Budapest University of Technology and Economics
Department of Highway and Railway Engineering

Railway Tracks BSc
Project guide

Veronika SÁRIK, teacher's assistant
Dr. Nándor LIEGNER, associate professor

2015.
Railway tracks project

1. Assignment statement
The goal of this assignment is to design a railway line and railway station connecting to the line section.

The line consists of one curve with transition curves, a connecting railway station with a number of tracks stated on the project sheet, and loading platforms.

2. Horizontal plan

2.1 Introduction of the base maps
The individual base maps needed for the project are available at the page of the Highway and Railway Department:


The number of the base map is presented on the project sheet, and different for every student. Each of the basemaps consists of 2 parts(a and b), indicated in the bottom right corner of the maps (see Figure1). Both of the maps should be downloaded with the same number but different letter.

Figure 1- Basemaps
The base maps are contour-maps: the lines on the map are contour lines representing the height above sea level. The numbers on the lines indicate the height in metric unit, and the bottom of the numbers is always towards the direction of the decrease of altitude (that is the reason they might be "upside down").

The origin of the coordinate system is in the bottom left corner of the map "a" (see Figure 2). This is going to be the point of reference for the following designing steps.

![Figure 2- Origin of the coordinate system](image2)

### 2.2 Design of the curve with transition curves

*Location of the beginning of the design section*

First of all, the beginning of the design section is needed to be positioned. The \((x;y)\) coordinates of point "P" are given on the project sheet. The first, coordinate \(x\) is 0, meaning the point \(P\) is going to be on the \(y\) axis, the \(y\) coordinate locates its exact position. The distance according to the coordinate \(y\) should be measured onto the axis \(y\). This is going to be the beginning of the designed line. The chainage of this particular point is to be chosen, it has to be an integer chain (see below).

The legends referring to a point of the railway line (beginning/end of design section, beginning/end of transition curve/circular curve etc.) are written on a line perpendicular to the designed railway line and drawn precisely to the referred point. For all of these points the name and the chainage must be indicated (see Figure 3).

![Figure 3- Format and positioning of legends and chainage](image3)
The chainage is the distance measured along the railway line from its beginning point. The integers indicate 100 m, represented by a small circle on the line (the centre of the circle indicates the exact location of the integer section) and a legend with a number under the circle, parallel to the line. In railway design the digits before the + sign indicates integer 100 meters, the first 2 digits after the + sign indicate integer meters, and the 2 digits after the decimal point indicate decimetre and centimetre.

For example: 314+31.21 means 31400+31 metres, 2 decimetres and 1 centimetre.

**Location of intersection point (IP)**

The first tangent of the curve is a straight from the point P to the point of intersection (IP). The angle (α) between the 2 tangents are given on the project sheet.

The second tangent is a straight from the IP and goes on until the end of design section. All of the points of the second tangent have the coordinate y=100, which means the second tangent will appear on the plan as a straight, parallel to the axis x (horizontal), with distance of 10 centimetres in case of scale 1:1000 (see Figure 4).

The exact location of the point of intersection can be defined by the following steps:

1. Location of the point P according to the given coordinates: P(0;y)
2. Drawing of the second tangent 100 m from the x axis (parallel to it)
3. Calculation of the x coordinate of the point of intersection (IP): \[ x = \frac{y-100}{\tan(\alpha)} \]
4. Location of the point of intersection according to the calculated coordinates: IP(x;100)
2.2.1 Transition curve

Calculations of the transition curve

1. Parameter of the clothoid transition curve, \( C \) [m\(^2\)]

The parameter of the clothoid transition curve (\( C \) [m\(^2\)]) depends on the design speed.

<table>
<thead>
<tr>
<th>( V ) [km/h]</th>
<th>( C ) [m(^2)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>16800</td>
</tr>
<tr>
<td>70</td>
<td>27300</td>
</tr>
<tr>
<td>80</td>
<td>40000</td>
</tr>
<tr>
<td>90</td>
<td>57000</td>
</tr>
<tr>
<td>100</td>
<td>78000</td>
</tr>
<tr>
<td>120</td>
<td>135000</td>
</tr>
<tr>
<td>160</td>
<td>320000</td>
</tr>
</tbody>
</table>

Table 1 - Parameter of the clothoid transition curve

2. Length of transition curve, \( L \) [m]

\[
C = R \times L \quad \rightarrow \quad L = \frac{C}{R}
\]

This length refers to one transition curve which means there are going to be 2 transition curves with the length of \( L \) on both sides of the circular curve.

3. Calculation of coordinate \((x;y)\) of detail points of the transition curve

Calculation is needed for the \((x;y)\) coordinate of detail points every 10 m...

\[
x = l - \frac{l^5}{40 \times C^2} + \frac{l^9}{3456 \times C^4}
\]

\[
y = \frac{l^3}{6 \times C} - \frac{l^7}{336 \times C^3} + \frac{l^{11}}{42240 \times C^5}
\]

...and for the calculation of the coordinates \((X;Y)\) of the end point \((l=L)\):

\[
X = L - \frac{L^5}{40 \times C^2} + \frac{L^9}{3456 \times C^4}
\]

\[
Y = \frac{L^3}{6 \times C} - \frac{L^7}{336 \times C^3} + \frac{L^{11}}{42240 \times C^5}
\]

4. Angle of end tangent of transition curve:

\[
\tau_L = \frac{L}{2 \times R} \text{ [rad]}
\]

The equation calculates the angle in the unit of radian.
5. **Shorter end tangent:**

\[ t_s = \frac{Y}{\sin \tau_L} \]

6. **Longer end tangent:**

\[ t_L = X - t_s \cos \tau_L \]

7. **Shift of circular curve:**

\[ f = Y - R \ast (1 - \cos \tau_L) \]

8. **Longitudinal shift:**

\[ x_0 = X - R \ast \sin \tau_L \]

9. **Tangent length:**

\[ T = x_0 + (R + f) \ast \tan \frac{\alpha}{2} \]

**Drawing of the transition curve**

Tangent length (T) should be measured from the point of intersection (IP) onto both of the tangents. The end of the tangent length will define the beginnings of the transition curve (BT) from both sides (see Figure 5).

![Diagram of the transition curve](image)

**Figure 5- Location of the beginnings of the transition curve**

As the beginning of the transition curve (BT) is located, the previously calculated points of the transition curve can be positioned.

![Diagram of points of the transition curve](image)

**Figure 6- Points of the transition curve**
2.2.2 Circular curve

Specifications of the circular curve needed to be written on the drawing (see Figure 7):

- **R**- radius of circular curve \([\text{m}]\) Given on the project sheet
- **V**- design speed \([\text{km/h}]\) Given on the project sheet
- **\(\alpha\)**- central angle of the curve \([\text{in units of degrees}]\) Given on the project sheet
- **L**- length of transition curve Calculated above
- **f**- shift of circular curve Calculated above
- **\(x_0\)**- longitudinal shift of circular curve Calculated above
- **\(\tau_l\)**- angle of end tangent of transition curve Calculated above
- **\(t_t\)**- length of longer end tangent of transition curve Calculated above
- **\(t_s\)**- length of shorter end tangent of transition curve Calculated above
- **\(I_C\)**- total length of curve \(I_C = I_R + 2L\)
- **\(I_R\)**- length of circular curve \(I_R = R(\alpha - 2\tau) \times \frac{2\pi}{360^\circ}\)
- **SK**- distance between intersection point (IP) and king point (K) \(SK = IP - K = R \times \left(\frac{1}{\cos \tau} - 1\right)\)
- **T**- length of tangent Calculated above
- **m**- superelevation \(m = \frac{11,8V^2}{R} - 153 \times a_0\) \(\left( a_0 = 0,65 \frac{m}{s^2} \right)\)

The legends should be positioned in the centre of the curve, perpendicular to the imaginary line between the intersection point and the centre of the circle (the red line on the drawing above is only for explanatory reasons NOT TO BE drawn it on the horizontal section).
2.3 One-alpha gathering tracks

The next part of the project to be drawn is the railway station, its connecting tracks, platforms and facilities. The railway station consists of 3 different track types: a through track, side tracks and a shunting track.

- The through track is the straight continuation of the open line, it has been already drawn in the previous parts of the project.
- The side tracks are parallel to the through track. Track connection needs to be provided within the railway station.
- The shunting track will provide connection to the loading platforms.

The track connection in the railway station is to be drawn. The type of the track connection is one-alpha gathering tracks, meaning that the angle of the main line and the diverging route equals to the central deflection angle of the turnouts.

2.3.1 Drawing of the track connection

- The first turnout needs to be set on the main line according to the coordinates given on the project sheet. This is going to result in having the beginning point of the turnout, which type is 60-XI-1:9 (60 kg/m rail, XI type of turnout, 1:9 deflection angle).
- The sizes of this type of turnout are to be measured and drawn on the design, such as deflection angle, b and b' sizes (see Figure 8 and Table 2). Note: the b' size of the turnout is filled in solid colour in case the turnout is remote controlled, and dashed in case it is switched manually on site.
Table 2 - Data of centre line diagrams of turnouts used by MÁV

<table>
<thead>
<tr>
<th>Type of the turnout</th>
<th>size &quot;a&quot; [m]</th>
<th>size &quot;b&quot; [m]</th>
<th>size b' [m]</th>
<th>deflection angle [°]</th>
<th>deflection</th>
<th>radius R [m]</th>
<th>V_{speed} [km/h]</th>
<th>V_{max} [km/h]</th>
</tr>
</thead>
<tbody>
<tr>
<td>48 XI-1:9</td>
<td>16,616</td>
<td>17,525</td>
<td>16,139</td>
<td>6° 20' 25&quot;</td>
<td>1:9</td>
<td>300</td>
<td>120</td>
<td>40</td>
</tr>
<tr>
<td>54 XI-1:9 &amp; 60 XI-1:9</td>
<td>16,616</td>
<td>17,525</td>
<td>15,927</td>
<td>6° 20' 25&quot;</td>
<td>1:9</td>
<td>300</td>
<td>160</td>
<td>40</td>
</tr>
<tr>
<td>54 XI-1:8,758 &amp; 60 XI-1:8,758</td>
<td>17,072</td>
<td>16,669*</td>
<td>15,927</td>
<td>6° 20' 25&quot;</td>
<td>18,758</td>
<td>300</td>
<td>160</td>
<td>40</td>
</tr>
<tr>
<td>48 XIII-1:9</td>
<td>10,625</td>
<td>17,525</td>
<td>16,369</td>
<td>6° 20' 25&quot;</td>
<td>1:9</td>
<td>192</td>
<td>100</td>
<td>40</td>
</tr>
<tr>
<td>54 XIII-1:9</td>
<td>10,625</td>
<td>17,525</td>
<td>16,027</td>
<td>6° 20' 25&quot;</td>
<td>1:9</td>
<td>200</td>
<td>100</td>
<td>40</td>
</tr>
<tr>
<td>60 XIII-1:9</td>
<td>10,625</td>
<td>17,525</td>
<td>16,369</td>
<td>6° 20' 25&quot;</td>
<td>1:9</td>
<td>200</td>
<td>100</td>
<td>40</td>
</tr>
<tr>
<td>48 XIV-1:9 &amp; 54 XIV-1:9</td>
<td>—</td>
<td>17,525</td>
<td>16,369</td>
<td>6° 20' 25&quot;</td>
<td>1:9</td>
<td>200</td>
<td>100</td>
<td>40</td>
</tr>
<tr>
<td>60 XIV-1:9</td>
<td>—</td>
<td>17,525</td>
<td>16,369</td>
<td>6° 20' 25&quot;</td>
<td>1:9</td>
<td>190</td>
<td>100</td>
<td>40</td>
</tr>
<tr>
<td>48 XVI-1:7,1</td>
<td>14,075</td>
<td>14,074</td>
<td>11,900</td>
<td>8° 03' 04&quot;</td>
<td>1:7,1</td>
<td>200</td>
<td>80</td>
<td>40</td>
</tr>
<tr>
<td>54 XVI-1:7,1</td>
<td>14,075</td>
<td>14,074</td>
<td>12,489</td>
<td>8° 03' 04&quot;</td>
<td>1:7,1</td>
<td>200</td>
<td>80</td>
<td>40</td>
</tr>
<tr>
<td>48 XVII-1:5,7</td>
<td>13,123</td>
<td>13,123</td>
<td>9,900</td>
<td>10° 00' 00&quot;</td>
<td>1:5,7</td>
<td>150</td>
<td>80</td>
<td>30</td>
</tr>
<tr>
<td>54 XVII-1:5,7</td>
<td>13,123</td>
<td>13,123</td>
<td>10,375</td>
<td>10° 00' 00&quot;</td>
<td>1:5,7</td>
<td>150</td>
<td>80</td>
<td>30</td>
</tr>
<tr>
<td>48 XVIII-1:4,7 &amp; 54 XVIII-1:4,7</td>
<td>10,510</td>
<td>10,510</td>
<td>8,100</td>
<td>12° 00' 00&quot;</td>
<td>1:4,7</td>
<td>100</td>
<td>40</td>
<td>25</td>
</tr>
<tr>
<td>54 800-1:14,3</td>
<td>27,936</td>
<td>27,936</td>
<td>27,936</td>
<td>4° 00' 00&quot;</td>
<td>1:14,3</td>
<td>800</td>
<td>160</td>
<td>80</td>
</tr>
<tr>
<td>60 800-1:14,3</td>
<td>27,936</td>
<td>27,936</td>
<td>26,321</td>
<td>4° 00' 00&quot;</td>
<td>1:14,3</td>
<td>800</td>
<td>160</td>
<td>80</td>
</tr>
<tr>
<td>60 800-1:15,44</td>
<td>25,880</td>
<td>29,902</td>
<td>29,992</td>
<td>3° 42' 21&quot;</td>
<td>1:15,44</td>
<td>800</td>
<td>160</td>
<td>80</td>
</tr>
<tr>
<td>60 1800-1:22,22</td>
<td>38,219</td>
<td>40,481</td>
<td>40,481</td>
<td>2° 34' 26&quot;</td>
<td>1:22,22</td>
<td>1800</td>
<td>160</td>
<td>120</td>
</tr>
<tr>
<td>54 1800-1:27,4</td>
<td>30,684</td>
<td>48,116</td>
<td>48,116</td>
<td>2° 05' 27&quot;</td>
<td>1:27,4</td>
<td>1800</td>
<td>160</td>
<td>120</td>
</tr>
<tr>
<td>60 1800-1:27,4</td>
<td>30,684</td>
<td>48,116</td>
<td>48,116</td>
<td>2° 05' 27&quot;</td>
<td>1:27,4</td>
<td>2200</td>
<td>160</td>
<td>100</td>
</tr>
</tbody>
</table>

- The diverging route is to be drawn according to deflection angle of the first turnout.

- The side tracks are to be set. They are numbered from the lowest track upwards, their total number is given on the project sheet. The through track (continuation of the main line) is going to be track no. II. The distance between the tracks (measured in the centre line of the track) is 5 metres, except for the tracks where passenger platforms are placed between them. The distance between these 2 tracks (track no. II. and III.) is set on the project sheet. The platforms are arranged according to the purpose of the tracks. The first 3 tracks (I., II., III.) are for passenger transport, the rest of the tracks are for freight transport.

- Lengthening the side tracks is needed until they cross the straight of the diverging route, providing intersection points of the track of the stations and the diverging route.

- The turnouts are going to be fit so their main point coincides with the IP of the track of the station and the diverging routes. The type of these turnouts is 54-XI-1:9 (54 kg/m type of rail, XI type of turnout, 1:9 deflection angle). As the table of turnouts shows the deflection angle is the same as the first turnout, this assures the tracks are going to be parallel to each other. The other sizes (b, b') are to be drawn and switching properties are to be indicated.

- The last track of the station is to be connected with a R= 300 m circular curve, no transition curve is required.

- The first track is to be drawn. The beginning point of the turnout of this track is going to be coincides with the b' size of the first turnout. The type of the turnout of the first track is 54-XI-1:9 as in the other tracks of the railway station. Its sizes are to be drawn. The straight given by the deflection angle and the b' size needs to be continued until crossing the straight of the first
track. A R=300 m circular curve is to be drawn here, no transition curve is required (see Figure 9).

"Figure 9- One alpha gathering tracks"

**Legends and symbol of the turnout**

The legends of the turnout consists of 2 main parts: the number of the turnout and the system of the turnout.

The number of the turnout indicated its position in the railway station. The even numbered turnouts are placed at the same side of the station, in increasing order of the chainage, the odd numbered turnouts are on the other side of the station, in reverse order of chainage: the lowest even number (2) indicates the first turnout of the railway station, the lowest odd number (1) indicates the last turnout of the railway station.

The legend of the system of the turnout consists of the type of the rail, the type of the turnout and its deflection.

The filled size of the circle in the symbol of the turnout represents the direction in which the turnout might divert the train from the straight direction (see Figure 10).

"Figure 10- Legend of the system of the turnout"
2.3.2. The shunting track

- The shunting track is parallel to the main line, distance between them is 6,50 m. The track connection is provided by a 54:XIII-1:9 turnout, the distance between the main line and the connecting section of the shunting track is 5 m. The transition between the 2 sections of the shunting track is provided by two, R=500 m, reverse circular curves (see Figure 11).

\[ \Delta = 6.50 - 5.00 = 2 \times R \times (1 - \cos \beta) \]
\[ l = R - R \times \cos \beta = R \times (1 - \cos \beta) \]
\[ H = 2 \times R \times \sin \beta \]

The length of the lead track is 170 m after the first turnout (connection to loading platform "A").
2.3.3. Connection to the loading platforms

The loading platforms are connected by the tracks diverging from the shunting track. The track to the first loading platform should end at the point annotated by the letter "A". The track to the second loading platform should go through the point annotated by the letter "C".

Connection to the loading platform at point "A"

- The connection between the shunting track and the track to point A" is provided by a 54-XIII-1:9 type of turnout. The angle (γ) of the straight from point "A" to the shunting track is up to your choice. The diverging route of the turnout and the straight from point "A" is to be linked with a R=200 m circular curve, no transition curve is required. Geometrical parameters can be calculated according to the following method:

\[
T = R \times \tan \frac{\gamma - \alpha}{2}
\]

\[
\overline{AS} = b + f + T
\]

\[
\frac{AM}{\overline{AS}} = \frac{\sin(\gamma - \alpha)}{\sin \gamma} \rightarrow \overline{AM} = \frac{\sin(\gamma - \alpha)}{\sin \alpha} \times \overline{AS}
\]
Connection to the loading platform at point "C"

The loading track to the second loading platform is parallel to the main line and the shunting track and should go through point "C". The distance between the shunting track and the loading track is annotated by the letter "p".

The length of the straight section between the two circular curves (annotated by the letter "S") must be between 20 and 25 metres.

Figure 13- Connection to point "C"
Projection method

The geometrical data needed to design the connection to platform "C" can be obtained by projection method. The principle of the method: taking the sum with the size of the length of the subdivisions of any curved route equals to zero. ($\sum l_i = 0$)

The direction of movement is to be chosen. The one indicated on the illustration above (Figure 15) is an arbitrary solution, the direction of movement can be either upwards or downwards.

As it can be easily noticed on the illustration, the projections of the subdivisions to the projection line results in ending at the same point on the projection line as the projection started from. This means that the sum of the projected lengths equals to zero.
Projection method in use of connection to platform "C"

Projection equation:

\[(b + \mathbf{f}) \sin \alpha + R \cdot (\cos \alpha - \cos \beta) + S \cdot \sin \beta + R \cdot (1 - \cos \beta) - p = \emptyset\]

After having the equation solved, angle "\(\beta\) (° ‘ ‘") can be obtained.

Figure 16- Projection method in use of connection to point "C"
Solving the equation:

As the unknown parameter is present in different functions, rearrangement of the equation is needed (the known parameters on the left, the unknown parameters on the right side):

\[(b + f) \sin \alpha + R_1 \cos \alpha + R_2 - p = R_1 \cos \beta + R_2 \cos \beta - S \sin \beta\]

The known parameters are going to be indicated by the letter "A":

\[A = (b + f) \sin \alpha + R_1 \cos \alpha + R_2 - p\]

Dividing both sides of the equations by \(S\):

\[\frac{A}{S} = \frac{R_1 + R_2}{S} \cos \beta - \sin \beta\]

\[\tan \varphi = \frac{R_1 + R_2}{S} \rightarrow \]

\[\varphi \ can \ be \ calculated\]

\[\tan \varphi = \frac{\sin \varphi}{\cos \varphi}\]

\[\frac{A}{S} = \frac{\sin \varphi}{\cos \varphi} \cos \beta - \sin \beta\]

Multiplying with \(\cos \varphi\):

\[\frac{A}{S} \cos \varphi = \sin \varphi \cos \beta - \sin \beta \cos \varphi\]

Trigonometrical rule:

\[\sin \varphi \cos \beta - \sin \beta \cos \varphi = \sin(\varphi - \beta)\]

\[\frac{A}{S} \cos \varphi = \sin(\varphi - \beta) \rightarrow\]

\[\varphi - \beta \ can \ be \ calculated\]

\[\beta = \varphi - (\varphi - \beta)\]
Distance annotated by the letter "H" can be obtained with a second projection equation to a second projection line, perpendicular to the first one (see Figure 18).

**Figure 18- Projection method in use of obtaining "H"

Projection equation:

\[(b + f) \cdot \cos \alpha + R \cdot (\sin \beta - \sin \alpha) + S \cdot \cos \beta + R \cdot (\sin \beta) - H = 0\]

After obtaining the missing angle and distance, the connection to platform "B" is to be drawn.
2.3.4. Platforms and joined facilities

4 platforms (2 passenger platforms and 2 loading platforms) are to be indicated on the horizontal layout, but as the long section is made on the through track only the one next to it is to be indicated on the long section.

Passenger platforms

- Passenger platforms are located next to track no. I., and between tracks no. II. and III.
- The chainage and legend of the beginning of the passenger platforms are to be indicated.
- The distance between the centre line of the track and the edge of the platform is 1,55 m.
- The width of the platform next to track no. I. is 4,90 m, the one’s between track no. II. and III. is wider (due to greater number of users, as this platform serves 2 tracks responsible for passenger traffic), the value of its width comes from the distance between the tracks, given on the project sheet subtracted by twice the distance between the centreline of the track and the platform.
- The length of the platforms (e.g. 250 m) should be written on the platforms (but indication of the total length is not required), also their height above rail top level (550 mm) needs to be indicated.
- Passenger subway is to be drawn between the passenger platforms, also the axis, the chainage and the subtitle of the axis of the passenger subway is to be indicated (see Figure19)

Figure 19- Layout of passenger platforms and joining facilities
Loading platforms

- Distance between the centreline of the track and the edge of the loading platforms is 1,50 m.
- The width of loading platform at point "A" is 10,00 m, the length is 40,00 m (see Figure 20).

![Figure 20- Layout of loading platform at point "A" and joining facilities](image)

- The width of loading platform at point "C" is 6,00 m, its length is to be chosen, but there must be at least 20 m long straight section of the track after the curve before the beginning of the loading platform.
- The width of the service roads to the loading platforms is 6,00 m, the width of the loading area (next to the loading platforms) is 20,00 m.
- Border of the design area is to be indicated (see Figure 21).

![Figure 21- Layout of loading platform at point "C" and joining facilities](image)
3. Long section

The long section is the line of intersection made by the centre line of the railway track and the vertical plane (Figure 22).

3.1 Format of the long section

1. Scale of the long section

The scales of the long section in this assignment are:

- horizontal scale: 1:1000
- vertical scale: 1:100

\[ \text{Scale}_h = 1:1000 \]
\[ \text{Scale}_v = 1:100 \]

2. Superstructure

The superstructure can consist of any type of rails, sleepers, fastening systems of your choice but compatibility issues should be taken into consideration.

Superstructure:
- 54 E1 Rails
- Sleeper spacing k=60 cm
- LM type of sleepers
- Rail fastening of Vossloh Skl -14
- Ballast bed with depth of 0.53 m
- Protecting subgrade with depth of 0.30 m
3. **Levels:**

- **Railtop level:** the *level* of the top of the rail *above sea level*, the highest point of the superstructure.

- **Top level of earthwork:** *level* of top of earthwork *above sea level*; the difference between this value and the value of rail top level depends on the height of the chosen rail profile, type of sleeper and the depth of ballast bed.

- **Cut:** If the top level of earthwork is below the level of original ground, cut is the *difference* between these two levels.

- **Fill:** in case the top level of earthwork is above the level of original ground, fill is the *difference* between these two levels.

- **Level of original ground:** the *level* of original ground *above sea level* in the centreline of the track (see Figure 23).

![Figure 23 - Levels to be indicated on the long section](image)

4. **Chainage**

Chainage is the distance measured along the railway line. The integers should be represented by a small circle and legend written horizontally, the other chains should be presented for every 25 metres and written vertically (see Figure 24).

![Figure 24 - Indication of chainage on the long section](image)
5. **Curvature**

Curvature is the diagram that represents the horizontal geometry of the railway line on the long section. It consists of 3 "zones": left curve, straight and right curve. On the diagram horizontal section is drawn in every case when the radius of curve is constant (R=const.). This can mean it is a straight section (R=∞) or a circular curve (0<R<∞). The length of these horizontal sections on the diagram also indicates the length of the straight/circular curve sections. The circular curves are positions above/below the straight zone of the diagram according to whether they are right or left curves — left and right curves are determined if the vehicle moves in increasing order of chainage.

The connecting slanting sections indicate the transition curves. The main data and parameters should be written on the diagram as shown on the sample long section (see Figure 25).

![Curvature diagram](image)

6. **Beginning and end of design section**

The Beginning/End of design section legend must be indicated at the beginning/end of the long section with their exact chain and altitude above sea level. All legends must be vertical as shown on the sample long section.

![Beginning and end of the designed section](image)

7. **Gradient**

The gradient indicates vertical geometry data of the railway track. Uphill means an increasing inclination, downhill means a decreasing inclination. The unit of gradient in railway engineering is perthousand [%]. The maximum value of the gradient is 1,5% at railway stations.

If the gradient is changed, the total length of the section with the same gradient must be written as shown in the sample long section. This length of the section with the same gradient should be an integer in metric units.

![Indication of the gradient on the long section](image)
When there is change in the gradient the following data should be indicated (see Figure 28):

- the chainage of the point of the change of the gradient
- its altitude above sea level

If the change of gradient ($\Delta e$-difference between the gradient of the former section and the gradient of the following section) is greater than 2‰, a vertical rounding curve must be designed, if $\Delta e<2‰$ application of vertical rounding curve is not necessary.

Parameters of the vertical rounding curve

- Radius ($R$)
  - $R=0,004 V^3$, if $V>100$ km/h
  - $R=0,4 V^2$, if $V\leq100$ km/h
  - rounding slightly upwards
- Tangent length ($T$)
  - $T = R * \frac{\Delta e}{2000}$
- Deflection of the curve ($y$)
  - $y = \frac{T^2}{2R}$

Point of change of gradient may not be designed at transition curve sections, at turnout sections, on road crossings and on bridges made of steel.

Points of change of gradient must be indicated on the horizontal plan, at their exact position too, with the uphill/downhill relation, the gradient, the length of the section of the same gradient, the chain and the height above sea level. The slanting lines indicate the inclination of the written gradient (line of uphill 9,0 ‰ is elevating, line of uphill 0,0‰ is horizontal) (see Figure 29).

![Figure 28- Indication of the change in the gradient and the vertical rounding curve](image-url)

![Figure 29- Indication of the point of change of gradient on the horizontal plan](image-url)
3.2 Drawing of the long section

After the "frame" of the long section is drawn, the following steps are to be done:

- A base level (integer in metric unit) needs to be stated in regard of the fact that all the points of your line must be drawn on the long section but the legend of the levels and the cut/fill relations must fit under the long section lines. This level is going to be the level of reference for the whole long section.

  Note: as the sample long section shows, there are strict criteria of form of the legends and their spacing so the base level should be stated according to the given sizes. This means at least 8 cm space under the lowest point of the original ground level needs to be left empty (see Figure 30).

![Figure 30- Stating of the base level and positioning of the legends of the levels](image)

- Indication of the original ground level on the long section should done with the help of the designed line and the contour lines. The altitude above sea level between the contour lines every 25 m section should be estimated and the point on the long section should be drawn. Additional contour lines can be drawn at halfway of the existing contour lines to help the estimation (see Figure 31).

![Figure 31- Drawing of assitional contour lines](image)

- After having altitude for every 25 metre points, linking them with a continuous line (preferably not straight but curve) is to be done.
3.3 Designing the vertical tracing of the railway line

- The first point of the rail top level should be approximately 1-2 metres above the original ground level.
- The vertical tracing should follow the original ground level as much as possible (in order to build the least earthwork), but with reasonable amount of change of gradient. Obviously the 2 levels to be set against each other are the level of original ground and the level of earthwork. Theoretically the amount of cuts and fills should be approximately equal but in practise the biggest amount of exploited soil in cuts is not suitable to be used in fills, so this is not a strict criterion.
- The gradient of the section is to be calculated: 
  \[ e(\%) = 1000 \times \frac{\Delta m}{\Delta h} \]
  (\(\Delta m\) - vertical difference (altitude) between 2 points, \(\Delta h\) - horizontal difference (distance) between 2 points)
- The altitude (above sea level) of points in every 25 metres to be calculated according to the gradient of the section and written on the long section.
- When the railtop level is set on the long section, the level of earthwork is to be calculated according to the sizes of the elements chosen in the superstructure and to be drawn.
- When the surface of the original ground changes in a way that change of gradient is reasonable, the design of a vertical rounding curve should be taken into consideration, if it is needed, calculation of its parameters should done as explained above and indicated on the long section and on the horizontal plan as well (the change of gradient must be represented on the horizontal plan regardless the existence of the vertical rounding curve). The vertical rounding is indicated on the railtop level.
- The curvature diagram should be drawn and needs to be taken into consideration when the points of the change of the gradient are stated (they cannot be in transition curve sections). Legends are also to be added on the diagram.
- Every object placed on the railway line (turnouts, railway stations, passenger platforms, bridges, culverts etc.) should appear on the long section too, at their exact position with their name, chainage, and official symbol.
List of Figures and Tables

Figure 1- Basemaps ...................................................................................................................................... 2
Figure 2- Origin of the coordinate system .................................................................................................. 3
Figure 3- Format and positioning of legends and chainage ....................................................................... 3
Figure 4- Definition of the intersection point ............................................................................................. 4
Figure 5- Location of the beginnings of the transition curve ....................................................................... 6
Figure 6- Points of the transition curve ...................................................................................................... 6
Figure 7- Specifications of the circular curve ............................................................................................... 7
Figure 8- Centre line diagram of the turnout and indication of its general data ............................................. 8
Figure 9- One alpha gathering tracks ....................................................................................................... 10
Figure 10- Legend of the system of the turnout ......................................................................................... 10
Figure 11- Layout of the shunting track .................................................................................................... 11
Figure 12- Connection to point "A" ........................................................................................................... 12
Figure 13- Connection to point "C" ........................................................................................................... 13
Figure 15- Explanation of the projection method ......................................................................................... 14
Figure 16- Projection method in use of connection to point "C" ................................................................. 15
Figure 17- Indications of the parameters used during calculating $\beta$ ..................................................... 16
Figure 18- Projection method in use of obtaining "H" .................................................................................. 17
Figure 19- Layout of passenger platforms and joining facilities .............................................................. 18
Figure 20- Layout of loading platform at point "A" and joining facilities ................................................... 19
Figure 21- Layout of loading platform at point "C" and joining facilities .................................................... 19
Figure 22- Sample long section ................................................................................................................ 20
Figure 23- Levels to be indicated on the long section ................................................................................. 21
Figure 24- Indication of chainage on the long section ............................................................................... 21
Figure 25- Curvature diagram .................................................................................................................. 22
Figure 26- Beginning and end of the designed section ............................................................................... 22
Figure 27- Indication of the gradient on the long section .......................................................................... 22
Figure 29- Indication of the point of change of gradient on the horizontal plan ....................................... 23
Figure 28- Indication of the change in the gradient and the vertical rounding curve ................................ 23
Figure 31- Drawing of assitional contour lines ......................................................................................... 24
Figure 30- Stating of the base level and positioning of the legends of the levels ....................................... 24

Table 1- Parameter of the clothoid transition curve ................................................................................... 5
Table 2- Data of centre line diaframs of turnouts used by MÁV ............................................................... 9
# Table of contents

1. Assignment statement ........................................................................................................ 2
2. Horizontal plan .................................................................................................................. 2
   2.1 Introduction of the base maps .......................................................................................... 2
   2.2 Design of the curve with transition curves .................................................................. 3
       Location of the beginning of the design section ........................................................... 3
       Location of intersection point (IP) ................................................................................ 4
   2.2.1 Transition curve ....................................................................................................... 5
       Calculations of the transition curve ............................................................................... 5
       Drawing of the transition curve ................................................................................... 6
   2.2.2 Circular curve ......................................................................................................... 7
2.3 One-alpha gathering tracks ............................................................................................ 8
   2.3.1 Drawing of the track connection .............................................................................. 8
   2.3.2 The shunting track .................................................................................................. 11
   2.3.3 Connection to the loading platforms ....................................................................... 12
       Connection to the loading platform at point "A" ......................................................... 12
       Connection to the loading platform at point "C" ....................................................... 13
       Projection method ...................................................................................................... 14
       Projection method in use of connection to platform "C" ........................................... 15
   2.3.4 Platforms and joined facilities ................................................................................ 18
       Passenger platforms .................................................................................................. 18
       Loading platforms .................................................................................................... 19
3. Long section ..................................................................................................................... 20
   3.1 Format of the long section ........................................................................................... 20
   3.2 Drawing of the long section ......................................................................................... 24
   3.3 Designing the vertical tracing of the railway line ......................................................... 25
List of Figures and Tables ..................................................................................................... 26