4th CRMCE

International Conference on Rehabilitation and Maintenance in Civil Engineering

Solo, Indonesia, 11 - 12 July 2018

Data Mining Applied for National Road Maintenance Decision Support System

Andri IRFAN – Directorate General Highway
Susanty Handayani – Greater Jakarta Transporation Authorithy
Ronald Al Rasyid – Jasa Marga Toll Road Company

Solo, 11 Juli 2018

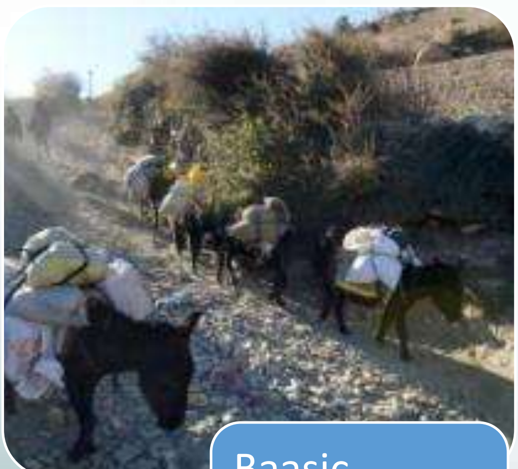
Contents

Background

Relevance of Sustainable Road Assets Maintenance

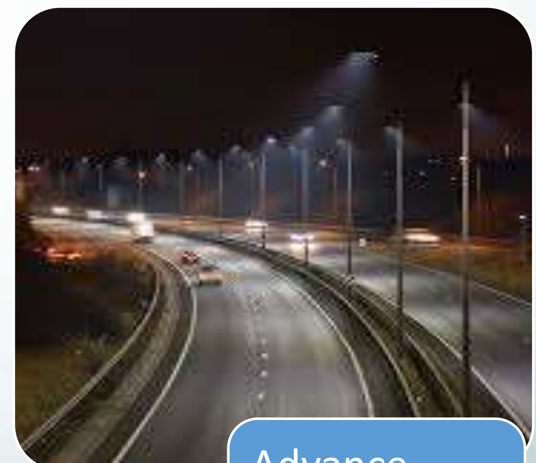
- Improvement of the roads service level
- Minimization of administration and user costs
- Reduction of environmental impacts; less resources consumption; less energy)
- Improvement of peoples’ quality of life (peoples’ health)

An integrated approach of plan, design, construction and maintenance of all road assets: essential to achieve main objectives.



Baasic
- Function
- Non Geometric

Intermediate
- Function
- Structural



Advance
- Safety
- Comfort
- Smart
- Sustainability

Background

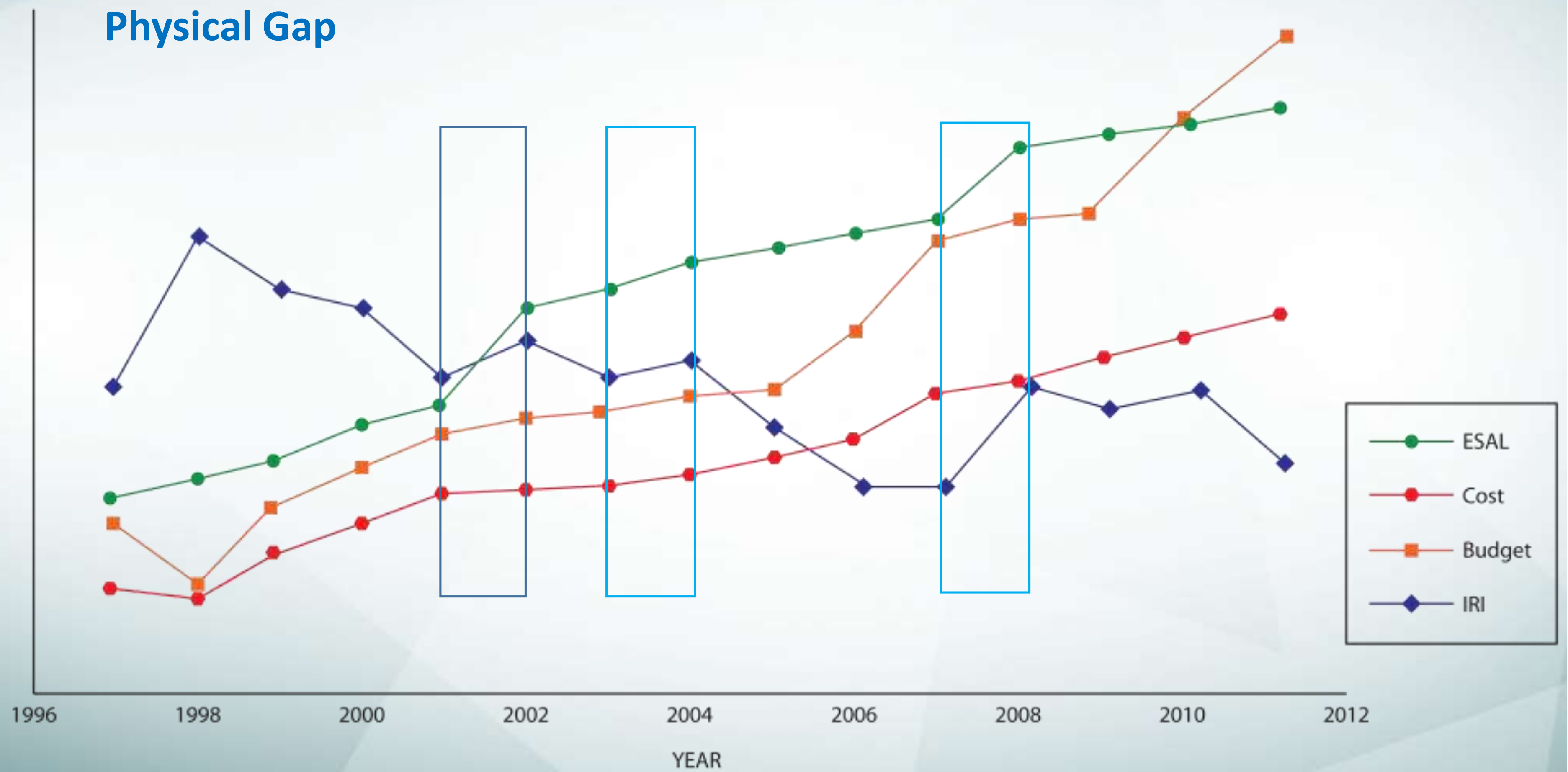
Infrastructures
Maintenance Optimization

Smart and Sustainable Mobility

Smart and Sustainable Cities

*) source : Pereira-CTAC

Background



Physical Gap
1996
1998
2000
2002
2004
2006
2008
2010
2012
YEAR
ESAL
Cost
Budget
IRI

Concept

Pavement Management Systems (PMS)

Network level

Project level

- Detailed engineering decisions
- Immediate consequences

Main Components

- **Geographical Information System**
- **Database**
- **Performance prediction models**
- **Decision support system**

Differences among PMSs

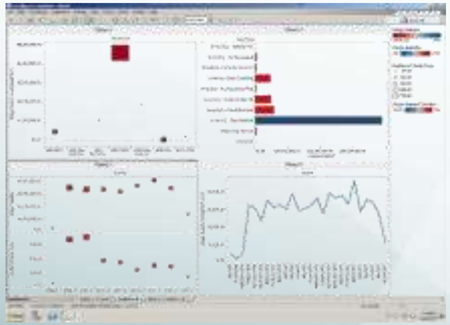
- Objectives
- Performance indicators
- Approach to the problem
- Mathematical Formulation

**) source : Pereira-CTAC*

Problem Statement

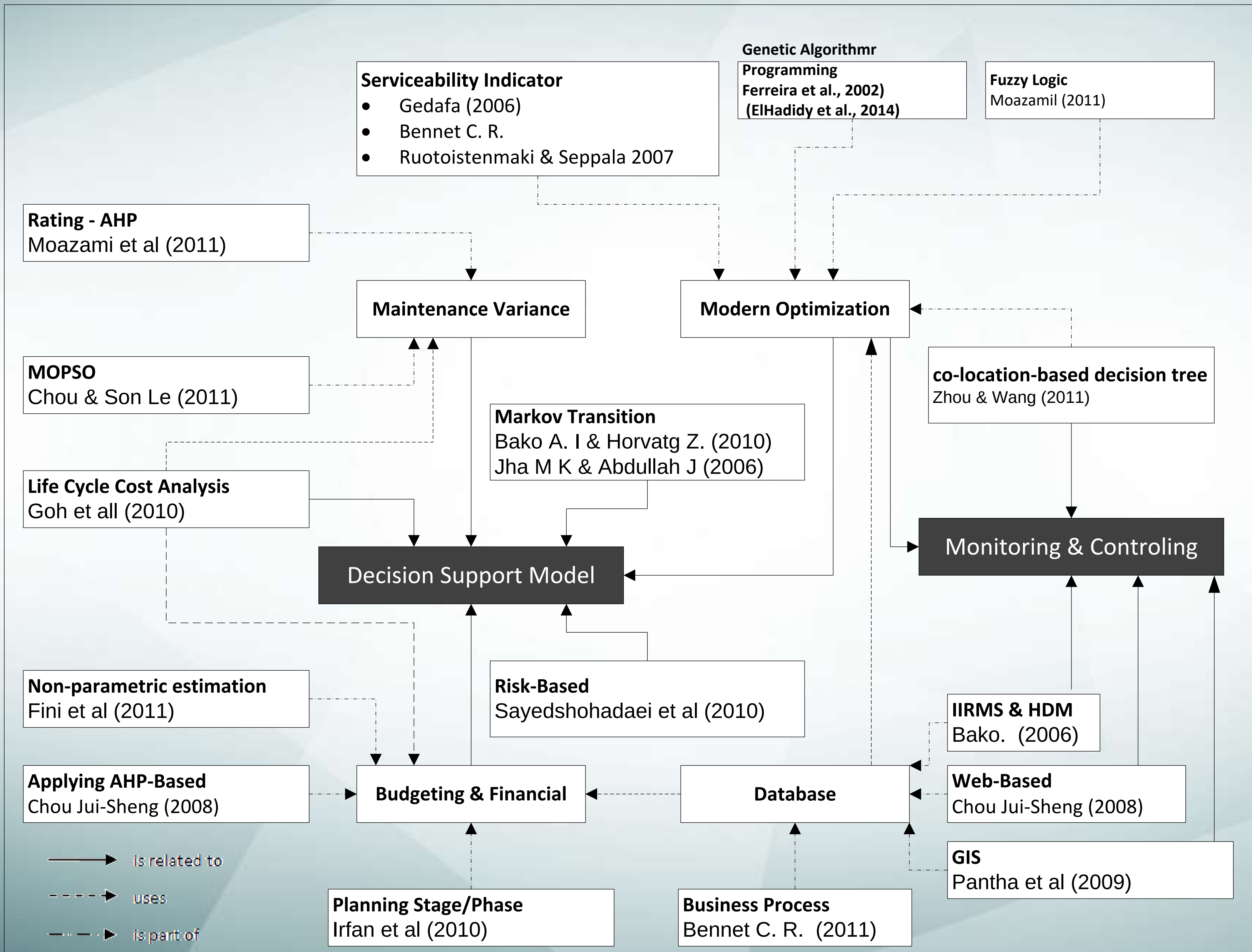
How to develop decision support system for pavement maintenance optimization?

Objective

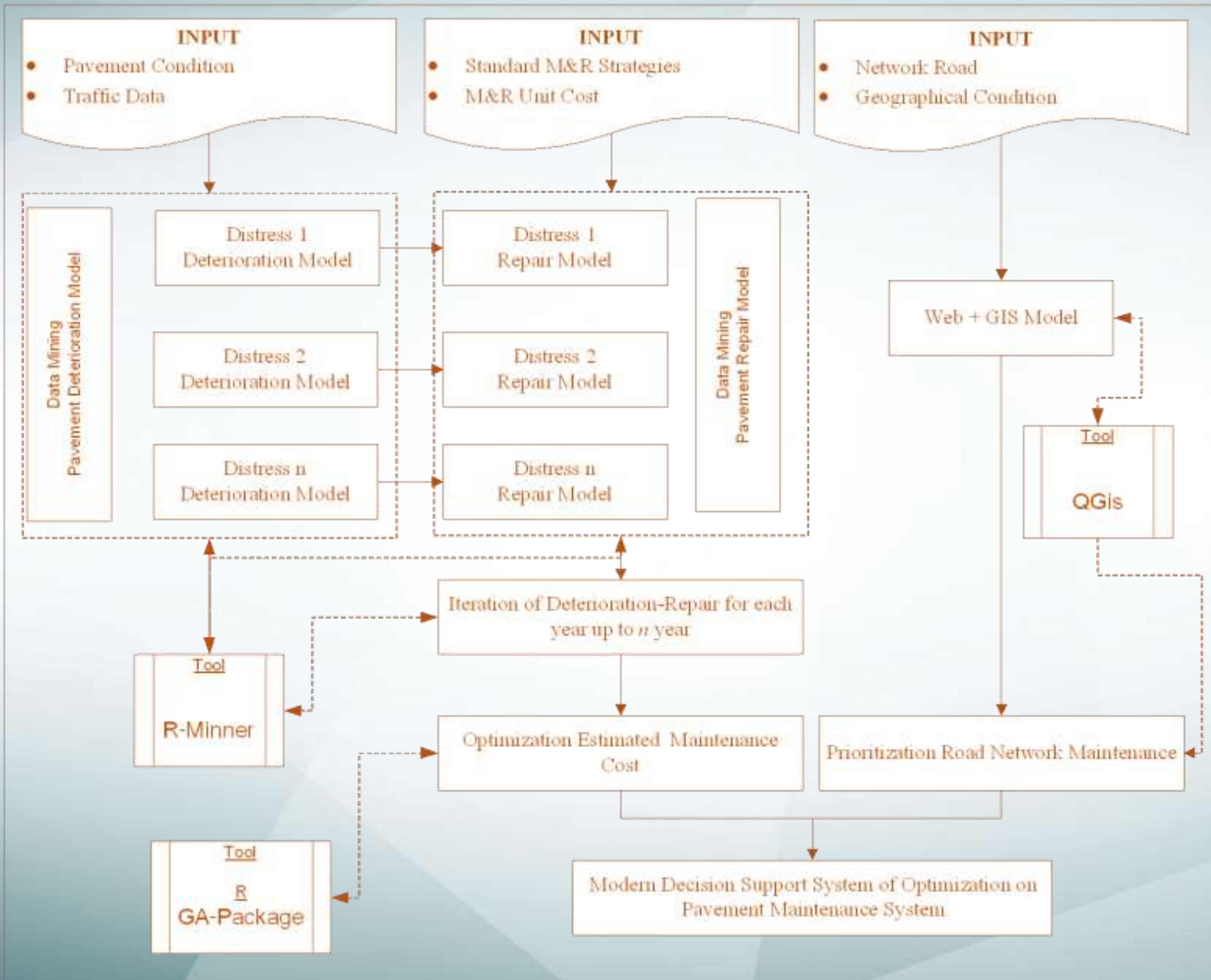


Develop DSS pavement maintenance optimization concept based on GIS

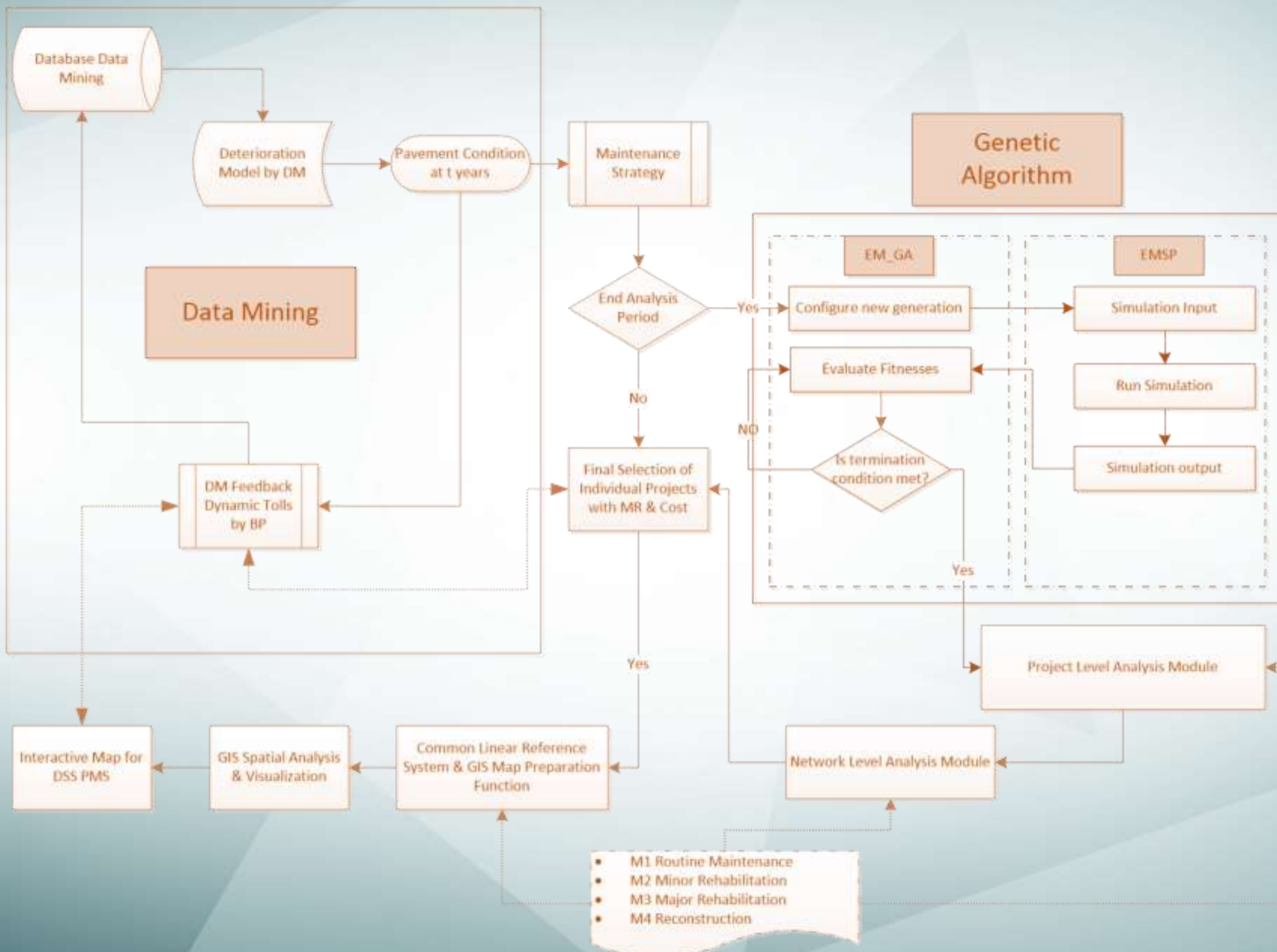
Literature Map



Frame Work


INPUT
Pavement Condition
Traffic Data
INPUT
Standard M&R Strategies
M&R Unit Cost
INPUT
Network Road
Geographical Condition
Data Mining
Pavement Deterioration Model
Distress 1
Deterioration Model
Distress 2
Deterioration Model
Distress n
Deterioration Model
Distress 1
Repair Model
Distress 2
Repair Model
Distress n
Repair Model
Data Mining
Pavement Repair Model
Web + GIS Model
Tool
QGis
Iteration of Deterioration-Repair for each year up to n year
Tool
R-Minner
Optimization Estimated Maintenance Cost
Prioritization Road Network Maintenance
Tool
R
GA-Package
Modern Decision Support System of Optimization on Pavement Maintenance System

Flow Chart


Database Data Mining
Deterioration Model by DM
Pavement Condition at t years
Maintenance Strategy
Genetic Algorithm
Data Mining
EM_GA
EMSP
End Analysis Period
Yes
Configure new generation
Simulation Input
Evaluate Fitnesses
Run Simulation
No
NO
Is termination condition met?
Simulation output
DM Feedback Dynamic Tolls by BP
Final Selection of Individual Projects with MR & Cost
Yes
Yes
Project Level Analysis Module
Interactive Map for DSS PMS
GIS Spatial Analysis & Visualization
Common Linear Reference System & GIS Map Preparation Function
Network Level Analysis Module
M1 Routine Maintenance
M2 Minor Rehabilitation
M3 Major Rehabilitation
M4 Reconstruction

Method

Decision Support System-Optimization

Objective: generate several possible decision scenarios with the corresponding information that may help and support the decision maker choices

Mathematical programing

- Linear
- Non-linear
- Geometric
- Integer
- Dynamic
- Stochastic

Qualitative Methods

- Analytic Hierarchy Process
- Fuzzy set theory
- Decision-trees

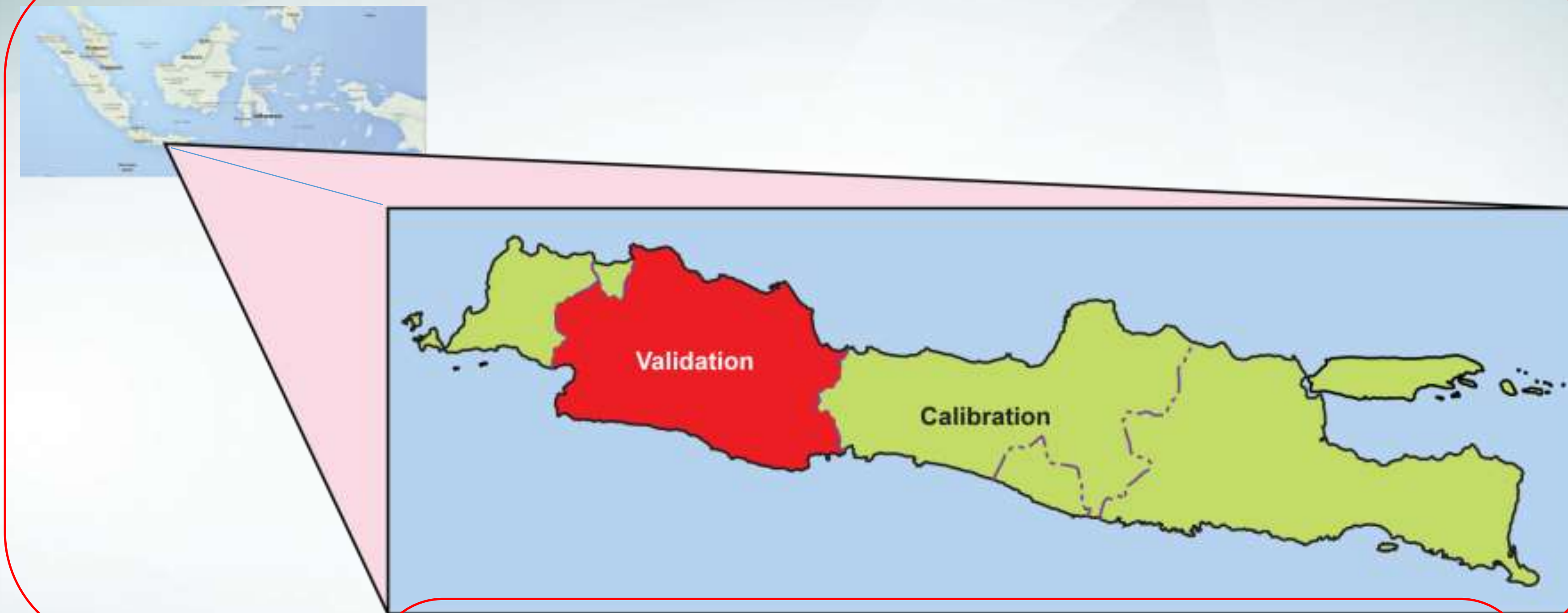
Evolutionary Algorithms

- **Genetic algorithms**
- Artificial neural networks
- Pattern search

Tools of Research

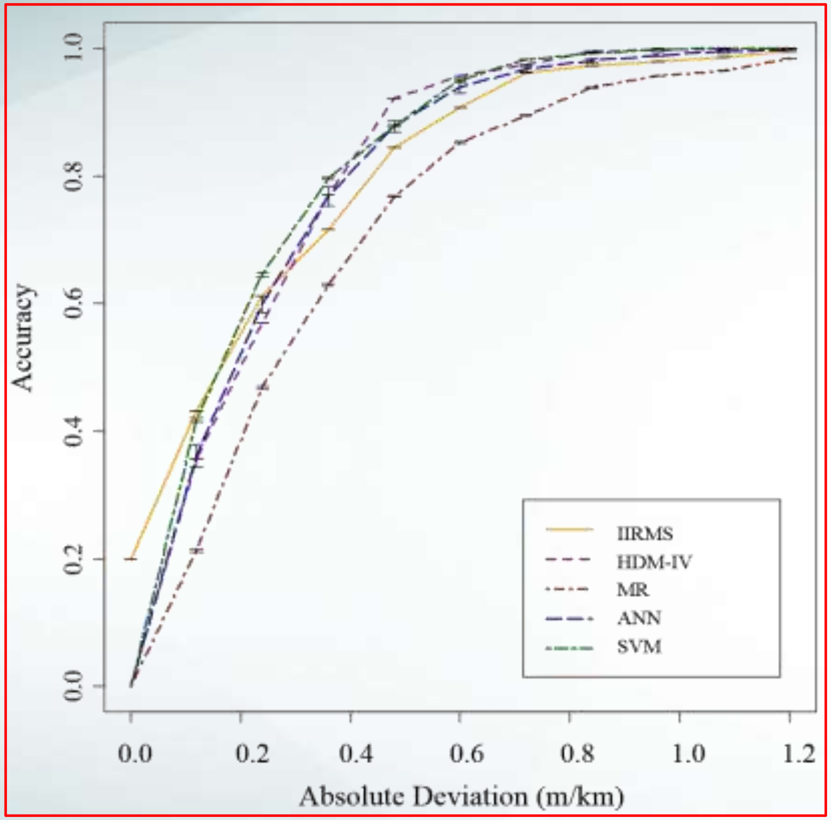
Objection	Model	Tools
Predict the IRI & Pavement Distress	Artificial Intelligence & Data Mining	R-Miner from R Tool
Optimization Pavement Maintenance	Genetic Algorithm	R-GA from R Tool
DSS-Concept	Spatial Decision Model	QGis Lisboa 1.8.0 From Quantum GIS

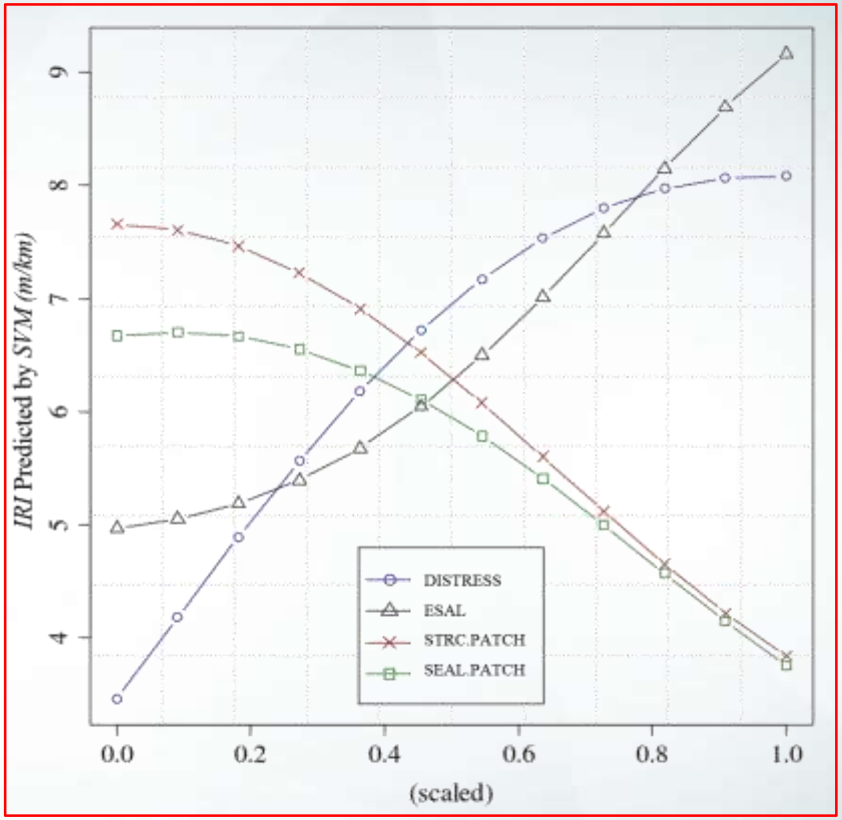
Data Source



No	ID	Province	No of Segment	Calibration	Model Development Validation	Optimization	GIS
1	A-JI	Banten	45	√			
2	B-JI	Jakarta	13	√			
3	C-JI	West Java	259		√	√	√
4	D-JI	Central of Java	237	√			
5	E-JI	Yogyakarta	36	√			
6	F-JI	East Java	381	√			

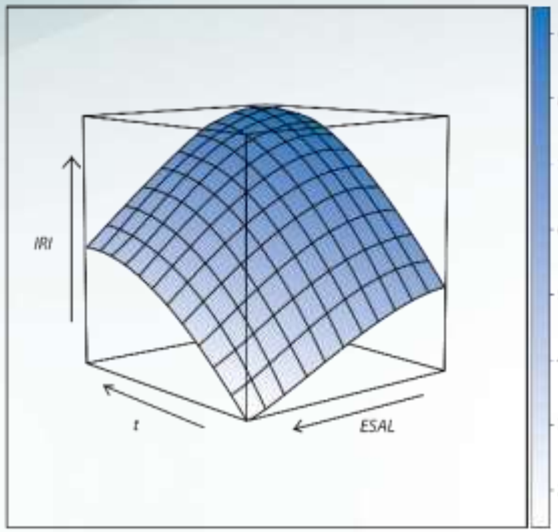
REC & VEC Curve

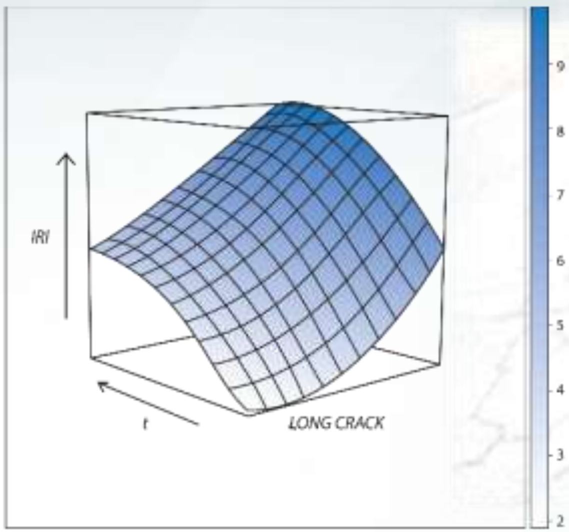


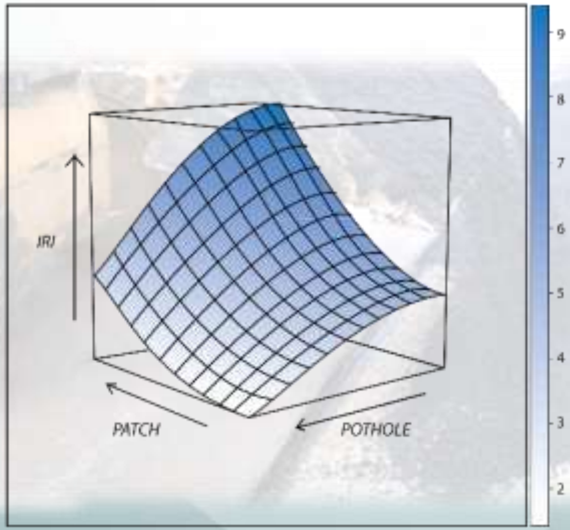


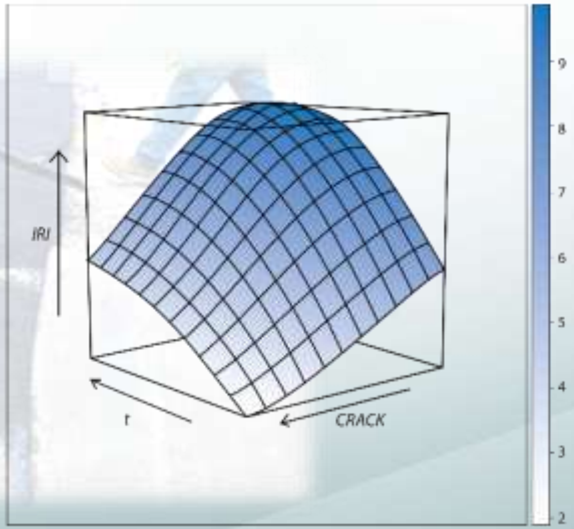
Model	Hyper-parameters	Time (s)
MR	-	3.21 ± 0.03
SVM	ϵ = 0.07 $\pm$ 0.01 and γ = 0.05$\pm$0.00	117.02 ± 0.67
ANN	H = 3 $\pm$ 1	102.37 ± 0.16

Sensitive Analysis

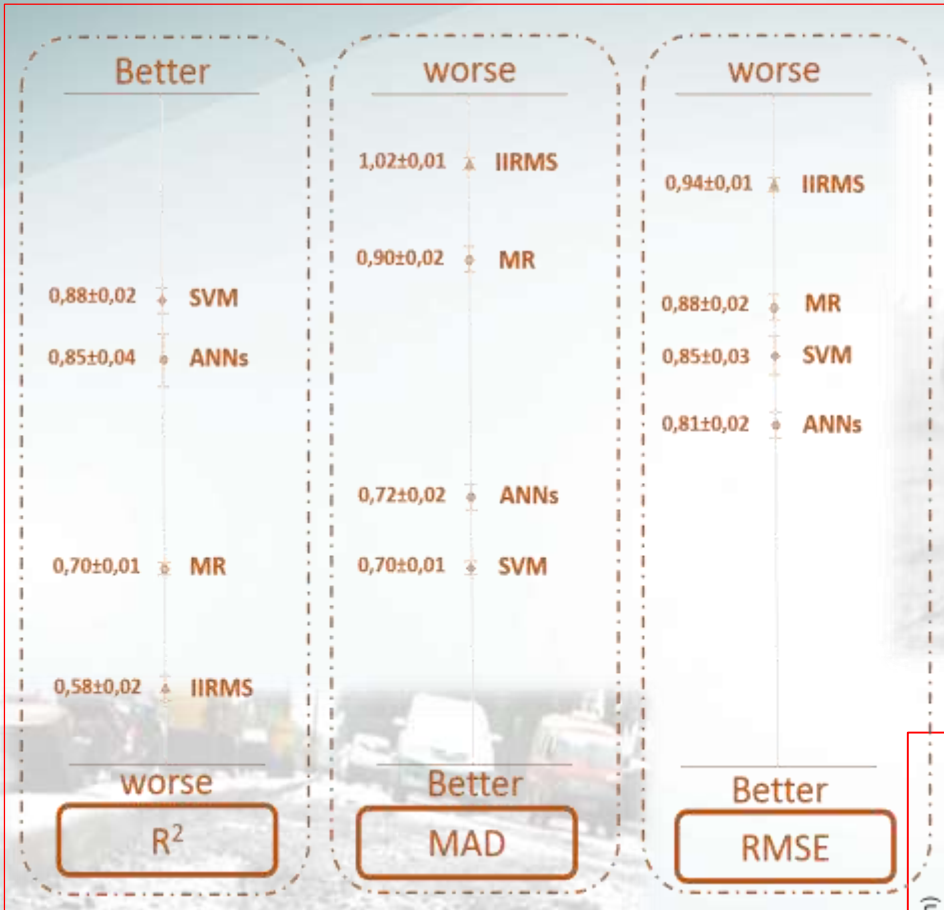




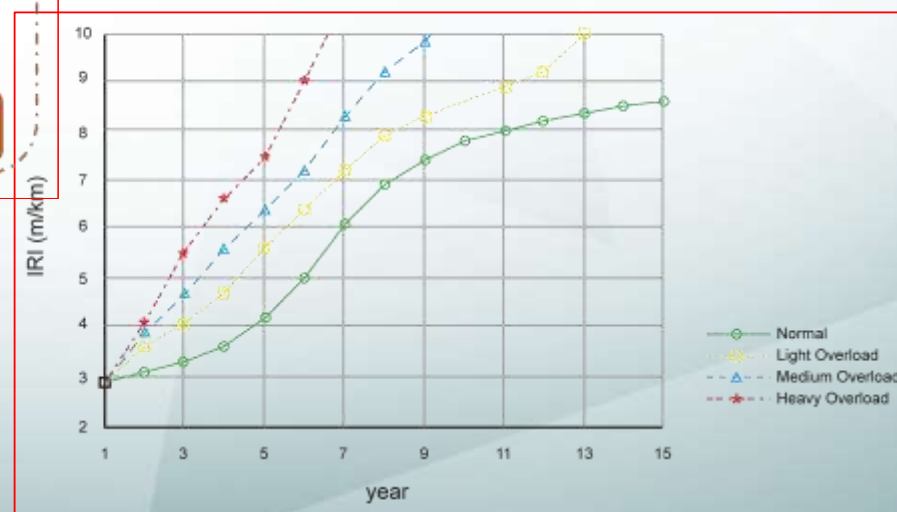




Case Study



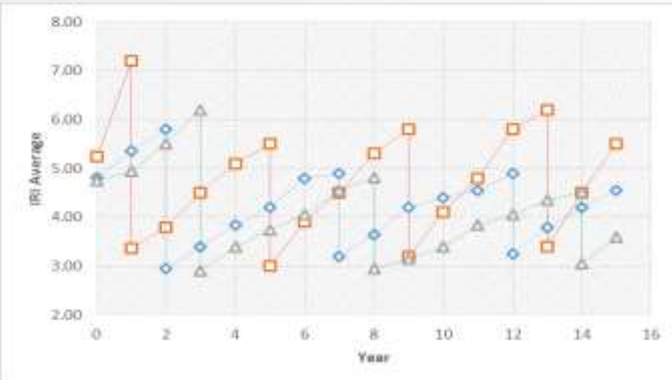
Better
0,88±0,02 SVM
0,85±0,04 ANNs
0,70±0,01 MR
0,58±0,02 IIRMS
worse
R^2
worse
1,02±0,01 IIRMS
0,90±0,02 MR
0,72±0,02 ANNs
0,70±0,01 SVM
Better
MAD
worse
0,94±0,01 IIRMS
0,88±0,02 MR
0,85±0,03 SVM
0,81±0,02 ANNs
Better
RMSE



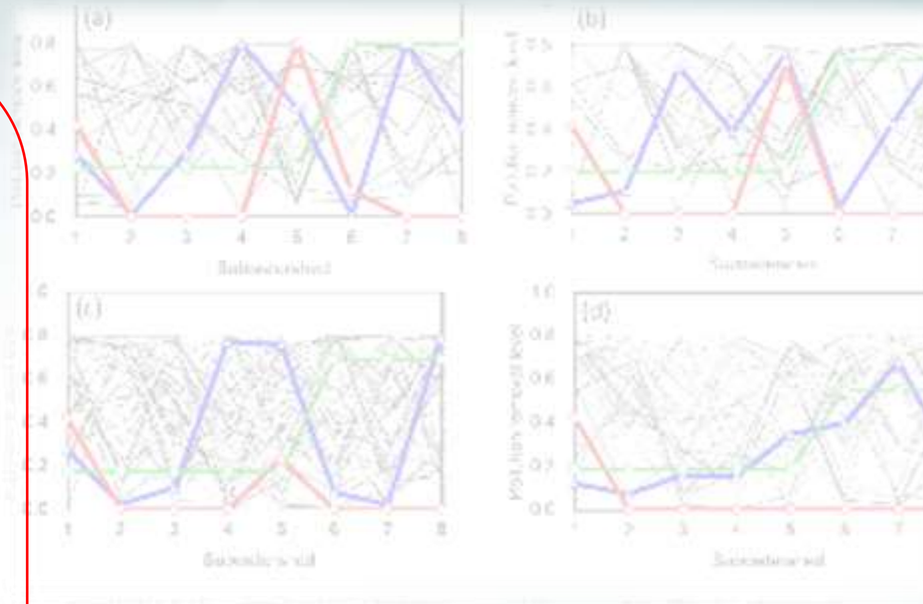
IRI (m/km)
year
Normal
Light Overload
Medium Overload
Heavy Overload

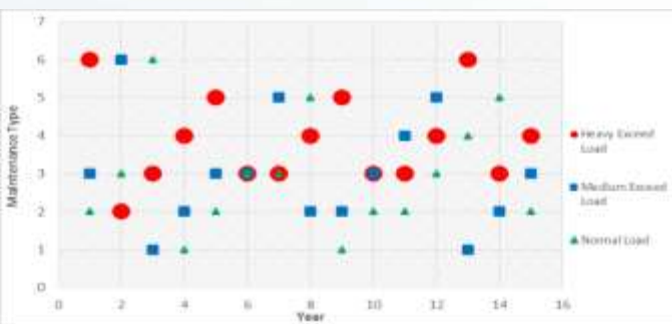
Post Optimization

Result

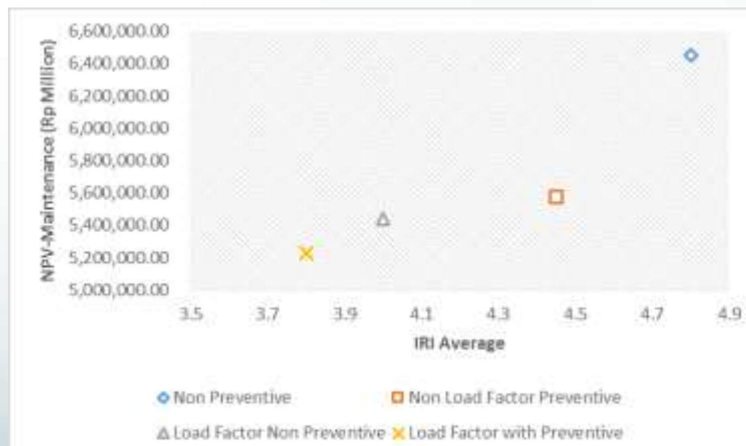


IRI Predicted post Treatment





Maintenance Scenario



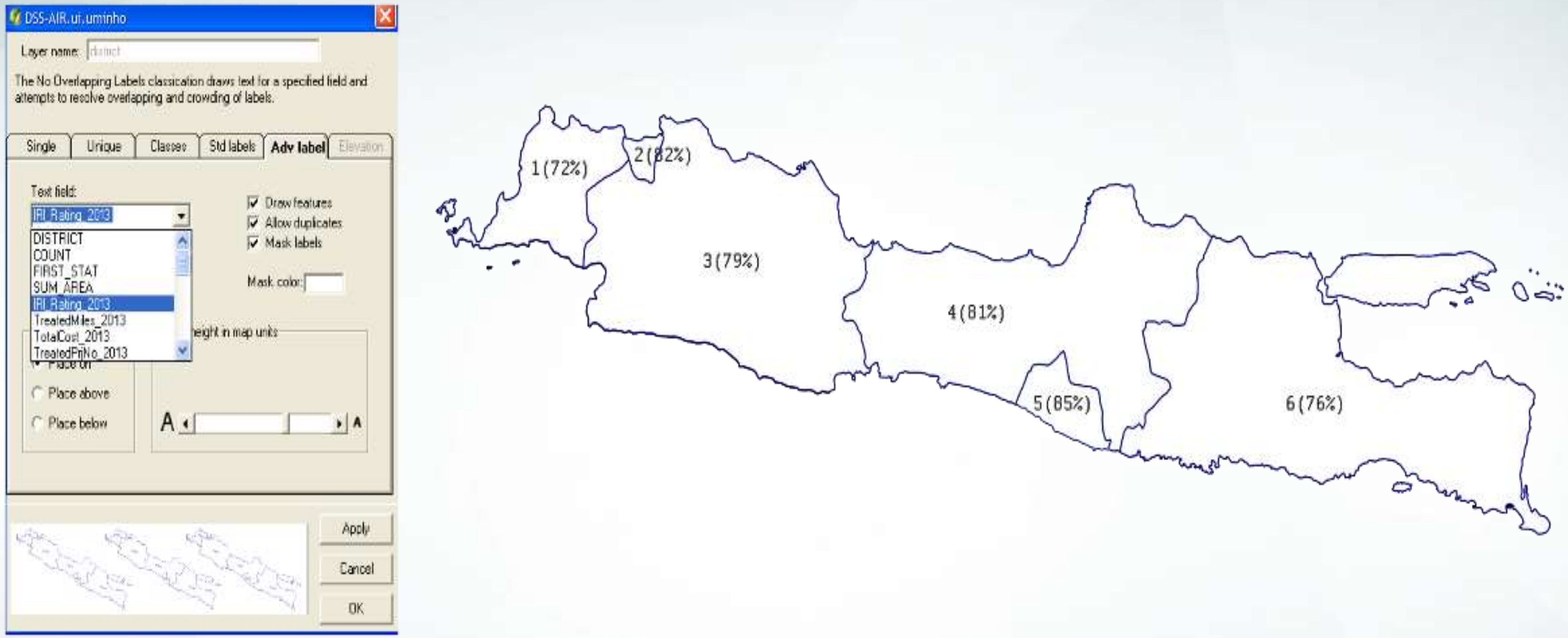
Sensitive Analysis

Map Concept

The five basic map layers below are used in the GIS module

ANALYSIS RESULTS		▪ **detailed project-level results** ▪ **project ratings** ▪ **treatment methods and costs,** ▪ **AADT, and** ▪ **spatial location information (such as SegmentNo, NetworkNo, ProvinceNo, Sta. From and Sta. To, District)**
STATEROUTE		Based on IIRMS concept (the complete information on state highway routes in Java Island)
DISTRICT		The detailed district information of Java Island
PROVINCE		IIRMS Province boundary information
NETWORK		Network boundary information

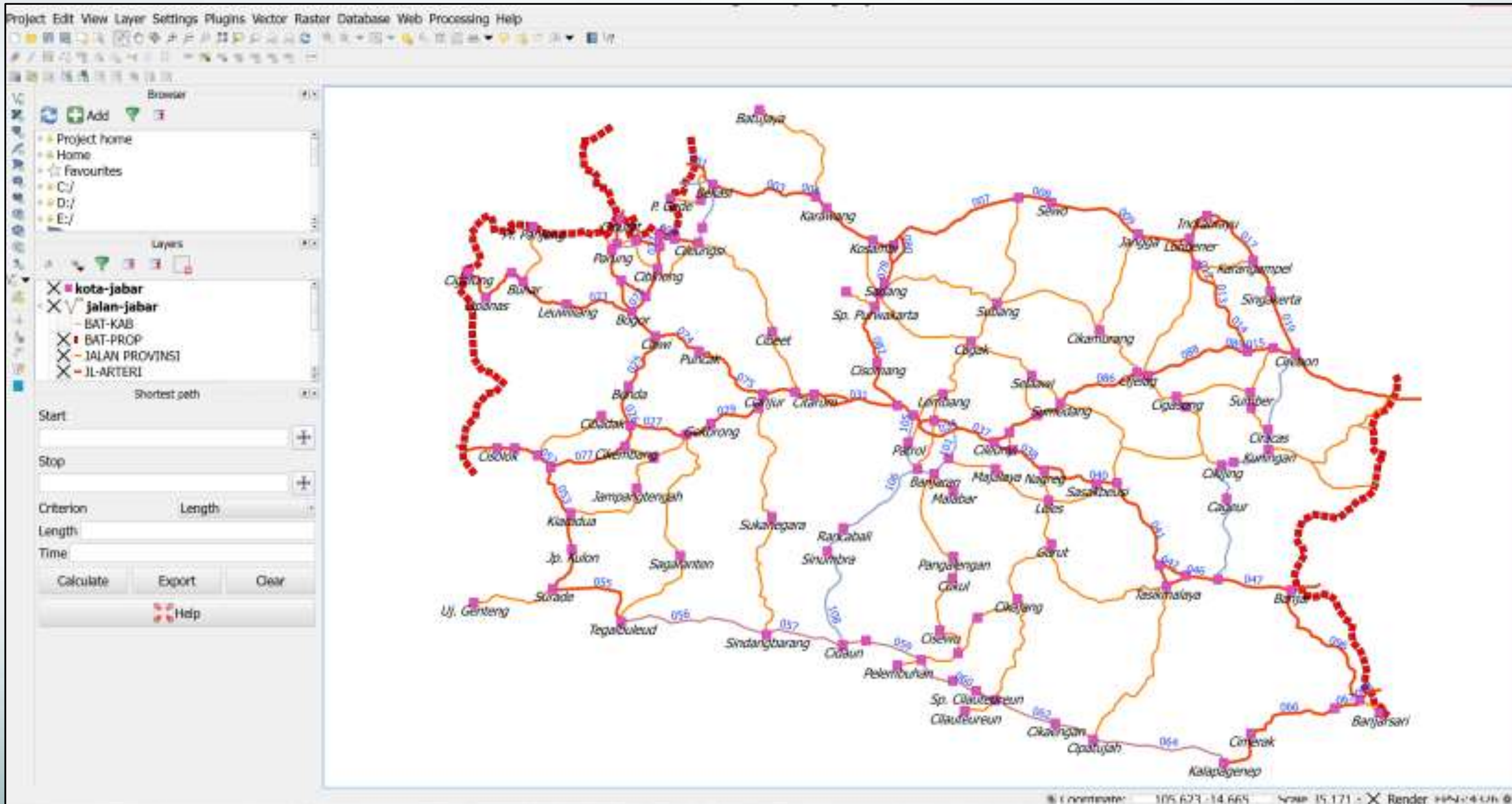
AddRelate Concept



The **AddRelate** method uses this common field to create a join between the map layer and the results table and creates a new record-set, which contains all the records (6 java island province)

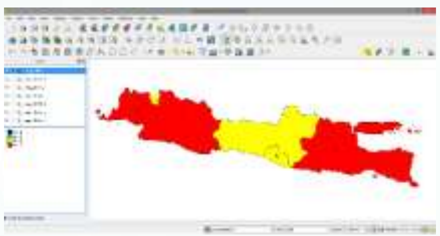
GIS Base-Map

These five basic map layers include most of the information generated from the maintenance model results that can be displayed on GIS maps

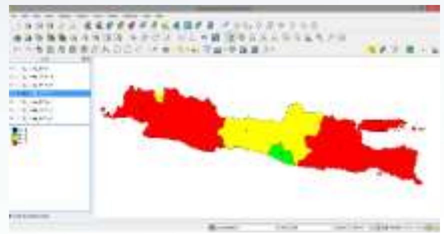


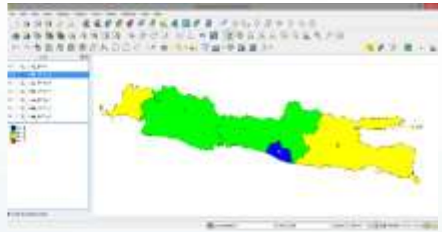
Interface-Interactive

Interactive Map-based Multi-year What-if Pavement Scenario Analysis

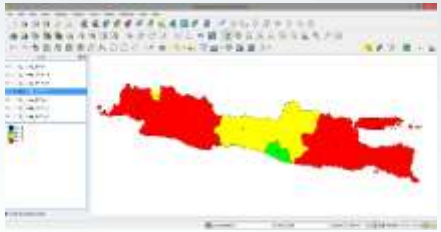


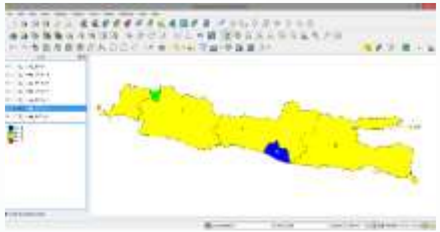
Year n

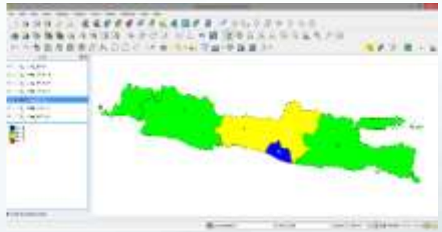




Year n+1







Year n+2

Main Result

DM techniques, particularly and Artificial Neural Network (ANN) and Support Vector Machine (SVM) algorithms, proved to be powerful tools for explore pavement deterioration model. Indeed, these tools were able to learn with high accuracy the complex relationships between IRI and their contributing factors. SVM achieved a performance higher than 0.91, using R^2 as a performance indicator.

The Genetic Algorithm Approach method, by taking advantages mathematical programming, offers a systematic, easy-to-use approach to the pavement maintenance optimization. Although only budget constraint is considered, other constraints could be easily added to the formulation.

GIS technology is fully utilized in the decision support system for pavement maintenance. The GIS technology integrates graphical information in the GIS maps and the pavement performance model results obtained from the segment-level and the network-level seamlessly

Thank You

Obrigado