## Road User Costs Knowledge System (RUCKS)

**HDM-4 RUC Model Version 2.00, February 12, 2010**

<table>
<thead>
<tr>
<th>Step</th>
<th>Inputs</th>
<th>Calculations</th>
<th>Outputs</th>
</tr>
</thead>
</table>
| 1)   | I-Vehicle Fleet & Country Data  
I-Vehicle Fleet Calibration |  | Road User Costs  
|      |        | Calculate Road User Costs | O-Road User Costs  
|      |        |                           | O-Resources and Performance  
|      |        |                           | O-Emissions |
| 2)   | I-Road Characteristics |  | Sensitivity Analysis  
|      |        | Calculate Sensitivity Analysis | O-Roughness Sensitivity  
|      |        |                           | O-Speed Limit Sensitivity  
|      |        |                           | O-Traffic Sensitivity  
|      |        |                           | O-RONET RUC Coefficients  
|      |        |                           | O-Charts One Vehicle  
|      |        |                           | O-Charts All Vehicles |
| 3)   | I-Sensitivity Parameters |  | Network Road User Costs  
|      |        | Calculate Network RUC | O-Network Road User Costs |
| 4)   | I-Network Characteristics |  | Cost Benefit Analysis  
|      |        | Calculate Cost Benefit Analysis | O-Cost Benefit Analysis Results |
| 5)   | I-Cost Benefit Analysis Data |  | Instructions |

Twelve Vehicles Types

- Motorcycle
- Small Car
- Medium Car
- Light Delivery Vehicle
- Four Wheel Drive
- Light Truck
- Medium Truck
- Heavy Truck
- Articulated Truck
- Light Bus
- Medium Bus
- Heavy Bus
Road User Costs Components

Vehicle Operating Costs
- Fuel
- Lubricant oil
- Tire wear
- Crew time
- Maintenance labor
- Maintenance parts
- Depreciation
- Interest
- Overheads

Time Costs
- Passenger time
- Cargo holding time

Accidents Costs
- New

Emissions
- New
Vehicle Speed and Physical Quantities

Road and Vehicle Characteristics

Vehicle Speed

Physical Quantities

Unit Costs

Road User Costs
## Physical Quantities

<table>
<thead>
<tr>
<th>Component</th>
<th>Quantities per Vehicle-km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel</td>
<td>liters</td>
</tr>
<tr>
<td>Lubricant oil</td>
<td>liters</td>
</tr>
<tr>
<td>Tire wear</td>
<td># of equivalent new tires</td>
</tr>
<tr>
<td>Crew time</td>
<td>hours</td>
</tr>
<tr>
<td>Passenger time</td>
<td>hours</td>
</tr>
<tr>
<td>Cargo holding time</td>
<td>hours</td>
</tr>
<tr>
<td>Maintenance labor</td>
<td>hours</td>
</tr>
<tr>
<td>Maintenance parts</td>
<td>% of new vehicle price</td>
</tr>
<tr>
<td>Depreciation</td>
<td>% of new vehicle price</td>
</tr>
<tr>
<td>Interest</td>
<td>% of new vehicle price</td>
</tr>
</tbody>
</table>
Free speeds are calculated using a mechanistic/behavioral models and are a minimum of the following constraining velocities.

- $V_{DRIKEu}$ and $V_{DRIKEd}$ = uphill and downhill velocities limited by gradient and used driving power
- $V_{BRAKEu}$ and $V_{BRAKEd}$ = uphill and downhill velocities limited by gradient and used braking power
- $V_{CURVE}$ = velocity limited by curvature
- $V_{ROUGH}$ = velocity limited by roughness
- $V_{DESIR}$ = velocity limited by safety and speed limit enforcement
VDRIVE

Drive Force

Grade Resistance
Air Resistance
Rolling Resistance

- Driving power
- Operating weight
- Gradient
- Density of air
- Aerodynamic drag coef.
- Projected frontal area
- Tire type
- Number of wheels

- Roughness
- Texture depth
- % time driven on snow covered roads
- % time driven on water covered roads
VCURVE

VCURVE is calculated as a function of the radius of curvature.

\[ V\text{CURVE} = a_0 \times R^{a_1} \]

\[ R = \text{Radius of curvature} \]

\[ R = \frac{180,000}{\pi \times \text{max}(18/\pi, C)} \]

\[ C = \text{Horizontal curvature} \]

\[ a_0 \text{ and } a_1 = \text{Regression parameters} \]
To consider reduction in speeds due to congestion, the “three-zone” model is adopted.

**Speed Flow Model**

- Car
- Pickup
- Bus
- Truck

**Graph**
- X-axis: Flow (PCSE/hr)
- Y-axis: Speed (km/hr)
- Key points: Qo, Qnom, Qult
To consider different levels of traffic congestion at different hours and days during a year, HDM-4 evaluates different traffic flow periods for which different hourly flows are applicable.
Fuel Model

- Based on ARRB ARFCOM model
- Predicts fuel use as function of power usage
Congestion Modelling

Uncongested

Congested

Acceleration in m/s/s
Maintenance parts consumption function of roughness and age of the vehicle
Capital Costs

• Comprised of depreciation and interest costs
• HDM-4 uses ‘Optimal Life’ method, in which vehicle service life is a function of roughness, or constant life method
Road Safety

• HDM-4 model estimates road safety costs of:
  - Fatal accidents
  - Injury accidents
  - Damage only accidents

• HDM-4 RUC model follows the International Road Assessment Program (iRAP) methodology and estimates road safety costs of:
  - Fatalities
  - Persons with Serious Injuries
iRAP Methodology

• User defines vehicle fleet fatality rate in number per 100 million vehicle-km
• User defines vehicle fleet serious injury rate per 100 million vehicle-km
• Cost per fatality computed function of GDP per capita (default: GDP per capita multiplied by 70)
• Cost per serious injury computed function of cost per fatality (default: 25% of fatality cost)

International Road Assessment Programme methodology (iRAP).
http://irap.net/
Emissions Model

- Road characteristics
- Traffic volume/congestion
- Vehicle technology

Fuel consumption

- Hydrocarbon
- Carbon monoxide
- Nitrous oxides
- Sulphur dioxide
- Carbon dioxide
- Particulates
- Lead
RUC Comparison

Roughness = 2.0 IRI m/km
RUC Composition

Roughness = 2.0 IRI m/km
RUC Roughness Sensitivity

Heavy Truck Unit Road User Costs Sensitivy to Roughness

- Road Safety Cost
- CO2 Emissions Cost
- Cargo Time
- Passenger Time
- Overhead
- Interest
- Depreciation
- Crew Time
- Maintenance Labor
- Maintenance Parts
- Tire
- Lubricants
- Fuel

Unit Road User Costs (US$ per vehicle-km)

2 IRI 6 IRI 12 IRI 18 IRI
RUC Roughness Sensitivity

![Graph showing the relationship between roughness and unit road user costs for different vehicle types. The x-axis represents roughness (IRI, m/km) ranging from 2.0 to 18.0, and the y-axis represents unit road user costs (US$ per vehicle-km) ranging from 0.000 to 1.400. Lines are color-coded for Medium Car (blue), Medium Bus (red), Heavy Truck (green), and Motorcycle (purple).]
RUC Roughness Sensitivity

6.0 IRI = 0.22 US$ per vehicle-km
2.0 IRI = 0.21 US$ per vehicle-km
Saving = 0.01 US$ per vehicle-km

AADT = 3,000 vehicles/day
=> 1,095,000 vehicles/year

Saving = 10,850 US$ per year per km
Fuel Consumption and Speed

Roughness = 2.0 IRI m/km
CO2 Emissions and Speed

Roughness = 2.0 IRI m/km
Fuel Consumption and Roughness

Speed function of roughness
CO2 Emissions and Roughness

Speed function of roughness
Road Software Tools Website

- HDM-4 Road User Costs Model Version 2.00 available for download at:

  http://worldbank.org/roadsoftwaretools/