Quality parameters for cycle infrastructure: longitudinal gradients

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EUROPEAN CYCLISTS' FEDERATION

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Table of Contents

1. Introduction

Longitudinal slopes affect cycling in two ways. Uphill cycling requires additional effort, which might be discouraging or prohibitive for some users (less fit, elderly, carrying children or significant luggage, on heavy cycles etc). Downhill cycling might seem easier, but with steep gradients it can be a safety hazard, due to higher speeds and much longer braking distance (in addition to higher speeds gravity is counteracting the braking power). Overall, elevation changes increase the energy expense of cyclists, therefore reducing the comfort of use and competitiveness of the cycle route.[1]

The key parameter for slopes is the longitudinal gradient (G), usually expressed in %:

$$G = H / L$$

where:

- H – height difference [m]
- L – slope length [m][2]

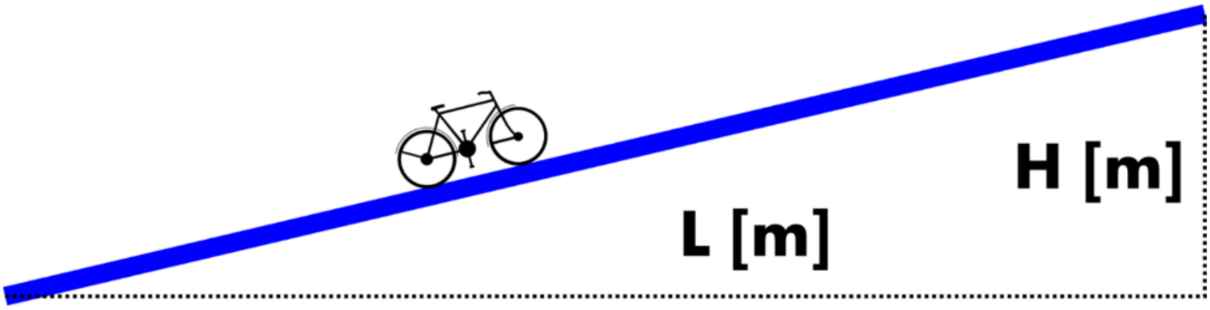

Figure 1. Basic slope parameters, height difference (H) and slope length (L).

A short steep slope might be acceptable, especially if there is a straight flat section at the bottom of the slope that allows one to pick up speed before climbing and reduce it safely in the downhill direction. A longer climb or descent requires a gentler slope to be able to sustain the effort or manage speed. The maximum acceptable gradient depends therefore on the height difference to overcome (or the length of the slope).

The factsheet gives an overview of how different national or regional guidelines quantify this aspect of the quality of cycle routes and compares the maximum gradients allowed in the function of height difference. The final section summarises the quantifiable requirements and provides a few additional recommendations related to slopes.

[1] There is a hypothesis that gradients will become less relevant with the growing uptake of electric pedal assisted cycles. While electrical assistance can help on uphill stretches and makes cycling more accessible to larger share of population, it does not resolve the problems encountered in the downhill direction. Therefore slopes should remain an important consideration in planning and design of cycle routes in the foreseeable future, also with widespread usage of electrical assistance.

[2] For practical applications, on bikeable slopes it does not matter whether L is measured on the surface or from the map. For example, on a slope with a gradient of 6% the difference in length between the longer leg and the hypotenuse of the triangle is lower than 0.18%.

Figure 2. With 1.9 million cycles counted in 2022, Rue de la Loi is the most popular cycle route in Brussels, Belgium. It funnels most of the cycle traffic between the centre and the European Quarter, because the street crosses the valley of Maelbeek on a viaduct, minimising elevation change on the way. Photo credit: Goran Lepen.

2. Analysed standards and guidelines

2.1. Austria

Document: **RVS 03.02.13 – Radverkehr** (Cycle traffic), 2022[3]

National guidelines for cycle traffic are published by the Austrian Research Association for Roads, Railways and Transport (Forschungsgesellschaft Straße-Schiene-Verkehr, FSV). Gradients are covered in section 7.5 "Trassierung", with table 9 providing recommended maximum gradients in function of the height difference to overcome (reproduced below as Table 1).

For new routes, gradients of 3% should not be exceeded on longer slopes. Overtaking opportunities are to be provided on uphill slopes. Wherever possible, resting stretches should be provided between slopes, and braking or run-out stretches should be provided for downhill slopes. In the case of combined facilities for cycle and pedestrian traffic, it should be noted that slopes of more than 6% from a length of 10 m are not permitted (due to the Austrian Accessibility Act).

Table 1. Maximum gradient depending on the height difference to overcome according to the Austrian guidelines.

Height difference [m]	Longitudinal gradient [%]	Maximum longitudinal slope length [m]
1	12	8
2	10	20
4	6	65
6	5	120
10	4	250
> 10	3	> 250

2.2. Belgium

Document: **Vademecum fietsvoorzieningen** (Handbook bicycle facilities), 2021[4]

The handbook produced by the Flemish road administration includes a dedicated fiche B.3 discussing slopes. The focus is on artificial height differences, for example, related to tunnels or bridges. Figure 2 in the fiche provides an assessment of slope (very good, good, usable, not applicable) as a function of gradient and height difference. The requirements are similar to the ones provided by the Dutch manual (see section 2.7), with "good" equivalent to "target" and "usable" to "maximum" in the latter.

On natural slopes, the gradient for cyclists may not exceed that for motorised traffic on parallel motorways. It can be useful to limit the natural slope by providing rest areas.

[3] Available for download through: https://www.klimaaktiv.at/mobilitaet/radfahren/rvs.html
[4] https://wegenenverkeer.be/sites/default/files/uploads/documenten/Vademecum%20Fietsvoorzieningen.pdf

2.3. Finland

Document: **Pyöräliikenteen Suunnittelu** (Cycling Design), 2020[5]

The guidelines published by the Finnish Transport Infrastructure Agency are obligatory for cycling infrastructure managed on the national level. Municipalities often also apply the same parameters but, in some cases, have their own standards.[6] The guidelines discuss the gradients in chapter 4.9.4 “Denivelation”. They recommend a maximum gradient value of 5%, lowered to 4% for high-quality cycle routes, and raised to 8% in exceptional cases.

In addition to “hard” limits, figure 91 presents maximum gradients in function of slope length and height difference. For example, if the height difference exceeds 8 m, the gradient should not exceed 3%.

2.4. France

Documents:

- **Fiche 7 – Les pistes cyclables** (The cycle tracks), 2013
- **Fiche 35 – Réseau cyclable à haut niveau de service** (Cycle network with high level of service), 2016

The Cerema[7] fiche 7 about cycle tracks does not provide any recommendation about longitudinal gradients. Fiche 35 includes a brief recommendation to avoid excessive ramps, with a maximum gradient set to 6%. It also indicates that grade-separated crossing cycle tunnels are preferred to cycle bridges, as tunnels usually require less elevation changes and the speed gained when descending into the tunnels can be used to facilitate the climb on the other side.

2.5. Germany

Document: ***Empfehlungen für Radverkehrsanlagen*** (Recommendations for cycling facilities), 2010[8]

German federal recommendations for cycling facilities have a very short section 2.2.3 on “gradients on ramps”. Table 7 provides maximum slope lengths for different gradients, from 250 m for 4% to 20 m for 10%. With a 3% gradient, the length of the slope is not limited.

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[5] https://ava.vaylapilvi.fi/ava/Julkaisut/Vaylavirasto/vo_2020-18_pyoraliikenteen_suunnittelu_web.pdf
[6] For example, Helsinki: https://pyoraliikenne.fi/
[7] Centre d'études et d'expertise sur les risques, l'environnement, la mobilité et l'aménagement - Centre for Studies on Risks, the Environment, Mobility and Urban Planning). Fiches are available at https://www.cerema.fr/fr/centre-ressources/boutique/velo-amenagements-recommandations-retours-experiences
[8] https://www.fgsv-verlag.de/era

2.6. Ireland

Document: **Cycle Design Manual**, 2023[9]

The maximum longitudinal gradients are given in section 4.1.5.2. The manual notes that gradients impact on two issues; the physical limitations of a cyclist to climb inclines, and their safety when descending. It specifies concrete requirements in table 4.10. The desirable maximum gradient is set to 3% and the absolute maximum gradient to 5%.

Additionally, for gradients exceeding 3%:

- design speed in the downhill direction should be increased to 40 km/h (section 4.1.1, table 4.1),
- signal timings in the uphill direction should be increased (section 4.4.5.4, table 4.22),
- cycle track width should be increased by 0.25 m to allow for greater lateral movement (section 2.6, notes to table 2.2).

2.7. Netherlands

Documents: **Design Manual for Bicycle Traffic**, 2016[10]

The most recent version of the CROW manual discusses slopes in section 3.5 Inclines. It introduces the concept of “slope severity”, calculated as the square of the height difference divided by slope length:

$$S = H^2 / L$$

Alternatively, slope severity can also be expressed as a product of gradient and height difference:

$$S = G\ H$$

The manual recommends designing for slope severity around 0.075, with a maximum of 0.2. Additionally:

- Even for very short slopes the gradient should not exceed 10%.
- Slopes with 1.75% gradient can be applied regardless of their length or height difference. In other words, a gradient of 1.75% is recommended for slopes with a height difference of 5 m or more, and obligatory for 15 m.

The manual also notes that there should be no junction, sharp bend or obstacle at the bottom of the slope. Sharp bends in the middle are also risky. They can cause single-bicycle or multiple-bicycle accidents.

For longer slopes, the gradient should be preferably lower in the higher part of the slope.

For level differences exceeding 5 m, it is recommended to break the slope with a flat section of around 25 m.

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[9] https://www.nationaltransport.ie/publications/cycle-design-manual/
[10] https://www.crow.nl/publicaties/design-manual-for-bicycle-traffic

2.8. Norway

Document: **N100 Veg og gateutforming** (Road and street design), 2023[11]

The guidelines published by the Norwegian Public Roads Administration[12] cover all aspects of road and street design. Maximum gradients for cycle infrastructure are set out by requirement 4.2.1.2—3 and table 4.2.1.2—1. Acceptable gradients depend on the length of the slope. If one recalculates the values from the table to express the same requirements in terms of height difference:

- In urban areas, a gradient of up to 8% is only allowed for height differences up to 0.24 m. After that, a maximum of 5% is required.
- Outside urban areas, the maximum gradient is 8% up to 2.8 m height difference, 7% between 2.8 m and 7 m, and 5% above 5 m.

Additionally, gradients affect visibility requirements. For downhill slopes, longer stopping sight distances and larger visibility splays on crossings are required.

2.9. Poland

Document: **WR-D-42 Wytyczne projektowania infrastruktury dla rowerów** (Design guideline for cycle infrastructure), 2022[13]

The national guidelines discuss slopes in part 2, section 11 “Cycle route in a longitudinal section”. The section requires the gradients to not exceed 6%, and recommends to not exceed 2%, but allows exceptions up to 12%. It also recommends that the longitudinal slope of a cycle track should not be steeper than that of a parallel carriageway.

If it is not possible to ensure gradients below 6%, it is recommended to:

- Assume design speed at least 40 km/h,
- Increase the width by at least 25%
- Break the slopes with 25-meter-long flat sections at least every 5 m of height difference,
- Avoid the need to stop a cycle,
- Ensure the slope is lit.

[11] https://viewers.vegnorm.vegvesen.no/product/859984?langUI=nb&filePath=db01916d-d18e-4033-b9d7-bb5196bfce6e.pdf&fileType=Pdf
[12] Some larger municipalities, such as Oslo and Trondheim, have created their own, more ambitious guidelines.
[13] All guidelines: https://www.gov.pl/web/infrastruktura/wr-d; direct link to download part 2 of WR-D-42: https://www.gov.pl/attachment/2a5fc4ea-6b73-483f-b150-5f9923a62062

Figure 3. Świderska Street, Warsaw, Poland. The cycle ramp leading from a bridge ends on a crossing with a local road without good visibility splay and without clear priority established. Six car-cycle accidents have been registered on the crossing between 2014 and 2022.

2.10. Slovakia

Document: **Technické podmienky. Navrhovanie cyklistickej infraštruktúry** (Technical requirements. Cycle infrastructure design), 2019[14]

Gradients are discussed in section 4.2 "Longitudinal slope" of the requirements. The recommendation is to not exceed gradients of:

- 3% in flat terrain
- 6% in hilly terrain
- 8% in mountainous terrain

In case of a slope steeper than 3%, table 7 sets maximum lengths of slopes for different gradient values, from 200 m for 4% to 44 m for 8%.

In case of a slope steeper than 4.50%, the width needs to be increased by 0.25 m.

[14] https://www.ssc.sk/files/documents/technicke-predpisy/tp/tp_085.pdf

2.11. Spain (Catalonia)

Document: **Manual for the design of cycle paths in Catalonia**, 2008[15]

Section 3.1.4 of the manual introduces requirements for longitudinal inclinations. In most cases, 5% is the maximum gradient, but the manual allows steeper inclinations for limited length (listed in Table 7). In extreme cases, short gradients of 25% seem to be allowed, but it is not clear in what situations this exception applies ("Should there be a need to save an obstacle…"). Outside the table, further in the section, limits are set for longer continuous climbs – 2 km for more than 4%, and 4 km for more than 2%.

Gradients affect many other parameters required in section 3.1. For every 1% of the incline, design speed should be increased by 2 km/h. This affects curve radii and sight distances. For the stopping distance, an additional increase is needed to consider slower deceleration downhill. For example, where 35 m of stopping sight distance would be required on a flat section of a paved road, the distance increases to 60 m for 5% descent and 100 m for 10% descent.

2.12. UK

Document: **Cycle infrastructure design (LTN 1/20)**, 2020[16]

The Local Transport Note 1/20 on Cycle infrastructure design, issued by the UK Department of Transport and applicable in England and Northern Ireland, discusses the longitudinal gradient in paragraphs 5.9.7 to 5.9.10. Table 5-8 lists maximum lengths for gradients, from 150 m for 2% to 30 m for 5%. The requirements are rather limiting, translating to a maximum height difference of 3 m. For more significant height differences the guidance suggests breaking the slopes with level sections of a minimum 5 m.

For gradients of more than 3%:

- design speed needs to be increased to 40 km/h, which affects required curve radii and sight distance;
- unguarded hazards (e.g. fixed objects, steep drops or water hazards) should not be permitted within 4.5 m of the route where they would lie in the path of an out-of-control cycle;
- on signalled intersections intergreen timings need to be increased for uphill direction.

To achieve level of service 2 (Green), no section of the route should be steeper than 2%.

[15] https://llibreria.gencat.cat/product_info.php?products_id=2283, https://terra.bibliotecadigital.gencat.cat/bitstream/handle/20.500.13045/263/manual-design-cyclepaths-catalonia.pdf
[16] https://www.gov.uk/government/publications/cycle-infrastructure-design-ltn-120

3. Comparison of maximum gradients

Table 2 and Figure 4 present a comparison of maximum recommended / acceptable gradients in the function of the height difference to overcome. While different standards and guidelines might formulate the requirement differently (for example, in terms of slope severity or function of slope length) have been recalculated to be expressed in the same way for the analysis.

Table 2. Comparison of maximum gradients depending on the height difference to overcome across national and regional standards and guidelines.

Height difference [m]	Austria	Belgium/ NL good	Belgium/ NL max	Catalonia	Finland	France / Poland	Germany	Ireland[17]	Norway[18]	Slovakia	UK
1	12%	7.50%	10.0%	25%	5.50%	6%	10%	3%	8%	8%	5%
1.5	10%	5.00%	10.0%	25%	5.25%	6%	10%	3%	8%	8%	5%
2	10%	3.75%	10.0%	25%	5.00%	6%	10%	3%	8%	8%	4%
3	6%	2.50%	6.67%	10%	4.50%	6%	6%	3%	7%	8%	2%
4	6%	1.88%	5.00%	9%	4.00%	6%	6%	3%	7%	6%	0%
5	5%	1.75%	4.00%	9%	3.60%	6%	5%	3%	7%	5%	0%
6	5%	1.75%	3.33%	7%	3.30%	6%	5%	3%	7%	5%	0%
7.5	4%	1.75%	2.67%	7%	3.10%	6%	4%	3%	5%	4%	0%
10	4%	1.75%	2.00%	6%	3.00%	6%	4%	3%	5%	3%	0%
15	3%	1.75%	1.75%	5%	3.00%	6%	3%	3%	5%	3%	0%
20	3%	1.75%	1.75%	5%	3.00%	6%	3%	3%	5%	3%	0%
30	3%	1.75%	1.75%	5%	3.00%	6%	3%	3%	5%	3%	0%
50	3%	1.75%	1.75%	5%	3.00%	6%	3%	3%	5%	3%	0%
75	3%	1.75%	1.75%	5%	3.00%	6%	3%	3%	5%	3%	0%
100	3%	1.75%	1.75%	2%	3.00%	6%	3%	3%	5%	3%	0%

Across the analysed standards and guidelines, the UK comes as the most restrictive. Catalan guidance is the most lenient for short slopes, while French and Polish documents are least restrictive for longer climbs, exceeding the 10 m level difference.

The guidelines can be roughly divided into three main categories:

- Maximum gradient is set regardless of slope length/level difference: France, Ireland and Poland; in practice also Finland and Norway (in urban areas).
- Maximum slope severity: Belgium and Netherlands. In this approach, the maximum gradient is inversely proportional to the height difference to overcome.

[17] Desirable maximum 3%, absolute maximum 5%.
[18] Values for routes outside urban areas. In urban areas 5% is the upper limit with the exception of very low height differences (up to 0.24 m).

- In-between approach, with maximum gradient depending on slope length/height difference, but the dependency is weaker than in the case of slope severity. The maximum gradients in the guidelines from Austria, Catalonia, Germany and Slovakia seem to be roughly inversely proportional to the square root from the height difference.

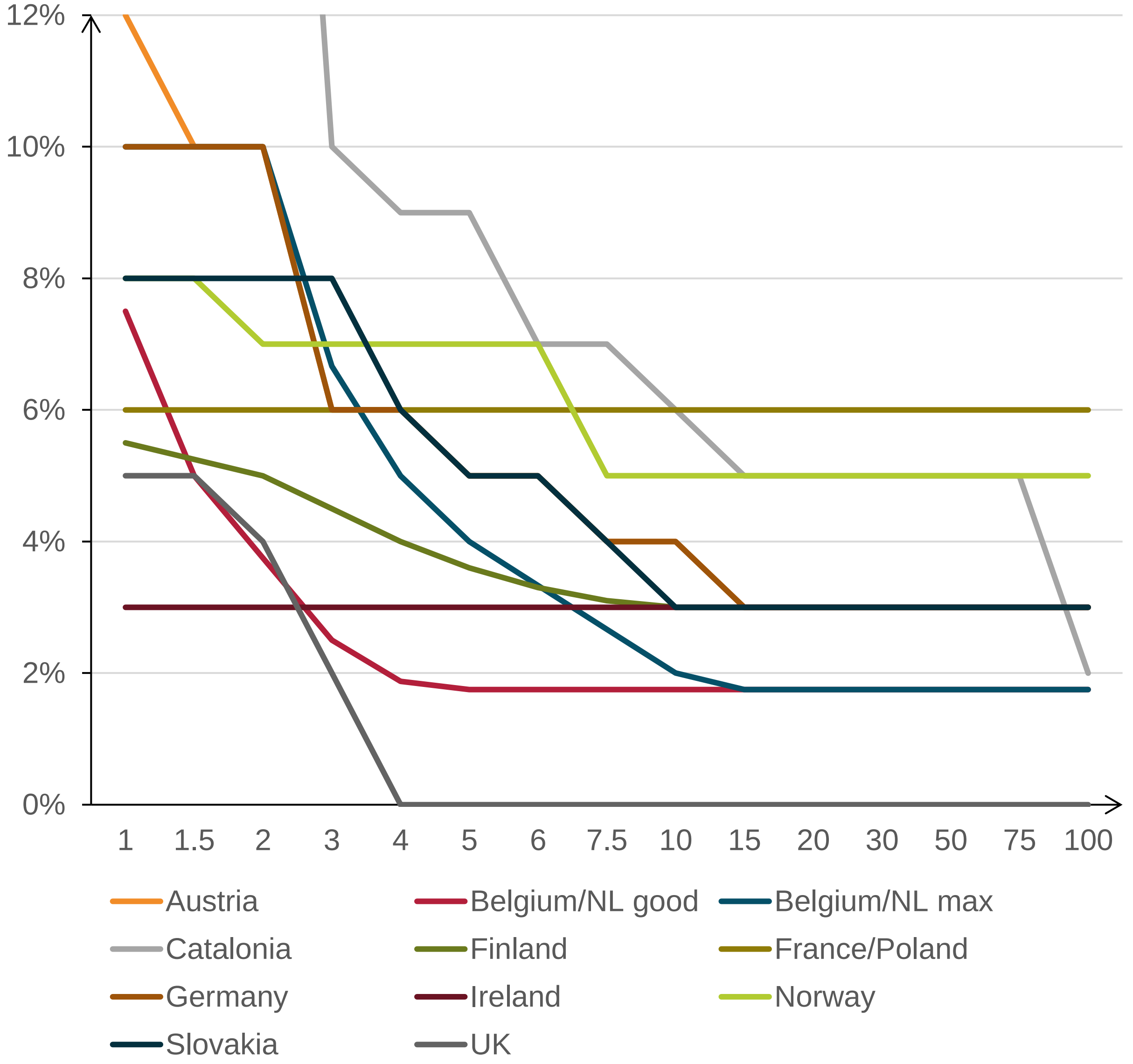

Figure 4. The maximum gradient in the function of height difference in meters across national and regional standards and guidelines.

4. Recommendations

Cycle routes should be planned in a way that minimises elevation changes. Slopes should be gentle enough to make it easy to:

a) cycle uphill without excessive effort,
b) stop in the downhill direction whenever the situation requires it.

While a short steep slope might be acceptable, the longer the climb or descent the gentler gradients are required.

Table 3 summarises recommended gradient thresholds for different categories of cycle routes in the function of the height differences to overcome. The same information is presented graphically in Figure 5.

- For basic cycle routes, the recommended maximum gradients are based on first quartiles (calculated for each height difference separately) of values from all the analysed documents (which means that 75% of standards require lower gradients for the same height difference).
- For main cycle routes, median values were used.
- For cycle highways, third quartiles from the analysed documents are listed as recommended.

Values in the table have been rounded to the closest 0.5%.

Table 3. Recommended maximum gradient values for different categories of cycle routes in the function of the height difference to overcome.

Height difference	Basic cycle route	Main cycle route	Cycle highway
1 m	10.0%	8.0%	6.0%
2 m	10.0%	7.5%	5.0%
3 m	7.0%	6.0%	5.0%
5 m	6.0%	5.0%	4.0%
7.5 m	5.0%	4.0%	3.0%
10 m	5.0%	3.5%	2.5%
15 m	4.5%	3.0%	2.0%
100 m and more	3.0%	3.0%	2.0%

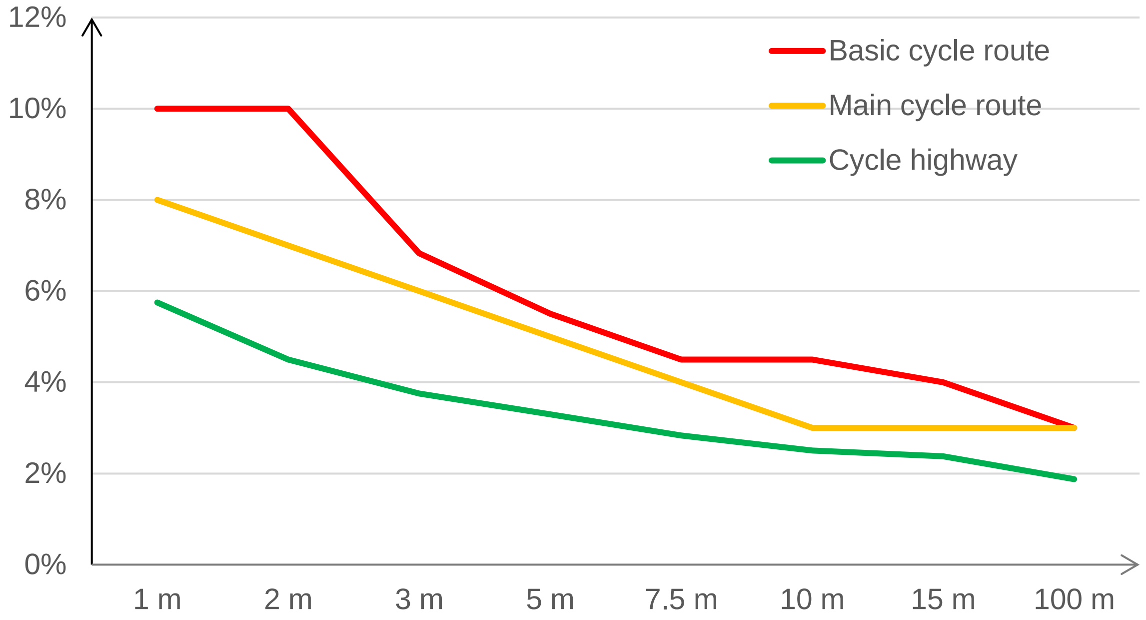

Figure 5. Recommended maximum gradient values for different categories of cycle routes in the function of the height difference to overcome.

Additionally, the following requirements or recommendations are recurring across different guidelines and standards:

1. On slopes with a gradient exceeding 3%:
   1.1. Infrastructure width should be increased by at least 0.25 m,
   1.2. A design speed of at least 40 km/h should be assumed and all the related geometric parameters, i.e. curve radii and sight distances[19], should be increased accordingly.
   1.3. Timings of traffic signals should be increased for cyclists travelling in the uphill direction.
2. No sharp curves, obstacles or crossings without priority should be located in the middle or at the bottom of the slope; a section of flat, straight cycle track is necessary to safely reduce the speed after descending the slope.
3. Level sections can also be used in between inclines to provide an opportunity to rest or reduce speed, especially if the height difference exceeds 5 m. The recommended length of such a level section varies between 5 and 25 m.
4. For grade-separated crossings, tunnels are usually better than bridges, as cyclists require less vertical clearance than a standard road or railway, and the cyclist can use the speed gained on the way down into the tunnel to facilitate climb on the other side. A bridge might be a better option if the road or railway is situated below the terrain level (because for example of noise protection).
5. There should be no sudden changes in gradient, which may cause "bumps" and crashes. The transition between flat sections and slopes, or between slopes with different gradients, should be designed with the use of vertical curves. See section

[19] https://ecf.com/files/reports/geometric-design-parameters-cycling-infrastructure

3 of "Geometric design parameters for cycling infrastructure"[20] for specific parameters.

Figure 6. The Hovenring cycle bridge over a major road intersection near Eindhoven, Netherlands. To reduce the elevation change for cyclists, the intersection of carriageways was lowered by 1.5 m. As a result, the ramps leading to the bridge have gentle gradients between 1.86% and 3.09%

[20] Ibidem.

Quality parameters for cycle infrastructure: longitudinal gradients

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A considerable effort has been made to ensure that the information presented is current and accurate. If outdated or incorrect information is brought to our attention, ECF will correct or remove it. Please also let us know if you would like to see other standards or guidelines added to the comparison or if you know about other relevant research that should be mentioned in the document.

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