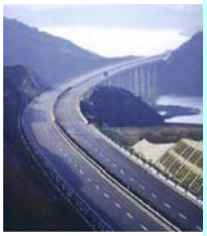
Author: Prof. Koji TSUNOKAWA

# Methodological Development of Maintenance Strategies Optimization of National Road Network



## Problem Statements

- ✓ Road asset consists of **different components**: pavements, bridges, tunnels, culverts and other structures.
- ✓ Techniques have not been well developed for managing a large network of an individual road asset component, such as a nationwide pavement. When dealing with a large network, it is typically subdivided into **several sub-networks**.
- ✓ Each sub-network is typically analyzed for optimal management strategies under several budget scenarios, but when it comes to integrate the results, results are combined in **ad-hoc manners**.

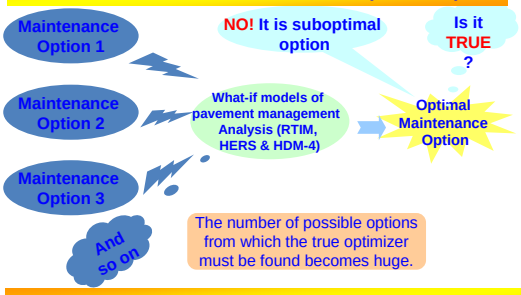
➡ There is a dearth of techniques for optimizing the management of the entirety of road asset.

Solution

## Solutions: The research presents a unified optimization framework to conduct **sound trade-off analyses** among its various components.

- ✓ Use **total transport cost** (TTC) comprising agency cost and user cost as the common denominator.
- ✓ The TTCs are first predicted for several budget levels for each road asset component in order to construct the TTC function of the component.
- ✓ Given a total budget for the entire road asset management, the TTC functions of all components may then be used to find the optimal allocation of the budget among all asset components.
- ✓ Once optimal budget allocation is found, optimal strategy for each component can be found by just identifying the strategy corresponding to the allocated budget for the component.

## Deficient of What-If Models (HDM-4)




The number of possible options from which the true optimizer must be found becomes huge.

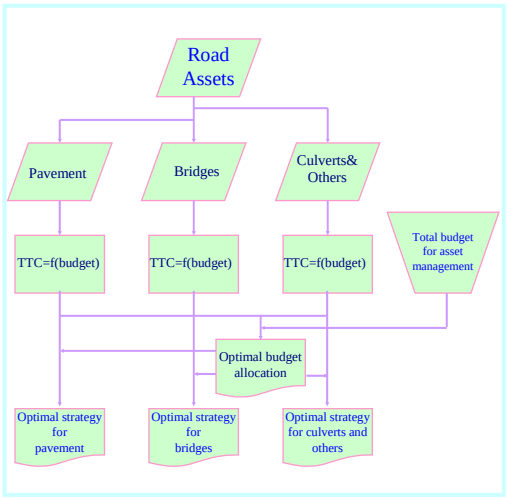
## Overview of HDM-4

The **H**ighway **D**evelopment and **M**anagement System (HDM-4), developed by the World Bank (2000), is a **decision-support tool** to investigate road investment choices

**SOLUTION: Use What-If Models with Gradient Search Methods to find the *True Optimal Maintenance Option***

- **Operability** to use What-If Models (HDM-4) along with GSM
- **Reliability** to use What-If Models (HDM-4) along with GSM

✓ However, GSM's are known to be trapped in **local optima** if objective functions are not well-shaped. Thus, **Trend Curve Optimal Control Model (TOCM)** can be applied to overcome this deficient.



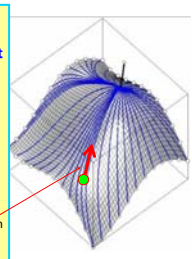

## Research Framework

## Overview of Gradient Methods

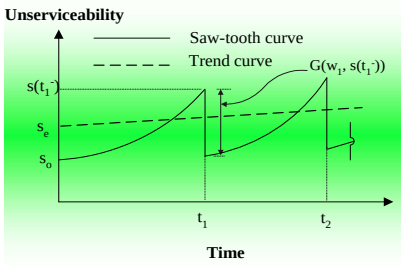
Gradient methods are used for an optimization problem, there are several methods, such as **steepest descend method** (SDM), **conjugate gradient method** (CGM), and Newton's method. All gradient methods can be written in the form

$$x_{i+1} = x_i + \alpha_i s_i$$

where: $\alpha_i$ = the step size
$s_i$ = the search direction



## Trend Curve Optimal Control Model:

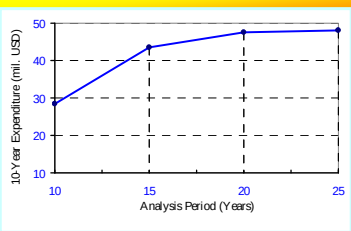



Saw-tooth and Trend Curves (Tsunokawa and Schofer, 1994)

- ➢ Trend curve optimal control model (TOCM) approximates the sawtooth-shaped pavement serviceability history by a smooth curve.
- ➢ Discrete jumps in the state variable are eliminated through this approximation.
- ➢ TTC found by the TOCM are very close to the true optimum.
- ➢ Therefore, although TOCM generates approximate solutions, precisions of solutions are not far from exact solutions.

# Pitfalls of Network Strategy Analysis

## Analysis Period versus Planning Period




### Problems:

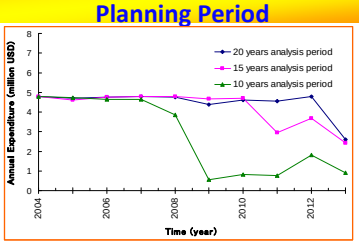
- ➢ HDM-4 does not take into account **network condition at the end of the Analysis Period** and as a result it suggests investment patterns **with no or fewer investments at the end of the Analysis Period.**
- ➢ Use of an Analysis Period same as the Planning Period will **underestimate the Expenditure Requirements.**

### Recommendations:

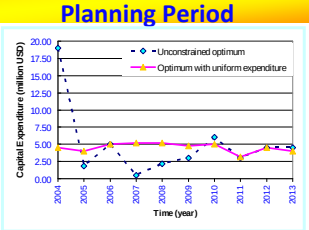
☞ HDM-4 Analysis Period must be **longer** than the Planning Period and Analysis Period **twice** as Long as the Planning Period are recommended.

### Road Network Improvement Project in Vietnam


## Expenditure in Later Years of 10 year-Planning Period




## Spreading Lumping Investments over Planning Period




**Problems:** When Budgets are unconstrained, HDM-4 may suggest Investment Patterns with several Maintenance Works schedule in the **first few years**

**Solutions:** The Strategic Plan must have more or less Uniform expenditure over the Planning Period.

- ✓ Find the unconstrained optimum expenditure for the entire Planning Period
- ✓ Impose a Budget Constraint that equals the Total Expenditure found above divided by the Number of Years in the Planning Period for each year of the Planning Period **with a large budget for the rest of the Analysis Period**