Pavement Management System Implementation for the Nigerian Federal Road Network

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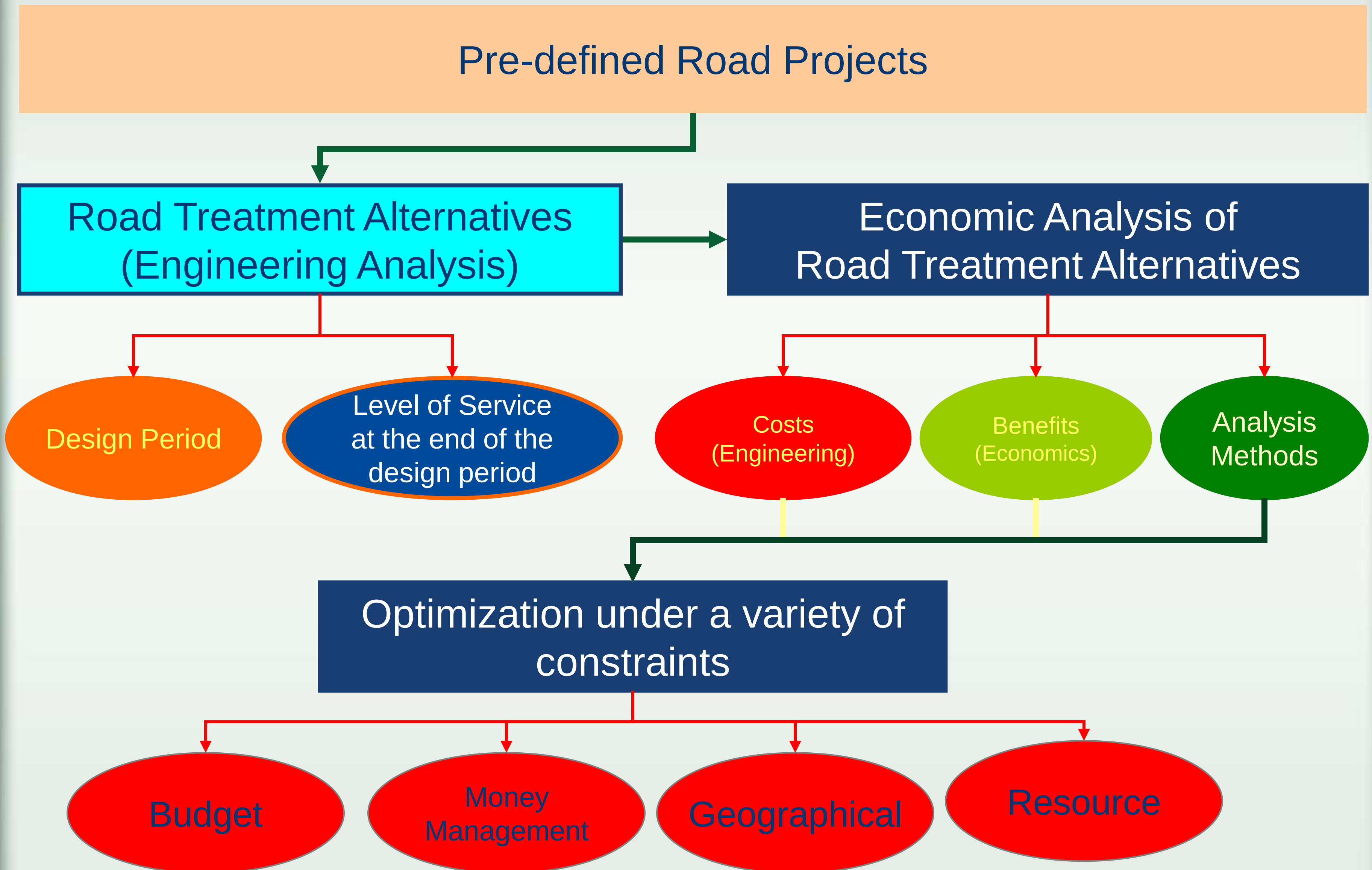
Background

- This implementation was part of a PPP (DBOMT) project, which is becoming more and more common in Africa
- The project was a DBOMT project, due to the Nigerian government's lack of sufficient funding
- The road network encompassed about 6,900 kms of the Nigerian Federal Road Network

Background (cont.)

- Dealt with multiple constraints:
  - Data constraints
  - Budget constraints
  - Money management constraints
  - Geographical constraints
  - Institutional constraints

PMS Description



Road Network Definition

- The road projects were already defined by existing collected databases - 3 in total.
- The first one encompassed about 2,700 kms, and had extremely detailed data - HDM based.
- The other two had just traffic and roughness data - almost 4,200 kms.
- Problems to solve - filling in the data requirements for a pavement management system
- Constraint - no budget for data collection - always the best solution

Filling in Road Network Data

Required data for PMS	Variables used	Technique
Condition data	IRI	Transforming IRI to a 0-100 scale
SN	SN from detailed DB	Regressing roads with similar IRI to their SN
MR (resilient modulus)	Traffic counts, IRI	Translating ESALs from the traffic counts, and regressing ESALs and IRI
Asphalt thickness	Local engineering knowledge	Checking those based on ESALs and a 10-year design life

Road Treatment Alternatives

- Requires decisions on a few variables:
- What minimum level of service do we want to obtain?
- What is the “design period”?
- What paving technologies can be implemented?

Road Treatment Alternatives (cont.)

- Level of Service
  - There is no requirement that a road should be treated only when it is destroyed.
  - Depending on traffic and other conditions, a road can be treated when it is in good condition!
  - The decision is an economic one - costs and benefits.
  - It is also dependent on the budget and other constraints.

Road Treatment Alternatives (cont.)

Design Period

For a given length of time (say, 20 years), which is better?

a) 1 rehabilitation which will last 20 years?

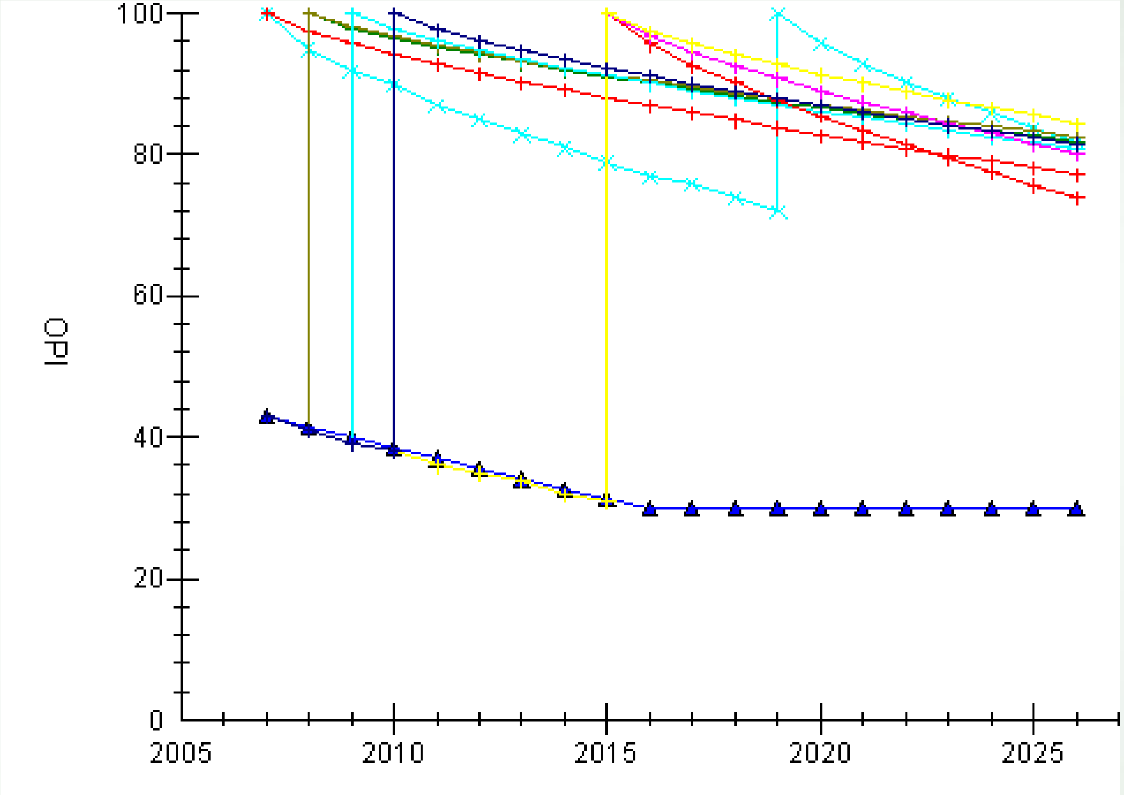
b) 2 rehabilitations, each of which will last 10 years?

c) Or, X rehabilitations, each of which will last Y years?

The Answer: It depends on the road in question!

We require an economic analysis to answer it.

Road Treatment Alternatives (cont.)



Evaluating 75 treatment alternatives, differentiated by various levels of service (triggers)

Economic Analysis

- Based on Benefits and Costs
- Costs:
  - Periodic treatment costs
  - Routine maintenance costs
- Benefits
  - Savings in Vehicle Operating Costs
  - Delay costs due to road closures
  - Salvage value of the top asphalt layer

Economic Indices

Net Present Value (NPV)

$$NPV = \sum_{i=1}^{EAP} \frac{Benefits_i - Costs_i}{(1 + r_i)^i}$$

EAP – Economic Analysis Period

- NPV > 0 – Project/alternative is economically feasible
- NPV < 0 – It is not worthwhile to invest in this project/alternative (unfeasible)
- To be used only for mutually exclusive alternatives (i.e., the different alternatives of the same transportation project)

Economic Indices (cont.)

Internal Rate of Return (IRR)

$$\sum_{i=1}^{EAP} \frac{Benefits_i - Costs_i}{(1+IRR)^i} = 0$$

- IRR > Interest Rate – Feasible
- IRR < Interest Rate – Unfeasible
- Impossible to calculate in certain cases, and gives erroneous results in others
- To be used only for mutually inclusive projects – choosing between different projects!

Economic Indices (cont.)

Benefit Cost Ratio (BC)

$$BC = \frac{B}{C} = \frac{\sum_{i=1}^{EAP} \frac{Benefits_i}{\prod_{j=1}^{EAP}(1+r_j)}}{\sum_{i=1}^{EAP} \frac{Costs_i}{\prod_{j=1}^{EAP}(1+r_j)}}$$

EAP – Economic Analysis Period

- Similar to IRR
- BC > 1 – Feasible
- BC < 1 – Unfeasible
- Permits variable interest rates.
- Eliminates all of IRR's weaknesses.
- Works on mutually inclusive projects – same as IRR.

Economic Indices (cont.)
Incremental Benefit Cost (IBC)

$$IBC = \frac{B_j - B_{j-1}}{C_j - C_{j-1}}$$

j - the jth alt.

- The IBC index has <u>all</u> the advantages of PV and IRR without their disadvantages
- IBC > 1 = The additional benefit is higher than the additional cost – Net Benefit > 0 – the project/alternative is feasible!
- IBC < 1 = The additional cost is higher than the additional benefit – Net Benefit < 0 – the project/alternative is unfeasible!
- This index is extremely useful in optimization under a budget constraint

Economic Optimization

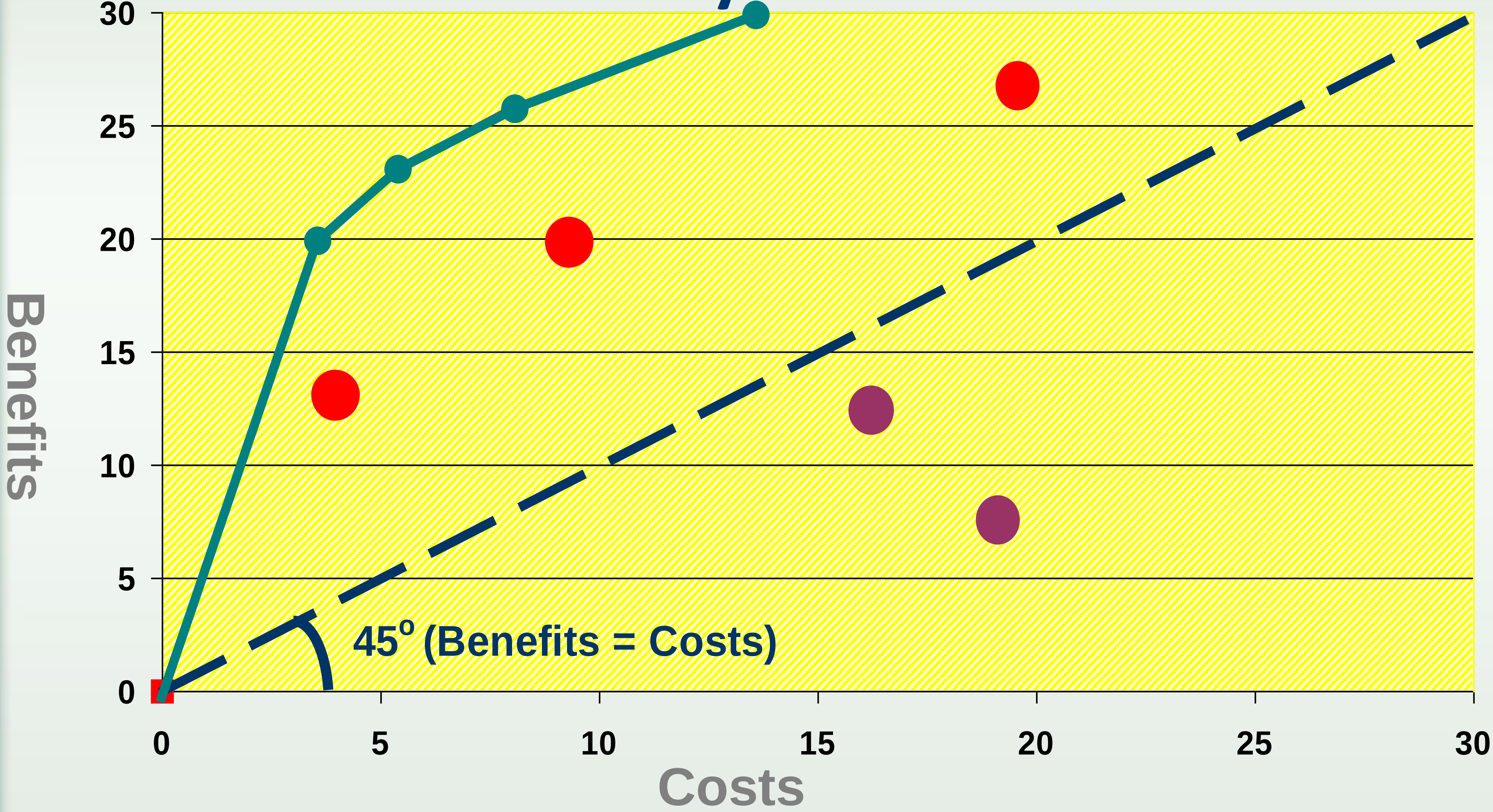
- As mentioned previously, this project had several constraints;
  - Annual budget
  - Money management
  - Resources (in terms of equipment)
  - Geographical

Annual Budget Constraint

- Uses an implementation of the IBC method.
- The IBC method uses the convexity constraint (efficiency frontier).
- For each project, the alternatives are ordered by *ascending cost*.
- The data for each alternative is the ***total*** discounted benefit and ***total*** discounted cost.
- Based on this data, we calculate the IBC index, for **each and every point**.
- The end result is the following graph:

Economic Optimization (cont.)

Convexity Constraint



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Economic Optimization (cont.)
Convexity Constraint (cont.)

The Convexity Constraint is a mathematical calculation which adheres to the following rules:

a) ***The first derivative all along the line is greater than one (1)***
   This means that for each point along the line, the incremental benefit is greater than the incremental cost

Economic Optimization (cont.)

Convexity Constraint (cont.)

b) ***The second derivative of each point along the line is negative*. This means that each point signifies a decreasing return of scale, which means that the point is considered to be economically efficient.

If an alternative does not meet the conditions described previously, that alternative is thrown out, all the IBC's are recalculated, until we are left with a minimal number of points which all adhere to the above conditions.

Other Constraints (cont.)

Monetary management constraints

- Remember, we are giving select sections of the road network for maintaining by a private contractor.
- The private contractor might not have sufficient equity and sufficient debt to deal with maintaining the government's road
- Solution: separating the total budget according to the limitations of the contractors.

Other Constraints (cont.)

Resources constraints

- The private contractor might not have sufficient equipment for dealing with the required quantities of asphalt concrete
- Solution - see what is the effective constraint - the contractor's ability to deal with X amount of money or with Y amount of asphalt
- This constraint ranged between 50 to 170 million dollars for a ten-year period

Other Constraints (cont.)

Geographical constraints

- It is necessary to insure that the roads to be treated by the contractor are in geographical proximity
- Solution - define a radius or a rectangle which will contain sufficient road kilometrage which is in the capabilities of the contractor to deal with
- Done with GIS techniques (selecting rectangles, and selecting radiuses)

Innovations in this PMS

- Road network - fill in the data based on regression techniques, and use local engineering knowledge
- Including new kinds of constraints and not just budget constraints
- Estimating average routine maintenance costs by regression and detailed RM data for part of the network - fixed term and variable term based on road condition

Summary

- Road network defined based on previous data collection of previous projects
- Engineering evaluation of 75 alternatives based on varying levels of service and timing
- Economic evaluation of the engineering alternatives
- Throwing out non-feasible alternatives
- Including additional constraints - not just budgetary
- Arriving at a work plan for each contractor, for each contractor’s capability

Thank you!

If more information is required, please be in touch:

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