Scope of Motorways

- Procedures for the calculation of free-flow speed, capacity, speed and degree of bunching on motorways designed for urban and interurban conditions
- Motorways are defined as roads for through traffic with complete access control, whether or not they are divided roads.
- In Indonesia, this definition is currently synonymous with 'toll road'.

Scope of Motorway

- Interurban Motorways Types
  - Two-lane two-way roads (MW 2/2 UD)
  - Four-lane two-way roads (MW 4/2 D)

Scope of Motorways

- **Conditions:**
- Flat, rolling or hilly alignment
- Specific grades (e.g. two-lane two-way undivided with climbing lane)

Scope of Motorways

- **Road Segments:**
- Between and unaffected by interchanges with on- and off-ramps, and
- Having similar geometric design and traffic flow characteristics along its length.

Objective of Motorways

- Design of motorways should be selected with the aim to ensure that degree of saturation does not exceed an acceptable value (**normally 0,75**)

Traffic Safety Considerations

- Widening of the lane decreases the accident rates between 2-5% per meter widening (the high number refers to small roads).
- Widening and improvement of shoulder surface conditions improves traffic safety, although to a smaller degree than lane widening

Traffic Safety Considerations

- Climbing lane in steep grades reduce the accident rate with 20-25%.
- A median reduces the accident rate with 30%
- Median barriers (used when the space is insufficient to make a full median) reduce fatal and severe injury accidents with 10-30%, but increase damage only accidents.

Motorways Performance Indicator

- Degree of Saturation (≤ 0,75)
- Level of Service (A – F)
- Actual Free-Flow Speed
- Travel Time
- Degree of Bunching (only for MW 2/2 UD)

STEP A-1: General Data

- Date (day, month, year) and Handled by
- Province
- Motorway name
- Segment code
- Segment between … or …
- Segment length
- Motorway type (MW 4/2 UD, MW 2/2 UD)
- Time period
- Case number

STEP A-2: Geometric Conditions

- Compass arrow showing North
- Km-posts
- Sketch of the horizontal alignment
- Arrows identifying Direction 1 (North or East-bound) and Direction 2 (South or West-bound)
- Names of the places
- Pavement markings

STEP A-2: Geometric Conditions

- Sight Distance Class

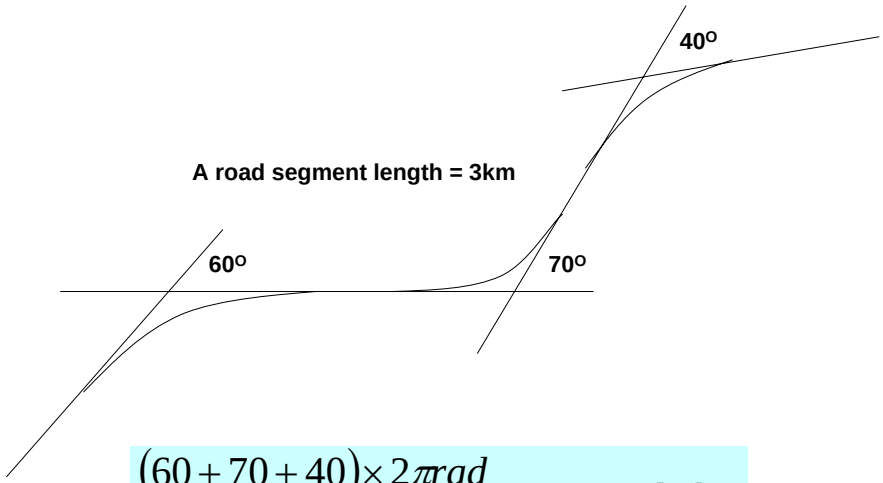
Sight Distance Class	% of Segment with Sight Distance of at least 300m
A	> 70%
B	30 – 70%
C	< 30%

STEP A-2: Geometric Conditions

- Alignment Type

Alignment Type	Rise + Fall (m/km)	Horizontal Curvature (rad/km)
Flat	< 10	< 1,0
Rolling	10 – 30	1,0 – 2,5
Hilly	> 30	> 2,5

CONVERSION INTO RADIANS/KM



$$\frac{(60+70+40)\times 2\pi rad}{3km} \approx 0{,}99 rad/km$$

STEP A-3: Traffic Conditions
Two-Way Undivided MW (2/2 UD)

Alignment Type	Total Flow veh/h	pce		
		MHV	LB	LT
Flat	0	1,2	1,2	1,8
	900	1,8	1,8	2,7
	1.450	1,5	1,6	2,5
	≥ 2.100	1,3	1,5	2,5
Rolling	0	1,8	1,6	5,2
	700	2,4	2,5	5,0
	1.200	2,0	2,0	4,0
	≥ 1.800	1,7	1,7	3,2
Hilly	0	3,5	2,5	6,0
	500	3,0	3,2	5,5
	1.000	2,5	2,5	5,0
	≥ 1.450	1,9	2,2	4,0

STEP A-3: Traffic Conditions
Four-Lane Two-Way MW (4/2 D)

Alignment Type	Traffic Flow veh/h	Pce		
	Divided MW per Direction	MHV	LB	LT
Flat	0	1,2	1,2	1,6
	1.250	1,4	1,4	2,0
	2.250	1,6	1,7	2,5
	≥ 2.800	1,3	1,5	2,0
Rolling	0	1,8	1,6	4,8
	900	2,0	2,0	4,6
	1.700	2,2	2,3	4,3
	≥ 2.250	1,8	1,9	3,5
Hilly	0	3,2	2,2	5,5
	700	2,9	2,6	5,1
	1.450	2,6	2,9	4,8
	≥ 2.000	2,0	2,4	3,8

STEP A-3: Traffic Conditions
Six-Lane Two-Way MW (6/2 D)

Alignment Type	Traffic Flow veh/h	Pce		
	Divided MW per Direction	MHV	LB	LT
Flat	0	1,2	1,2	1,6
	1.900	1,4	1,4	2,0
	3.400	1,6	1,7	2,5
	≥ 4.150	1,3	1,5	2,0
Rolling	0	1,8	1,6	4,8
	1.450	2,0	2,0	4,6
	2.600	2,2	2,3	4,3
	≥ 3.300	1,8	1,9	3,5
Hilly	0	3,2	2,2	5,5
	1.150	2,9	2,6	5,1
	2.150	2,6	2,9	4,8
	≥ 3.000	2,0	2,4	3,8

STEP A-3: Traffic Conditions
Specific Grades Up-hill

Length (km)	pce									
	Gradient (%)									
	3		4		5		6		7	
	MHV	LT	MHV	LT	MHV	LT	MHV	LT	MHV	LT
0,50	2,00	4,00	3,00	5,00	3,80	6,40	4,50	7,30	5,00	8,00
0,75	2,50	4,60	3,30	6,00	4,20	7,50	4,80	8,60	5,30	9,30
1,00	2,80	5,00	3,50	6,20	4,40	7,60	5,00	8,60	5,40	9,30
1,50	2,80	5,00	3,60	6,20	4,40	7,60	5,00	8,50	5,40	9,10
2,00	2,80	5,00	3,60	6,20	4,40	7,50	4,90	8,30	5,20	8,90
3,00	2,80	5,00	3,60	6,20	4,20	7,50	4,60	8,30	5,00	8,90
4,00	2,80	5,00	3,60	6,20	4,20	7,50	4,60	8,30	5,00	8,90
5,00	2,80	5,00	3,60	6,20	4,20	7,50	4,60	8,30	5,00	8,90

STEP B-1: Analysis of Free-flow Speed

$$FV = FV_0 + FV_W$$

- FV → free-flow speed for LV at actual conditions (kph)
- FV_0 → Base free-flow speed for light vehicles (kph)
- FV_W →Adjustment for effective carriageway width (km/h)

STEP B-1: Analysis of Free-flow Speed

Road Type/Alignment Type/Sight Distance Class	Base Free-Flow Speed FV_0 (km/h)			
	LV	MHV	LB	LT
Six-Lane Divided				
Flat	91	71	93	66
Rolling	79	59	72	52
Hilly	65	45	57	40
Four-Lane Divided				
Flat	88	70	90	65
Rolling	77	58	71	52
Hilly	64	45	57	40

STEP B-1: Analysis of Free-flow Speed

Road Type/Alignment Type/Sight Distance Class	Base Free-Flow Speed FV_0 (km/h)			
	LV	MHV	LB	LT
Two-Lane Undivided				
Flat SDC A	82	66	85	63
Flat SDC B & C	78	63	81	60
Rolling	70	55	68	51
Hilly	62	44	55	39

STEP B-2: Free-flow Speed Adjustment FV_W for Carriageway Width [Table B-2:1]

- Four and Six-Lane Divided
- For Flat → $FV_W = 8W_C^2 - 50W_C + 77$
- For Rolling & Hilly → $FV_W = 4W_C - 14$

- Two-lane Undivided
- For Flat → $FV_W = -2W_C^2 + 31W_C - 119$
- For Rolling & Hilly → $FV_W = 4W_C - 14$

STEP B-3: Determination of Free-flow Speed for Actual Conditions

- Free-flow speed for light vehicles (LV)
- $FV = FV_0 + FV_W$

- Free-flow speed for other vehicle types
- $FVMHV = FV_{MHV0} + FV_W \times FV_{MHV} / FV_0$

- FV_{MHV0} → Table B-1:1

STEP B-6: Determination of Free-flow Speed for Specific Grades

Length km	Direction 1, Uphill Gradient %					Direction 2, Downhill Gradient %				
	3	4	5	6	7	3	4	5	6	7
0,5	77,0	73,0	69,4	65,1	60,8	81,0	80,0	79,0	76,0	72,0
1,0	75,0	69,4	64,5	59,6	54,6	81,0	80,0	78,2	74,8	70,4
2,0	73,2	66,9	61,3	56,3	51,2	81,0	80,0	77,4	73,6	68,8
3,0	72,6	66,1	60,3	55,3	50,2	81,0	80,0	76,6	72,4	67,2
4,0	72,3	65,7	59,9	54,9	49,8	81,0	80,0	75,8	71,2	65,6
5,0	72,0	65,4	59,5	54,5	49,5	81,0	80,0	75,0	70,0	64,0

STEP B-6: Determination of Free-flow Speed for Specific Grades

Length km	LT Uphill Gradient %				
	3	4	5	6	7
0,5	53,3	47,1	41,3	35,8	30,5
1,0	49,0	42,0	35,4	30,8	26,5
2,0	45,9	39,1	32,8	28,7	24,9
3,0	44,9	38,3	32,1	28,1	24,4
4,0	44,5	37,9	31,8	27,8	24,2
5,0	44,1	37,6	31,5	27,6	24,0

STEP C-1: Base Capacity

Road Type /Alignment Type	Base Capacity pcu/h/lane
Four and Six-Lane Divided	
Flat	2.300
Rolling	2.250
Hilly	2.150

STEP C-1: Base Capacity

Road Type /Alignment Type	Base Capacity Total Both Direction pcu/h
Two-Lane Undivided	
Flat	3.400
Rolling	3.300
Hilly	3.200

STEP C-2: Capacity Adjustment Factor FC_W for Carriageway Width [Table C-2:1]

- Four or Six-lane divided (4/2 D or 6/2 D)
- $FC_W = -0{,}08W_C^2 + 0{,}7W_C - 0{,}47$

- Two-lane undivided (2/2 UD)
- $FC_W = 0{,}08W_C + 0{,}44$

STEP C-3: Capacity Adjustment Factor FC_{SP} for Directional Split

Directional split SP %-%		50-50	55-45	60-40	65-35	70-30
FC_{SP}	Undivided Motor ways	1,00	0,97	0,94	0,91	0,88

STEP C-4: Determination of Capacity for Actual Condition

$$C = C_0 \times FC_W \times FC_{SP}$$

- C → Capacity (pcu/h)
- C_0 → Base capacity (pcu/h)
- FC_W → Adjustment factor for carriageway width
- FC_{SP} → Adjustment factor for directional split

STEP C-5: Determination of Capacity for Specific Condition

Length of Grade /Slope of Grade	Base Capacity pcu/h
Length ≤ 0,5 km / all slopes	3.300
Length ≤ 0,8 km / slope ≤ 4,5%	3.250
All other cases	3.000

STEP C-5: Determination of Capacity for Specific Condition

$$C = C_0 \times FC_W \times FC_{SP}$$

- C → Capacity (pcu/h)
- C_0 → Base capacity (pcu/h)
- FC_W → Adjustment factor for carriageway width
- FC_{SP} → Adjustment factor for directional split

STEP D-1: Degree of Saturation

$$DS = Q / C$$

- Q → Traffic flow (pcu/h)
- Q → MW-2 (column 12 row 5 for undivided road)
- Q → MW-2 (column 12 row 3 & 4 for each direction of travel on divided road)

- C → Capacity (pcu/h)
- C → MW-3 (column 14)

STEP D-2: Speed and Travel Time

- Determine the speed at actual traffic
- Figure D-2:1 (two-lane undivided roads)
- Figure D-2:2 (four or six-lane divided roads)

- Enter segment length (km) in column 24 Form MW-1

- Calculate average travel time (hour) for Light Vehicle

$$TT = L / V_{LV}$$

STEP D-3: Degree of Bunching (Platooning)

- Determine Degree of Bunching (DB) on **two-lane two-way undivided motorway** based on Degree of Saturation (DS) column 22 Form MW-3, see figure D-3:1 or using equation:

$$DB = \frac{DS}{(0{,}814600\,DS + 0{,}2584581)}$$

STEP D-4: Speed and Travel Time for Specific Grades

- For analysis of a specific grade on undivided motorways, follow chapter 6 step D-4 (Interurban Roads), but use figure D-2:1 p.7-53 (Motorway) to determine uphill speed at capacity.

STEP D-5: Evaluation of Traffic Performance

- If DS > 0,75 → revise calculations