL-50	OL-60	OL-60	OL-60	REH-AC	REH-AC
5 - 6			OL-50	OL-50	OL-60	OL-60	OL-60	OL-80	REH-AC	REH-AC
6 - 8			OL-50	OL-50	REH-ST	REH-ST	REH-AC	REH-AC	REH-AC	REH-AC
8 - 10			REH-ST	REH-ST	REH-ST	REH-ST	REH-AC	REH-AC	REH-AC	REH-AC
> 10			REH-ST	REH-ST	REH-ST	REH-ST	REH-AC	REH-AC	REH-AC	REH-AC

RM - Routine Maintenance
Seal - Slurry Seal or Surface Treatment
OL-50 - 50mm Asphaltic Concrete Overlay
OL-60 - 60mm Asphaltic Concrete Overlay
OL-80 - 80mm Asphaltic Concrete Overlay
REH-ST - Rehabilitation with Granular Base and DBST
REH-AC - Rehabilitation with Granular Base and 50mm Asphaltic Concrete

Table 8.2

Treatment Matrix for the TPMS Budgeting Module
AC Surface - High Strength

Roughness Range (IRI m/km)	Deterioration Minor	Deterioration Major	Traffic Range - AADT < 200	201 - 500	501 - 1,000	1,001 - 2,000	2,001 - 4,000	4,001 - 6,000	6,001 - 10,000	> 10,000
< 3	< 30%	< 10%	RM	RM	RM	RM	RM	RM	RM	RM
	> 30%	< 10%	Seal	Seal	Seal	Seal	RM	RM	RM	RM
		> 10%	Seal	Seal	Seal	Seal	OL-50	OL-50	OL-50	OL-50
3 - 4	< 30%	< 10%	RM	RM	RM	RM	RM	OL-60	OL-60	OL-60
	> 30%	< 10%	Seal	Seal	Seal	Seal	RM	OL-60	OL-60	OL-60
		> 10%	Seal	Seal	Seal	Seal	OL-50	OL-60	OL-60	REH-AC
4 - 5	< 30%	< 10%	RM	RM	OL-50	OL-60	OL-60	OL-60	OL-60	OL-80
	> 30%	< 10%	Seal	Seal	OL-50	OL-60	OL-60	OL-60	OL-60	OL-80
		> 10%	Seal	Seal	OL-50	OL-60	OL-60	OL-60	REH-AC	REH-AC
5 - 6			OL-50	OL-50	OL-60	OL-60	OL-60	OL-80	REH-AC	REH-AC
6 - 8			OL-50	OL-50	REH-ST	REH-ST	OL-80	OL-80	REH-AC	REH-AC
8 - 10			REH-ST	REH-ST	REH-ST	REH-ST	REH-AC	REH-AC	REH-AC	REH-AC
> 10			REH-ST	REH-ST	REH-ST	REH-ST	REH-AC	REH-AC	REH-AC	REH-AC

RM - Routine Maintenance
Seal - Slurry Seal or Surface Treatment
OL-50 - 50mm Asphaltic Concrete Overlay
OL-60 - 60mm Asphaltic Concrete Overlay
OL-80 - 80mm Asphaltic Concrete Overlay
REH-ST - Rehabilitation with Granular Base and DBST
REH-AC - Rehabilitation with Granular Base and 50mm Asphaltic Concrete

TPMS Maintenance Action Decision Matrix

PROBLEMS

-Road sections are no longer identical.

-Traffic pattern is varied, not uniformed.

-Distress observed is scattered and need multiple indicators rather than just IRI.

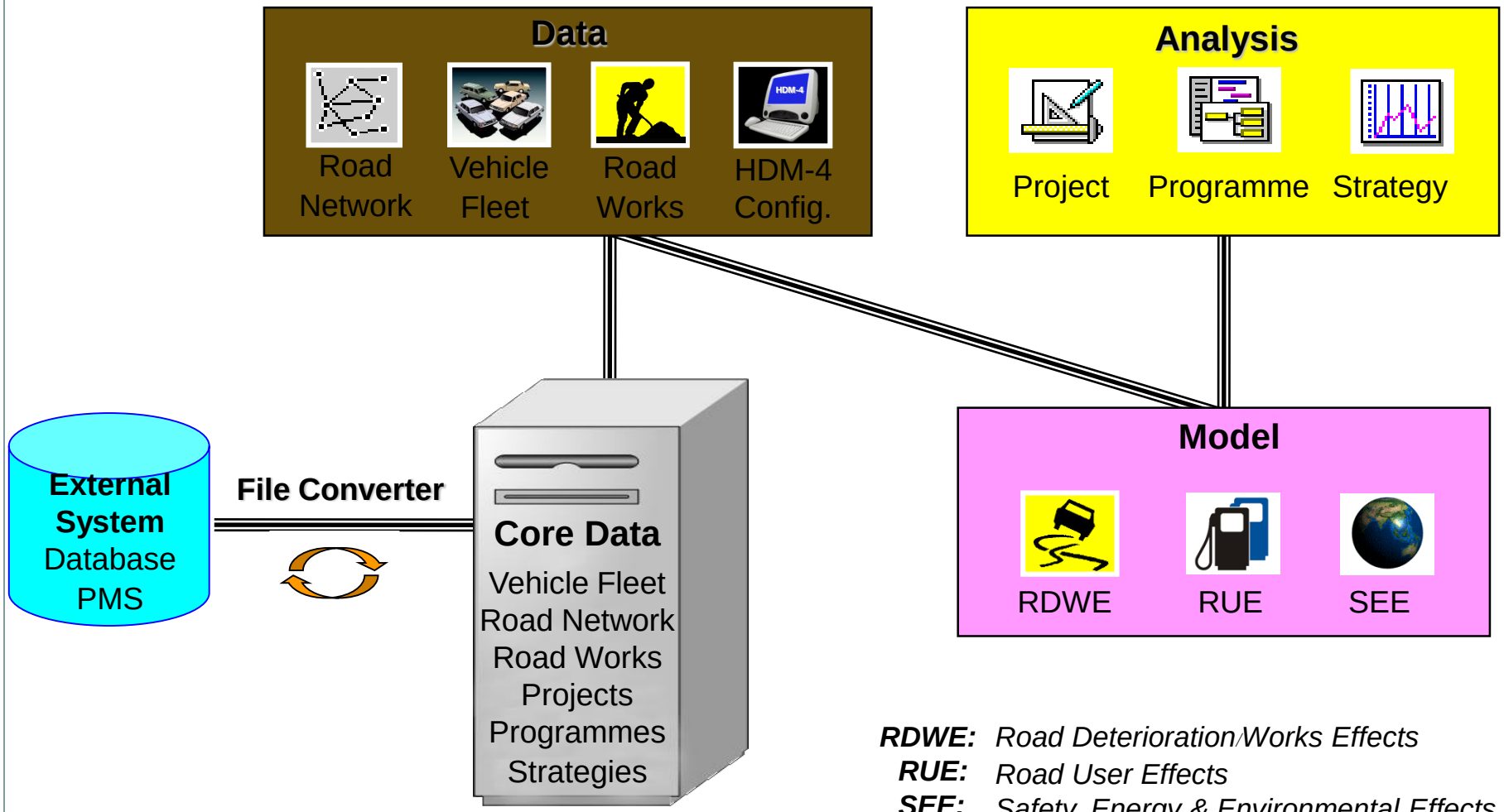
TPMS (NEW SYSTEM)

-Using road condition survey data

-Consider IRI, Rut Depth, Texture Depth, AADT, time since latest maintenance activities of each 1 km section

Developing Pavement Management System

Present Optimization tools to find the most cost effective alternatives.



RDWE: *Road Deterioration/Works Effects*
RUE: *Road User Effects*
SEE: *Safety, Energy & Environmental Effects*
PMS: *Pavement Management Systems*

Thailand Pavement Management System

- Decision supporting tools for suggesting the appropriate maintenance actions in terms of engineering and economic
- Supporting analysis at both project level and network level (70,000-section (1 km each) for maximum of 10-year analysis)
- Suggesting the most cost-effective maintenance strategy while satisfying the budget constraints
- Suggesting operational and strategic maintenance plan
- Analysis results can be presented on GIS Map

PMS: Decision supporting tools

- Deterioration Model:

  predict future pavement condition

- Road Works Effects Model:

  update condition after road work

- Road User Effect Model:

  quantify direct benefits

- Social/Environment Effect Model:

  quantify indirect benefits

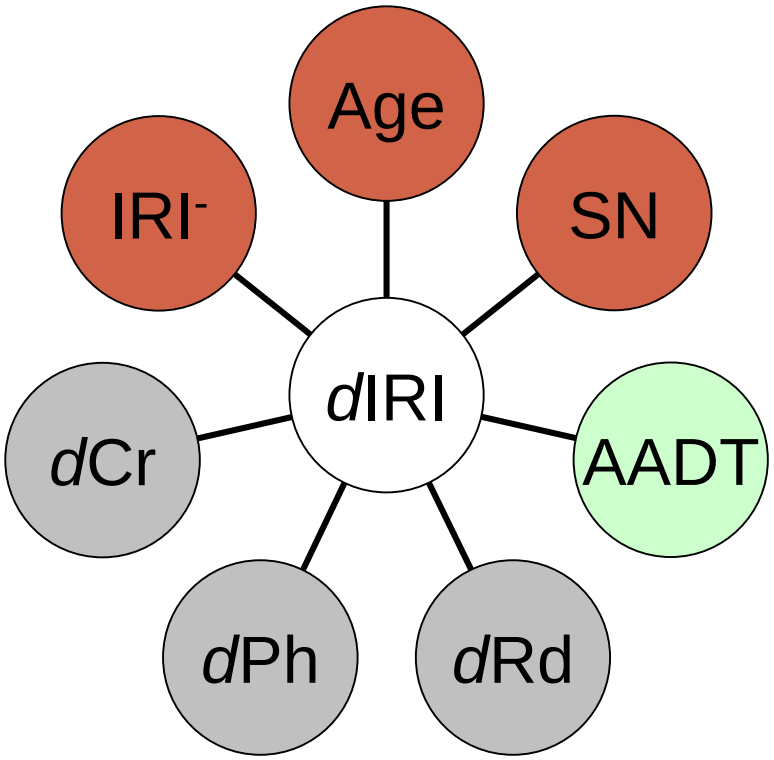
Road Deterioration Model

Forecasting Road Condition based on the Deterioration Factors

Condition Assessment & Forecasting

dIRI (Changes in International Roughness Index)

- IRI^- :Current IRI
- Age :Age of Pavement
- SN :Structural Number
- AADT: Avr. Annual Daily Traffic
- dCr :Changes in Crack Area
- dPh : Changes in # Pot Holes/km
- dRd : Changes in SD of Rut Depth



Distress Model

Road Deterioration Model

Determine Annual Change in Roughness due to Traffic

Roughness Increment during the analysis year

ΔIRI

Roughness at the End of the Year

IRI_e

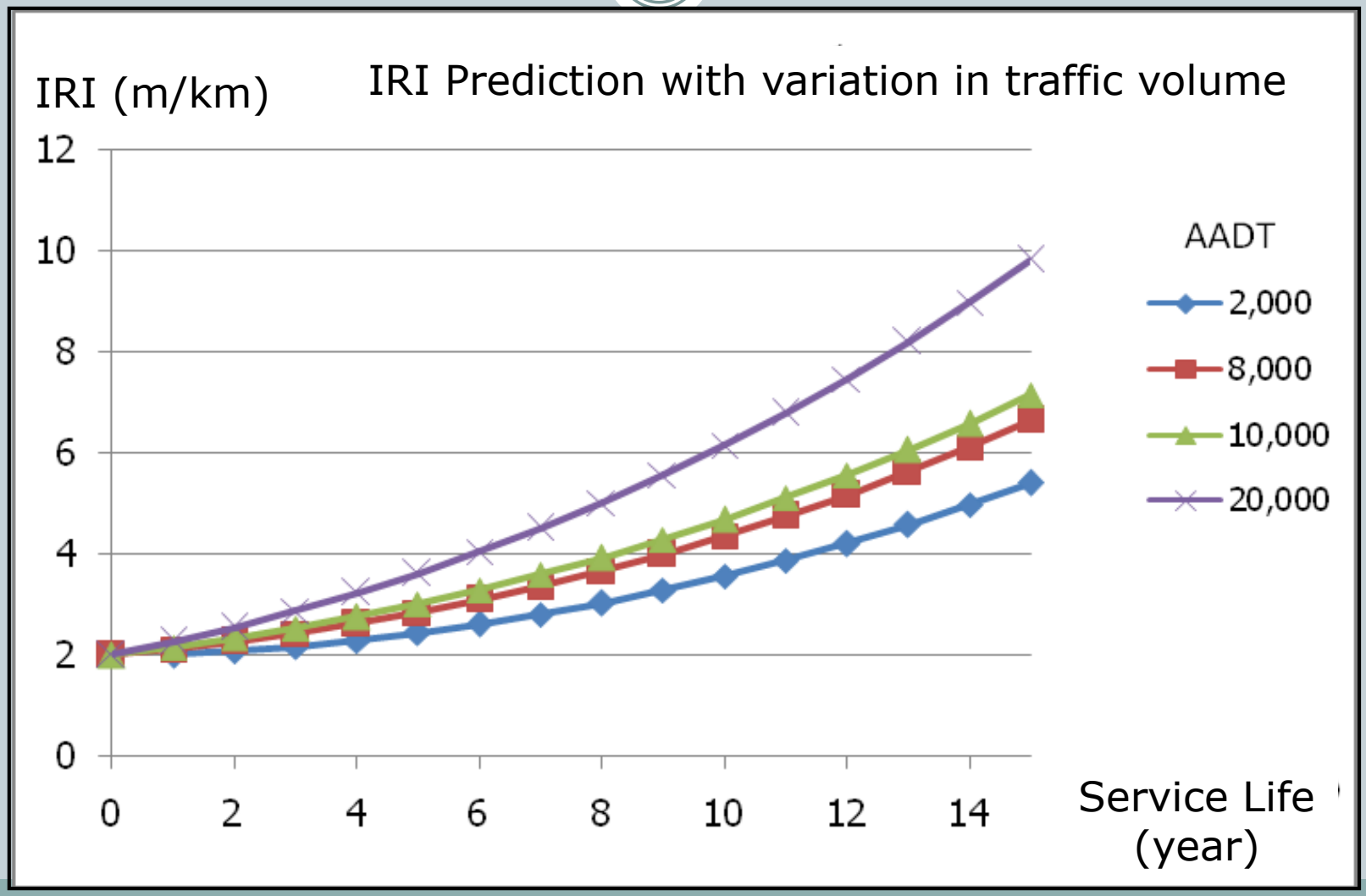
Roughness at the Beginning of the Year

IRI_b

$$IRI_e = IRI_b + \Delta IRI$$

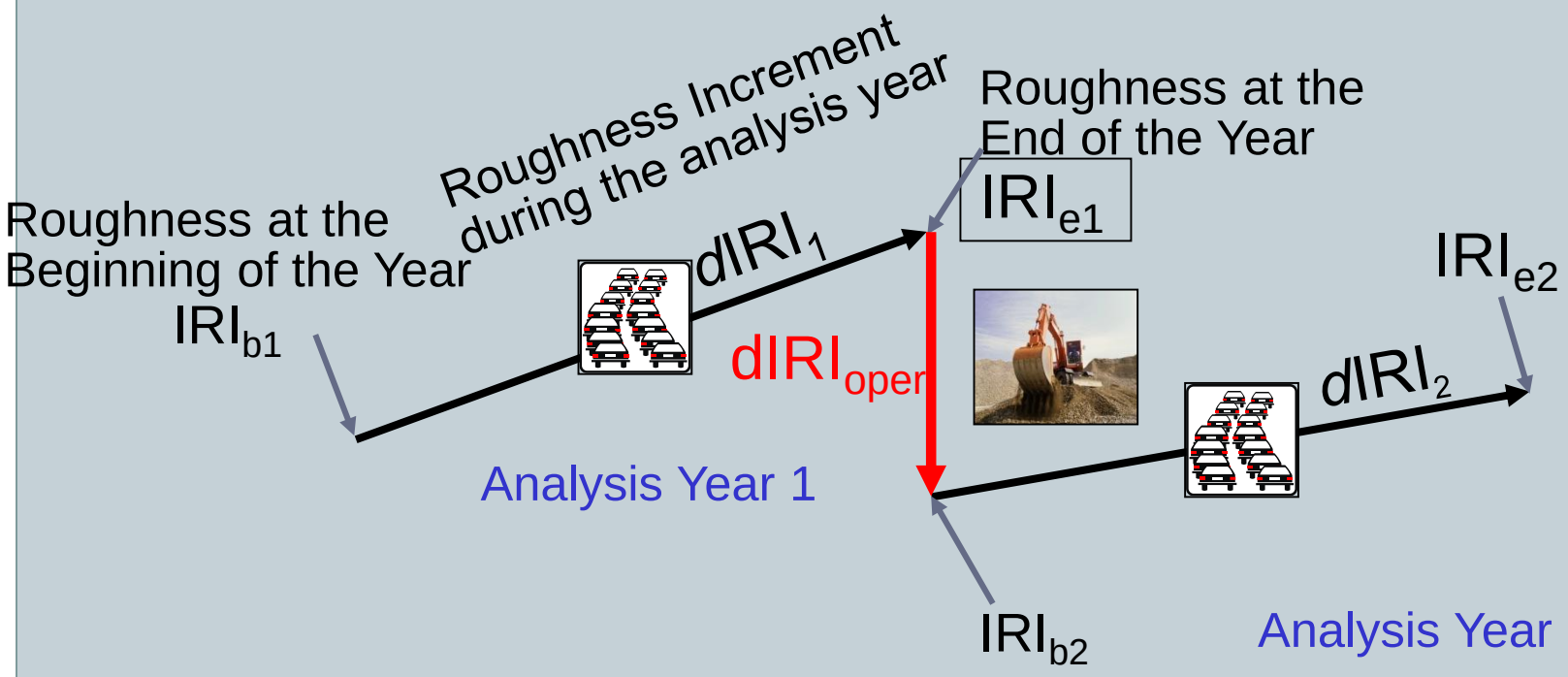
Analysis Year

Deterioration Model



Road Works Effects Model

Determine Road Condition Improvement due to Maintenance Activities



$$IRI_{b2} = IRI_{b1} + dIRI_1 + \mathbf{dIRI_{oper}}$$

Maintenance Operation Effect

Road Work Effect Model:
Road Condition After Maintenance Activities

M&R Options

- Routine Maintenance
- Sealing (Reduce IRI)
- Overlay (Reduce IRI)
- Rehabilitation (Reset to 2.0)

Reset

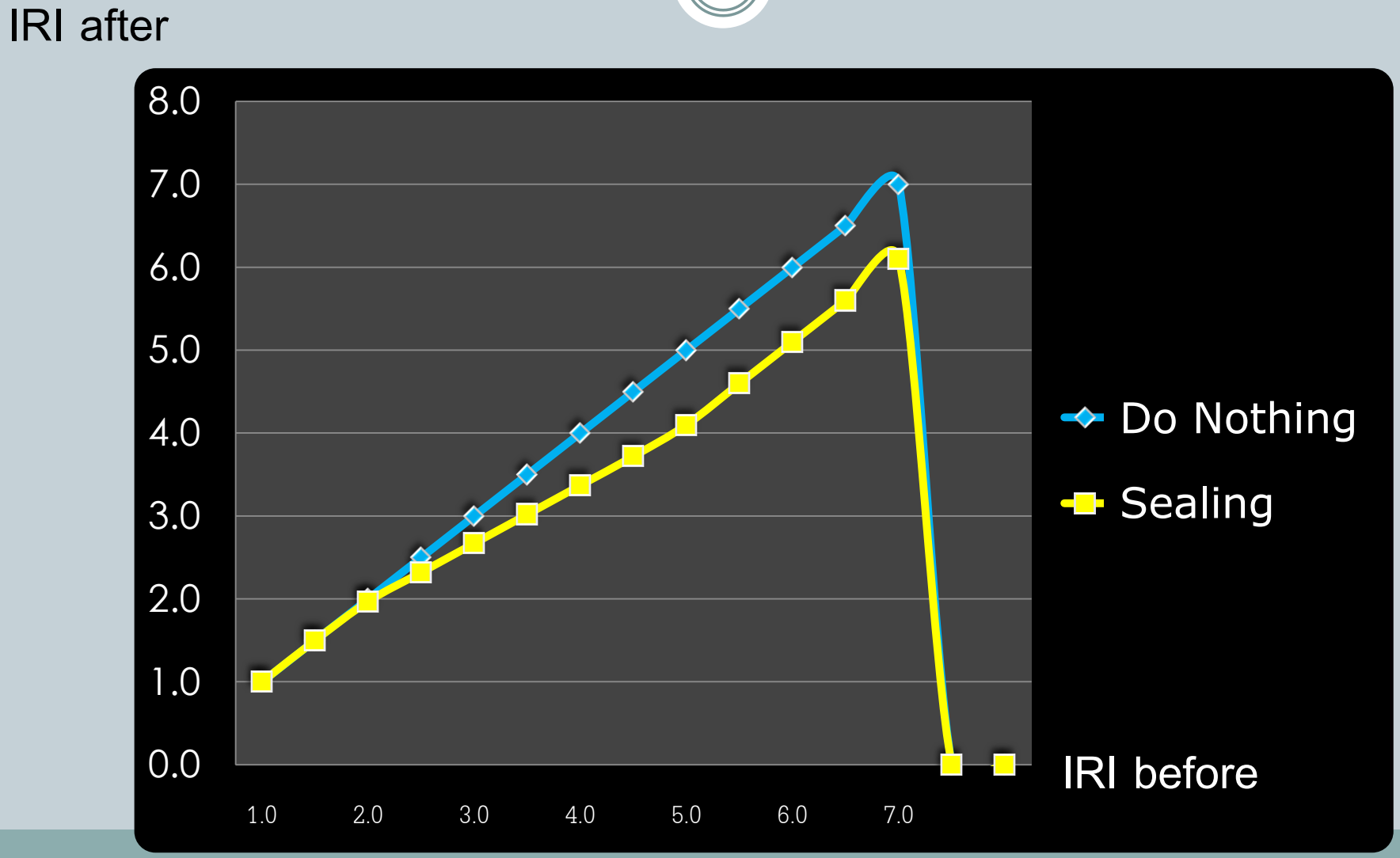
•Crack

•Rut Depth

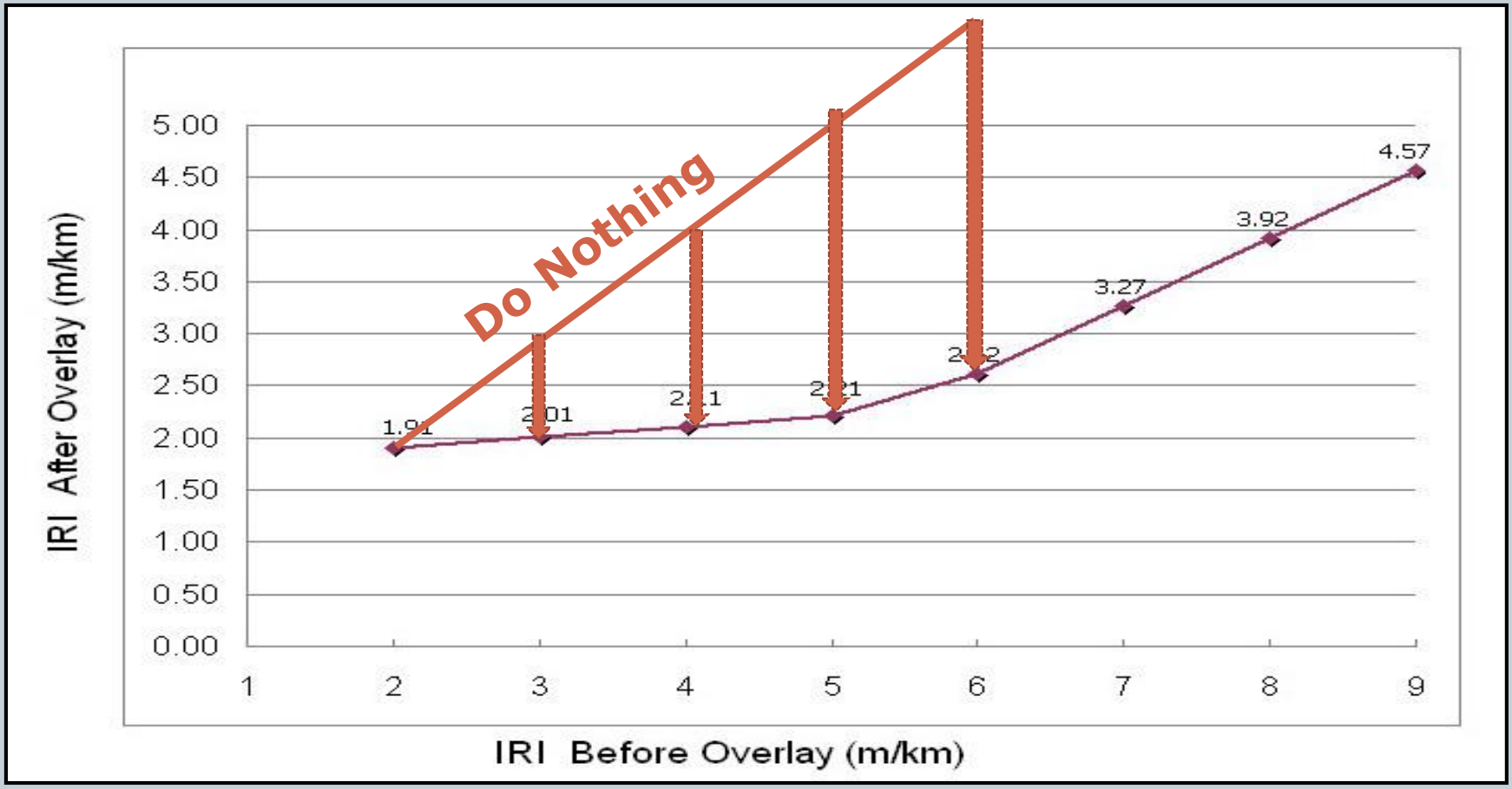
•Pot hole

to “None”

Roughness before and after Sealing



Roughness before and after overlay (5 cm thick)



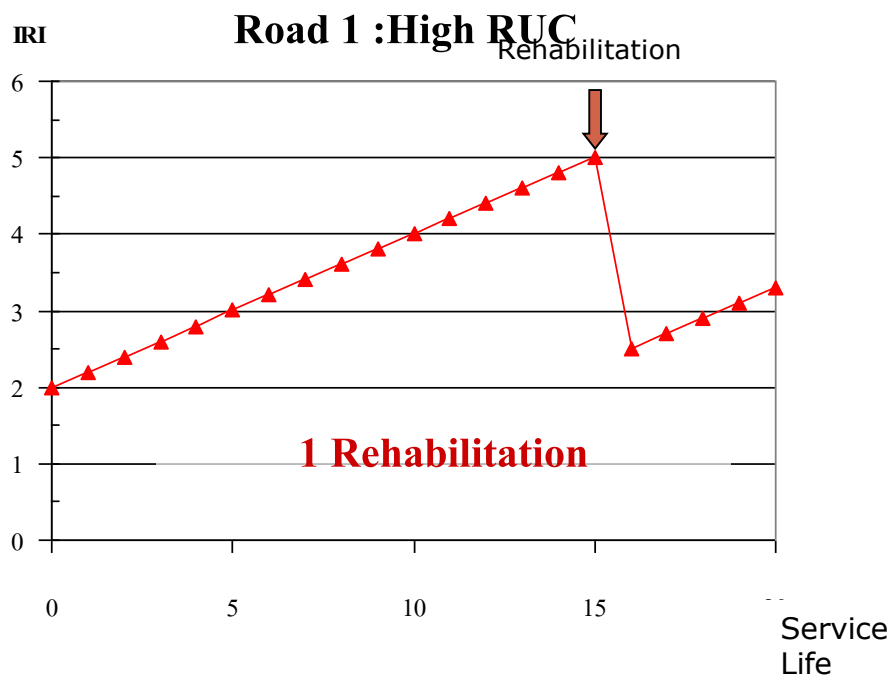
Road User Effects Model

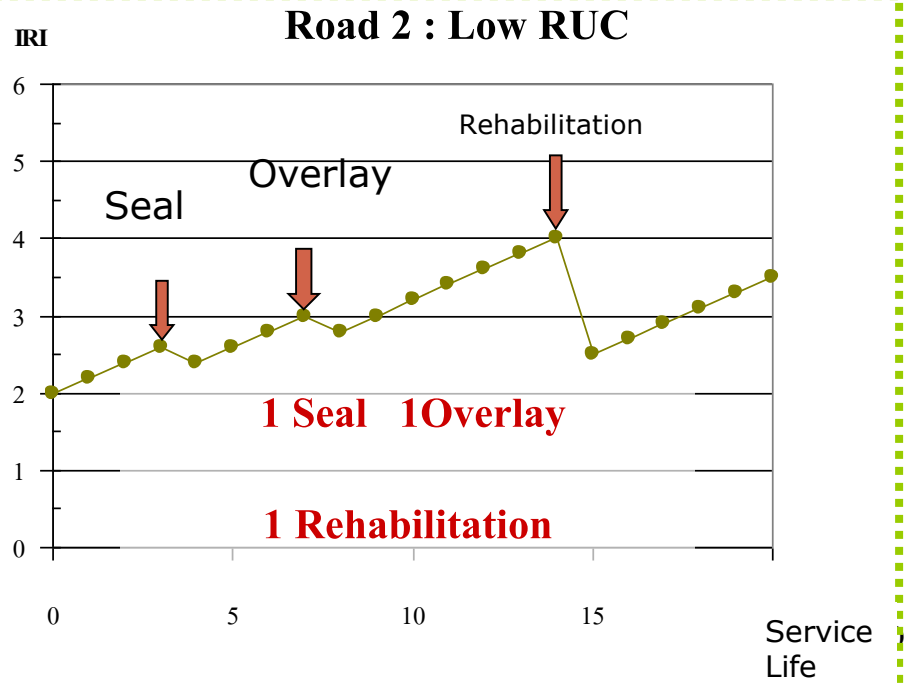
Quantifying costs to road users according to the road condition

Factor affects RUC = Speed, Road Condition

- Operating cost
- Maintenance cost

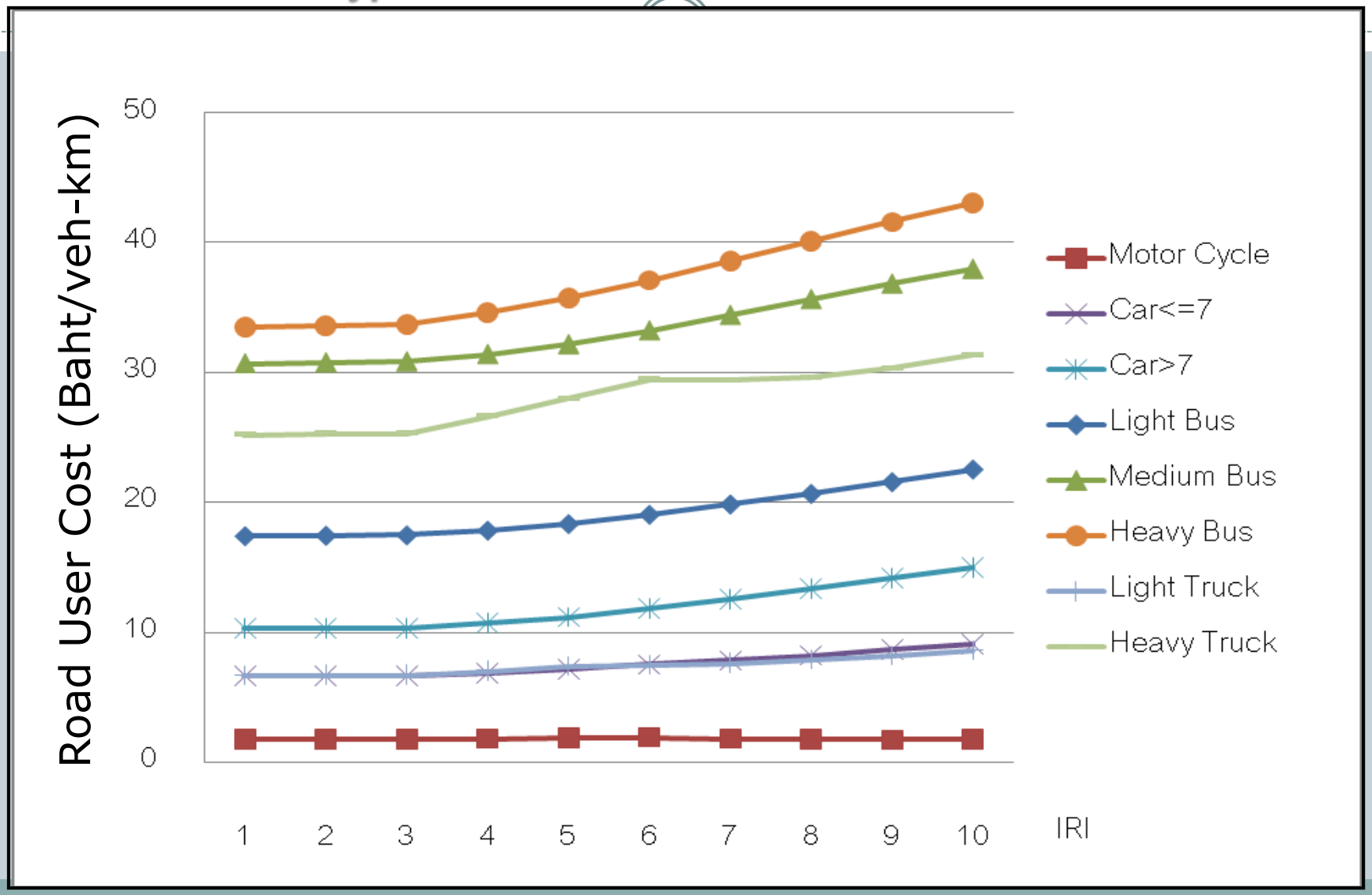
Example



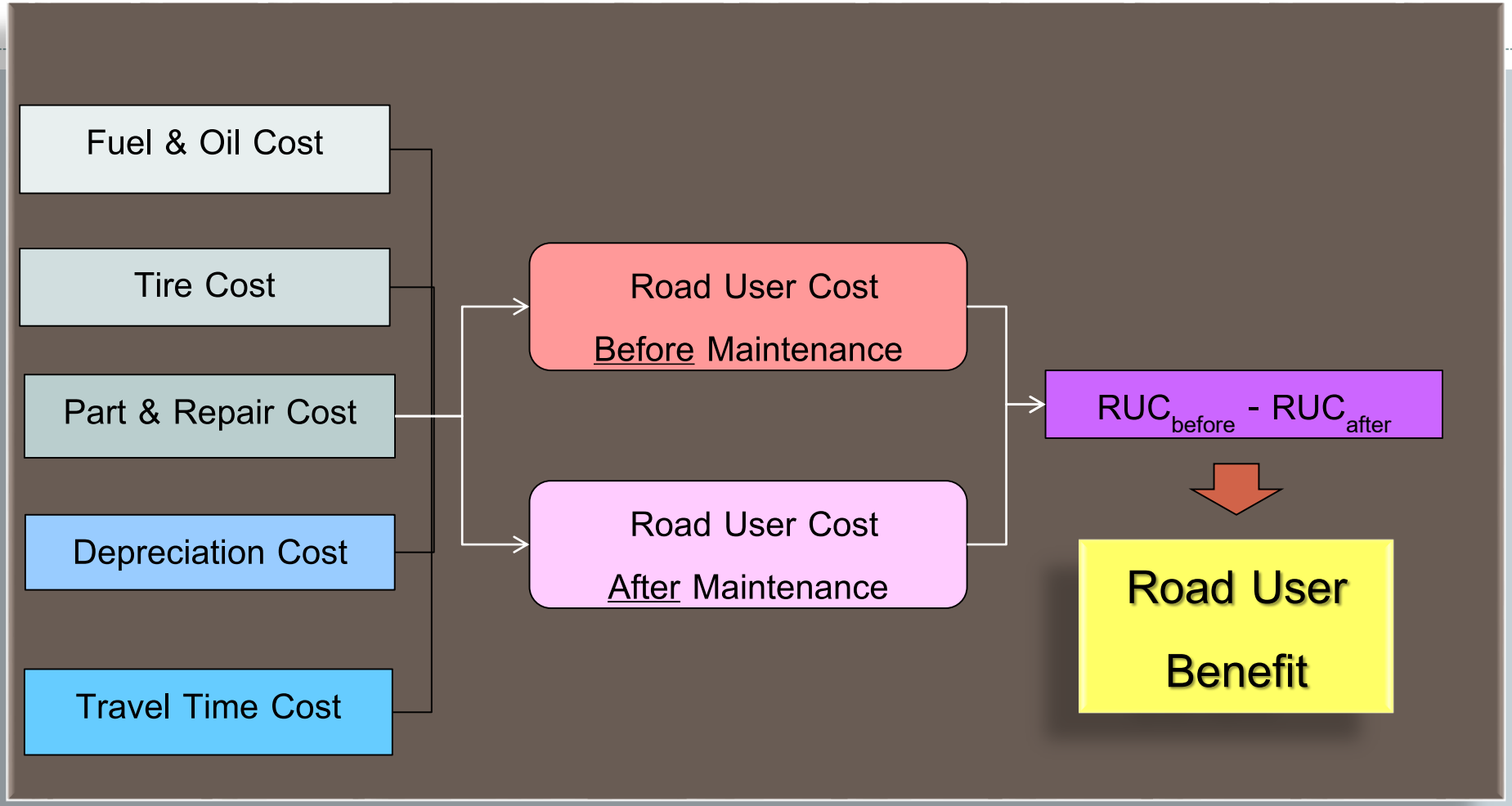


Road User Costs with variation of road roughness

For each vehicle type



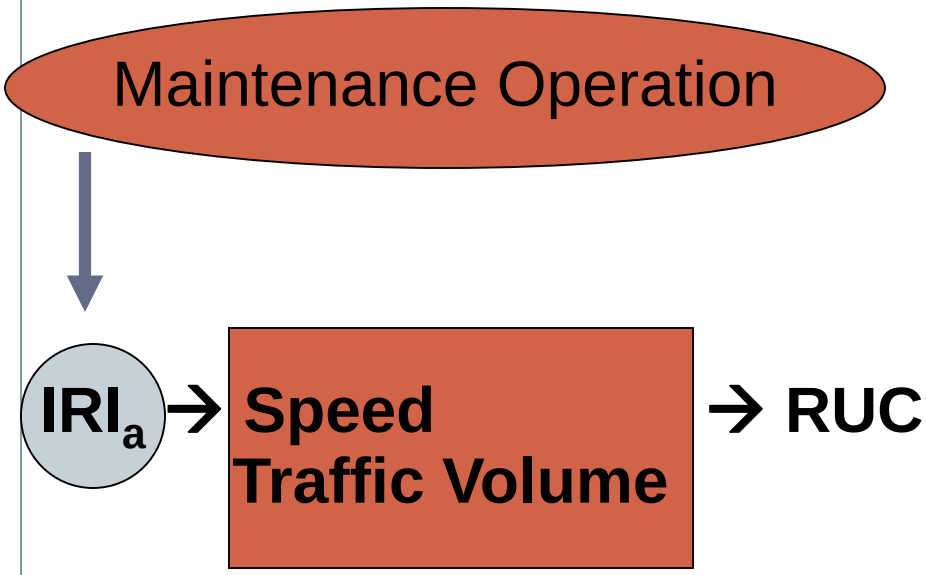
Road User Benefit & Net Benefit



Net Benefit = Road User Benefit – $Cost_{Maintenance}$

M&R Decision Making:
Benefit: Road User Effect Model

Road User Benefit = Cost before M&R - Cost after M&R



Item	Cost (Baht/km)
Gas	3.03
Lubricant	0.16
Tire	0.20
Repair & Part	0.85
Depreciation	0.91
Time	0.29
Total	5.45

Road Work Effect Model:
Road Condition After Maintenance Activities

M&R Options

- Routine Maintenance
- Sealing (Reduce IRI)
- Overlay (Reduce IRI)
- Rehabilitation (Reset to 2.0)

} Reset Crack, Rut Depth, Pot hole to "None"

Criteria for triggering M&R options

- IRI
- Rut Depth
- Texture Depth
- Pavement Age

M&R Decision Making:
Economic Analysis & Budget Optimization

Project Selection Method:

1. Computing Benefit, Cost of each M&R options
2. For each section, selecting M&R option that

Unconstrained Optimization

- Max NPV (Net Present Value)
- Selecting projects that NPV>=0

Constrained Optimization

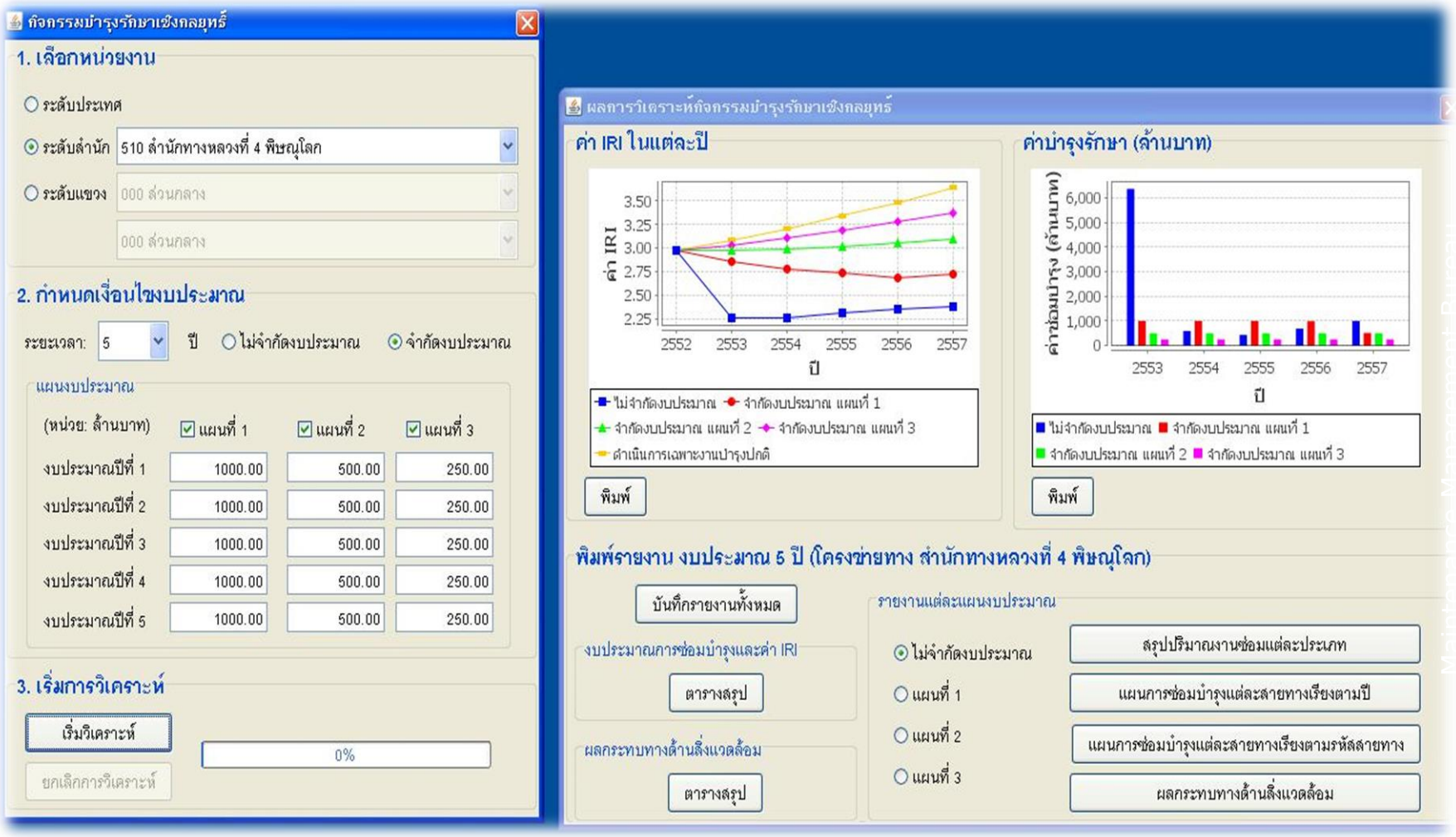
- Max B/C where C satisfied Budget Constraints
- Selecting projects that B/C >=1

- Benefit=RUC (do nothing) – RUC (with Maintenance)
- Optimization= find the combination of projects that lead to the maximum social benefit within a given budget

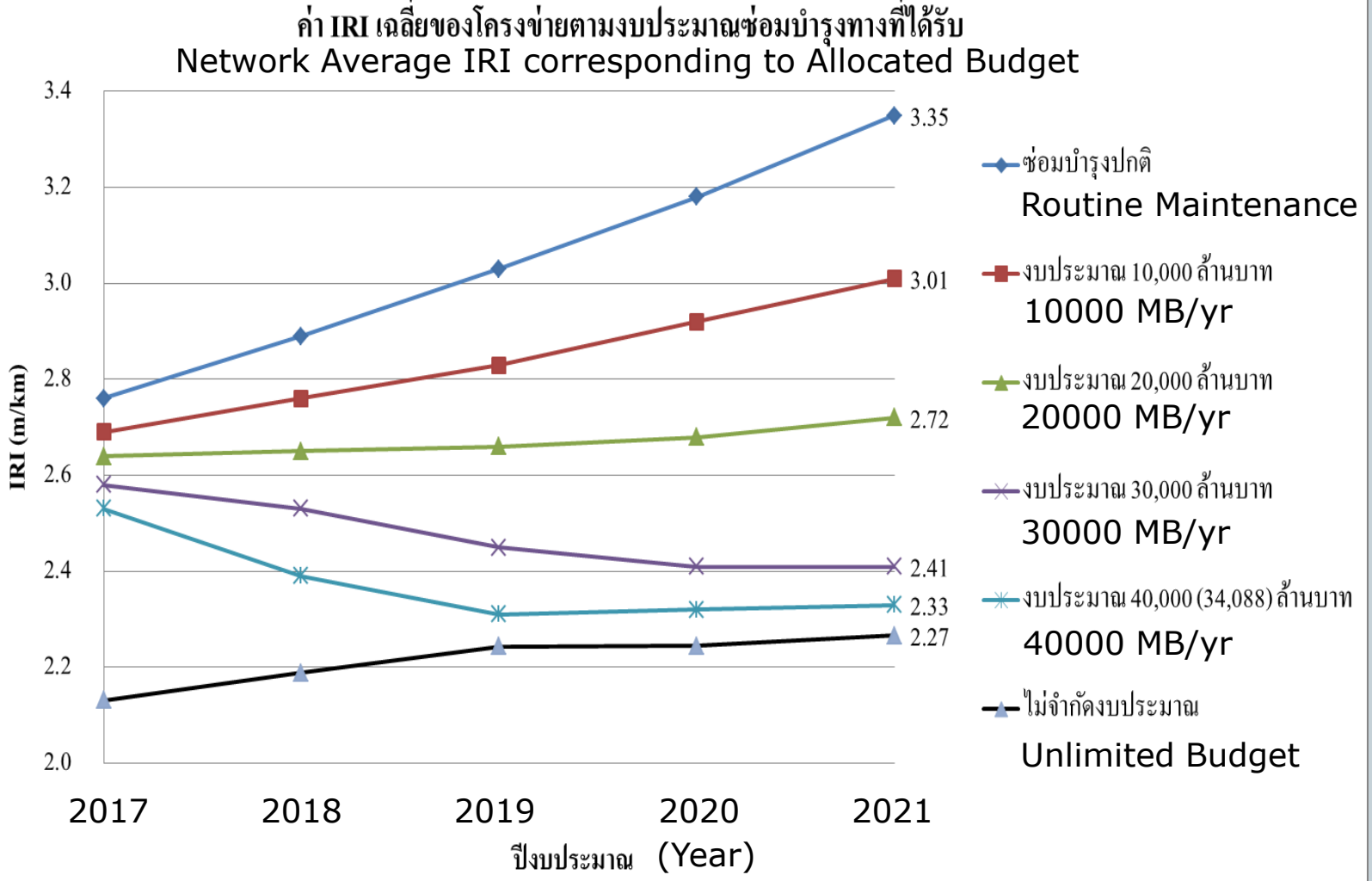
Pavement Management System

- **Data**: Road inventory & **distress** data from PCS
- **PMS**: Selecting Maintenance method:
  - Computing **Benefits, Cost** of each M&R action
  - Selecting action that maximizes **social** benefits
- **Outcome**: suggested **an appropriate treatment**
  - In corresponding to the distress (IRI, Rut, Texture, Age)+ future uses (AADT)
  - Map-based Results
- **Options**
  - Synchronize maintenance actions for nearby sections
  - Change priority of urgent work

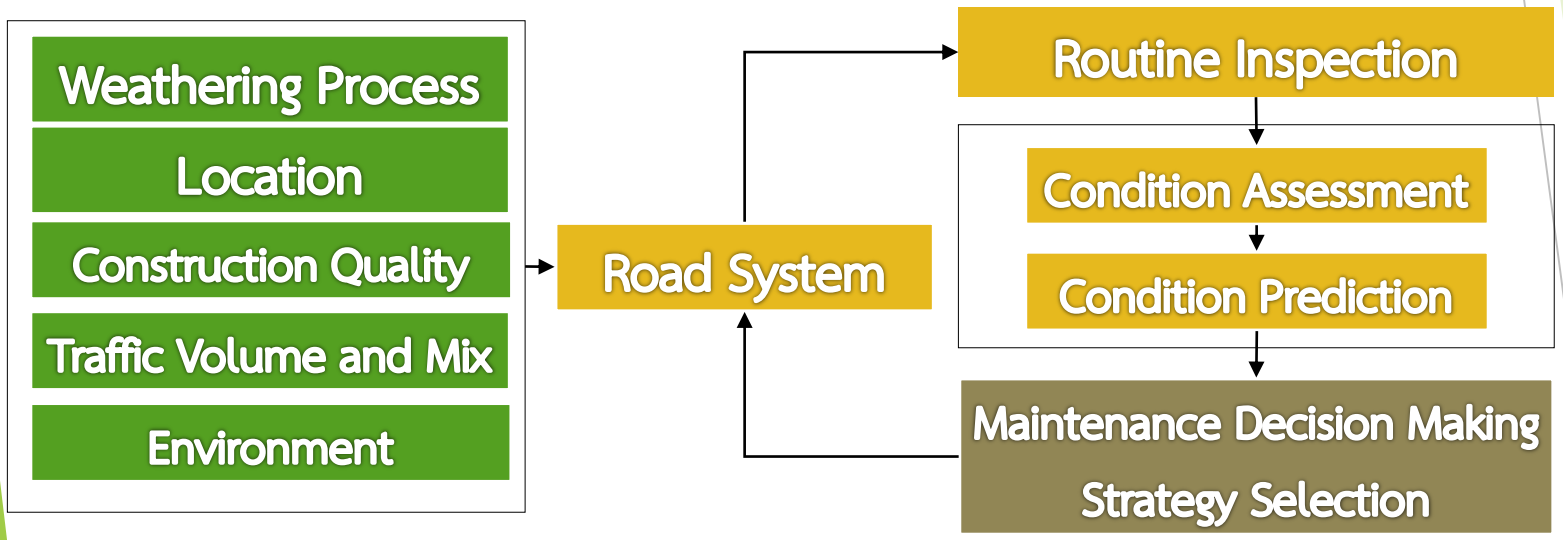
Thailand Pavement Management System (TPMS 2009)



Network Analysis of year 2017 - 2021



Road System Maintenance Process



Maintenance & Repair Problem

- **WHEN** to schedule M&R to facilities.
- **Intensity?** (measure in $ or condition improvement)