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ERTMS USERS GROUP – ENGINEERING GUIDELINE

28. Gradient segmentation

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Table of Contents

1. Introduction

1.1 Foreword

1.1.1.1 The use of gradients by the on-board system is defined technically in chapter 3 of SUBSET-026 [1].

1.1.1.2 The actual gradient profile of a track must be split into segments, giving a gradient value for each segment (see SUBSET-026 [1], 3.11.12). The segmented gradient profile is used by the train for its braking curves calculation.

1.1.1.3 SUBSET-026 [1] also requires that the lowest gradient value underneath the train length must be taken into account (see SUBSET-026 [1] 3.13.4.2.1).

1.1.1.4 SUBSET-026 [1] chapter 3 does not describe how the segmentation shall be engineered. There are no rules linked to safety, performance or ergonomics.

1.1.1.5 The TSI CCS does also not describe any rules about measuring the gradient data.

1.1.1.6 The aim of this document is to provide a uniform method for the segmentation of gradients. The objective is to support an efficient and safe implementation of ERTMS, from a technical and operational point, simplifying and harmonising future system implementations taking advantage of the experience obtained from projects already in operation.

1.1.1.7 The aim of this document is also to provide information about the measuring method of gradient data.

1.1.1.8 This guideline is part of a bundle of guidelines with the Overall ETCS guideline [3] being the main guideline which will redirect the reader to the relevant guidelines. Be aware that the Overall ETCS guideline may also include recommendations which are related to the topics addressed in this guideline.

1.2 Scope and Field of Application

1.2.1.1 This document is based on ERTMS/ETCS Baseline 2 and 3 and applicable for ETCS Levels 1,2 and 3.

1.2.1.2 It is strongly recommended that any entity using ERTMS/ETCS follows the recommendations defined in this document.

1.2.1.3 Although not recommended, it is also possible to use the worst-case gradient on track section. This could lead to unnecessary longer braking curves and less performance.

1.2.1.4 This guideline is applicable for a trackside where the System Version is 1.Y or 2.Y.

1.2.1.5 This guideline takes into consideration the following on-board systems:

- On-board system with pure System Version 1.Y (i.e. they are not fitted with any other System Version)
- On-board system supporting System Version 1.Y and 2.Y, with active System Version 1.Y or 2.Y

1.3 Document structure

1.3.1.1 Chapter 1 introduces the document and defines the scope.

1.3.1.2 Chapter 2 provides references, terms and abbreviations used in this document.

1.3.1.3 Chapter 3 provides a list of issues to be considered.

1.3.1.4 Chapter 4 provides the guideline for gradient segmentation.

1.3.1.5 Chapter 5 provides the guideline for gradient data collection.

1.3.1.6 Chapter 6 provides detailed information

2. References and Abbreviations

2.1 Abbreviations

2.1.1.1 The following table includes acronyms and abbreviations which are used in the current document:

Abbreviation	Description
a	Acceleration
a_{brake}	Acceleration due to braking
a_{slope}	Additional acceleration due to the slope
DP	Danger Point
EBI	Emergency Brake Intervention
EOA	End of Authority
F	Force accelerating the train due to the slope
F_g	Gravity
G	Gravity constant, strength of gravitational field
GNSS	Global Navigation Satellite System
M	Mass of the train
S	Distance
SBI	Service Brake Intervention
SvL	Supervised Location
S_{12}	Distance between location 1 and 2
φ	Angle of the slope
v	Speed of the train
Δh	Height difference between 2 locations
δh	Height margin
δS	Distance margin

2.2 References

2.2.1.1 The following documents and versions apply:

Ref. N°	Document Reference	Title	Version
[1]	SUBSET-026	System Requirements Specification	2.3.0 (B2)

Ref. N°	Document Reference	Title	Version
			3.4.0 (B3 MR1) 3.6.0 (B3 R2)
[2]	SUBSET-040	Dimensioning and Engineering rules	2.3.0 (B2) 3.3.0 (B3 MR1) 3.4.0 (B3 R2)
[3]	22E087	Overall ETCS	1-

3. Issues to be addressed

3.1 Introduction

3.1.1.1 This chapter lists the issues that need to be considered for the segmentation of gradients and gradient data collection and most of them are further detailed in the recommended solutions given in chapter 4 and 5. The issues that are not part of the recommended solutions are mentioned here because projects may still need to consider them.

3.2 Issues gradient segmentation

3.2.1 Limitation number of gradient changes

3.2.1.1 SUBSET-040 [2] limits the number of gradient changes per packet to 31, with a minimum of 50 memorized by the train (see SUBSET-040 [2] 4.3.2.1.1 f)).

3.2.1.2 Using Level 1 with gradient information from balises the number of gradient changes per packet are furthermore limited by the maximum data size per balise group, which could be the limit for one balise if duplicated or switchable balise groups are used.

3.2.1.3 The segmented gradient profile is a simplified model of the actual gradient profile in the track and will therefore not be exactly the same. This error will result in over- or underestimation of the braking capability of the train.

3.2.1.4 An overestimation of the braking capability can result in overpassing a supervised location or exceeding a target speed.

3.2.1.5 Underestimation of the braking capability leads to a performance loss because the train starts braking too early.

3.2.1.6 Under- or overestimation can influence driver ergonomics, possibly leading to train trips or speed loss.

3.2.2 The segmented gradient profile shall be safe

3.2.2.1 The train shall not pass a SvL as a result of the gradient segmentation.

3.2.2.2 The train shall not exceed the allowed speed at the target location by more than an acceptable margin.

3.2.3 The segmentation shall have a minimal impact on the operational behaviour

3.2.3.1 There shall not be a brake intervention caused by underestimation of a downhill slope (leading to overestimation of the braking capabilities on that slope).

3.2.3.2 Because gradient information is shown on the DMI planning area, the actual track going up shall be presented as track going up on the DMI, track going down shall be presented as track going down on the DMI to anticipate speed decrease / increase.

3.2.3.3 If there is a roll away risk, e.g. at waiting tracks or along platforms, also information of small slopes shall be correct to advise the driver.

3.2.4 The segmentation shall not lead to performance loss due to braking too early

3.2.4.1 The braking distance shall not be extended more than required for requirement 1 and 2 by the segmentation of the gradients.

3.3 Issues gradient data collection

3.3.1 Balance between safety, performance and costs

3.3.1.1 There is a need to balance the safety and performance of the resulting system with the costs of collecting data.

3.3.1.2 Increasing accuracy will lead to increasing costs.

3.3.1.3 Underestimating the braking distance to a SvL due to inaccurate gradient data will lead to safety issues.

3.3.1.4 The supervision of the SvL is based on max safe front end so there is a margin of odometry error which gives a small buffer. There is also the fact that the EBI curve and associated SBI curve are conservative with a number of allowances for system reaction.

3.3.1.5 The driver is being provided with an indication and warning curve for the EOA (or SVL if the curves for that are more restrictive) so it should be considered that it is unlikely that a full intervention will be what decides when the train will stop.

3.3.1.6 However there are other factors which could use up any margins such as braking faults or low adhesion.

3.3.1.7 The measured data will not be the actual height measurements along the line. It will be within a probability distribution of those actual heights.

3.3.1.8 What has been measured is known and it can be confident that the actual is within the confidence interval of the measurements, but it is not know exactly where the actual is.

3.3.1.9 The more measurements are taken then the more opportunity there is to smooth the data or apply other statistical processes to get more confidence that the profile is correct and accurate even though individual measurements are not known to be.

3.3.1.10 The required SIL level of the measured data is to be determined based on project specific safety requirements.

3.3.1.11 The sample rate of the gradient data collection is to be determined based on project specific safety and performance requirements.

3.3.2 Managing measurement errors

3.3.2.1 The following questions should be checked:

- Could it be assumed that “random” errors are available on either side of the actual?
- Could a series of random errors (all the same side of the actual) mask a feature in the actual and introduce a risk?

- How much cumulative error (or drift) in the measurements would lead to a hazardous situation?

3.3.3 Measuring methods

3.3.3.1 The measuring method is to be determined based on the requirements on safety, requirements and costs.

3.3.3.2 Some known measurement techniques are:

- Use of ground surveying
- Use of fixed reference points
- Use of a measurement train
- Use of aerial surveying
- Use of DGPS (Differential Global Positioning System)
- Use of LIDAR (LIght Detection And Ranging or Laser Imaging Detection And Ranging)

4. Recommended solution gradient segmentation

4.1 Basic considerations

4.1.1.1 The expected benefit of the described rules is:

- No performance reduction due to the engineering of the gradients;
- The gradients shown on the DMI are resembling the actual slopes;
- No modification of the RBC needed.

4.2 List of rules

4.2.1 Rule I

4.2.1.1 In order to discuss the validity of the segmentation, the concept of ‘Virtual target height’ is introduced. This concept and its consequences are explained under chapter 6.1.

4.2.2 Rule II

4.2.2.1 The gradient value assigned to each gradient segment shall generally be the average gradient between beginning and end of the segment. This is generally safe, as is explained under chapter 6.2. Necessary exceptions are listed below in rules III till IX

4.2.3 Rule III

4.2.3.1 It is advised to start with an initial segmentation with only few segments,

- with its divisions at the local highs and lows of the track
- with the average gradient assigned to it

and then check the segmentation against the rules, listed below. If a rule is not met, the configuration must locally be adjusted.

4.2.4 Rule IV

4.2.4.1 Tracks are to be segmented in such a way, that the virtual target height from any possible approach distance where the gradients are of impact (EBD distance of the braking curve of the worst case allowed train) for any of the Supervised Locations is never higher than the actual height at this location. Chapter 6.3 explains the background of this rule. Exceptions are only acceptable under conditions listed under chapter 6.3.

4.2.5 Rule V

4.2.5.1 For all other locations than SvL’s, the virtual target height must not exceed the actual height more than 1 meter. The rationale behind this margin is explained under chapters 6.4 and 6.6. If a track or an infrastructure manager requires a different margin, this can be developed in a similar manner.

4.2.6 Rule VI

4.2.6.1 With the segmentation, the limitation described in SUBSET-040 [2] to the number of gradient segments within an MA or MA-message, must be respected. Specific

RBC's might have functionality to handle the limitations described in SUBSET-040 [2] or functionality to handle the gradient segmentation 'online' as a whole. Other RBC's might also introduce extra limitations for the gradient segmentation, like a maximum number of segment per RBC.

4.2.7 Rule VII

4.2.7.1 At specific locations, adjustments to the gradient segmentation can be made, to limit the negative consequences of clause 3.13.4.2.1 in SUBSET-026 [1], stating that the lowest gradient value underneath the train must be taken into account at every location. Examples of adjustments are given under chapter 6.5.

4.2.8 Rule VIII

4.2.8.1 To limit the number of gradient changes presented to the driver in the DMI planning area, the number of segments must only be as high as necessary to meet the rules above.

4.2.9 Rule IX

4.2.9.1 A positive slope shall be presented as positive (or flat) to the driver in the DMI planning area, a negative slope shall be shown as negative (or flat) to avoid confusing by the driver. Deviations are allowed for a short distance if the other rules are still met.

5. Recommended solution gradient data collection

5.1 Basic considerations

5.1.1 Introduction

5.1.1.1 It is possible to require a sample rate of the measurements. Some typical sample rates are 10m and 50m.

5.1.1.2 However, it could also be considered to define a limited deviation of the actual heights, without requiring a specific sample rate.

5.1.2 Managing measurement errors

5.1.2.1 It could be assumed that if each measured point is somewhere in a distribution centred on the actual then, provided that distribution is reasonably random, then simple smoothing techniques can be applied.

5.1.2.2 Since the ETCS profiles are “quantised” into 1:1000 units and it is acceptable to approximate subject to the error not exceeding 1m in height over the braking distance of a train and not being the “wrong side” of reality on approach to an SVL, then it seems that one does not need to be too precise.

5.1.2.3 It could be accepted that cumulative drift is not a real issue based on the likelihood that a series of errors the same side of the actual combined with any smoothing disguises a feature which would require a different ETCS profile and would affect the safety of the system.

5.1.2.4 GNSS Based measurements are not subject to drift. Measurement systems which combine inertial measurement sensors and GNSS combine the best of both worlds (Low noise on short distances and no drift on long distances). See Figure 1.

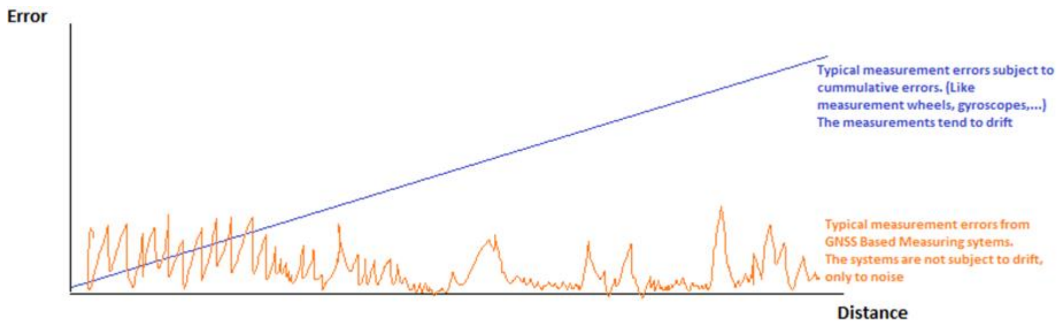

Figure 1: Example GNSS based measurement

5.1.2.5 It is more likely that it could disguise the location of the start of change in gradient. But over a typical braking distance of 1000m this is probably not significant.

5.1.2.6 The most likely things in the measured data are discontinuities – one off errors which are quite big, obvious and easy to discount – and random “noise” which simple smoothing can eliminate (if needed at all).

5.1.2.7 It should be considered to apply a simple smoothing algorithm to remove discontinuities e.g. more than a certain distance from the average of the measured heights either side.

5.1.2.8 It should be considered to not smooth “random” data.

5.1.2.9 It should be considered that a specific error range, typically +/- 50-75mm, with a broadly normal distribution is acceptable.

5.1.2.10 The justification is that it is unlikely that there will be three or more measurements both towards the wrong side of the actual (reporting higher) such that it could lead to an ETCS profile error of more than 1:1000 or the start of a segment being wrong by more than 100m.

6. Detailed information gradient segmentation

6.1 The concept of virtual target height and its consequences

6.1.1.1 An actual track height profile description usually consists of a chain of arcs and straights. For an ERTMS MA-description, this actual profile must be simplified to a chain of straights only, according to the rules described in SUBSET-026 [1]. Therefore, the simplified track description is different from the actual profile.

6.1.1.2 The differences can be expressed in several ways, as is shown in the Figure 2 below. At one specific location on the track, the local gradient in the segmented gradient profile can be different from the actual gradient at this location. The height difference between two locations within a segmented gradient profile is not the same as the actual height difference between these two points.

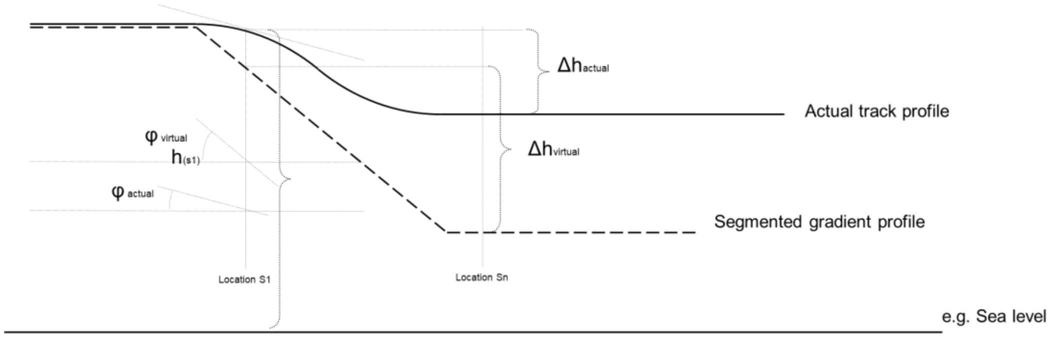

Figure 2: Actual track profile versus segmented gradient profile

6.1.1.3 Slopes and height differences have an impact on the braking distance of trains. In Figure 3 the effect of a slope on a train is given.

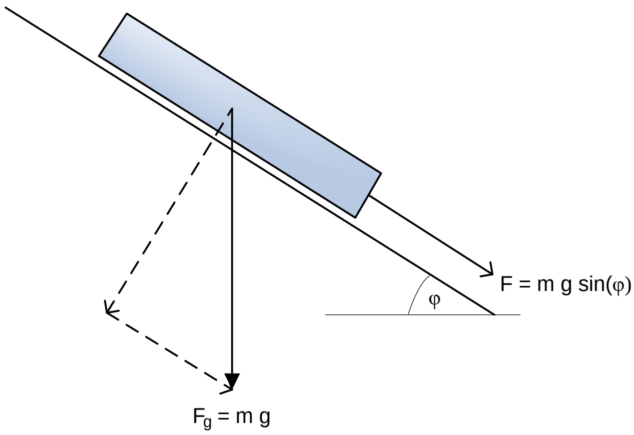

Figure 3: Influence gravity on a train

6.1.1.4 The gravity results in an additional force downhill on the train. The extra acceleration a_{slope} (or deceleration) as a result of the slope is

- $a_{slope} = g * \sin \varphi$

6.1.1.5 For small angles $\sin \varphi \approx \varphi$, so the slope can be approximated as

- $a_{slope} \approx 9{,}8 * \varphi$

6.1.1.6 The gradient of the slope is the tangent of the angle, and for small values of the angle, tan φ ≈ φ. If φ is expressed in ‰, and using gradient = tan φ ≈ φ, the approximation of the slope simplifies to

- a_{slope} = = 9,8 * gradient

6.1.1.7 A train experiences g * $φ_{actual}$, but the train expects g * $φ_{virtual}$.

6.1.1.8 Expressed in terms of energy: The total kinetic energy consists of the kinetic energy of the horizontal movement and the kinetic energy of the rotating mass.

- $E_{kinetic} = ½mv^2 + ½Jω^2$

This can be rewritten by using ω = v/R and the dynamic mass (m_dyn= m + J / R^2) and:

- $E_{kinetic} = ½mv^2 + ½J (v/R)^2$
- $E_{kinetic} = ½* (m + J/ R^2)* v^2 = ½*m\_dyn* v^2$

If there are height difference the potential energy also changes

- $E_{potential} = m*g*Δh$.

The braking energy can be written as

- $E_{brake} = m\_dyn*a_{brake}*S$

When braking the energy conversion between start and end is

- $E_{kinetic} + E_{potential} = E_{kinetic} + E_{potential} + E_{brake}$

Due to the segmented gradient profile a train experiences $m*g*Δh_{actual,}$ but the train expects $m*g*Δh_{virtual}$.

6.1.1.9 The virtual target height is the height at location S1 plus the virtual height difference from all segments between location S1 and target location Sn on that track, calculated with the (partial) length (S_m) and the gradient value ($φ_m$) of the gradient segment parts between S1 and Sn.

- $h_{virtual\ (S1,Sn)} = h_{(S1)} + Δh_{virtual(S1,Sn)} = h(_{S1}) + \sum_{(m=1..n)} (φ_m * S_m)$

6.2 Why average gradients are better for performance and safety.

6.2.1.1 Clause 3.11.10.3 in version B2 of SUBSET-026 [1] stated that each gradient segment must be assigned the value corresponding to the worst-case actual gradient within the segments track. Therefore, technically Rule II of the gradient segmentation is not in line with the Baseline 2 specifications, which force to use the lowest value of the gradient between two locations. This clause is removed in version B3 MR1 of SUBSET-026 [1], but the issue should be addressed to ensure a good solution for gradient segmentation. Figure 2 shows a situation where this rule was applied. Following this rule, most slopes will be presented to the trains as being 'more downhill' than the actual track is and this means that the train will underestimate its local braking capability, asking for earlier braking, leading to performance loss.

6.2.1.2 Taking the worst-case gradient is not necessary for safety as braking distance is calculated with the following equations according to the formula for uniform acceleration:

- $s = (v_1^2-v_2^2) / 2 * a$, or: $(v_1^2-v_2^2) = 2 * a * s$

6.2.1.3 By introducing the deceleration due to the brake force (see Figure 4), the equation can be rewritten as:

- $v_1^2 - v_2^2 = 2 * (a_{brake} + a_{slope}) * s$

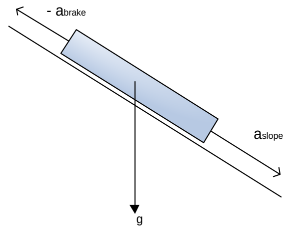

Figure 4: Impact slope on braking

6.2.1.4 The equation indicates that the change in speed depends on the distance and gradient. The calculation can be split into smaller speed changes over smaller distances:

- $v_1^2 - v_2^2 + v_2^2 - v_3^2 + .. +v_{n-1}^2 - v_n^2 = 2 * a_{brake} S_{1..n} + 2*\Sigma_{(m=1..n-1)} (a_{slope\_m} * S_m)$

6.2.1.5 This shows that the braking distance is independent from the subdivision of the shape of the track profile. The sum of the height differences divided by the sum of the track lengths leads to an average gradient.

6.3 Risk of underestimating slopes close to Supervised Locations.

6.3.1 Introduction

6.3.1.1 Figure 5 below shows a situation in which the local actual gradient near a SvL is steeper downhill than the average gradient in the gradient segment.

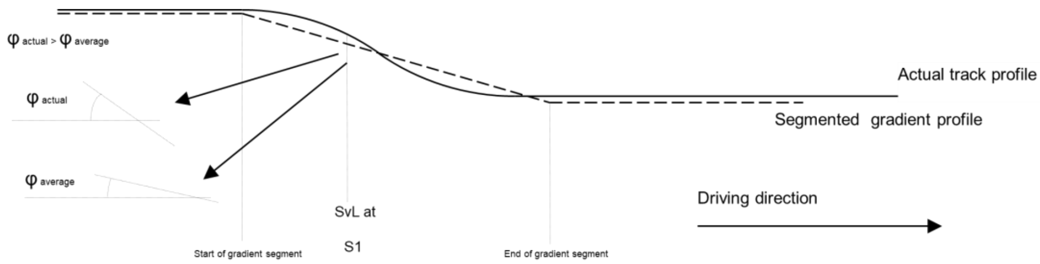

Figure 5: Situation near SvL

6.3.1.2 While the train is still at a longer distance from the SvL at S1, the virtual target height of the SvL is slightly below the actual height of the SvL. From this distance, the influence of the slope will be slightly overestimated, leading to a safe braking curve calculation. However, if the train is close to the SvL, the actual slope is steeper downhill than the gradient presented to the train. At close range, this may lead to an underestimation of the potential energy to be dissipated with braking, therefore to overpassing the SvL. This is not allowed. For this reason, the virtual target height of a SvL shall be equal to or lower than its actual height, calculated from any possible approach distance where the gradients are of impact. This is the EBD distance of the braking curve of the worst case allowed train.

6.3.2 Exceptions

6.3.2.1 Under certain conditions, the virtual target height of the SvL can be higher than the actual height. This is only allowed if there is a distance between the defined SvL and the actual danger point.

6.3.2.2 The allowed margin for the virtual target height depends on the length beyond the SvL that is still considered safe. While the allowed margin is small, it can be assumed that the brakes will be fully applied at the moment the SvL is passed.

6.3.2.3 The allowed margin δh can be calculated with the following equation:

According to the law of conversation of energy added to the train when going from height h_1 to height h_2 is converted in linear forward motion and brake energy:

- $\frac{1}{2}$ m_dyn v_1^2 + m g h_1 = $\frac{1}{2}$ m_dyn v_2^2 + m g h_2 + m_dyn a_{brake} S

By rewriting the law of preservation of energy equation including the allowed margin δh and available additional braking distance δS:

- $\frac{1}{2}$ m_dyn v_1^2 + m g h_1 = $\frac{1}{2}$ m_dyn v_2^2 + m g (h_2 + δh) + m_dyn a_{brake} (S+δS)

By simplifying using $v_2 = 0$ and $h_1 = 0$ and comparing situation without margin and with margin using the same start speed and height the margin can be calculated

- $\frac{1}{2}$ m_dyn v_2^2 + m g h_2 + m_dyn a_{brake} S = $\frac{1}{2}$ m_dyn v_2^2 + m g (h_2 + δh) + m_dyn a_{brake} (S+δS)
- m g h_2 + m_dyn a_{brake} S = m g (h_2 + δh) + m_dyn a_{brake} (S + δS)
- 0 = m g δh + m_dyn a_{brake} δS
- -δh = m_dyn/m * δS * a_{brake} / g

6.3.2.4 With δS as the available extra distance in meters, a_{brake} as the deceleration rate for the worst braking train expected or allowed on the track and m_dyn/m is the rotating mass factor.

6.3.2.5 To calculate a safe margin the worst-case situation for the possible rotating mass should be used. This is the “Minimum possible rotating mass as a percentage of the total weight of the train” of 2%, as defined in SUBSET-026 A3.1 [1]. Therefore, m_dyn/m = 1,02/1 = 1,02.

6.3.2.6 Example:

if 10 meters are available beyond the defined SvL, the expected worst case train brakes at 0.5 m/s^2, the allowed margin for the virtual target height is 1,02 * 10 * 0.5 / 9.8 ≈ 0.5 m.

6.3.3 Measuring inaccuracies

6.3.3.1 Distance between SvL and danger point can either be already available (e.g. due to a standard distance between signal and track section division, if SvL=EOA) or can be created by purposely configuring the SvL a bit in rear of the identified Danger Point.

6.3.3.2 Allowing a margin in the virtual target height can be useful to solve local segmenting difficulties. It is also helpful to compensate for the measuring inaccuracy of the track heights.

6.4 Virtual target height margins at other locations than SvL's

6.4.1.1 At other locations than the SvL's, targets can only be speed targets higher than 0 km/h. Local underestimation of slopes can lead to relatively small overspeeding over a small distance.

6.4.1.2 As a result of height difference the speed of the train will increase. According to the law of conversation of energy all energy added to the train when going from height h_1 to height h_2 is converted in linear forward motion

- $½\ m\_dyn\ v_1^2 + m\ g\ h_1 = ½\ m\_dyn\ v_2^2 + m\ g\ h_2 + m\_dyn\ a_{brake}\ S$

6.4.1.3 The increase in speed δv can be calculated by using

- $\delta v = v_2 – v_1$ and $v_1 = v_{target}$; $v_2 = v_{target} + \delta v$
- $\delta h = h_2 - h_1$

Rewriting the law of conversation of energy

- $½\ m\_dyn\ (v_1^2 - v_2^2) = m\ g\ (h_2 - h_1) + m\_dyn\ a_{brake}\ S$
- $½\ m\_dyn\ (v_{target}^2 – (v_{target} + \delta v)^2) = m\ g\ \delta h + m\_dyn\ a_{brake}\ S$

By introducing $\rho = m / m\_dyn$ the formula can be rewritten

- $½\ (v_{target}^2 – (v_{target} + \delta v)^2) = \rho\ g * \delta h + a_{brake}\ S$

6.4.1.4 The relation between the allowed virtual target height and the overspeeding δv is given in the following equation:

- $\delta h = (½\ (v_{target}^2 – (v_{target} + \delta v)^2) – a_{brake}\ S) / (\rho * g)$.

6.4.1.5 If the target speed is higher, the overspeeding is smaller.

6.4.1.6 If the virtual target height is 1 meter above the actual height, thus between h_1 and h_2, there is 1 meter additional height difference, the overspeeding of a target speed of 80 km/h is 1.6 km/h. At 40 km/h it's approximately 3 km/h.

6.4.1.7 This is visualized in Figure 6 below with v_{target} and δv:

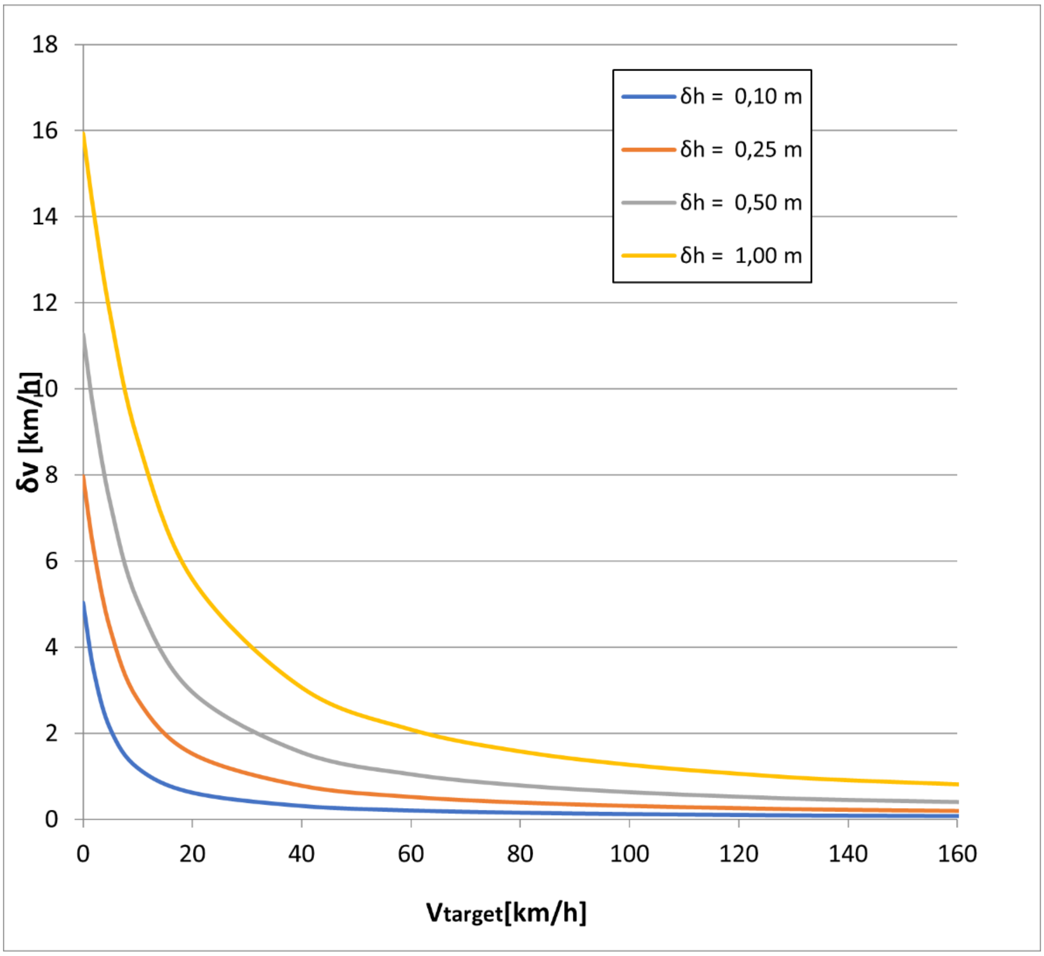

Figure 6: Overspeed as a function of the target speed for different virtual target heights

6.4.1.8 The advised virtual height margin of 1 meter is based on an expected lowest speed of 40 km/h. This leads to a maximum overspeed of 3 km/h. This is assumed acceptable, because of three reasons:

1) The 3 km/h is in line with the allowed overspeeding at warning speed. This can only be an intuitive justification, because a margin may not just be used for other reasons than where it was meant for. And besides, the braking model in Baseline 3 already aims the EBD at a speed, higher than the nominal speed.
2) The distance over which the overspeeding occurs is limited. The extra braking distance necessary, can be calculated with $\delta h = S * a_{brake}/g$. For an assumed worst case train with 0.5 m/s^2, this is 20 meters, in which the overspeed is reduced gradually. Considering that speed restriction often have intrinsic margins for speed and starting location, the virtual target height margin of 1 meter is considered acceptable.
3) The overspeeding occurs within the actual deceleration curve (compare to EBD). Generally, speeds will already be limited well in rear of the target location, due to other curves (i.e. intervention and permitted). Actual overspeeding will not only be limited in speed and distance but will also be rare. Considering that most speed restrictions are based on comfort

and maintenance and not directly on safety, the small chance of overspeeding is acceptable.

6.4.1.9 If a different margin is needed, generally or for a certain track, this can be calculated in a similar manner, but based on other requirements. E.g. another overspeed margin and other assumed worst-case train.

6.4.1.10 If no overspeed is acceptable at speed changes, these targets can be given the same requirements as SvL when it comes to virtual target height, see chapter 6.3.

6.4.1.11 Generally, it is assumed that every location can become a speed target location, because of Temporary Speed Restrictions. If TSR's are preconfigured or limited to certain locations, the virtual target height requirement needs only to be checked at the specific locations from any possible approach distance where the gradients are of impact. This is the EBD distance of the braking curve of the worst case allowed train.

6.4.1.12 However: then ergonomical issues might arise, see chapter 6.6. Therefore, the rule applies to every location.

6.5 Examples of segmentation adjustments

6.5.1.1 If not all rules are met, the basic gradient segmentation must be adjusted until it fits. Adjustments can consist of:

- Altering the gradient value for a segment
- Moving a gradient segment division
- Adding a gradient segment division (splitting a segment)
- Adjusting the configuration for SvL or adjusting the speed profile.
- Joining segments

6.5.1.1.1 Note:

- There's no direct necessity for rounding down of the average gradient value to the nearest integer value. Rounding up can be acceptable as well, as long as rules are met.
- Locally a deliberate underestimation of the gradient value might be acceptable, but is not advised. The expected performance benefit is generally very low.
- The braking model within the train (as defined in Baseline 3), takes the worst-case segment gradient underneath the whole train, as the gradient to calculate the braking curve with. This has a strong negative effect on the braking curves and may locally lead to train being stranded at steep uphill slopes if there is a speed restriction shortly beyond it.
  Because this rule is an unnecessary conservative safety assumption about the worst-case weight distribution of the load a CR 874 is raised on this issue.
  To limit this negative effect within the current rules, short steep segments may be altered into longer but less steep segments.

6.6 Braking interventions due to underestimation of slopes

6.6.1.1 Braking curves are calculated, based on the segmented, virtual gradient profile. Among the calculated curves are the permitted curve, the warning curve and an intervention curve. Assuming that the train follows a permitted braking curve, underestimation of slopes may temporarily lead to a speed which is higher than the permitted speed. This may possibly lead to an audible warning or even an intervention. For ergonomical reasons, this is not allowed (see Rule II).

6.6.1.2 If the difference between virtual target height and actual height never exceeds 1 meter, as stated in Rule V, an undue intervention will not occur. Therefore, an extra rule is not necessary. The second ergonomical requirement (uphill tracks being presented as going up, downhill as going down), is basically met by following Rule III.