Digital Terrain Models for Road Design and Traffic Simulation

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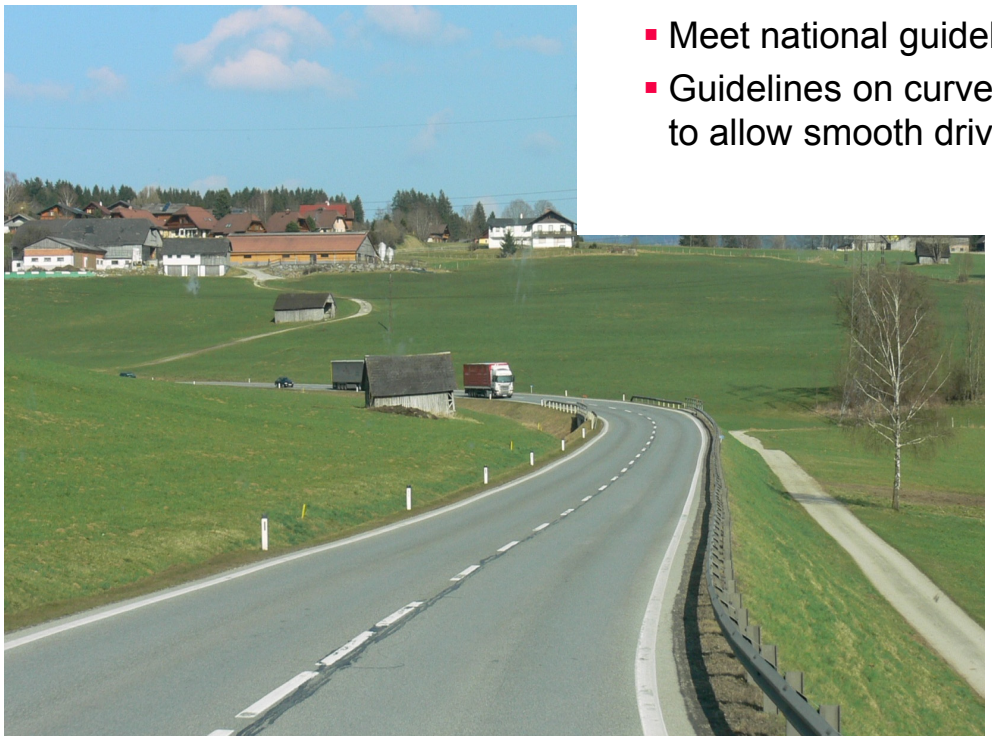
Terrain oriented highway design

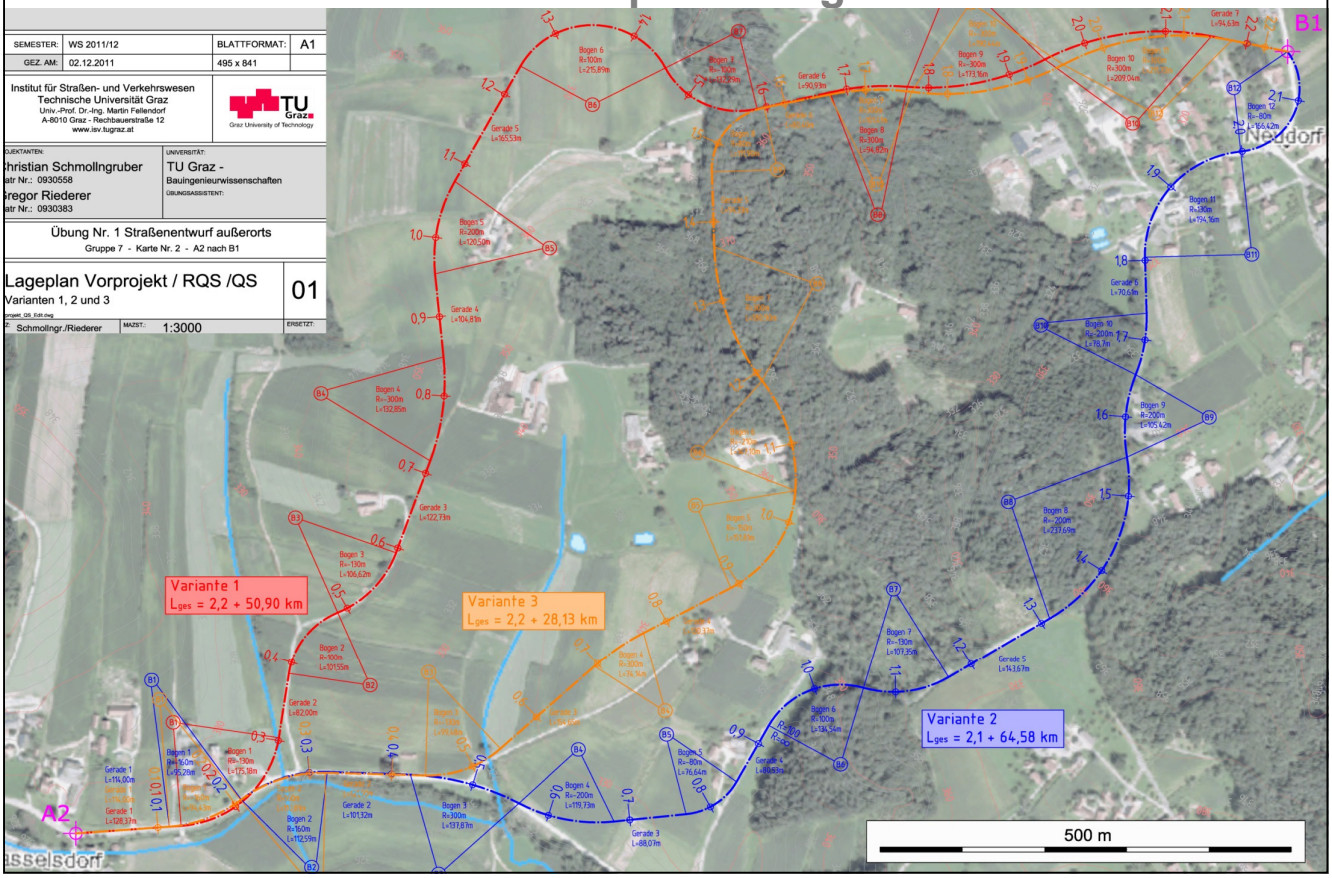


- Meet national guidelines
- Guidelines on curves and gradient to allow smooth driving

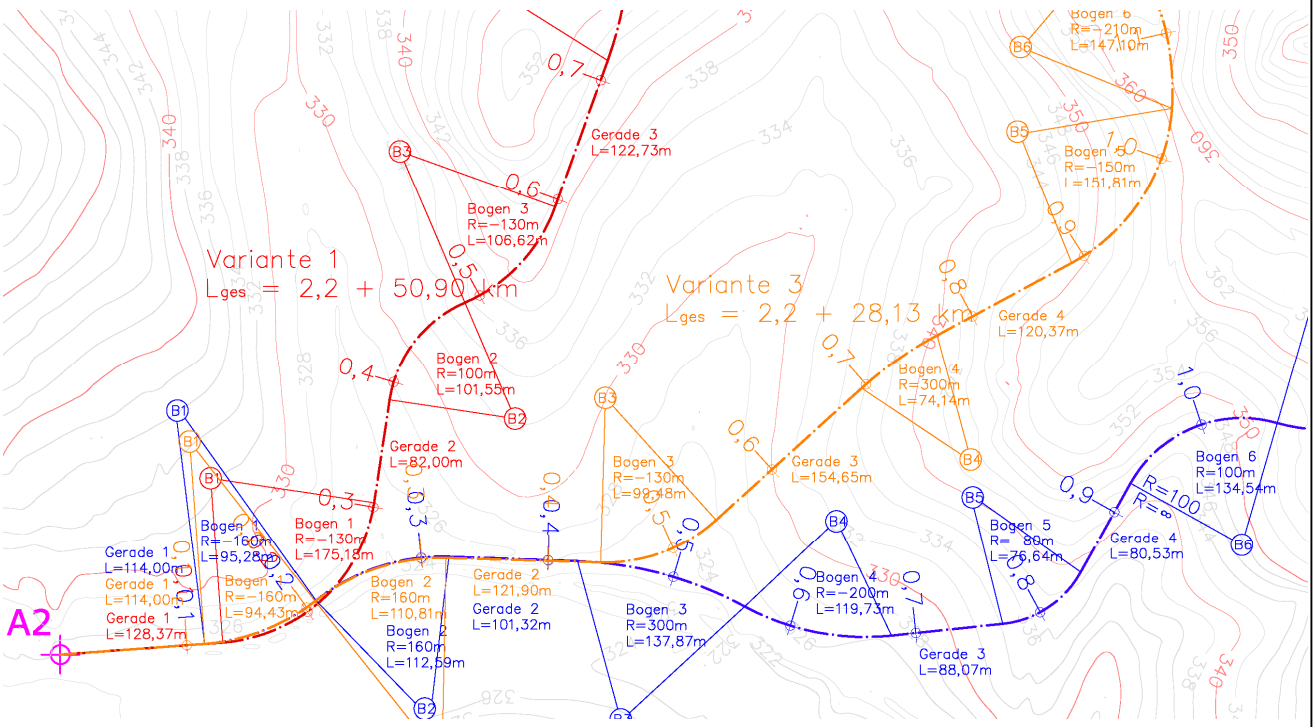
Highway Design requires accurate height information

- CAD design in 1 cm accuracy
- Vertical gradient and horizontal slope to clear water

Search for optimal alignment

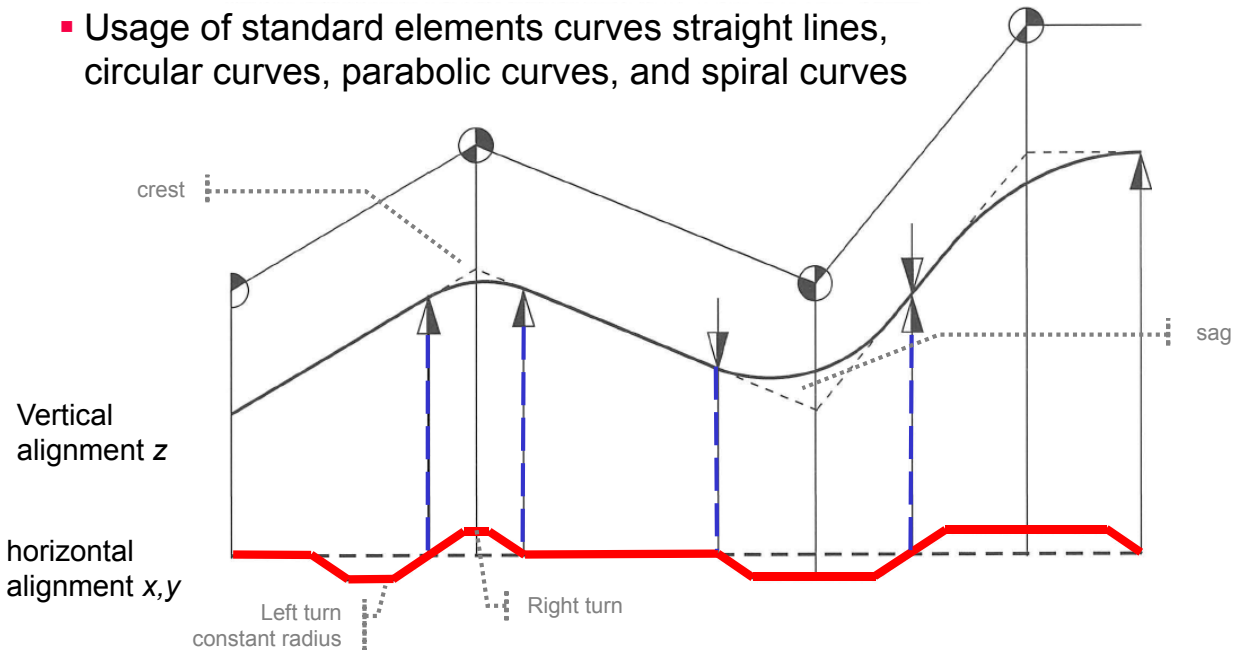


Alternative alignment



Highway Design: good practise

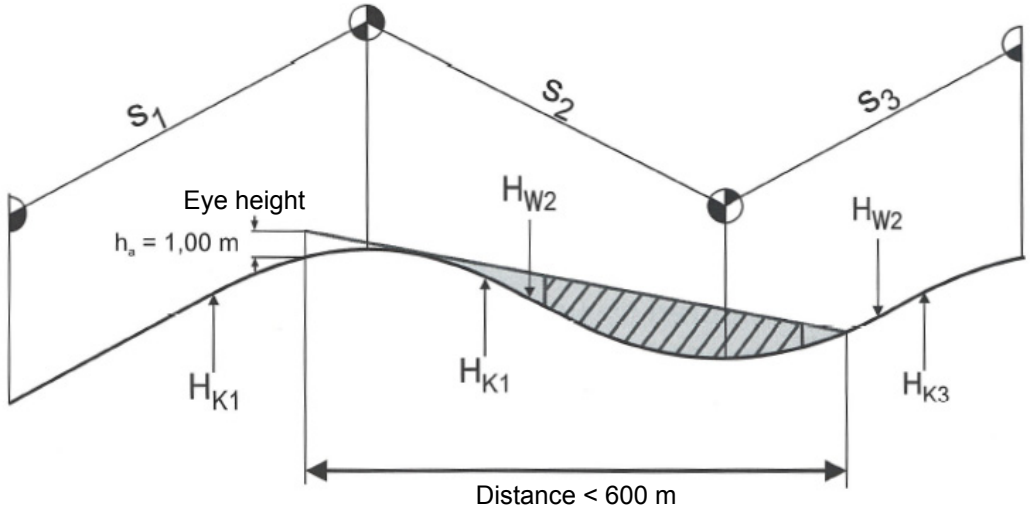
- Identical Inflection points of curvatures in vertical alignment and horizontal alignment
- Usage of standard elements curves straight lines, circular curves, parabolic curves, and spiral curves



FGSV (2012): RAL

Highway Design: problems with sight distance

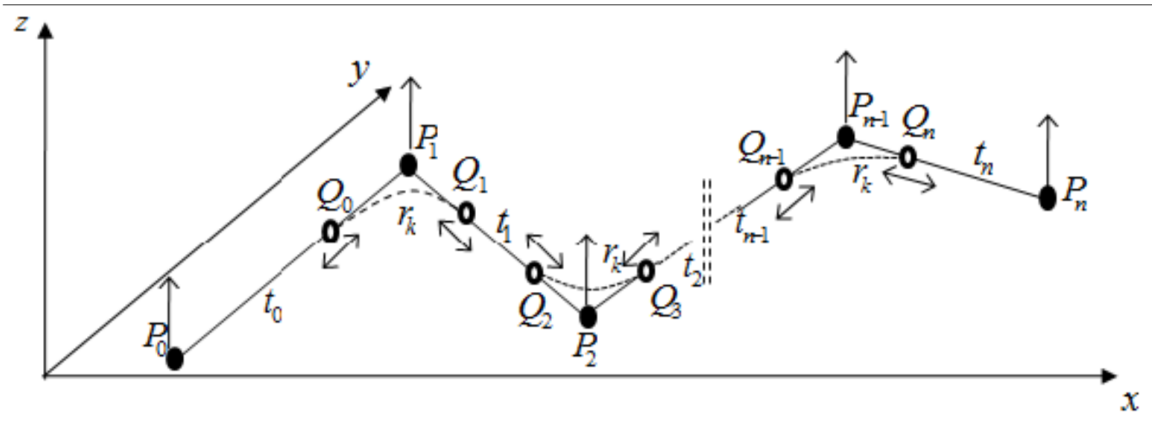
- vertical curve at crest
- Objects within sight shadow are invisible



Sight shadow
Sight shadow with height > 0,75 m

FGSV (2012): RAL

3D Highway Design with polynomials and splines



Fixed point P_i, i=0(1) of the tangent polygon

Transition curve r_k, k=0(1)m between two tangents

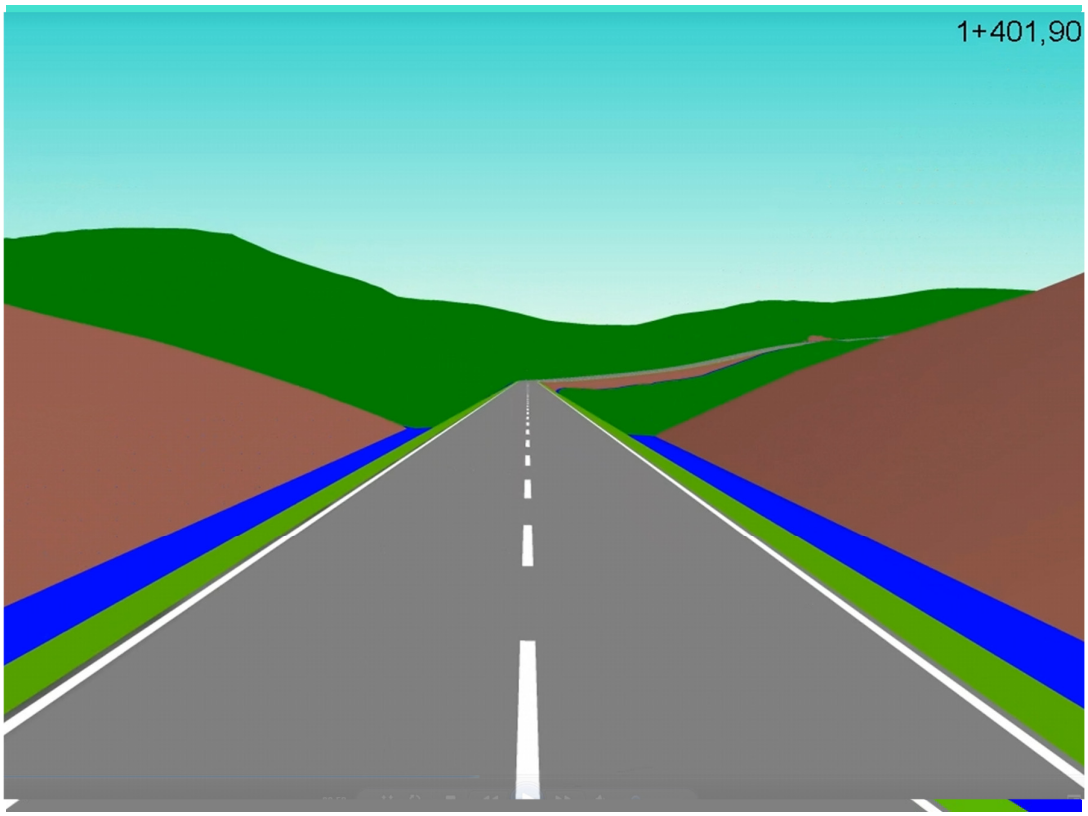
Manipulation point Q_i, i=0(1)n for transition curve r_k

Manipulation of P_i in z direction

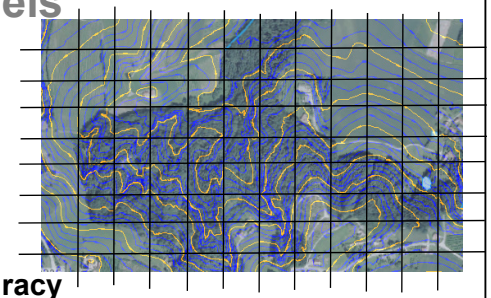
Manipulation of Q_i along tangent t_j, j=0(1)n transition curve

JHA, M. etal, TRB 5392-2013

3D highway design by simulation



Digital Terrain Models

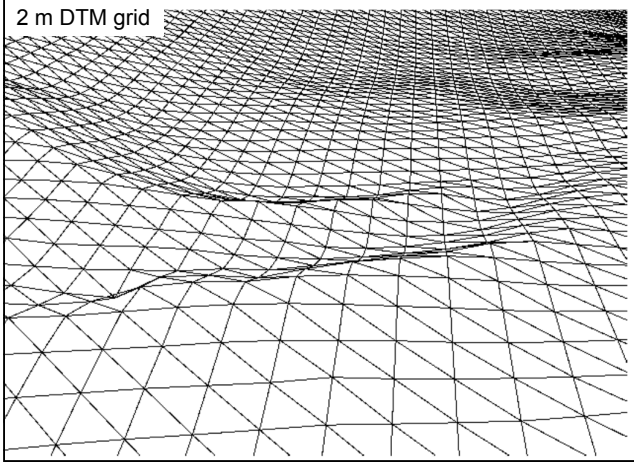


Agency	Item	Accuracy
Austria: Bundesamt für Eich- und Vermessungswesen www.bev.gv.at	Grid width	10 m
	Height accuracy	±1m to ±3m (urban areas, farmland)
	Height accuracy	±10m to ±25m (forest, alpine region)
Germany: Bundesamt für Kartographie und Geodäsie www.bkg.bund.de	Grid width	10 m
	Positional accuracy	±0,5m to ±3m
	Height accuracy	±0,5m to ±2m
Switzerland: Swisstopo www.swisstopo.ch	Grid width	2 m
	Position and Height	±0,5m to ±1m below 2000 m altidude
	Position and Height	±1m to ±3m above 2000 m altidude
Aerial photography of Styria, used for the following examples	Grid width	1 m
	Position	±40 cm
	Height	±10 cm

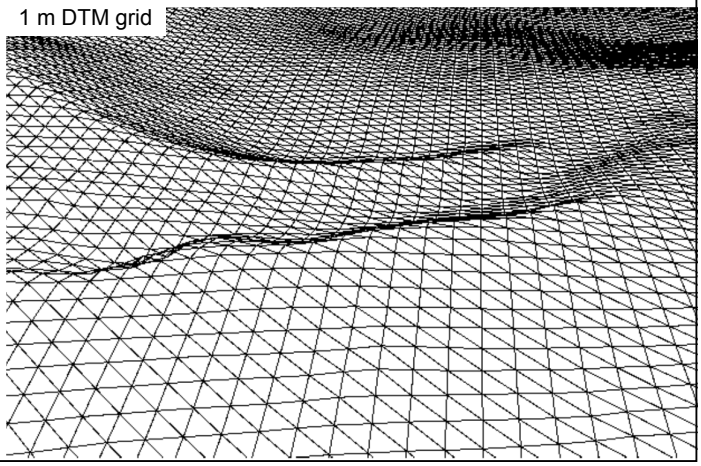
Triangulated Irregular Network for Highway Design

2,2 * 1,3 km	Data points		TIN	
Cell size of Grid	# cells	storage [MB]	# triangles	storage [MB]
1	2.860.000	80	5.715.600	268
2	715.000	16	1.427.800	67
5	114.400	3	227.900	10,7
5 (10cm red.)			196.600	9,9

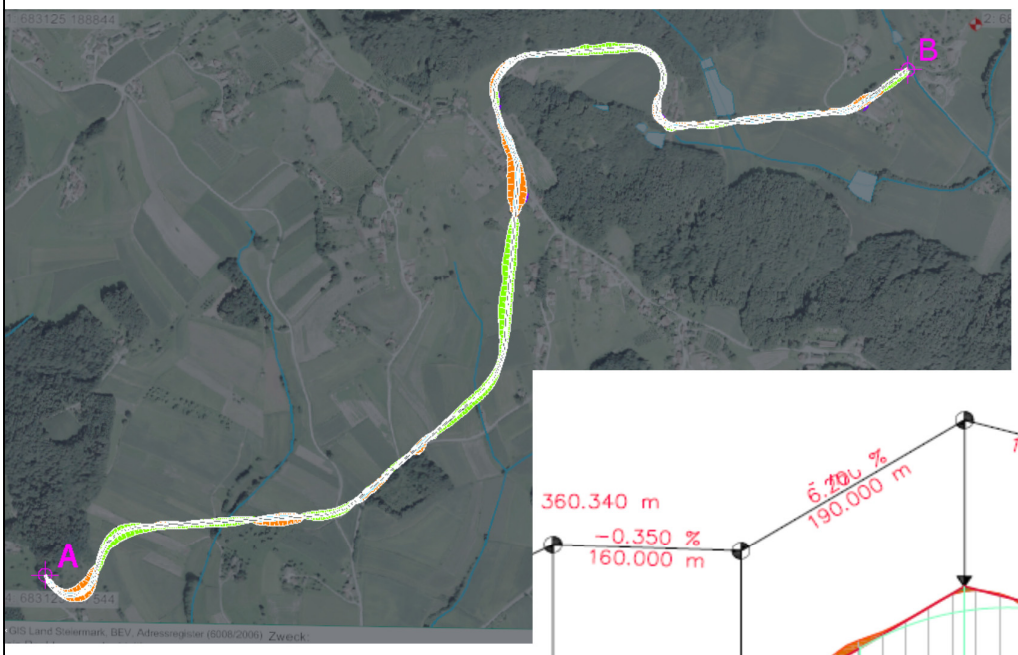
2 m DTM grid



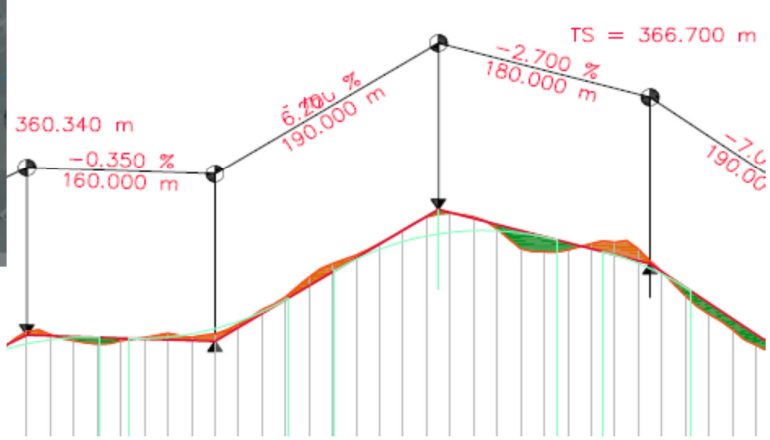
1 m DTM grid



Horizontal and vertical alignments - sketch

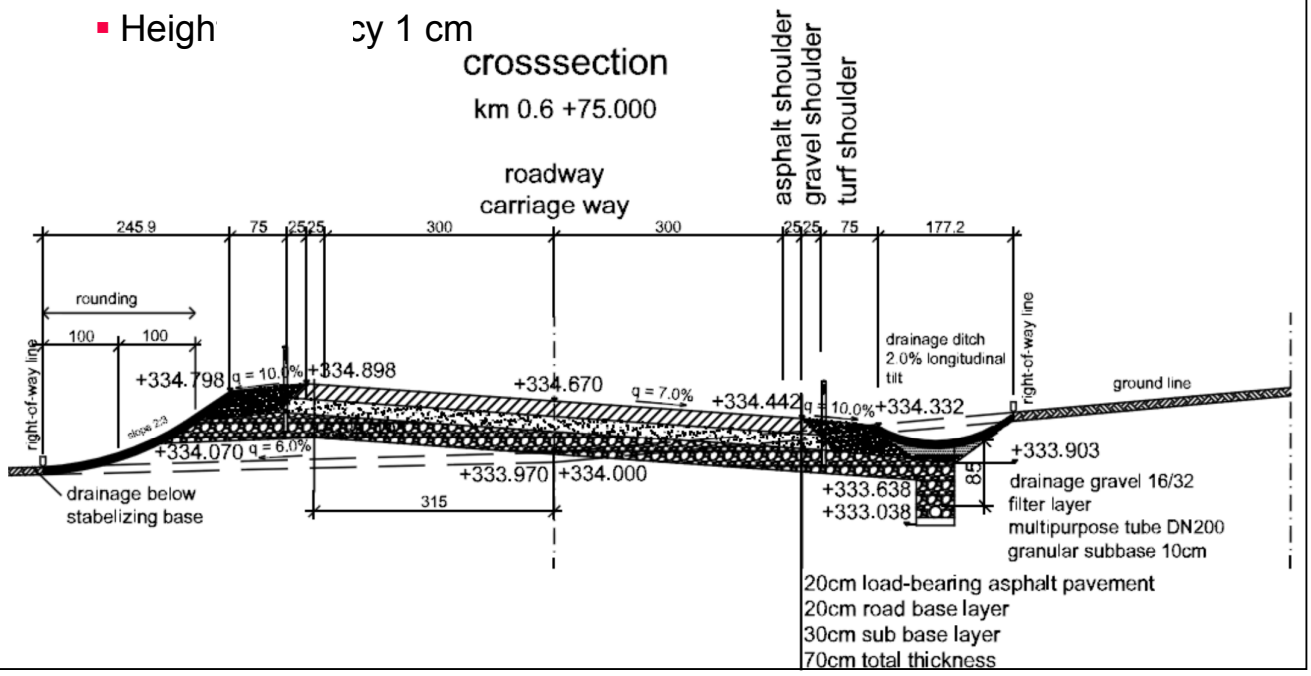


- Height accuracy 10 cm required

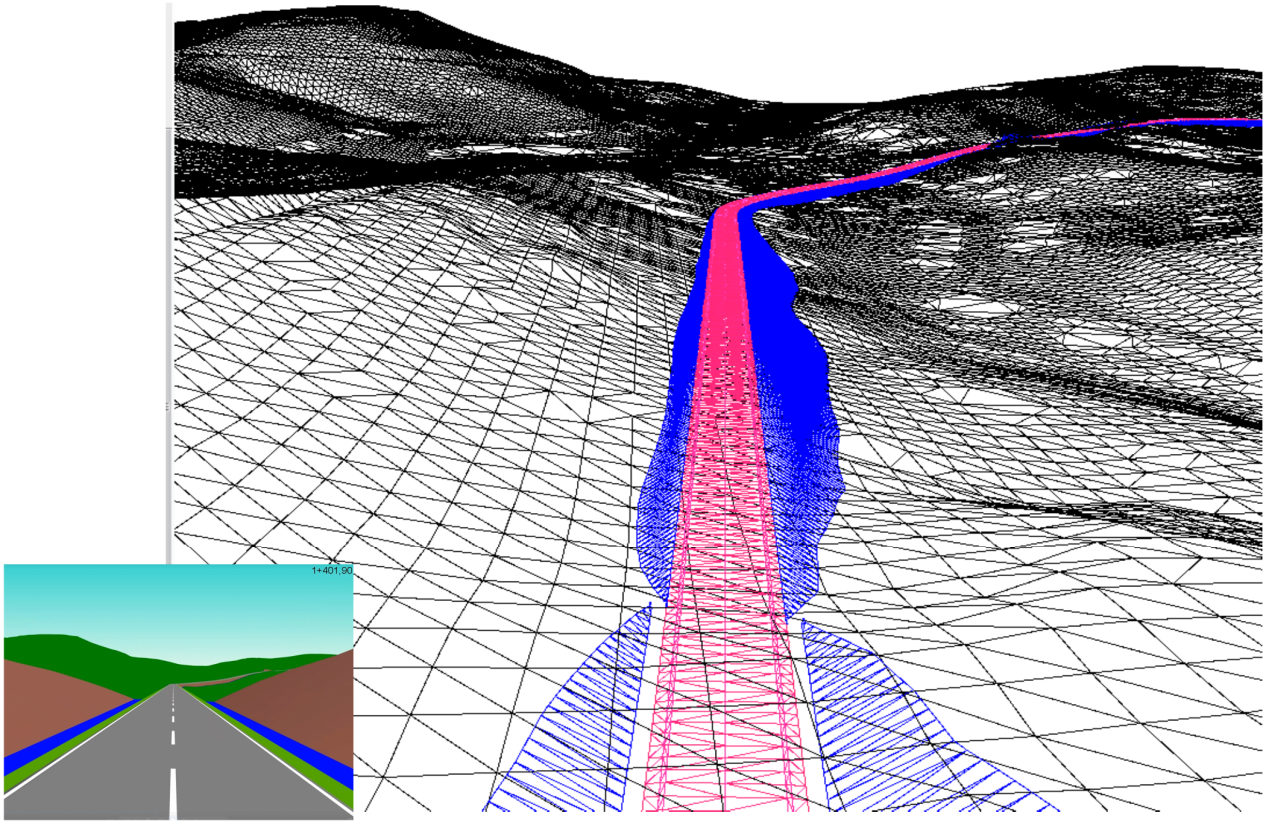


Cross sections - detailed

- Width and usage of roadway
- Drainage and superelevation
- Road structure
- Heigh cy 1 cm



Highway design on DTM



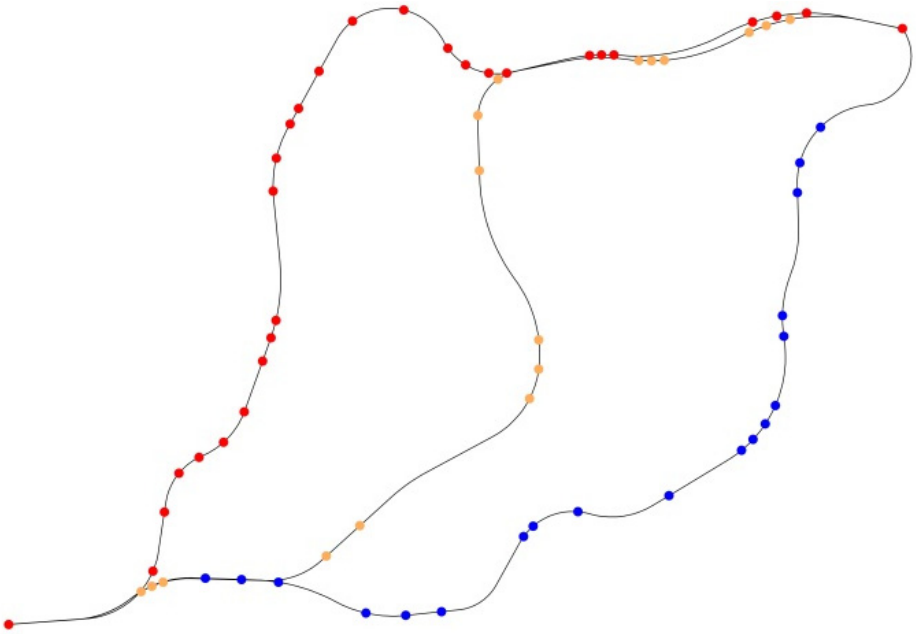
Environmental analysis of highway design

- Evaluation of alternative scenarios
- Traffic flow simulation and dynamics
- Desired speed and reduced speed at gradients and curves

VECTRA SEVEN CAD

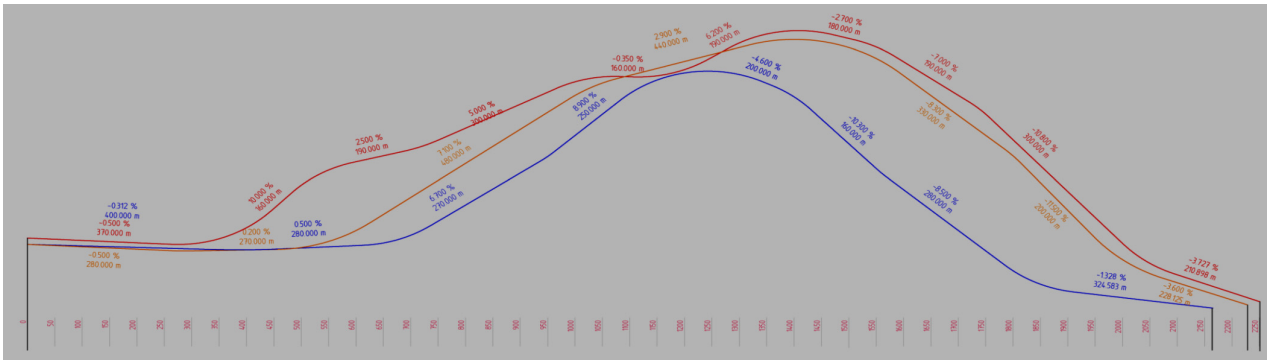
PTV VISSIM
the mind of movement

PHEM
Passenger car and Heavy duty Emission Model



Microscopic Traffic Simulation – single vehicle dynamics

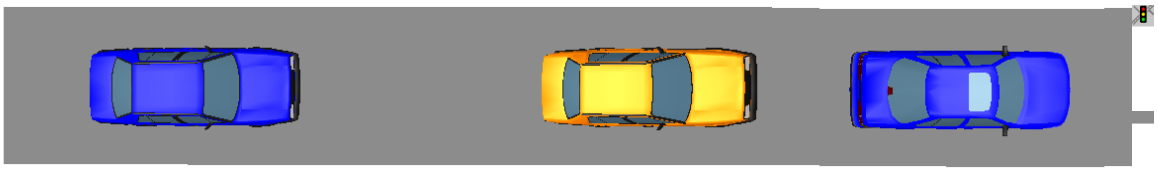
3D Highway Design and Emission Calculation



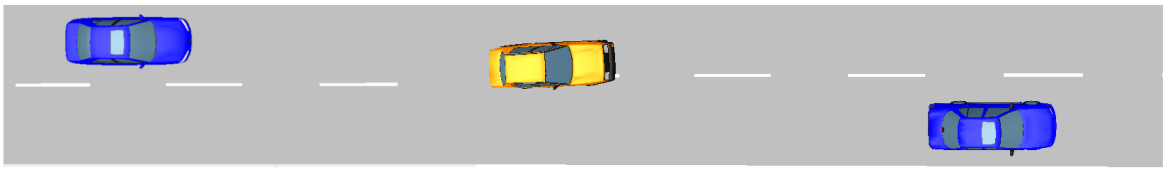
road design szenario	Fuel conspt [g/Fz]	NOx [g/Fz]	particals [g/Fz]	Link length [km]	Travel time [s]	Total height [m]	Max slope %
V1 w/o gradient	110,8	1,458	0,0318	2,2297	**99,7**		
V2 w/o gradient	100,4	1,142	0,0306	**2,1472**	104,3		
V3 w/o gradient	**99,1**	**1,127**	**0,0302**	2,2071	102,9		
V1 with gradient	115,3	1,571	0,0339	2,2301	**100,4**	45	10,8
V2 with gradient	**111,1**	**1,416**	**0,0333**	**2,1473**	104,6	37	10,3
V3 with gradient	112,1	1,429	0,0336	2,2074	103,6	44	11,5

Traffic flow simulation – multiple vehicles

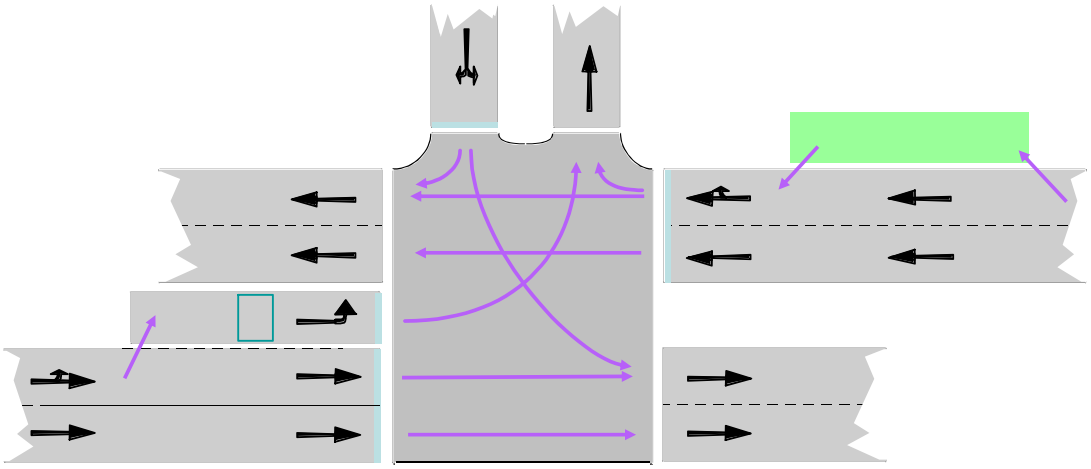
Longitudinal movement → Car following



Lateral movement → Lane Change



Network for 3D traffic flow simulation

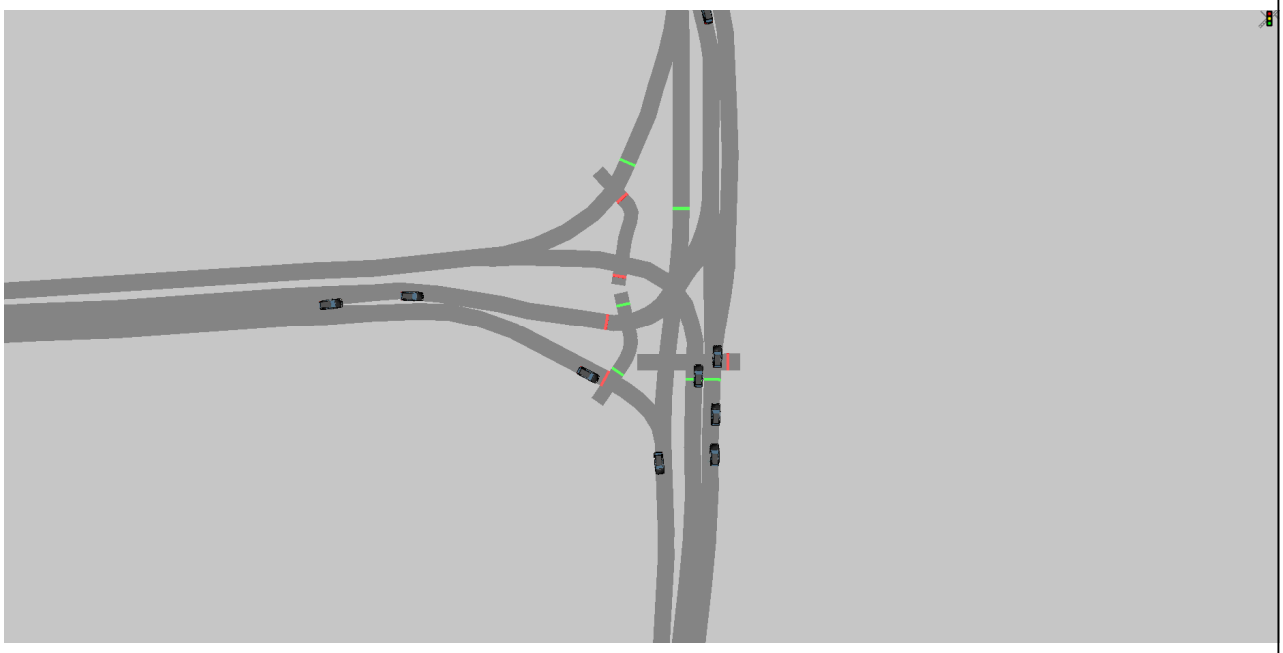


VISSIM link with one or multiple lanes

Connector between lanes of same or different link(s)
Detectors
Stop lines, signal heads
PuT stops

Networks are assembled by different building blocks

Network for 3D traffic flow simulation



Traffic simulation → Virtual Reality

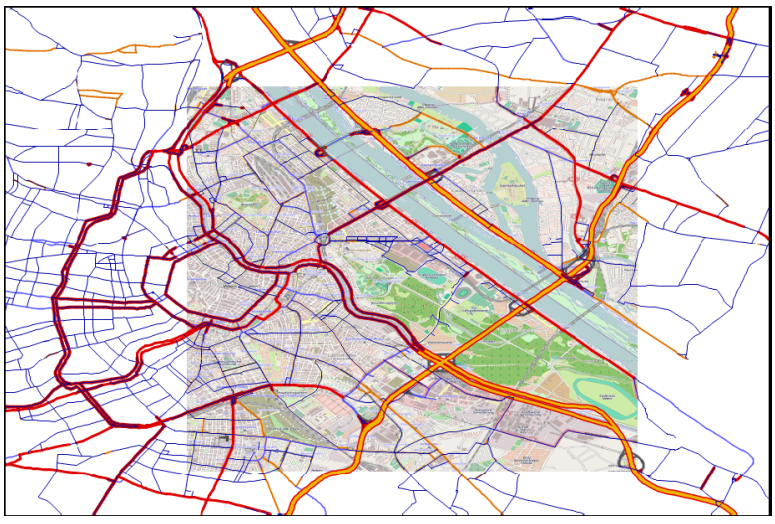
- Static 3D objects (road network, light poles, traffic lights, trees, …)
  → stereo-photography, orthogonal photo
- Import vehicles as dynamic 3D objects
- Rendering to video HD quality

Coming next – energy based in-vehicle navigation

- Objective function: minimize energy consumption from A to B

$$E_{link} = E_{cruise} \times p_{cruise} + E_{acc} \times p_{acc} + E_{dec} \times p_{dec} + E_{idle} \times p_{idle}$$

- Considering **gradient**, vehicle dynamics, street surface, …
- Height required (5 m grid with 10 cm accuracy)



Conclusion

- Transport Planning Models benefited from accurate GIS-data (x,y)
- Road design benefited from CAD plus terrain surveying (x,y,z)
- Both would benefit from accurate x,y,z data
- OSM with height in 1m accuracy (absolute) and 10 cm between neighbouring points
- Solution ?
  Network-based real time kinematic GPS (NPTK) on-route