RAILWAYS

Design of track geometry 1

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HUMAN CAPITAL
HUMAN – BEST INVESTMENT!
Wrocław University of Technology
EUROPEAN SOCIAL FUND
Project co-financed from the EU European Social Fund

Map



Representation of real terrain drawn on a paper taking into account 4 conventions:

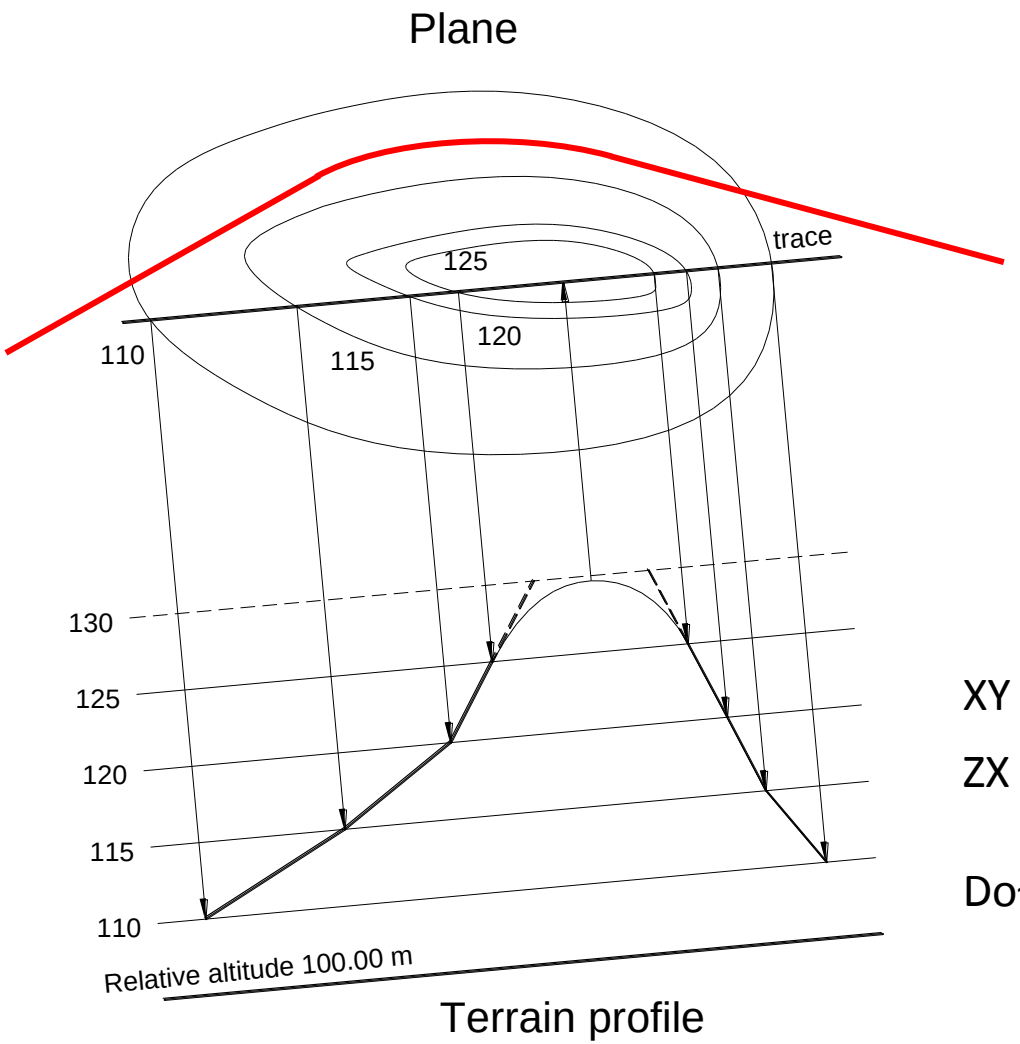
1. Scale
2. Generalization of details



3. Legend (symbols)

4. Altitude representation (contour lines)

How to use contour lines?



Inclination

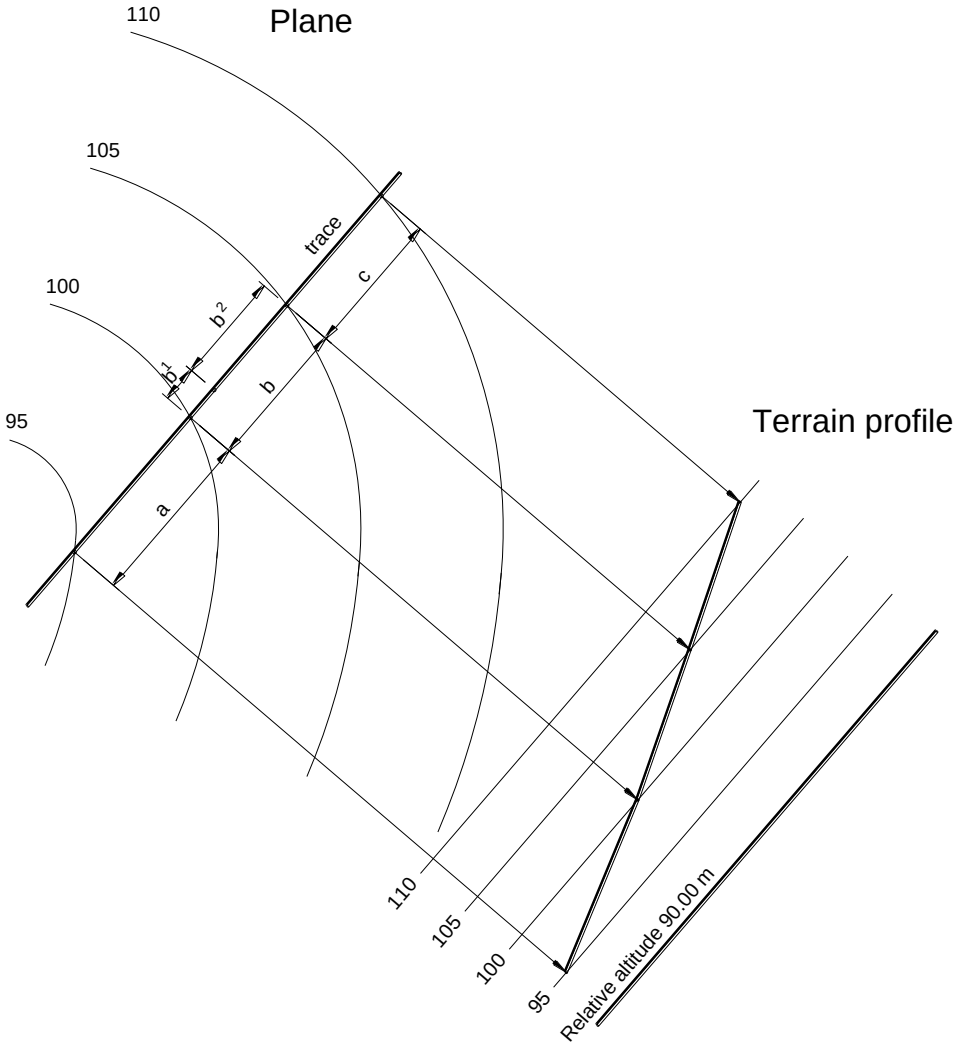
$$i = \frac{\Delta z}{\Delta x}$$

XY plane scale 1:25 000

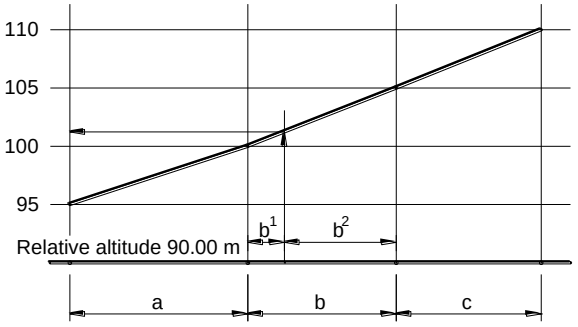
ZX plane scale 1:5 000

Dołożyć animację

How to use contour lines?



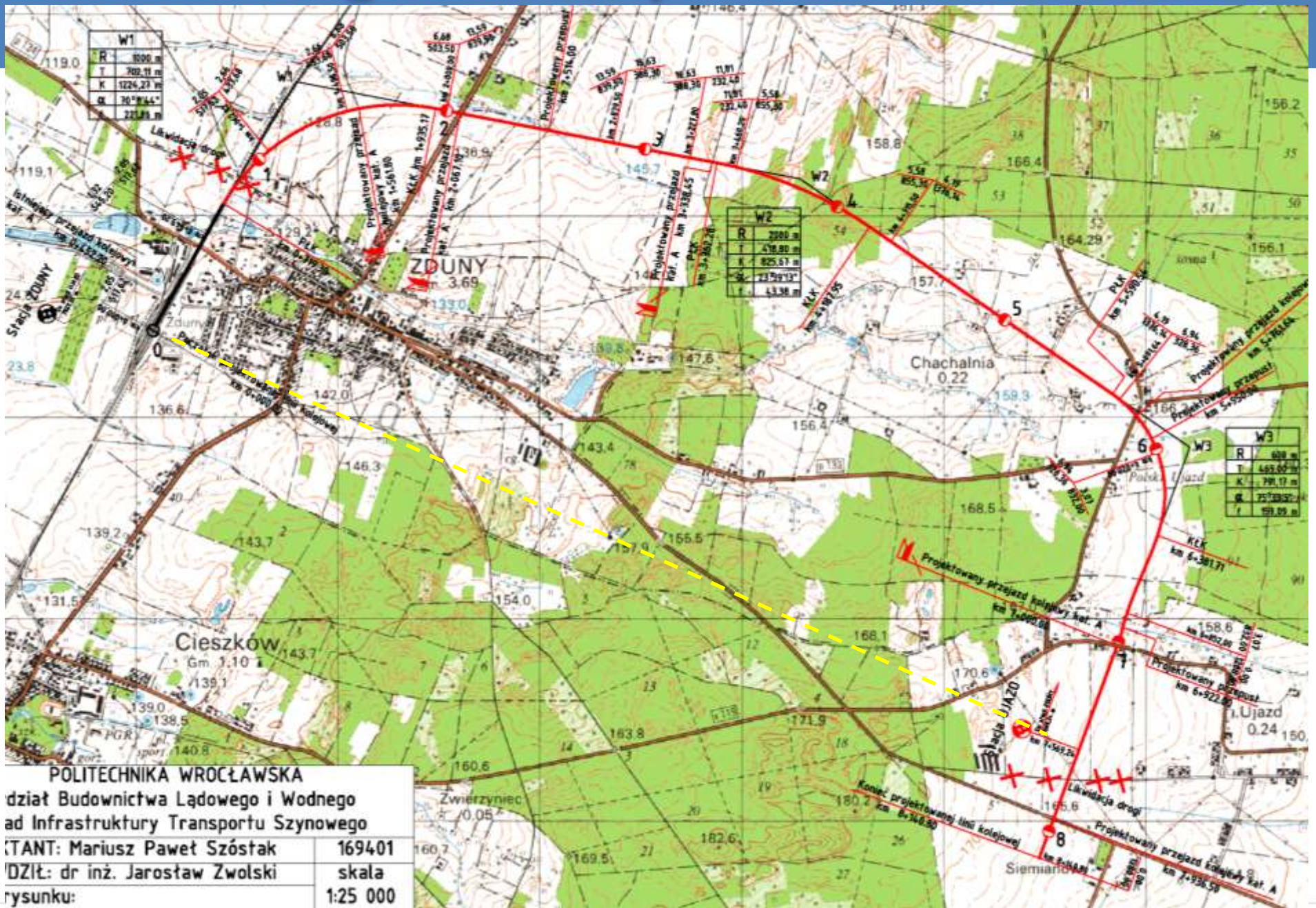
Interpolation rule



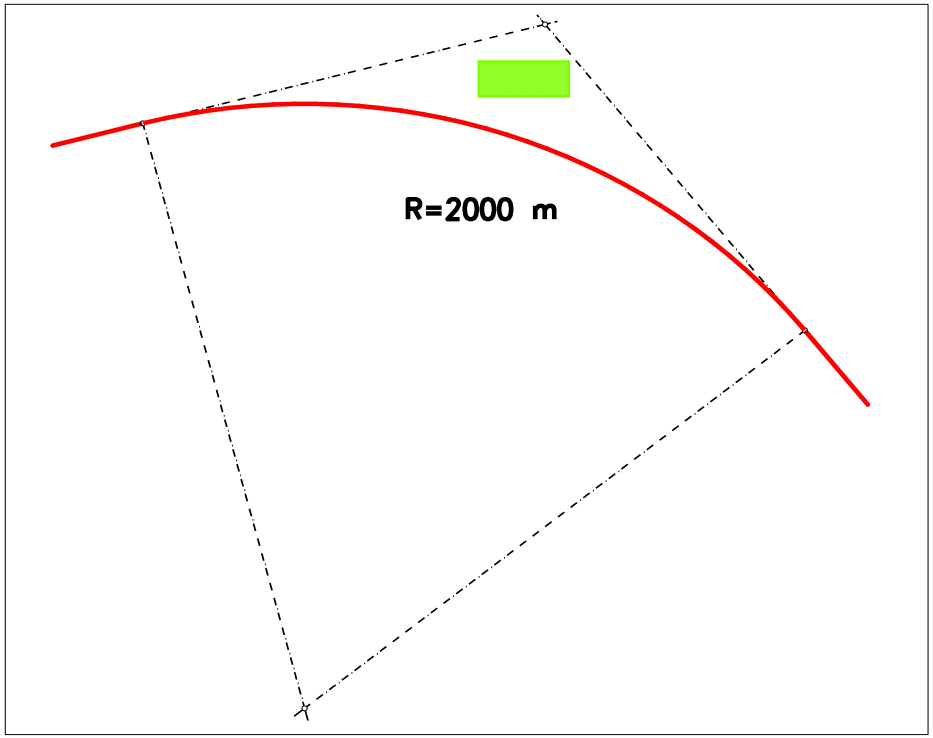
Criteria for the design of the railway route

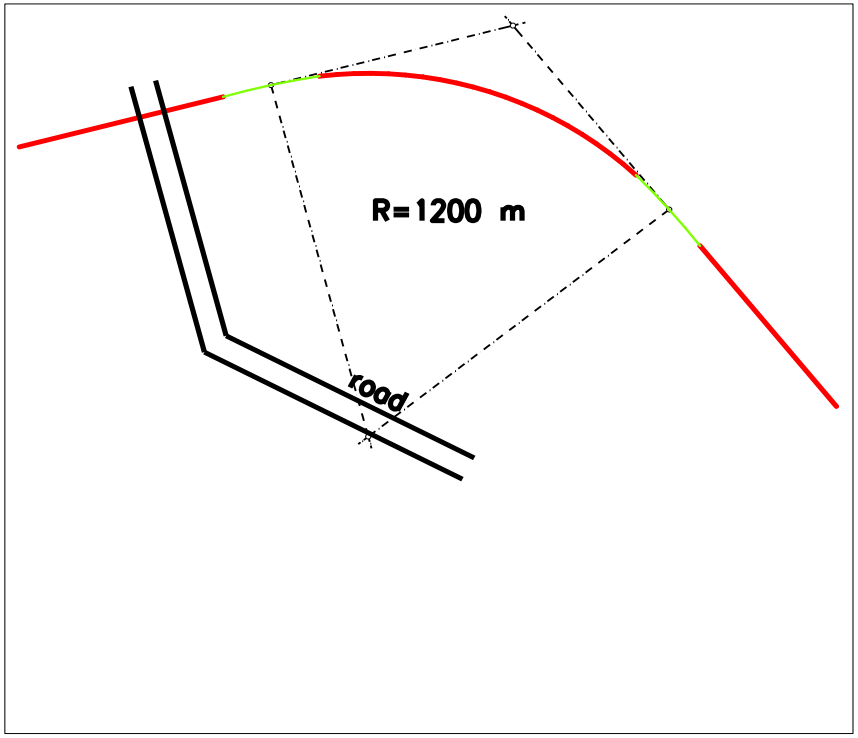
1. The route closest to the direct straight line is the best.
2. If curves are required – the radius should be as long as possible.
3. Intersecting angles between tangents should be as small as possible.
4. Watch the contour lines – the route inclination should be as small as possible.
5. Crossing of roads, other railway lines, rivers, wetlands should be avoided.
6. In case of crossing – right angle (90°±30°) and overhead crossing is preferred.
7. The route should bypass village buildings by at least 200 (300) m.
8. If a station is concerned the section of track provided should be flat (inclination 0%) and straight on the distance 800 – 1500 m (depending on the line category).
9. The track section for a railway stop (for passengers only) should be straight on the distance 400 m (or radius at least 600 m - visibility on platform) and preferably flat.

How to design a railway route?



Basic rules for curves in railways





Classification of railway lines

Depending on the terrain characteristic 4 types of railway lines are distinguished:

1) lowland lines – the steepest slopes reach 5-10 per mill,
2) sub-mountain lines - the steepest slopes reach 10-15 per mill,
3) mountain lines - the steepest slopes reach 15-25 per mill.
(Natural adhesion of the wheel to the rail enables running on the slope of 35 – 38 per mill without slippage),
4) special mountain lines - A rack-and-pinion railway (a railway with a toothed rack rail, usually between the running rails, which ensures traction). The steepest slope of the rack railway is 250 per mill.

The first 3 types are standardized.

Permitted radius of arc

Line category	Minimum radius of arc [m] for line type		
	lowlands line	sub-mountain line	mountain line
0	1400	1200	600
1	1200	600	400
2	600	400	300
3	400	250	200

Source: Dz.U. No. 151 (PL)

Recommended radius:

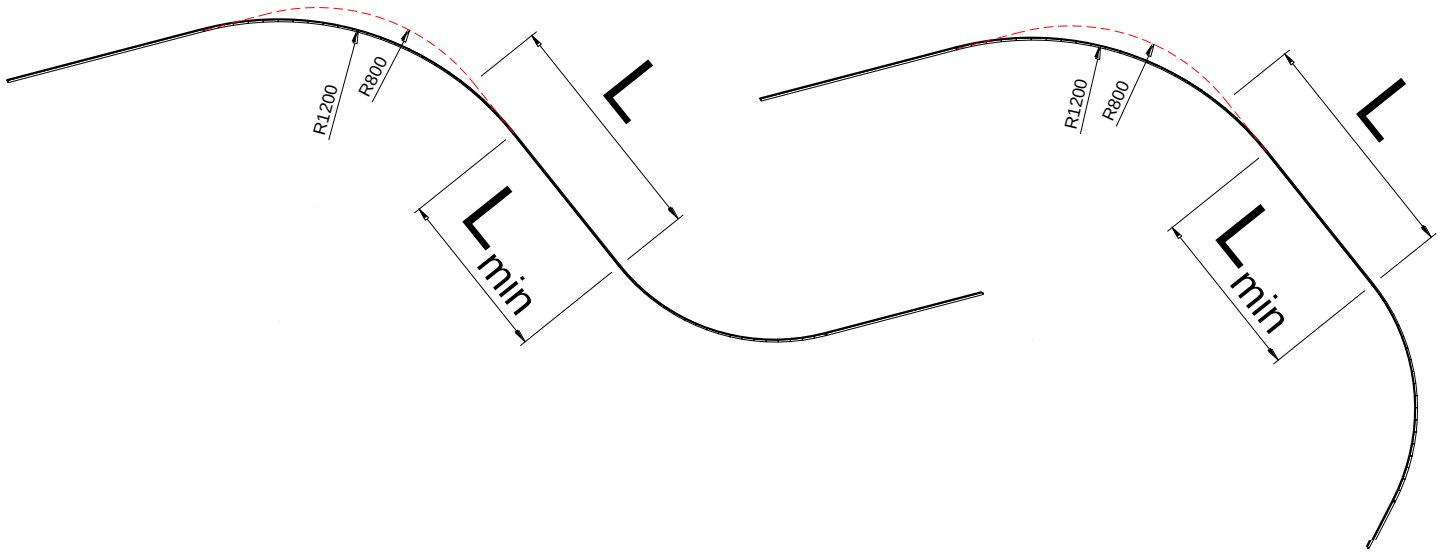
R > 500 m due to possibility of continuous welded track application

R > 1500 m due to rails and wheels wear comparable to straight track section

Length of straight sections

The minimal length of a straight section of the route should be at least equal:

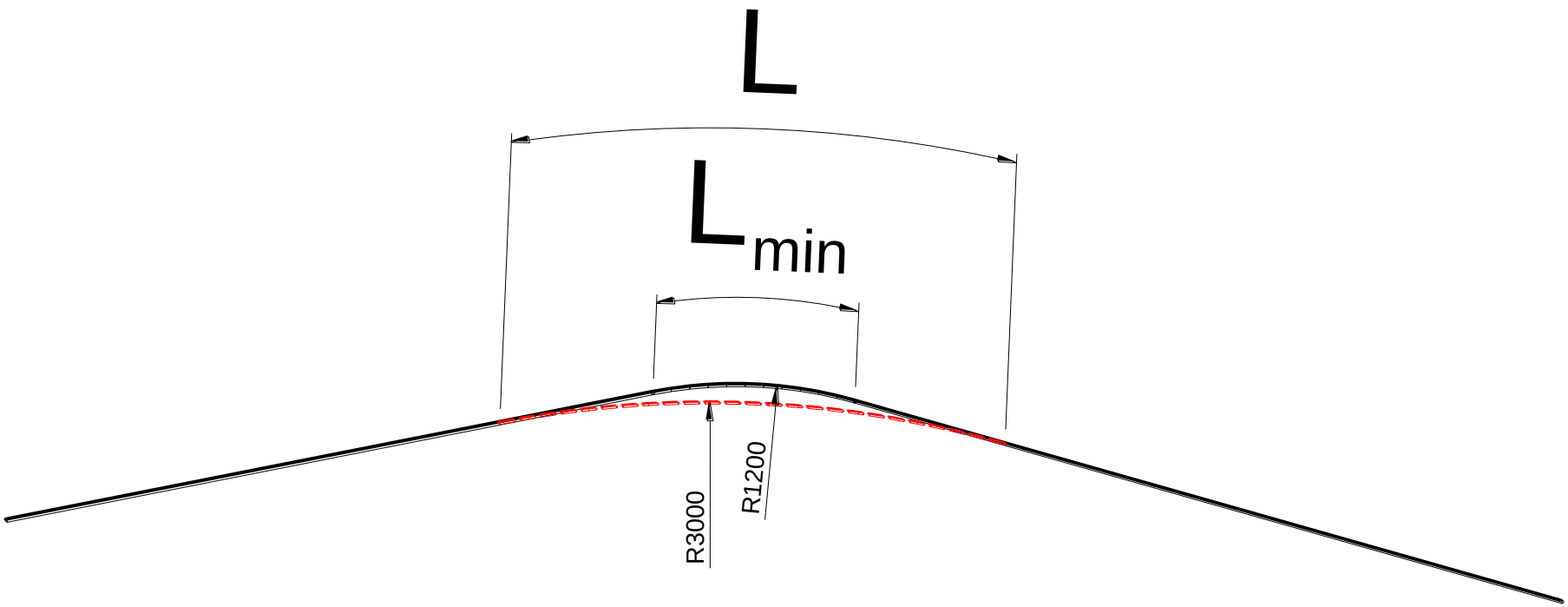
- V_{max}[km/h]/1.8 and more than 30 m for lines of category 0 and 1 (acceptable V_{max} [km/h]/2.5 in case of difficult conditions),
- 30 m for lines of category 2,
- 10 m for lines of category 3.



Length of curved sections

The minimal length of a curved section of the route should be at least equal:

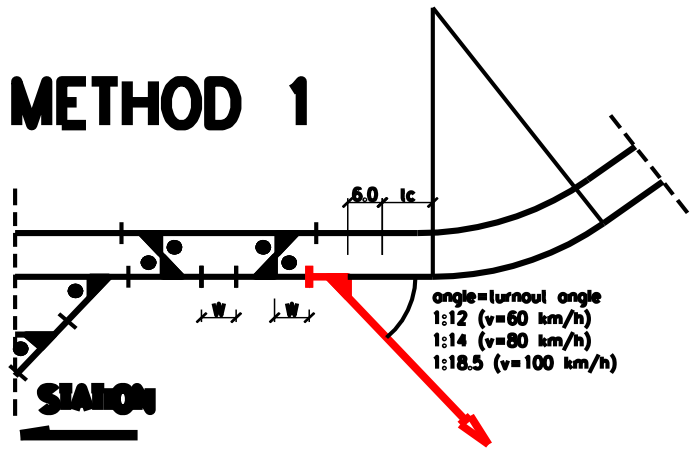
- V_{max}[km/h]/2.5 and more than 30 m for lines of category 0 and 1,
- 30 m for lines of category 2,
- 10 m for lines of category 3.

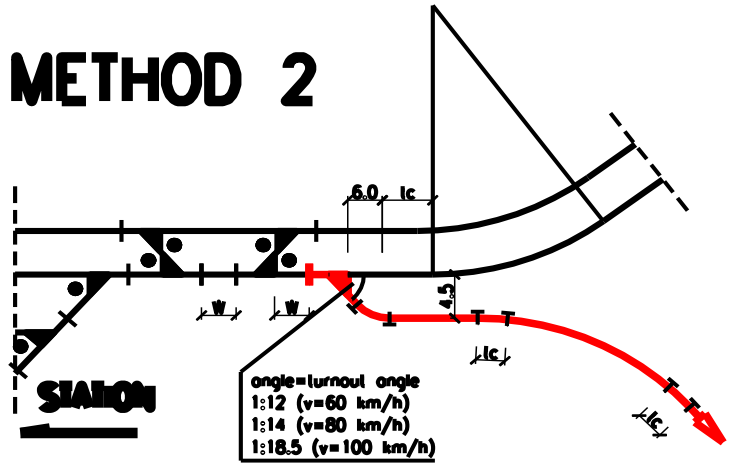


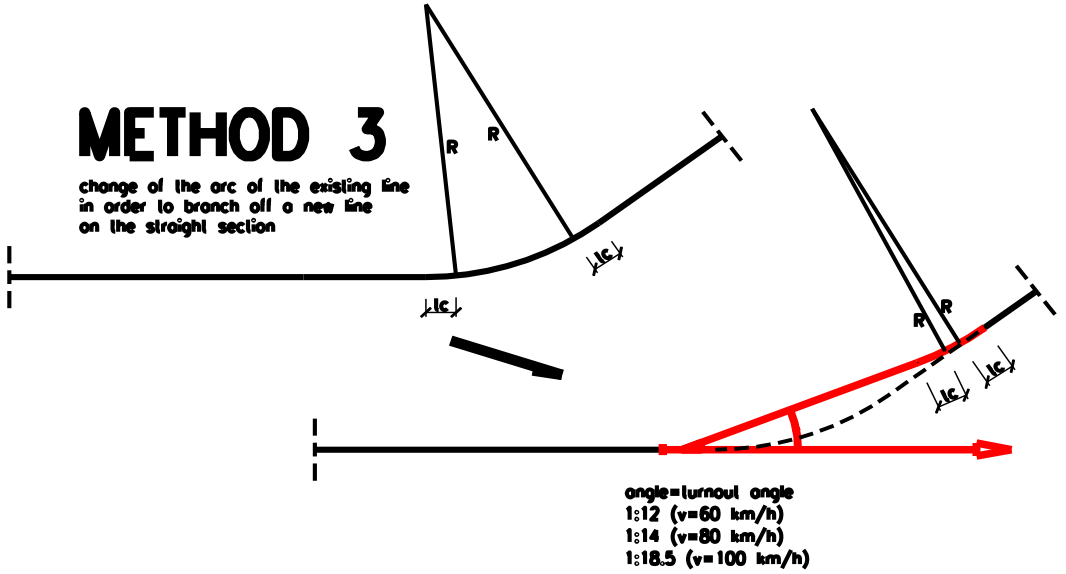
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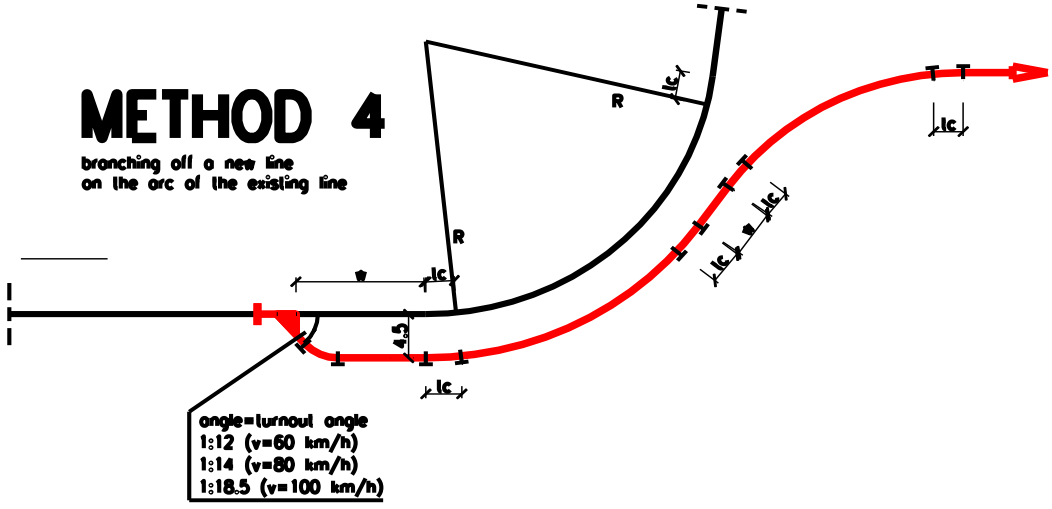
1. The route closest to the direct straight line is the best.
2. If curves are required – the radius should be as long as possible.
3. Intersecting angles between tangents should be as small as possible.
4. Watch the contour lines – the route inclination should be as small as possible.
5. Crossing of roads, other railway lines, rivers, wetlands should be avoided.
6. In case of crossing – right angle (90°±30°) and overhead crossing is preferred.
7. The route should bypass village buildings by at least 200 (300) m.
8. If a station is concerned the section of track provided should be flat (inclination 0%) and straight on the distance 800 – 1500 m (depending on the line category).
9. The track section for a railway stop (for passengers only) should be straight on the distance 400 m (or radius at least 600 m - visibility on platform) and preferably flat.
10. The new trace should diverge from the existing line by means of a turnout.

How to branch off a new line from the existing one?

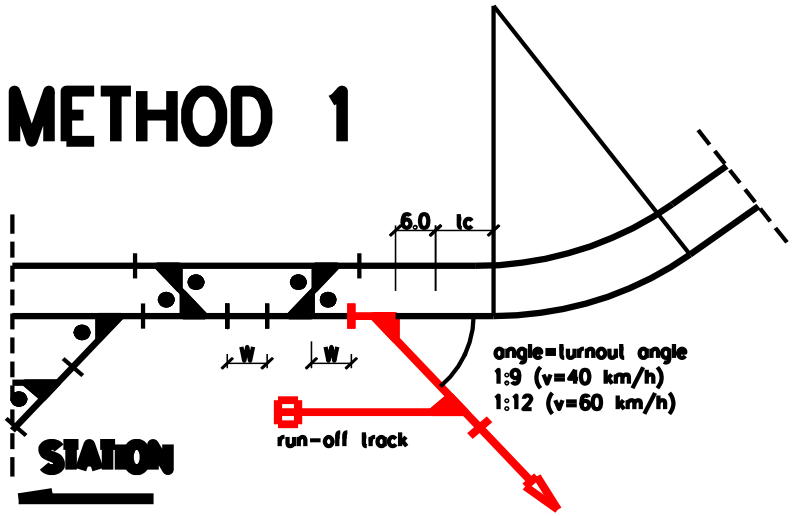


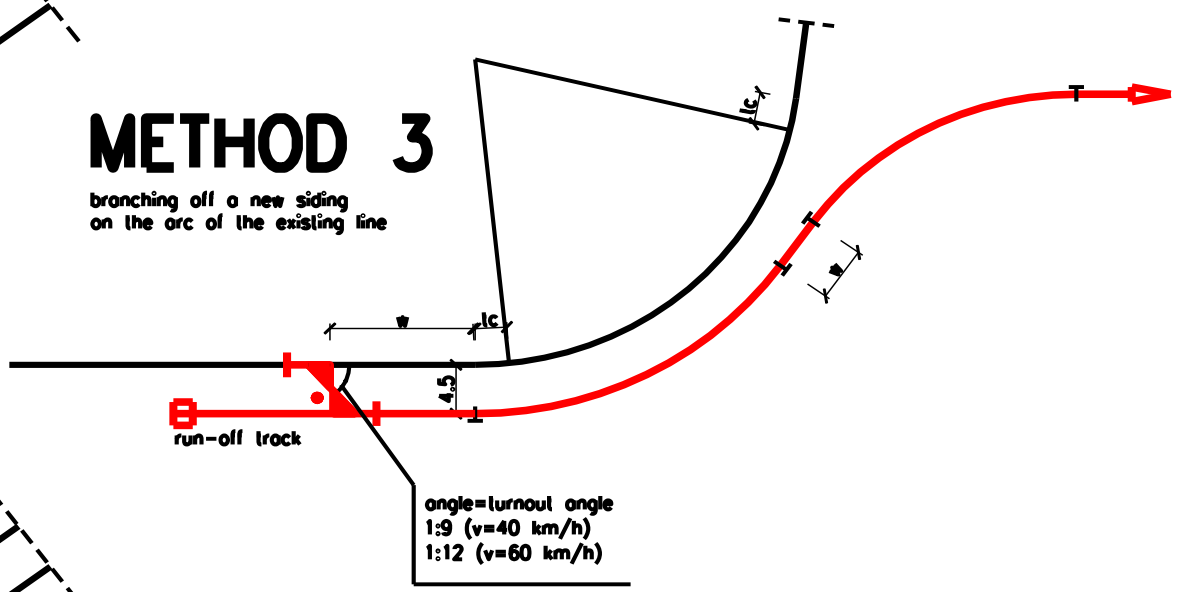


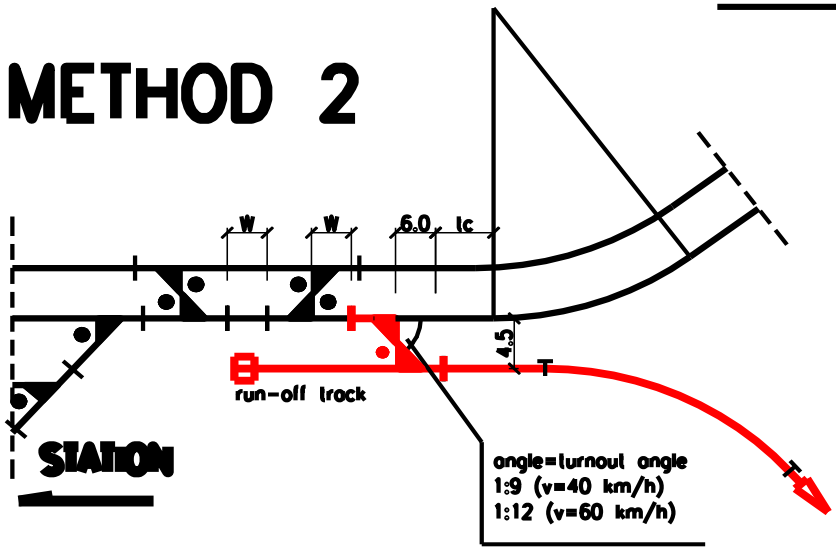




How to branch off a new siding from the existing line or station?



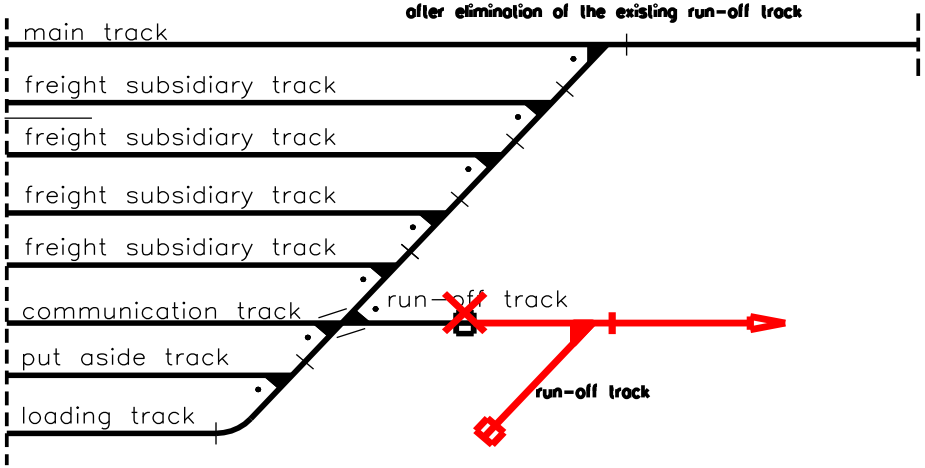




How to branch off a new siding from the existing line or station?

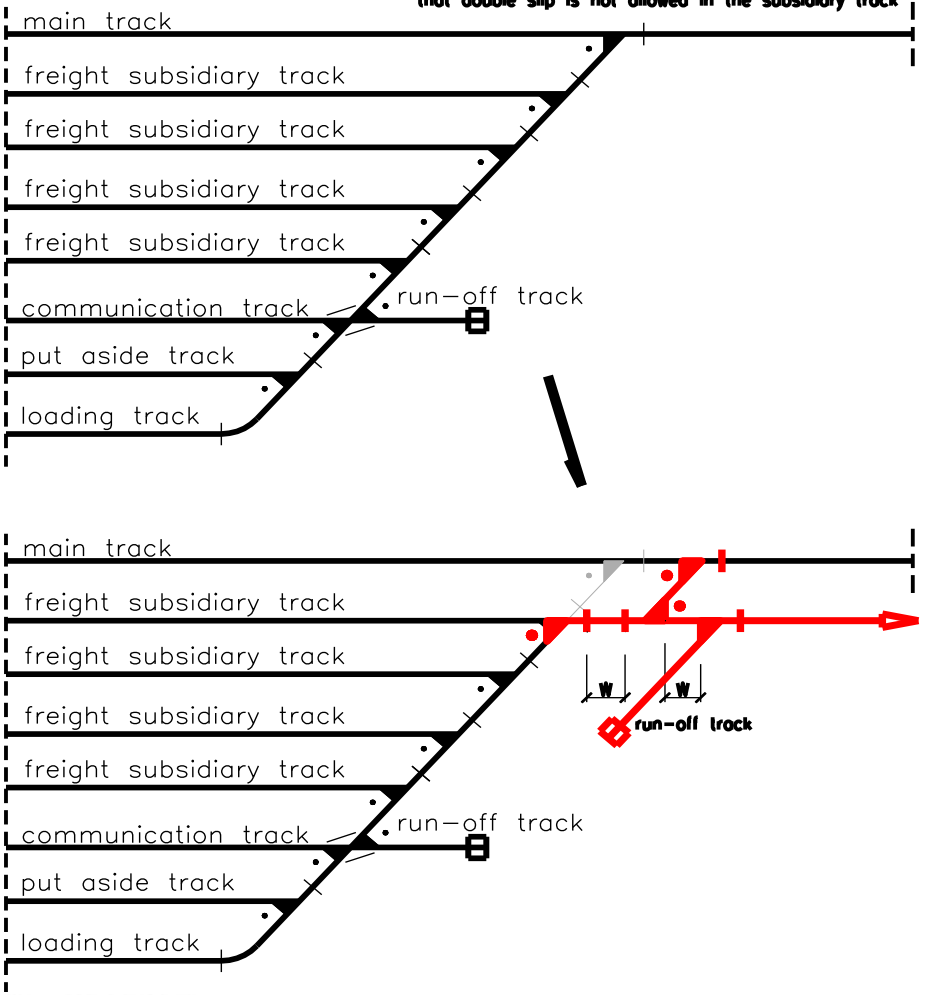
METHOD 4

branching off a new siding
on the extension of the communication track
after elimination of the existing run-off track



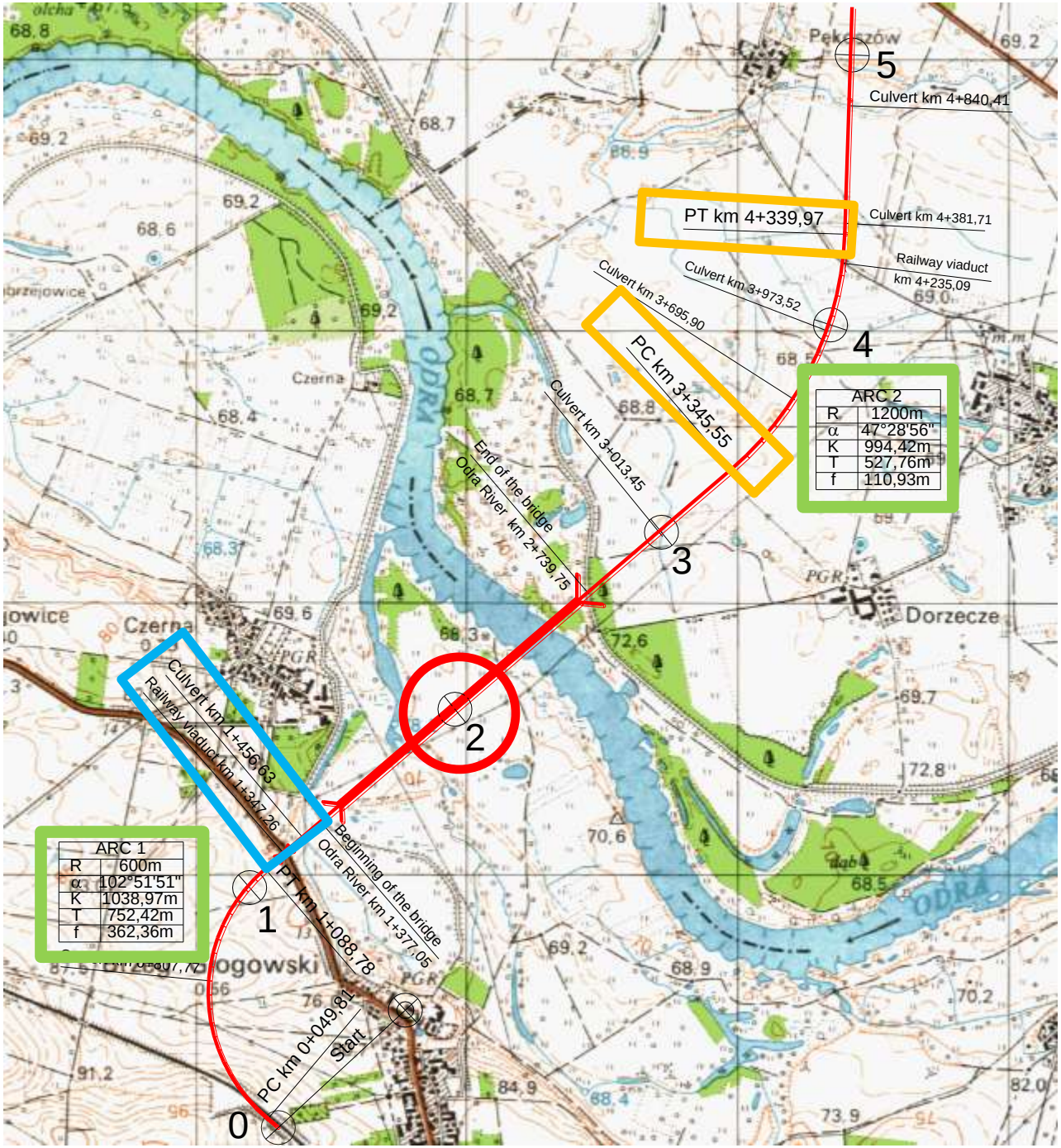
METHOD 5

branching off a new siding
on the extension of the freight subsidiary track assuming
that double slip is not allowed in the subsidiary track



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Example of a route design in plane

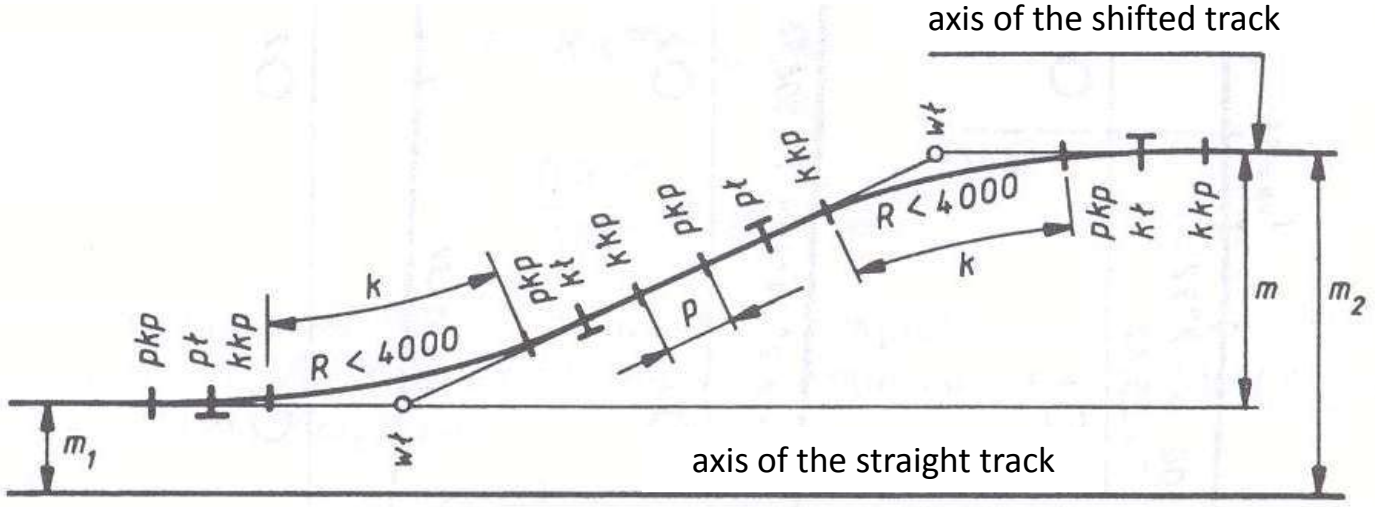


How to change the space between tracks

METHOD 1

<u>Two reverse arcs (R<4000 m) with 4 transition curves</u>

1. The most often R is between 1500 m and 2500 m
2. Tangent section p:
   - for category 0 and 1:
     p_{min} [m] = V_{max} [km/h] / 2.5 and min. 30 m,
   - for category 2 p_{min} = 30 m,
   - for category 3 p_{min} = 10 m,
3. The lenght of the arc: $k_{min} = p_{min}$

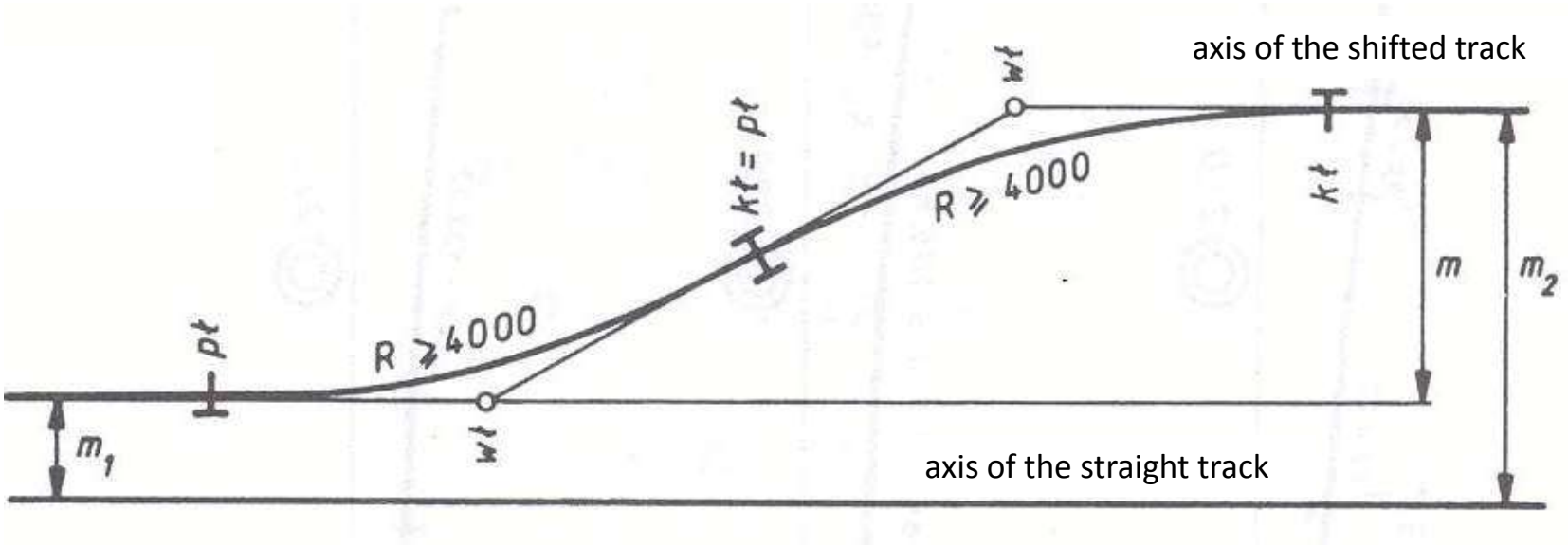


How to change the space between tracks

METHOD 2

<u>Two reverse arcs (R>4000 m) without transition curves</u>

1. The arc have to be tangent one to another
2. There are neither transition curves nor cant and nor superelevation ramp

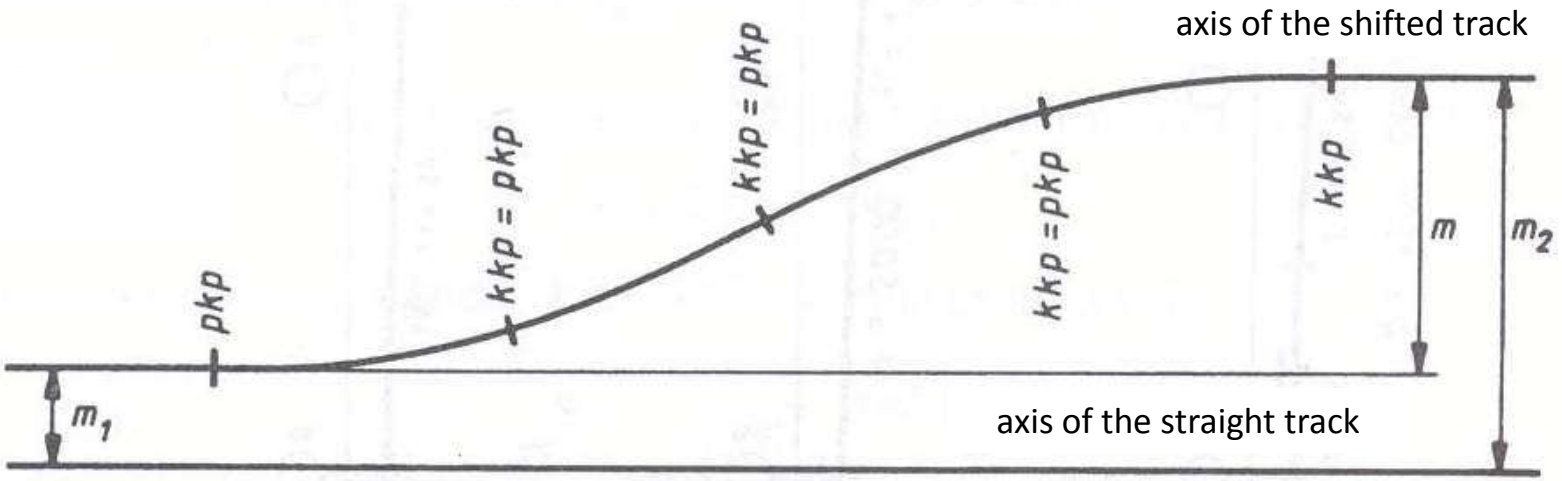


How to change the space between tracks

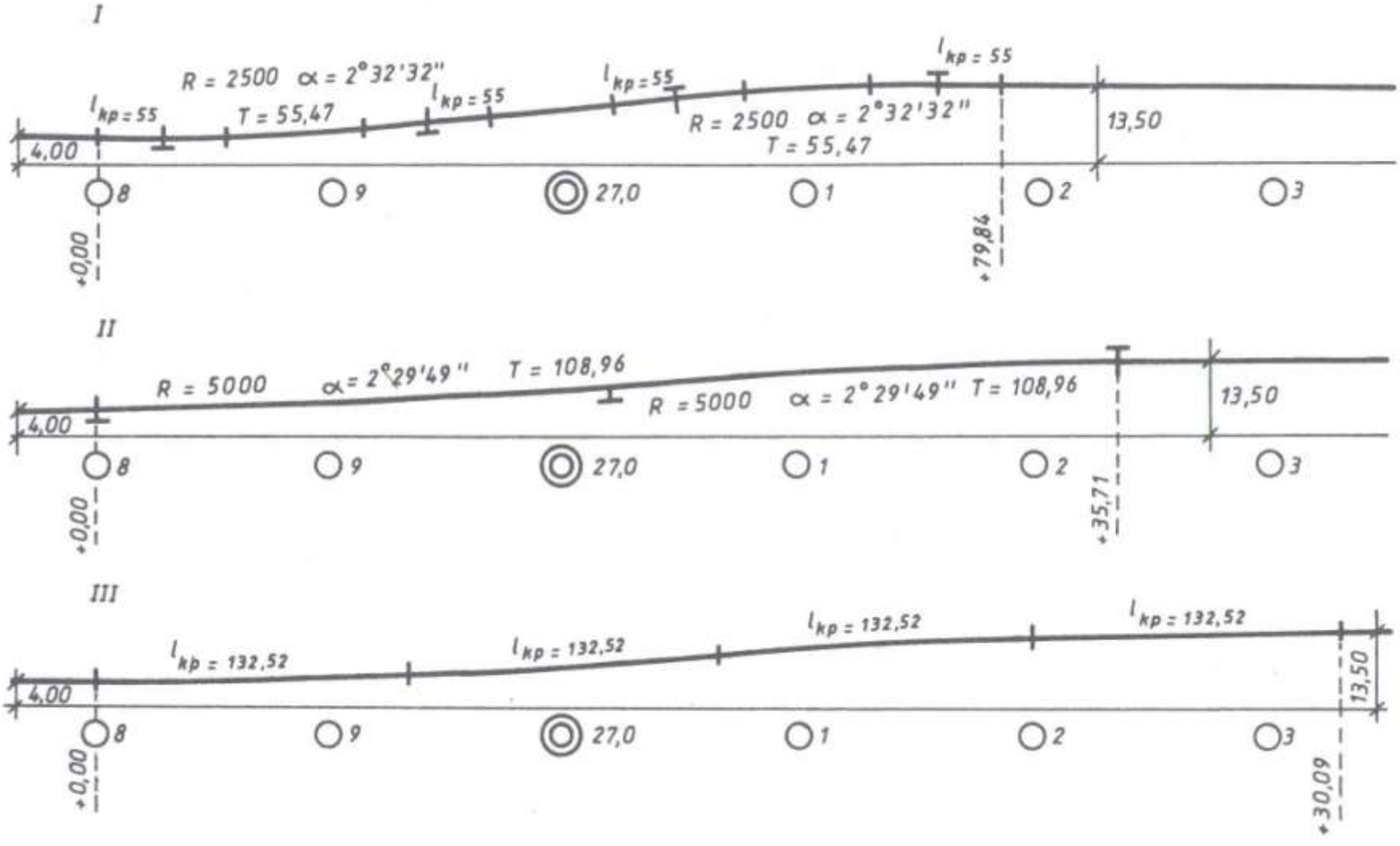
METHOD 3

<u>Four transition curves without circular arcs</u>

1. Such geometry should be checked if the speed of the unbalanced acceleration increase, Ψ is less than 0.3 m/s^3.
2. There are neither transition curves nor cant and nor superelevation ramp



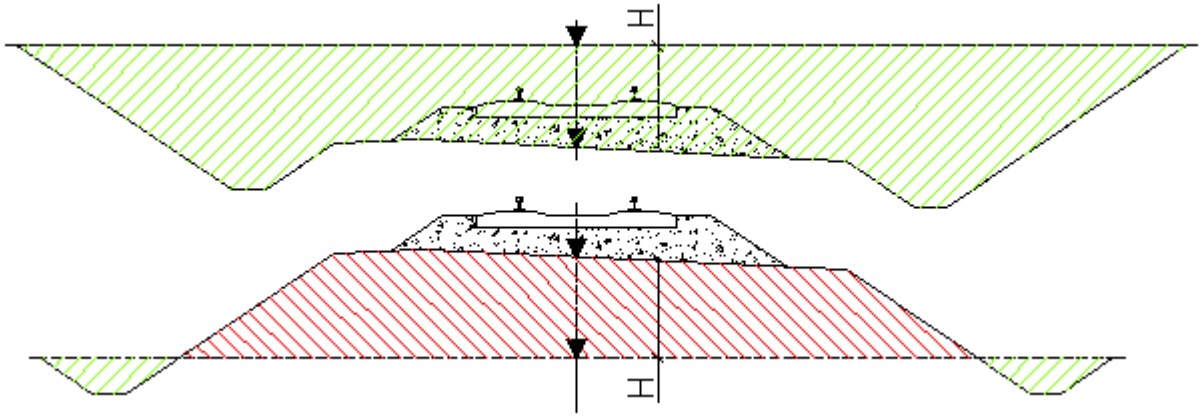
How to change the space between tracks



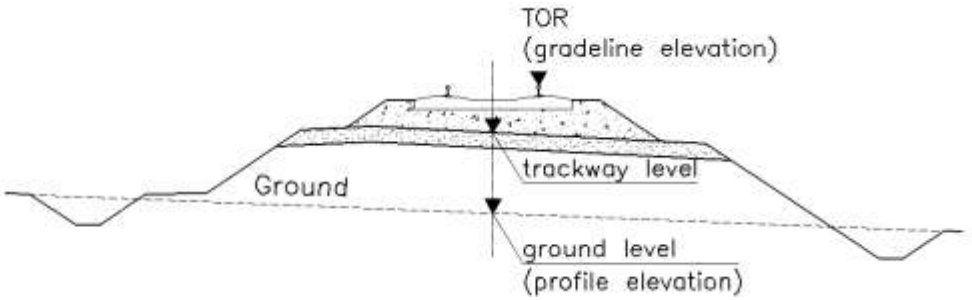
Rules for a design in profile

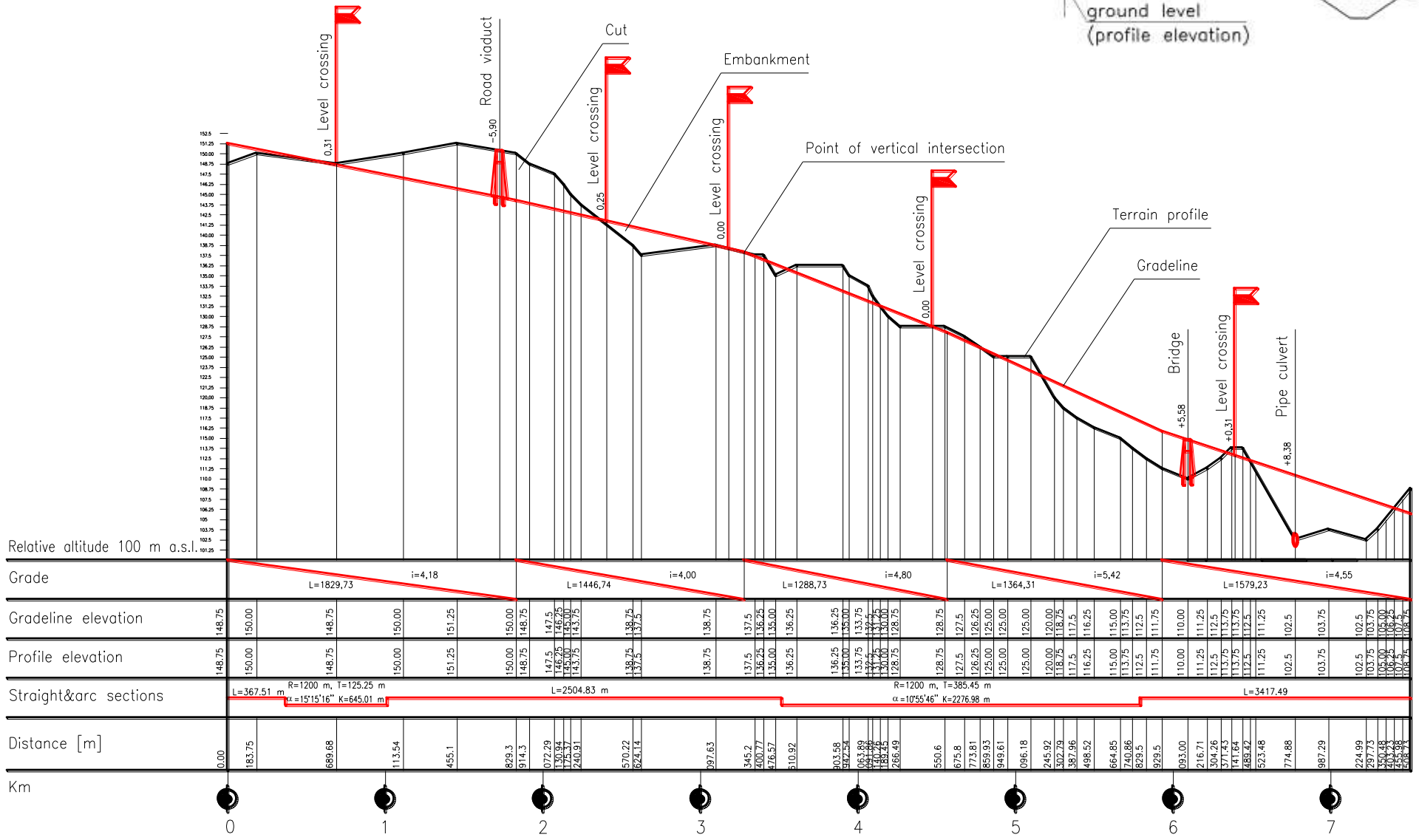
Basic rules:

- The embankment should have at least 0.6 m of height (dewatering).
- Preferably the line should be driven on 0.6 – 1.5 m embankment (dewatering).
- Concave changes of inclination mustn't be located in the cutting (dewatering).
- Inclination in the cutting should be at least 3 per mill (dewatering).
- Tracks in a yard shouldn't be inclined - 0 – 0.5 per mill (free rolling of wagons),
- Changes of inclination shouldn't coincide with engineering objects (add. force).
- Balancing of embankments and cuttings is recommended (economy), however a low embankment (0.6 – 1.5 m) is preferred (winter maintenance).



Example of a profile





Rules for a design in profile

„i”

Rule #1 – maximum longitudinal inclination

$$i_m\ [\text{permil}] = i_o + i_R$$

where:

i_m – the cumulative inclination taking into account 2 sources of the movement resistance: the designed inclination and movement on a curve in plane,

i_o – the designed inclination,

i_R – substitute inclination describing the resistance coming from movement on a curve in plane

$$i_R\ [\text{permil}] = 690/R\ [\text{m}]$$

R – radius of the arc.

The cumulative inclination mustn’t be more than:

- 6 permil for lines of category 0 and 1,
- 10 permil for lines of category 2,
- 20 permil for lines of category 3.

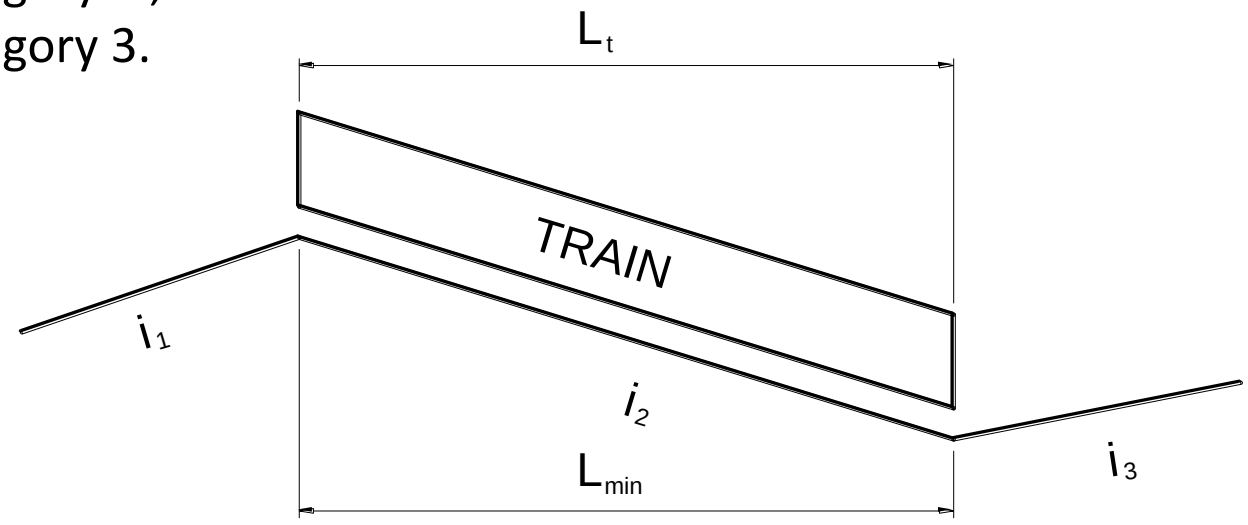
Rules for a design in profile

„l_{min}”

Rule #2 – minimum length of a section with uniform longitudinal inclination

The length of a section with uniform longitudinal inclination mustn’t be less than the length of the longest train passing the track. Authoritative length l_{min} is given for categories of line:

- 400 m for lines of category 0 and 1,
- 300 m for lines of category 2,
- 200 m for lines of category 3.



Rules for a design in profile

„Δi”

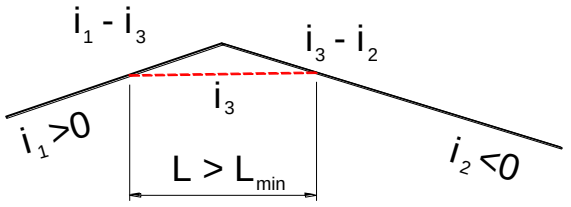
Rule #3 – maximum difference between two consecutive longitudinal inclinations

$$\Delta i = i_1 - i_2 \text{ (with the sign)}$$

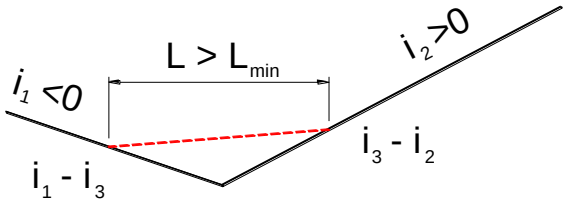
The difference between two consecutive longitudinal inclinations mustn't be more than:

- 5 permil for lines of category 0 and 1,
- 5 permil for lines of category 2,
- 10 permil for lines of category 3.

convex



concave



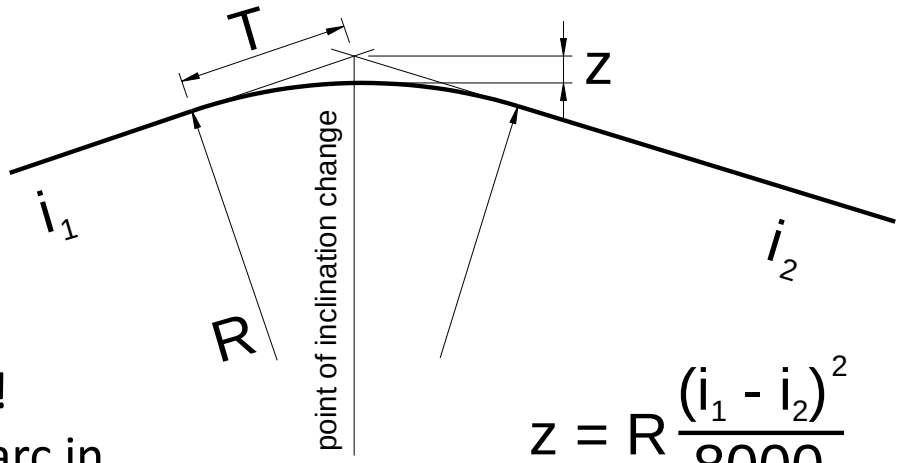
Rules for a design in profile

„R”

Rule #4 – all points of inclination change should be equipped in an arc in vertical plane

The radius of the arc is given for the maximum speed or category of line :

- 20 000 m for lines with speed over 160 km/h (new lines),
- 15 000 m for lines with speed from 141 to 160 km/h (new lines) or over 160 km/h (modernized lines),
- 10 000 m for lines of category 0 and 1,
- 5 000 m for lines of category 2,
- 2 000 m for lines of category 3.



If the external distance z < 8 mm --> no arc!

If the external distance 8 < z < 30 mm --> arc in the ballast layer.

$$z = R\frac{(i_1 - i_2)^2}{8000}$$

$$T = R\frac{(i_1 - i_2)}{2000}$$

Rules for a design in profile

„R_v/R_h”

Rule #5 – location of arc in vertical plane and transition curve in horizontal plane mustn’t interfere.

