BASIC PARAMETERS FOR THE TRAMWAY TRACK ALIGNMENT

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SPECIFICATIONS DOCUMENT

1. INTRODUCTION

The present document gathers all specifications which are adhered to in the preparation of the design concerning the Tramway Line extension.

Part A provides the principles for the alignment design and the reinstatement of roads, pavements, pedestrian streets and heavy traffic areas. (Source: Design and Performance Specifications, TRAM S.A. 2001).

Part B provides the basic parameters for track alignment design related to fixed route modes running at speeds less than 100km/h. (Source: Low Speed Track Alignment Instructions, NAMA A.E., April 2002).

ALIGNMENT OF TRAMWAY CORRIDOR

PART A

GENERAL PRINCIPLES FOR THE TRAMWAY ALIGNMENT DESIGN AND REINSTATEMENT OF ROADS AND PAVEMENTS

A 1. BASIC PRINCIPLES AND REQUIREMENTS OF THE DESIGN STUDY

The design study's basic principles and requirements shall be in accordance with the Approved Regulations and Specifications described herebelow:

- PD 696/74: Technical specifications for design studies
- Standard Technical Specifications for Roadworks, issued by the Ministry of Public Works
- Configuration of Cross-Sections for Greek Roads No. 103/1.E 60-62, Ministry of Public Works – Transport Projects Division – Dept. C.2
- A POLICY ON GEOMETRIC DESIGN OF HIGHWAYS AND STREETS. American Association of State Highway and transportation Officials, (AASHTO), Washington D.C., 1994.
- Basic design principles, as stated below.

A2. BASIC DESIGN PRINCIPLES

LATERAL ACCELERATION

On each curve with an "r: radius, lateral acceleration a_q is developing (both on the vehicle and the passengers) equal to:

$$a_q = \frac{V^2}{11,8} * (r - u) / 153 \ [m/s^2]$$

Where a_q lateral acceleration [m/s^2]
v speed [kph]
r curve radius [m]
u cant [mm]

For reasons of comfort, the lateral acceleration a_q shall not exceed the value of 0.65 m/s^2. At critical sections, TRAM S.A. also accepts lateral acceleration in the order of 0.98 m/s^2. The lateral acceleration value is also correlated to the calculation of the maximum permissible speed:

$$V_{max} = \sqrt{\frac{r}{11.8}(u+150)} \quad [kph]$$

LAYOUT PORTION OF THE TRANSITION CURVE *(CLOTHOID)*

The variation of the lateral accelerations Δa_q at the point of transition from a curve to a straight section shall not exceed, for reasons of comfort, the value of C_{max} = 0.67 m/s3

Calculation of Δa_q:

- On similar flexture curves : $\Delta a_q = a_q2 - a_q1$:
- On opposite flexure curves : $\Delta a_q = a_q1 + a_q2$

The length of each clothoid must be:

$l_u \geq v * \Delta a_q / 2.4$ *[m]*

When cant is applied to a curve, it would be prudent that the cant variation would take place within the length of the clothoid. Moreover, the following equation applies for a clothoid:

$$A^2 = R * l_u$$

όπου A= Clothoid constant *[m]*
R = circ. arc radius *[m]*
l_u= clothoid length *[m]*

If the application of a clothoid between two curves is not feasible, then the maximum permissible speed is:

(for LRT standards) $V_{max} = 6.8^3 \sqrt{\frac{1000}{R_1 * R_2}(R_1 - R_2)}$ *[kph].*

From a straight section to a curve and vise-versa:

(for LRT standards) $V_{max} = 6.8\sqrt[3]{R}$ *[kph]*

The distance between two successive curves shall be at least 11 m.

$L_u \geq$ *[m]* για LRT standard.

If this criterion is not met, the permissible speed should be calculated as if no straight section intervenes between the curves.

TRACK CANT

In order to balance the lateral accelerations, it is imperative to apply cant to the curved sections of the alignment. The cant is obviously chosen in relation to the train speed.
The theoretical cant value is given by the following formula:

$$U = 11.8 * v^2 / r \; [mm]$$

A regular cant U_{reg} shall not lead to lateral acceleration exceeding the value of $a_q \approx 0.2$ m/s^2. The mathematical equation then becomes:

$$U_{reg} = 11.8 * v^2 / r - 152 * a_q \Rightarrow U_{reg} = 11.8 * v^2 / r - 30 \; [mm]$$

The absolute minimum cant leading to lateral accelerations equal to a_q = 0.65 m/s2 is given by the following equation:

$$reg_{Umin} = 11.8 * v^2 / r - 100 \; [mm]$$

At critical only sections, TRAM S.A. accepts as an absolute minimum cant the one that corresponds to lateral accelerations aq = 0.98 m/s2 and is calculated according to the following equation:

$$min_{umin} = 11.8 * v^2 / r - 150 \; [mm]$$

where v = Speed *[kph]*
r = curve radius *[m]*

The maximum cant between two rails is 150 mm.

At stations and stops the cant shall be zero. The cant at level crossings shall not exceed the value of 30 mm.
The following table briefly presents the corresponding speeds for specific radii, lateral accelerations and cants.

R Radius [m]	ν speed [kph]											
	u = 0 [mm]			u = 50 [mm]			u = 100 [mm]			u = 150 [mm]		
	a_q [m/s^2]			a_q [m/s^2]			a_q [m/s^2]			a_q [m/s^2]		
	0.2	0.65	**0.98**	0.20	0.65	**0.98**	0.20	0.65	**0.98**	0.20	0.65	**0.98**
25	8	15	**18**	13	18	**21**	17	21	**23**	20	23	**25**
35	10	17	**21**	15	21	**24**	20	24	**27**	23	27	**30**
50	11	21	**25**	18	25	**29**	24	29	**33**	28	33	**36**
100	16	29	**36**	26	36	**41**	33	41	**46**	39	46	**50**
150	20	36	**44**	32	44	**50**	41	50	**56**	48	56	**62**
190	22	40	**49**	36	49	**57**	46	57	**63**	54	63	**69**
300	28	50	**62**	45	62	**71**	58	71	**80**	68	80	**87**
400	32	58	**71**	52	71	**82**	67	82	**92**	78	92	**101**
500	36	65	**80**	58	80	**92**	74	92	**103**	87	103	**113**

RAIL CANT TRANSITION PART (CANT RAMP)

During the transition from a section without cant to another canted section, or from one section to another section with different cant, a section must intervene where the longitudinal sloping is constant. Moreover, it is advisable that the length of this section would be same as the length of the clothoid. The length of the section where cant variation occurs is define by the following equation:

l_R = m * u / 1000 *[m]*

where u = cant *[mm]*

1/m = sloping of section when cant changes

The usual sloping of the part where cant changes is equal to:

1/m = 1/(10*v)

where v = Maximum running speed *[kph]*

The maximum sloping of the part where cant changes is equal to:

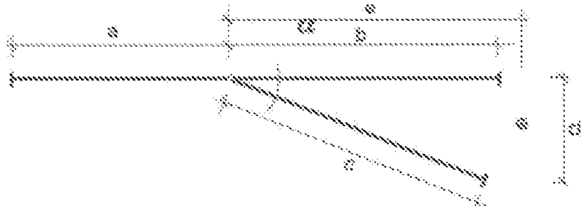
1/m = 1 /(6 * v)

Moreover, maximum sloping must not exceed 1 :300.
Finally, maximum sloping must not be applied at the edge of stations and stops.
The following table presents the required length of cant transition for various speeds and cant values.

Speed	l_R[m]						
v	u = 0 *[mm]*		u = 50 *[mm]*		u = 100 *[mm]*		u = 150 *[mm]*
[kph]	minimum	regular	minimum	regular	minimum	regular	minimum
25	7	15	15	30	30	45	45
30	8	15	15	30	30	45	45
35	9	18	15	35	30	53	45
40	11	20	15	40	30	60	45
45	12	23	15	45	30	68	45
50	14	25	15	50	30	75	45
55	15	28	17	55	33	83	50
60	16	30	18	60	36	90	54
65	18	33	20	65	39	98	59
70	19	35	21	70	42	105	63
75	20	38	23	75	45	113	68
80	22	40	24	80	48	120	72

CROSSOVERS (TURNOUTS)

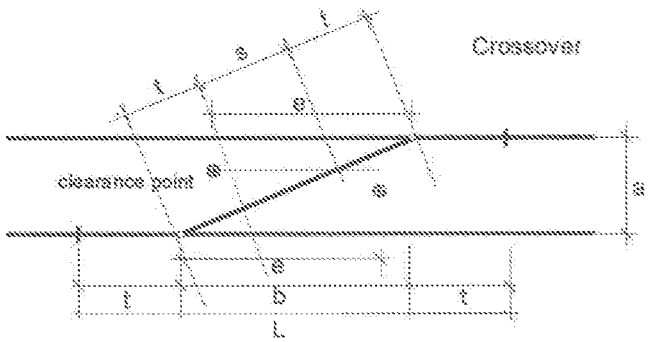
The usual turnouts for various running speeds are presented below:



Designation	EW 500 - 1 :12	EW 300 - 1:9	EW 100 - 1:5	EW 50 - 1:3,5
Speed **LRT**	*50 [kph]*	*45 [kph]*	*30 [kph]*	*25 [kph]*
Radius *[m]*	500	300	100	50
Angle α [1:]	1 :12	1 :9	1 :5	1:3,5
Length a *[m]*	20.797	16.615	9.902	7.003
Length b *[m]*	20.797	16.615	9.902	7.003
Length c *[m]*	20.797	16.615	9.902	7.003
Length d *[m]*	1.727	1.835	1.942	1.924
Length e *[m]*	≥ 34.00	≥ 25.80	≥ 15.00	≥ 11.00

Turnouts on curves:

Designation	EW 190 - 1:9	EW140 - 1:7	EW 100 - 1:6	EW 50 - 1:6
Speed **LRT**	*35 [kph]*	*35 [kph]*	*30 [kph]*	*25 [kph]*
Radius *[m]*	190	140	100	50
Angle α [1:]	1 :9	1 :7	1 :6	1 :6
Length a *[m]*	10.523	9.950	8.276	4.138
Length b *[m]*	16.483	13.224	11.528	10.989
Length c *[m]*	16.483	13.224	11.528	10.898
Length d *[m]*	1.820	1.870	1.895	1.800
Length e *[m]*	≥ 23.50	≥19.40	≥ 16.70	≥ 13.90



CROSSOVERS

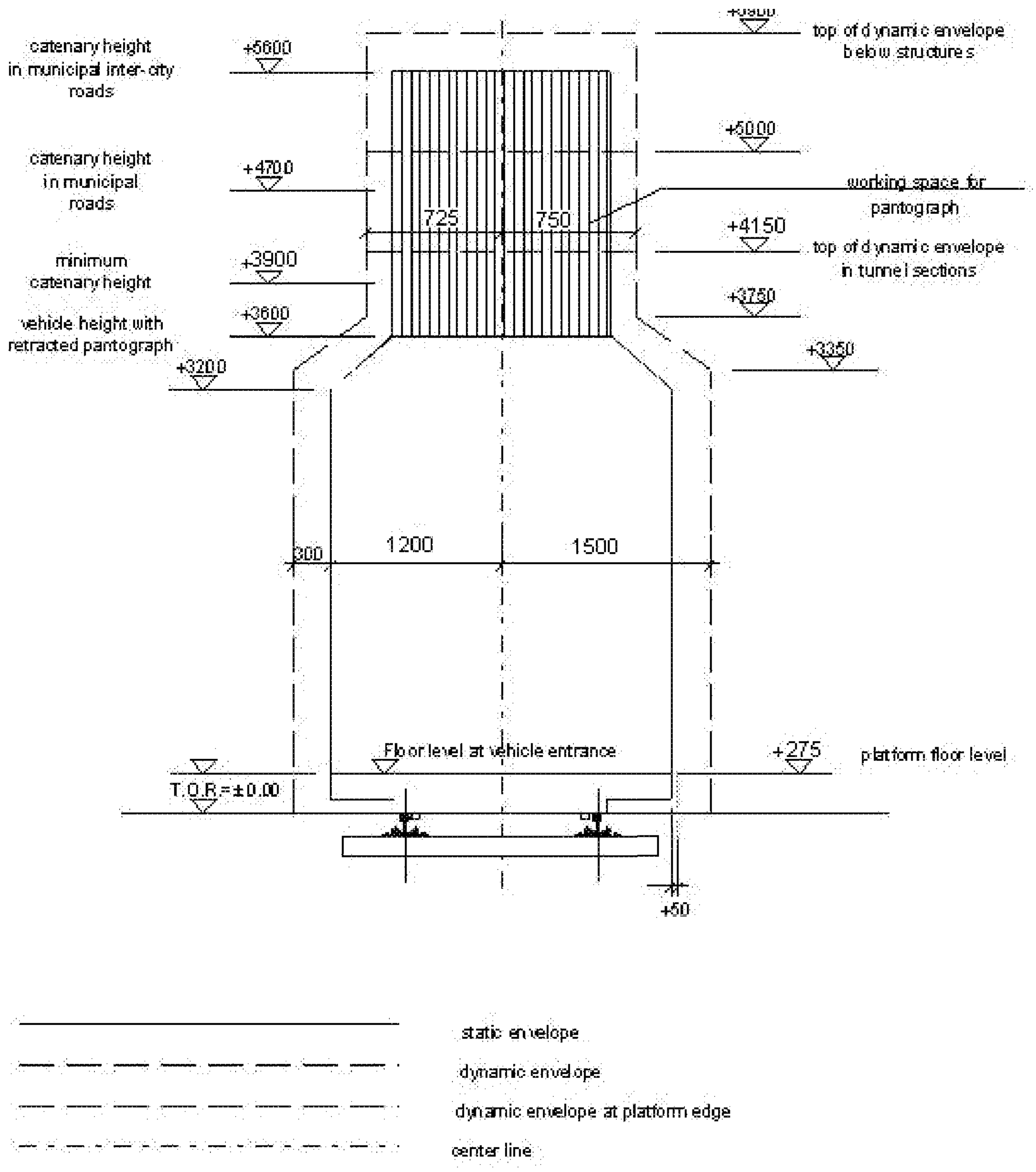
The crossover for various running speeds are presented below :
The letters in italics refer to the smaller distances between rails, without any additional speed reduction (straight section between two curves 11m.) The proposed applications are presented in bold characters.

Designation	**R 190 -1:9**	R 140 - 1:7	R 100 - 1:6	**R 50 - 1:6**	**R 50 - 1:6**	R 25 - 1:4
Speed LRT	***35 [kph]***	*35 [kph]*	*30 [kph]*	***25 [kph]***	***25[kph]***	*15 [kph]*
Radius *[m]*	**190**	140	100	**50**	**50**	25
Angle α [1:]	**1 :9**	1 :7	1 :6	**1:6**	**1 :6**	1 :4
Track distance a *[m]*	**3.65**	≥ 4.46	≥ 4.40	**3.65**	**3.25**	3.15
Totallength l *[m]*	**53.896**	≥ 51.120	≥ 47.352	**30.176**	**27.776**	19.755
Tangentt[m]	**10.523**	9.950	8.276	**4.138**	**4.138**	3.078
Straight c *[m]*	**11.732**	≥ 11.000	≥ 11.000	**13.926**	**11.493**	6.833
Length b *[m]*	**32.850**	≥ 31.220	≥ 30.800	**21.90**	**19.500**	12.600
Length e *[m]*	**≥23.5**	≥ 19.4	≥ 16.6	**≥ 13.9**	**≥13.9**	≥27.0

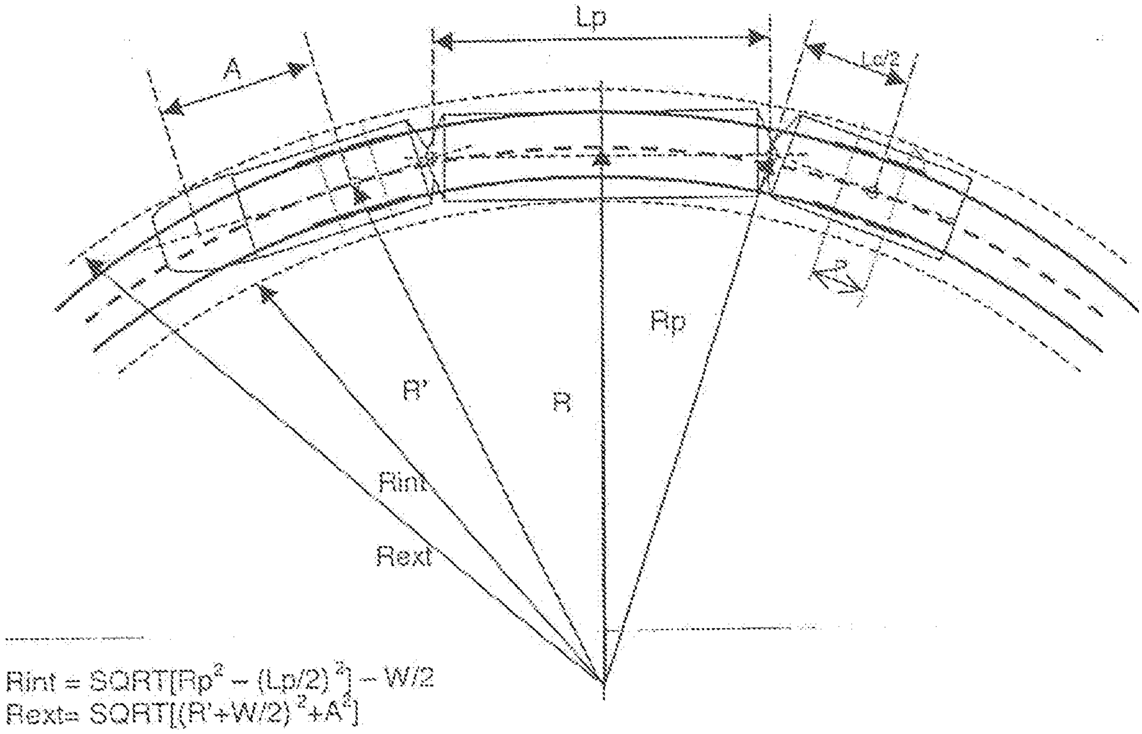
ENVELOPE

The selected vehicle width is 2,40 m. On the vehicle perimeter *(static envelope)* a gap is required to accommodate the vertical movement of the vehicle and the probable failures. Some of the failures are: incorrect suspension, probable vertical and horizontal displacement during construction. The width of these tolerances must be in the order of 300 mm (and 400 mm when the vehicle is moving in a tunnel or under a bridge). This latter width is called *dynamic envelope.*

Figure: Tramway envelope



*WIDENING AT CURVED SECTIONS **



R	Curve radius (at centre line)	
W	Car Body width	=2400mm
A	distance between the bogie centre and the front mask bending point	=3900mm
P	Distance between the Bogie Axles	=1700mm
Lp	Suspended Body Length (bearing to bearing)	=7100mm
Lc	Trailer Body Length (bearing to bearing)	=4000mm
Rp	Bearing Radius	Rp=SQRT[R'^2 + $(Lc/2)^2$]
R'	Centre Bogie Radius	R'=SQRT[R^2 + $(P/2)^2$]

** Source: Line Interface Data, Ansaldo Breda, 2002*

At curved sections, an additional width should be taken into account for either side of the vehicle width, due to the vehicle's larger displacement occupied by the vehicle when located on the curved section.
These distances (static envelope), on either side of the track axis and for a vehicle 2,40m. wide, are given in the following table:
The additional dynamic envelope should be added to the valued presented below.

Static envelope width for vehicles on a curved section, without cant

	Max. widening	
Radius (m)	Interior curve (mm)	Exterior curve (mm)
25	1388	1475
26	1380	1465
27	1374	1455
28	1367	1447
29	1361	1439
30	1356	1431
31	1351	1424
32	1346	1417
33	1342	1411
35	1334	1399
36	1330	1394
38	1323	1384
40	1317	1375
42	1311	1367
44	1306	1360
45	1304	1356
48	1297	1347
50	1294	1341
60	1278	1318
75	1262	1295
80	1258	1289
90	1252	1279
100	1247	1272
150	1231	1248
200	1224	1236
300	1216	1224
400	1212	1218
500	1210	1215
750	1207	1210
1000	1205	1208
2000	1203	1204
4000	1202	1202

WIDENING DUE TO CANT

At the curved sections with cant u [*mm*] one additional widening t_s, should be taken into consideration at the interior side of the curve

- t_s = 2.13 x u *[mm*] for LRT vehicles

Next to a safety corridor, the width is reduced as follows:

- t_s = 1.43 x u [*mm*] for LRT vehicles

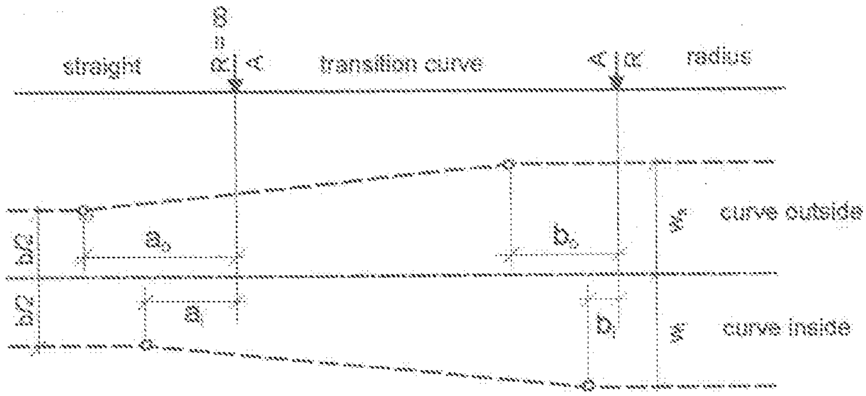
WIDENING AND TRANSITION CURVES

The widening depends on the kinematics of the vehicle, starts before the point where the transition curve commences and reaches its highest value before the curved section. The widening can be considered as linearly increasing.

Min. distance		a *[m]*	b *[m]*
LRT	Exterior curve	15.00	4.00
	Interior curve	11.00	0.00

Beginning and end of the widening of the static envelope at a curved section

Note: A 50 mm horizontal distance between the stopping platform and the vehicle is not allowed. On an LRT platform where the layout radius is lower than 500 m, distance ‘a’ should be kept from the end of the compulsory area.



CROSS - SECTIONS

In case of vehicle evacuation due to an emergency and for reasons of safety of people working on the rails, a 0.70-wide safety path is required with a net height of 2.00.
This path could be found on either sides of the rails and/or between them. The width of this path can be reduced to 0.45m for a length of 6m. This path should be level and its elevation should reach the Top of Rail (TOR). Finally, a maximum height up to TOR+300mm is acceptable.

POLES

As far as poles are concerned, provision should be made for a minimum width of 0.40m between the rails and/or on either sides of the rails. The maximum distance between the pole on a straight line can be up to 60m. At curved sections, the densification shown in the following table must be followed as a rule:

R_{min} / m	L/ m	R_{min} / m	L/ m
20	10	240	32
24	11	280	34
28	12	330	36
32	13	380	38
38	14	450	40
44	15	520	42
50	16	610	44

60	17	700	46
65	18	800	48
75	19	900	50
85	20	980	52
100	22	1050	54
120	24	1120	56
150	26	1210	58
170	28	1290	60
210	30		

DISTANCES FROM STREETS

The minimum horizontal distances from fixed obstacles or road traffic are shown in the following table:

	Lighting poles	Safety parapets	Bridge foundations
Local street	0.4 m	0.2 - 0.4 m	-
Main street	0.6 m	0.2 - 0.4 m	1.0 m
Interurban street	0.8 m	0.2 - 0.4 m	1.2 m

Clearances between Tramway vehicles and the road traffic can be overlapped. Tramway and other vehicles can move in parallel; however, the distance between them should not be less than 0.60 m in total.

Brief presentation of the Design criteria:

DIMENSIONS

VEHICLE DATA **LRT**

Max. vehicle length Max. length of the coupled vehicle (double)		35m 70m
Width of the vehicle		2.40m
Floor height in the entrance area		0.30m
No. of doors		12 per vehicle
Horizontal distance between the entrances and the platforms		0.10m
Vehicle height		3.60m
Weight of an empty vehicle / fully loaded (5 standees /m^2, 75 kg per person)		Approx. 42.5t/70t
Max. load per axis		12t
Vehicle body		1.7-2.0m
Max. transfer capacity	Seated/standing/total [4 per./m2]	54+2 / 143 /197

STATION DATA

Platform length		70m
Min. required platform width	side platform center platform	2.60m 4.20m

Platform height (TOR to platform)		30mm
Alignment curve	Horizontal	≥ 500m
	Vertical	1.500m
Recommended max. gradient		4%

ALIGNMENT DATA

Line width		1.435m
Design speed		50 Km/h
Min. curve in horizontal alignment		50m
Proposed min. horizontal curve in critical areas		35m
Absolute min. horizontal curve		25m
Min. platform distance from beginning/end of the curve or turnout		11.0 m
Min. vertical radius *[m]*	general	650m
	Transition curve / Crossover cant	≥ 5.000m
Max. gradient		4%
Abs. max. gradient at critical cross sections		9%
Max cant		150mm
Max cant at level crossings		30mm
Rail type		Existing project: Ri60N, S49 New project (Piraeus): Ri53N

A3 REINSTATEMENT OF ROADS AND PAVEMENTS

Reinstatement and improvement of roads and pavement shall be in full accord with the pre-existing alignment and geometry, unless otherwise instructed.

The reinstatement or improvement of a specific area shall improve the layout, longitudinal section and the cross sections among the fixed points of the boundaries of the area being reinstated. Whenever curbs of a significant distance (larger than 20 m.) are reinstated, the new curbs shall be 16cm high and shall agree with the standards of the Municipality where the specific project section belongs to.

The paved surfaces to be disturbed due to traffic diversions, worksite installations, PUO network diversions, etc., shall be reinstated carefully so as to be smooth throughout the length of the joints. At locations where disturbance is major and very irregular, an asphalt pavement shall be laid over the entire length of the street.

The detailed design to be prepared by the Project Contractor and approved by TRAM SA shall contain a clear distinction between traffic lanes used for cars and the Tramway corridor, using appropriate obstacles (cylinders, elevated sidewalks, etc.) which shall absolutely prohibit any access of cars to the Tramway Lane.

A3.1. Roads and Pavements

Table 6.1 presents the basic geometric features and typical cross sections of streets of various categories. These elements are in agreement with the current practices in Greece and are provided since no relevant Greek Codes or Regulations are available.

Wherever the use of the geometrical features mentioned in this paragraph is not feasible, either due to topography, or to pre-existing conditions, then other less satisfactory features can be used, at the approval of TRAM S.A.

Calculation of the thickness of flexible pavements shall be based on the following assumptions:

- Lifetime = 20 years
- CBR (California Bearing Ratio) Index = 5

Whenever it is necessary to examine the effects of unusual wheel loading, DIN 1072 shall be taken into account (Beton Kalender, Greek Publication 1984, Design of Bridges, loading).

The joints at non-flexible pavements and the joints with existing pavements shall be designed so as to adjust to the specific conditions in the subject area.

Pavements

Whenever existing roads are repaired or improved, as well as when new roads are constructed, the pavement shall have the following layers:

Road pavement layers

a. sub-base layer STP 0-150 with a thickness after compaction equal to 0.10 m, each.
b. Base layer STP 0-155 with a thickness after compaction equal to 0.10 m, each.

Asphalt layers

a. asphalt base layers STP A-260 with a thickness after compaction equal to 0.05 m. each.
b. Asphalt concrete layer STP A-265 with a thickness after compaction equal to 0.05 m.
c. anti-slip layer 0,04 m thick.

Temporary roads

As regards the temporary pavements at location of diversions, the construction must be properly designed for the entire temporary diversion period, but the surface layer of the pavement shall be at least 30 mm thick made of hot asphalt or asphalt mix on a 50 cm thick base made of crushed material. The Contractor shall be fully responsible for the quality and the maintenance of this pavement.

Table 6.1 Basic features and geometrical characteristics of urban streets

Characteristics, Geometrical standards	Road category				
	Freeway	Other main arteries	Secondary artery	Collector road	Local road, road to Depot
Trips served	Interurban and long distance urban	Long and medium distance urban	Medium distance urban	Short distance urban and access trips	Access trips
Sideroads	Yes	Often	No	No	No
Median island	Always	Normally	Desirable	No	No
Median openings	Not allowed	Allowed Left turn lane required		-	-
Design speeds (Km/h)	120	80	70	50	40
Traffic capacity (passenger cars per hour and lane)	1400-1600	800-1000	600-800	300-600	200-400
Number of traffic lanes	4-8	4-8	2-4	2	2
"Occupation width" (meters): (Minimum-Desirable)	36-60	17-30	10-18	9-15	7-9
Max. longitudinal gradient	4%	5%	6%	12%	15%
Horizontal curve min radius	700	300	200	75	40
Traffic lane width	3,75	3,50	3,50	3,25	2,50-3,00
Parking on the street	Not allowed	Not allowed	Non desirable	Allowed	Allowed
Bus lines and stops	Usually interurban or suburban No stop on the Avenue	Yes. Stops always in recesses	Yes. Desirable to locate stops in a recess	Ends of Bus lines	No
Intersections					
-With local road	No connection	STOP sign without discontinuing the median	STOP Sign	STOP sign or no sign	Usually no sign
-With collector road	No connection	STOP sign, Usually without discontinuing the median	STOP sign	STOP sign	
-With a secondary artery	Plain level crossing without connections or grade separated junctions	Signalling	STOP sign or signalling		
-With other main arteries	Grade separated junctions	Signalling with directing islands and left turn lanes			
-With a Freeway	High standard Grade Separated Junctions				

A3.2 Highly-Loaded Road pavement areas

The design of highly-loaded road pavement areas will be mainly affected by the maximum values of the structural loads exercised on the road pavement and not by repetitive exercise of lower loads. If specific instructions are not given, then the design will be based on the worst load or on load combinations that may be exercised in the subject highly-loaded area.

The analysis of the highly-loaded areas shall be effected using any recognized method for identifying maximum deformation under loading. The maximum deformation shall be less or equal to 2mm.

A3.4 Pedestrian Ways – Paved Surfaces

Pedestrian ways and other paved surfaces shall be loaded in accordance with DIN 1072.

The calculation methods to be utilized shall be as described for highly-loaded areas.

Joints shall be properly spaced, in case non-flexible road pavements and stiff material are used.

The design shall be based on a 20-year life cycle as well as on a CBR=5.

A3.5 Signaling, Horizontal and Vertical Signage

The signaling, horizontal and vertical signage design shall be based on the following:

- "Instructions for Greek Roads' Signage", Ministry of Transport and Public Works, General Directorate of Public Works, 1960.
- "Roads Signs", Ministry of Public Works, General Directorate of Public Works, Traffic Section (A6), November 1974.
- "Road Traffic Code", Law 2696, 1999 (FEK 57A/23.03.1999).
- "Road Pavement Markins", Ministry of Public Works, General Directorate of Public Works, Traffic Section (A6), 1975.
- "Technical Instructions for the Signage of Typical Road Networks", Ministry of Public Works, Traffic and Safety Directorate (Δ2), Traffic Signage (Δ), January 1992.

A3.6 Parapets, Traffic barriers

Parapets or temporary traffic barriers with containment capacity equal to the capacity of the permanent parapets shall be installed, where necessary, in order to provide protection at the perimeter of the temporary traffic diversions or even protection against any eventual traffic-related risks adjacent to the areas where works are executed. As regards occupation of areas and long-term traffic diversions, decorative and environment-friendly parapets shall be installed, where deemed necessary for reasons of aesthetics. Light fencing shall be installed only in case of short-term area occupation or traffic diversion (of less than one-week duration).

A3.7 Curbs, Sidewalks

The typical curb shall be 16cm high in accordance with the Standards of the Municipality it crosses. Sidewalks shall also be in accordance with the Standards of the Municipality where the section of the Project belongs – in terms of geography. The curbs shall be constructed on the re-configured sidewalks, as well as on the foreseen traffic isles. The lower part of the road pavement sub-base shall also continue underneath the basis of the curbs.

- Energy absorption arrangements (such as traffic barriers for vehicles, pedestrian balustrades etc. or a combination thereof) shall be provided as required, in view of the project completeness and compliance with the safety instructions for pedestrians and vehicles.

A3.8 Sewage network

The typical details concerning the rainwater sumps shall comply with the requirements of EYDAP. Rainwater sewage pipes shall be made of prefabricated cement pipes, in line with the specifications of Standard Technical Specifications T. 110, FEK 253/B/84 and Circular E177/12.11.84 of the Ministry of PEHODE/General Secretariat of Public Works.

Drains, where foreseen, shall be manufactured in line with the Standard Technical Specifications T. 110. The entire structure intended for collection and drainage of rain water must be waterproofed (i.e., at its outer surface “taking” water of any origin) using appropriate waterproofing materials, so as to prevent water ingress or the presence of moisture. Water at the outer surface of the structure must be collected and discharged directly to the rainwater sump system, regardless of the existence of the respective rainwater sump system of the underground station. The water shall be discharged either in part or in total towards the roads’ rainwater sump system. Special attention must be drawn to the sensitive parts of the joints, so that even the signs of moisture be completely eliminated from the visible parts of the structure. The water sewage pipes shall be manufactured in accordance with the requirements of this Technical Description.

A3.9 Asphalt

The supply of the asphalt 80/100 shall be made by the Contractor through the market without any tax exemption. The asphalt shall meet the requirements of the Standard Technical Specifications. Its quality shall be checked either through check certificates, to be issued by the asphalt manufacturing plants and made available by the Contractor or through checks to be performed by TRAM S.A., as stipulated by the Ministry of Public Works Circular No. Γ3/β/οικ./0337/13.02.1970. The Contractor shall be exclusively responsible for checking the quality of the asphalt.

One month prior to the commencement of the asphalt works, the Contractor shall submit mix designs for the asphalt-mixes, to be utilized in the subject Project. TRAM S.A., based on the aforesaid mix designs, shall determine the type of the asphalt-mix to be used for each work-phase. The asphalt layer, wherever laid, shall be anti-slip made of pre-coated fine aggregate 9 with p.s.v. > 65 to be spread on the surface of the asphalt layer under construction before its compaction.

PART B

BASIC PARAMETERS FOR THE ALIGNMENT DESIGN OF LINES FOR FIXED ROUTE MODES OF TRANSPORT RUNING AT A VELOCITY LESS THAN 100 Km/h

B1. GENERAL

The alignment of lines presupposes that the following parameters have been set, namely:

- Design Velocity v_e
- Allowable Longitudinal Inclination
- Vehicle Type
- Train Length
- Daily Tonnage (Tones/ Day)
- Type and Location of the Areas to be Utilized
- Dimensions regarding the Lines Alignment
- Project Construction Organization Chart and Project Development Perspectives

For selecting the design elements sequence and their parameters, relevant threshold values are taken into consideration (see Table 1-1).

Table 1-1: Determination of design threshold values

Acceptable values	Construction limit
	Typical value
	Threshold value
Values by exception	Value by exception
	Absolute minimum value

In general, the following apply:

- The threshold acceptable value is set on the basis of the corresponding specifications and constitutes the minimum acceptable value.
- The construction limit concerns the construction capacity of a value, as well as the possibility for this value to be maintained in the future through project maintenance. The construction limit concerns the maximum limit of a parameter.
- The range of the values by exception concerns values which apply in exceptional cases subject documentation and approval by the Service.
- Generally, typical values must be selected as parameter values.
- Frequent alternation of the design elements must be avoided. The minimum length of a straight line or of a total arc, that must correspond to a running length of approximately 1.5 sec, is
  $L = 0.4 \cdot v$, where L expressed in m and v expressed in [km/h]
- The values for balanced cant and the circular arc radius are presented in Table 1-2.

Table 1-2: Design values for u_0 and r

	Lines	Crossovers, Turnouts
Acceptable Values	Construction limit r ≤ 30 000 mm	
	Typical value	
	u_0 = 170 mm In platforms: u_0 = 130 mm r ≥ 300 m in main lines r ≥180 m in the remaining lines Especially for the TRAMWAY r ≥ 240 m	u_0 = 120 mm
	Threshold value	
	u_0 = 290 mm In platforms: u_0 = 230 mm	u_0 = allowable u + allowable u_f see Table 3-3
Values by exception	Value by exception u_0 = allowable u + allowable u_f (see Tables 4 and 5) Especially for TRAMWAY r_{min} = 25 m	

where:

r [m]	: circular arc radius
u [mm]	: cant
u_0 [mm]	: balanced cant (fixed cant at circular arc)
allowable u [mm]	: allowable cant
allowable u_g [mm]	: allowable cant deficiency

B2. CURVED SECTIONS

- Curved sections are, generally, configured through transition arcs and cants.
- Value L= 0.4 · v_e [m] is set as the minimum length of circular arc and a straight line.
- Otherwise, top arc (arc with a zero length of circular arc) shall be applied.
- The radii of circular arcs are calculated as a function of the design velocity v_e and the balanced cant u_0.

$$r = \frac{11.8 \times v_e^2}{u_0} [m]$$

where:

u_0 (cant balancing the lateral acceleration)

- The corresponding design values for parameter u_0 are given in Table 1-2.
- It is advisable that the r values for circular arcs be selected as r ≥150m.
- In case of platforms at the inner part of the curve, the radius of the circular arc must exceed the value of r ≥500m.

B3. CANT

- Cants are configured by lifting the outer rail through cant ramps.
- A uniform cant is maintained in canistroeid curves on condition that the typical values of the cants in individual circular arcs do not differ between them significantly.
- Cants are rounded up in values divided by 5.
- The cant design values are given in Table 3-1.

Table 3-1: Design values for outer rail cant (u)

<table>
<tr><td rowspan="6">Acceptable Values</td><td>Lines</td><td>Crossovers, Turnouts</td></tr>
<tr><td colspan="2">Construction limit
u = 20mm</td></tr>
<tr><td colspan="2">Typical value</td></tr>
<tr><td>u = 100m
in platforms: u = 60mm
Especially in TRAMWAY:
u = 0 mm</td><td>u = 60 mm

Especially in TRAMWAY:
u = 0 mm</td></tr>
<tr><td colspan="2">Threshold values</td></tr>
<tr><td>Ballasted superstructure:
allowable u = 160 mm
Fixed roadway: allowable u = 160mm
In platforms = allowable u = 100 m
Especially in TRAMWAY:
allow. u = 150 (165) mm</td><td>allowable u = 120 mm
V - Crossover without movable parts
allowable u = 100 mm</td></tr>
<tr><td rowspan="3">Values by exception</td><td colspan="2">Values by exception</td></tr>
<tr><td>160 < allowable u ≤ 180 mm
170 < allowable u ≤ 180 mm</td><td>120 < allowable u ≤ 150 mm
100 < allowable u ≤ 130 mm</td></tr>
<tr><td colspan="2">Absolute minimum value
allowable u > 180 mm</td></tr>
</table>

Table 3-2: Design values for u_f

<table>
<tr><td rowspan="6">Acceptable Values</td><td>Lines</td><td>Crossovers, Turnouts</td></tr>
<tr><td colspan="2">Construction limit</td></tr>
<tr><td colspan="2">Typical value</td></tr>
<tr><td>u_f = 70 mm</td><td>u_f = 60 mm</td></tr>
<tr><td colspan="2">Threshold values</td></tr>
<tr><td>allowable u_f = 130 mm</td><td>allowable u_f = 120 mm in line with Table 3-3</td></tr>
<tr><td rowspan="3">Values by exception</td><td colspan="2">Values by exception</td></tr>
<tr><td>150 < allowable u_f</td><td>allowable u_f ≤ 150 mm in line with Table 3-3</td></tr>
<tr><td colspan="2">Absolute minimum value</td></tr>
</table>

	-	allowable u_f in line with Table 3-3 with an increase of 20%

- In arcs with a radius r < 300m, the maximum value of cant is:

allowable u = $\frac{r-50}{1.5}$

where:
r [m] : radius
u [mm] : cant

- In curved sections, stations and sections where frequent stops, the value of the cant shall be selected between the minimum value and the typical value (reg u).

reg u = $\frac{7.1 \times v_e^2}{r}$

where:
r [m] : radius
u [mm] : cant

- In sections with uniform speed, the value of the cant shall be selected between the typical value (reg u) and the balanced cant u_0.
- Balanced cant u_0 equals to:

$u_0 = \frac{11.8 \times v_e^2}{r}$

where:
r [m] : radius
u [mm] : cant

- The cant deficiency u_f is set as follows:
  $u_f = u_0 - u$

where: u = the selected or existing cant.

- The minimum cant value equals to:

min u = $\frac{11.8 \times v_e^2}{r}$ - allowable u_f

B4. TRANSITION ARCS

- The Transition arcs are required when the difference of the cant deficiency values between two design items Δu_f is in general:

  $\Delta u_f \geq 40$ mm

- The Δu_f value is calculated based on the relationship:

$$\Delta u_f = \left(\frac{11.8 \cdot v_e^2}{r_1} - u_1\right) \mp \left(\frac{11.8 \cdot v_e^2}{r_2} - u_2\right)$$

where:
the positive sign [+] applies for opposite flexure arcs
the negative sign [-] applies for similar flexure arcs

- The length of the transition arc coincides with the length of the cant transition branch (cant ramp).

- Generally, the clothoid is selected as transition arc.

- When the values of Table 5-1 cannot be observed, then transition arcs with an S-shaped curvature function or arcs by BLOSS shall be selected.

- The minimum lengths of the transition arcs are as follows:

  - Clothoid:

$$\text{Min}l_u = \frac{4 \cdot v_e \cdot \Delta u_f}{1000} \text{ [m]}$$

  - S-shaped arc:

$$\text{Min}l_u = \frac{6 \cdot v_e \cdot \Delta u_f}{1000} \text{ [m]}$$

  - Arc by BLOSS:

$$\text{Min}l_{UB} = \frac{4.5 \cdot v_e \cdot \Delta u_f}{1000} \text{ [m]}$$

- The lengths of the transition arcs must be selected, so as to generate a deviation of $f \geq 15$ mm:

- Deviations f are calculated as follows:

  - Clothoid:

$$f = \frac{l_U^2 \cdot 1000}{24 \cdot r}$$

  - S-shaped arc:

$$f = \frac{l_{US}^2 \cdot 1000}{48 \cdot r}$$

  - Arc by BLOSS:

$$f = \frac{l_{UB}^2 \cdot 1000}{40 \cdot r}$$

- In case of opposite flexure arcs, two transition arcs intervene as clothoids when a straight line of a minimum length of $L_g \geq 0.4\ v_e$ can intervene between them.

- When there is a small distance between opposite flexure arcs and the solution presented above cannot be applied, then:

  - the cant shall be transformed linearly from value u_1 to value u_2 (creation of a scissor cant)
  - two S-shaped transition arcs intervene with a corresponding cant change function

- When successive circular arcs are constructed, it is required to apply minor changes at the value of the cant deficiency Δu_f through the intervention of straight sections or other third arc of a minimum length L of:
  $L \geq 0.2\ v_e$

- The minimum length of the intervening arcs is:

  Min $L = 0.10 \cdot v_e$
  and min L = 6m in similar flexure arcs or
  min $L = \frac{1000}{r_1} + \frac{1000}{r_2}$ > 9m in opposite flexure arcs
- The minimum length of circular arcs and straight sections in crossovers is:
  $L = 0.10 \cdot v_e$ when $v_e \leq 70$ km/h

- The minimum values for changes to the cant deficiency Δu_f when $v_e \leq 100$ km/h is:
  allowable $\Delta u_f = 106$ mm

- Circular arcs can follow straight sections, when, in line with the aforementioned rule, radius r of the circular arc is greater than:

r = 180 m when v_e = 40 km/h
r = 280 m when v_e = 50 km/h
r = 400 m when v_e = 60 km/h
r = 550 m when v_e = 70 km/h
r = 710 m when v_e = 80 km/h
r = 900 m when v_e = 90 km/h

B5. CANT TRANSITIONS (RAMPS)

- The change function of the cant transitions coincides with the transition arc change function.
- Between linear cant transitions, the value of the cant (including the zero value) remains fixed at a length of at least $L \geq 0.1 \cdot v_e$
- Lengths L_R and gradients 1: m of the cant transitions are presented in Table 5-1.

Table 5.1: Design values concerning the length and the inclinations of the cant transitions (ramps)

	Straight transition	Transition Curve S-shaped	/ as per BLOSS
Acceptable Values	Construction limit		
	1:m = 1:3000	$1:m_M$ = 1:1500	$1:m_M$ = 1:1500
	Typical Value		
	$l_R = 10v_e \frac{\Delta u}{1000}$ 1:m ≤ 1:600 Especially for TRAMWAY	$l_{RS} = 10v_e \frac{\Delta u}{1000}$ 1:m ≤ 1:600	$l_R = 7.5v_e \frac{\Delta u}{1000}$ 1:m ≤ 1:600

	$I_R = 6v_e \frac{\Delta u}{1000}$ 1:m ≤ 1:300		
	Threshold value		
	$I_R = 8v_e \frac{\Delta u}{1000}$ 1:m ≤ 1:400	$I_{RS} = 10v_e \frac{\Delta u}{1000}$ 1:m ≤ 1:600	$I_{RB} = 6v_e \frac{\Delta u}{1000}$ 1:m ≤ 1:400
Values by exception	Values by exception		
	$8v_e \frac{\Delta u}{1000} > I_R \geq 6$ 1:m ≤ 1:400	- -	- -
	Absolute minimum value		
	$6v_e \frac{\Delta u}{1000} > I_R \geq 5$ 1:m ≤ 1:400	- -	- -

B6. LONGITUDINAL PROFILES

- In TRAMWAY lines and in secondary lines, the maximum longitudinal gradient is 40‰ at absolute maximum inclination in critical sections of a limited length of 90‰.
- Rounding arcs are applied at the longitudinal profile when the change of the values of the longitudinal gradients is:

  $\Delta I \geq 1‰$

- The minimum length of the rounding arc is set at:

  $L_a \geq 20$ m

minimum vertical radius: $r_a = 0.4 \cdot v_e^2 \leq 650$ at crossovers minr_a = 5000 m
where:
r_a [m]
v_e [km/h]

The design values of the vertical rounding arc are given in Table 6-1.

Table 6-1: Design values of rounding arc radius r_a at longitudinal profiles

Acceptable Values	Construction limit $r_a \leq$ 30 000 m
	Typical value $r_a \leq 0.4 \cdot v_e^2$ [m]
	Threshold value $r_a \leq 0.25 \cdot v_e^2$ [m] $r_a \geq$ 2 000 m
Values by exception	Value by exception $r_a = 0.16 \cdot v_e^2$ [m] in curved sections of curves $r_a = 0.13 \cdot v_e^2$ [m] in hollow curves $r_a \geq$ 2 000 m

	Absolute minimum value - -

B7. DETERMINATION OF MAXIMUM ALLOWABLE SPEED DUE TO TRACK ALIGNMENT

The constructed geometrical dimensions of a line's alignment determine the maximum allowable speed for fixed-route modes of transport passing a curve.

In general, with regard to the speed when passing a curve, further to the consent of the Project Management Division, the following general principles can be kept, namely:

a. The maximum allowable velocity deriving from the existing cant deficiency can be rounded up to 1%.
b. The minimum lengths of the transition arcs can be reduced by 20%.
c. Linear cant transitions are permitted up to lengths:

   $L_R = 6 \cdot v_e \cdot \frac{\Delta_u}{1000}$

   or 1:m = 1:400
d. The allowable limits for change of the cant deficiency Δu can be increased by 20%.

With regard to fixed-route transport modes with <u>body inclination technology</u>, the following threshold values apply:

- In curve arcs without obligatory points, the cant deficiency may range up to 300 mm:
  $u_f \leq 300$ mm
- In arcs with crossovers or obligatory points, the cant deficiency cannot be greater than 150 mm
  $u_f \leq 150$ mm
- In transition cants, as regards the velocity v_N of vehicles with body inclination technology, the following apply:

a. in case of linear cants change, then:

   $L_R = 6 \cdot v_N \cdot \frac{\Delta_u}{1000}$ (1: m $\leq$1:400)
b. in case of parabolic cant change (s-shaped), then:

   $L_{RS} = 8 \cdot v_N \cdot \frac{\Delta_u}{1000}$ (1: m $\leq$1:400)
c. in case of arcs per BLOSS:

   $L_{RB} = 9 \cdot v_N \cdot \frac{\Delta_u}{1000}$ (1: m $\leq$1:400)

The relations for calculating the maximum allowable velocity max v [km/h] for vehicles passing a curve on the basis of design data are given in Table 7-1. The lower value resulting from the calculated values should be always taken into consideration.

Table 7.1: Maximum Allowable Velocity

S/N	Criterion	Maximum Allowable Velocity Max v [km/h]	Reference
1	Cant deficiency	$\sqrt{\frac{r}{11{,}8} \cdot (u + allow.u_f)}$	allow. u_f Table 3-2
2	Change of curvature in successive arcs allow. Δu_f = 106 mm	<u>Case</u>: Straight Sections – Circular Arcs $\sqrt{\frac{r}{11{,}8} \cdot allow.\Delta u_f}$ <u>Case</u>: Successive opposite or	Chapter B4

		similar flexure circular arcs $\sqrt{\frac{r_1 \cdot r_2}{11{,}8(r_1 \cdot r_2)} \cdot allow.\Delta u_f}$	
3	Distance between straight cant transition branches (ramps) Cant transition branches (ramps)	10 · L	Chapter B5
4	Case: straight line	$\sqrt{\frac{L_R \cdot 1000}{6 \cdot \Delta u}}$	Chapter 5-1
	Case: parabolic line (S-shaped)	$\sqrt{\frac{L_{RS} \cdot 1000}{8 \cdot \Delta u}}$	
	Case: BLOSS	$\sqrt{\frac{L_{RS} \cdot 1000}{6 \cdot \Delta u}}$	
5	Longitudinal profile rounding arc	$2 \cdot \sqrt{r_a}$	Table 6-1