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UNITED STATES OF AMERICA



# Economic Analysis of Road Investments: HDM-IV Modeling

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# Highway Development and Management Model-IV - Introduction

Specialized road performance modelling software applied to:

- Road sector policy studies
- Strategic planning of road network development, improvement & maintenance
- Determination of funding requirements
- Preparation of multi-year road work programmes
- Economic appraisal of individual road projects
- Research studies
  - Road pricing
  - Vehicle regulations
  - Pavement design standards
- MCC has primarily relied on the use of HDM-IV for the economic evaluation of road investments ex ante and in the course of Compact implementation and will likely use the tools for Compact completion re-assessments.

# HDM-IV - Features

- Predicts road and road network performance as a function of:
  - traffic volumes and loading
  - road pavement type and strength
  - maintenance standards
  - environment and climate
- Quantifies benefits from:
  - savings in vehicle operating costs (VOC)
  - reduced road user travel times
  - decrease in number of road accidents
  - environmental effects

# HDM-IV – Economic Evaluation 1

- Distinguish between:
  - Primary Effects (change in value of goods moved, change in road maintenance costs, increased travel, changes in accident costs, changes in environmental effects) as opposed to
  - Secondary Effects (changes in agricultural output, changes in services, changes in industrial output, changes in consumer behavior, changes in land value)

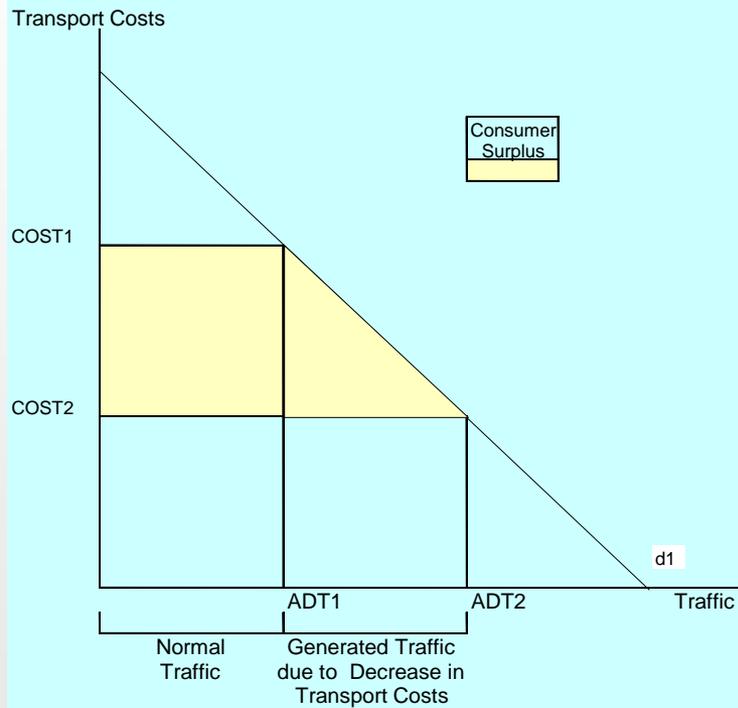


# HDM-IV – Economic Evaluation 2

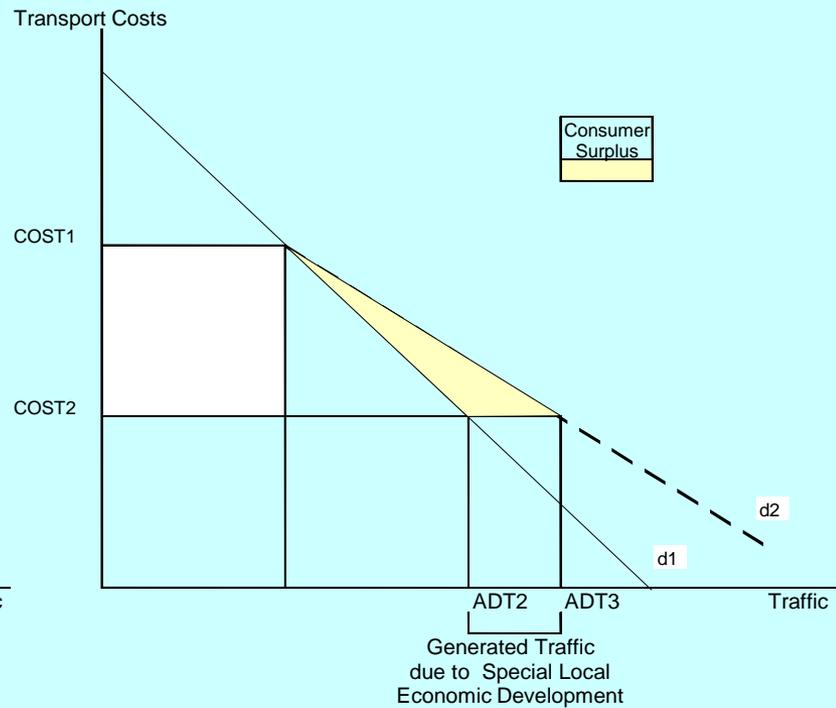
- Adding primary and secondary effects results in double counting
- HDM-IV estimates primary effects via a consumer surplus (CS) approach (changes in road user costs)
- In approximately competitive environments the CS approach should be adequate as a proxy of spectrum of benefits (with secondary effects reflected in generated and induced traffic)

# HDM-IV – CS Review

Decrease in Transport Costs



Special Local Economic Development (Induced Traffic)



# HDM-IV – Traffic Definitions

- Normal: Traffic without new investment (typically increasing over time in w/o project scenario)
- Generated: Traffic associated with existing users of a road driving more frequently or further than before
- Induced: Traffic attracted to the project road from other roads, changing its origin or destination, due to increased economic activity in the road's zone of influence brought about by the project
- Diverted: Traffic that diverts to the project road from an alternative road with the same origin and destination as the project
- HDM-IV refers to generated and induced traffic as “generated” traffic

# HDM-IV – Estimating VOC Benefits

Normal traffic benefits:  $\text{trips}_N * d_1 * (\text{VOC}_1 - \text{VOC}_2)$

Diverted traffic benefits:  $\text{trips}_D * ((d_1 * \text{VOC}_1) - (d_2 * \text{VOC}_2))$

Generated traffic benefits:  $\text{trips}_G * d_2 * (\text{VOC}_1 - \text{VOC}_2) / 2$

$d_1$  = existing road length       $d_2$  new road length

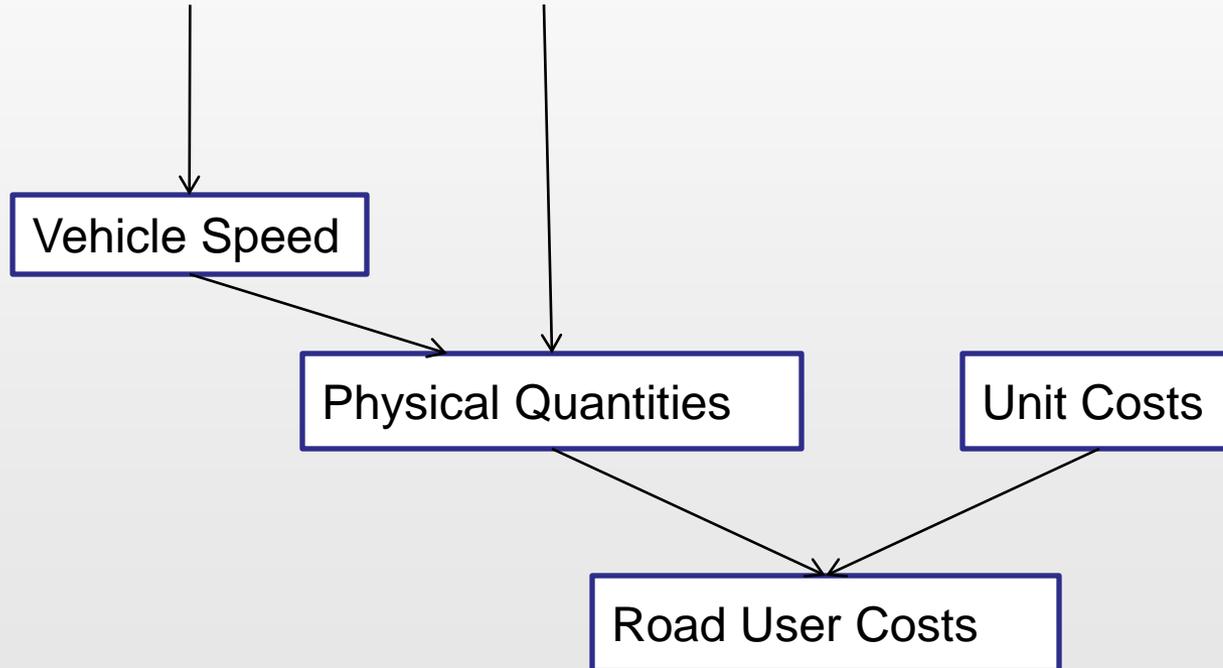
$\text{VOC}_1$  = vehicle operating costs per km “without” investment

$\text{VOC}_2$  = vehicle operating costs per km “with” investment

VOC data relates to each road section and its condition at the time

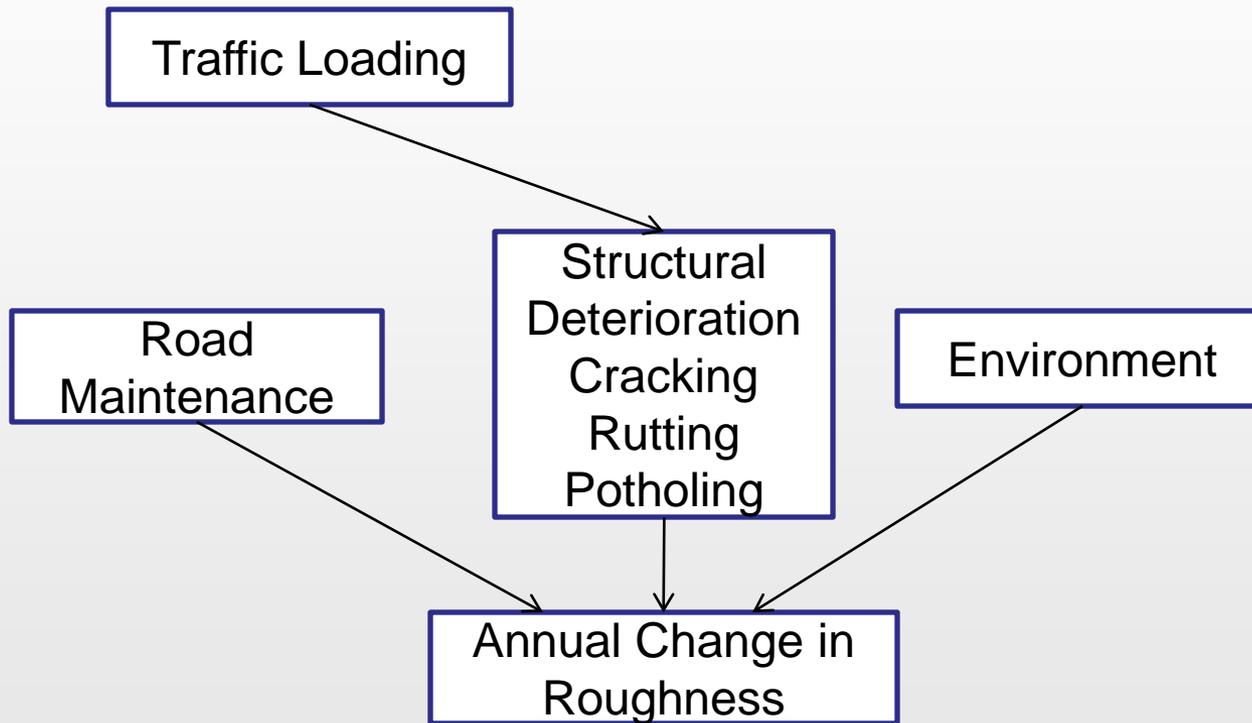
# HDM-IV – Estimation of VOC Benefits

## Road Roughness and Terrain and Vehicle Characteristics



# HDM-IV – Determination of Road Roughness

Annual Changes in IRI Without and With Project



Calibrated HDM-IV forecasts roughness for different road surfaces

# HDM-IV – Modeling Inputs 1

- Representative traffic fleets (mode may change with change in road user costs with investment)
  - Motorized
    - Motorcycle
    - Small Car
    - Medium Car
    - Large Car
    - Light Delivery Vehicle
    - Light Goods Vehicle
    - Four Wheel Drive
    - Light Truck
    - Medium Truck
    - Heavy Truck
    - Articulated Truck
    - Mini-bus
    - Light Bus
    - Medium Bus
    - Heavy Bus
    - Coach
  - Nonmotorized
    - Bicycles
    - Rickshaw
    - Animal Cart
    - Pedestrian

# HDM-IV – Modeling Inputs 2

## Characteristics, utilization and economic data on fleet by vehicle type

- Cost new
- Type of tires, tire replacement cost
- Hourly cost of maintenance labor
- Hourly crew wages
- Unit cost of lubricants
- Unit cost of fuel
- Hourly time value of passengers (in working time and non-working time)
- Hourly cargo time value
- Annual interest
- No. of axels, wheels
- passenger car space equivalent
- Annual kilometers driven
- Working hours
- Average life
- No. of passengers
- No. of work related passenger trips
- % private use
- Operating weight
- Loading
- Physical performance calibration data

# HDM-IV – Modeling Inputs 3

## Definition of Road Network

- Links
- Length
- Flow
- Surface class
- Material type
- Surfacing thickness
- Initial conditions (IRI, % structural cracks, % wide structural cracks, % thermal cracks, % ravelled area, no. of potholes (no./km), mean rut depth, condition of drainage...)
- Geometry (rises and falls (m/km), no. of rises and falls/km, average horizontal curvature, speed limit, altitude, speed reduction factors,...)
- Initial traffic
- Asset valuation data (breakdown of replacement costs and residual values)



# HDM-IV – Modeling Inputs 4

- Definition of Road Investment Alternatives
  - Specification of improvement or new construction (length, carriageway width, flow direction, surface class, traffic flow patterns, climate zone, calibration data, ...)
  - Specification of geometry
  - Costs and salvage value
  - Pavement characteristics and initial conditions
  - Specification of initial, generated and diverted traffic
  - Accidents
- Definition of Maintenance Regimes
  - Work items and costs
  - Technical design characteristics (surface thickness, relative compaction, construction defect indicators, ...)
  - Scheduling or triggering of intervention
  - Specification of effects (roughness and rutting after works)
  - Asset valuation (breakdown of replacement costs and residual values)

# HDM-IV - Outputs

- Economic Indicators
  - Net Present Value (NPV)
  - Economic Rate of Return (ERR)
  - Benefit Cost Ratio (BCR), NPV/C
- Sensitivity Analysis results
  - Scenario analysis
  - Road condition indicators
  - Road user cost details
  - Energy & emissions

# HDM-IV - Conclusions

- Transparency of analysis
- Life cycle analysis capable of:
  - Short, Medium & Long term analyses
  - What-if analysis
- Internationally accepted analysis framework
- Availability of technical expertise
- Local calibration



# Roads Economic Decision Model

- WB Modeling tool alternative to HDM-IV for use in Africa region
- RED platform developed for evaluating low-volume (AADT<300)roads
- Features similar to HDM-IV but simplified and limited options for calibration
- Draws on HDM-IV database to simplify calibration of VOC as function of IRI and speeds
- Allows for wet season/dry season differentiation of road use and conditions
- Executed in MS Excel
- Facilities for budget constraint optimization (program analysis module)
- Facilities for risk analysis (risk analysis module)

## Reducing Poverty Through Growth