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Railway applications — Technical Report about the revision of EN 14363

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National foreword

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Applications ferroviaires - Rapport technique de la révision de la norme EN 14363

Bahnanwendungen - Fachbericht zur Überarbeitung der EN 14363

This Technical Report was approved by CEN on 12 January 2017. It has been drawn up by the Technical Committee CEN/TC 256.

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European foreword

This document (CEN/TR 17039:2017) has been prepared by Technical Committee CEN/TC 256 "Railway applications", the secretariat of which is held by DIN.

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1 Scope

EN 14363 contains a lot of requirements which were modified during the last revision. The scope was also extended. It was found in the working group, that many decisions that were taken to formulate these modifications need to be documented to improve understanding and to allow a later further development if practice of applications shows the necessity. The work for the revision was organised in 8 subgroups. Many of these subgroups recorded the way to the proposals in reporting templates, which were used for the editing work. Afterwards discussion was ongoing in WG 10 and in the enquiry process. This available information needs to be summarised and presented in a common format in order to allow people not involved in the discussions to understand the background of the modifications.

2 Members of the different drafting groups for the revision of EN 14363

Bold **X** means group leader Normal X means group member	8.1 Editing	8.2 Test Conditions	8.3 Track Quality, Contact Conditions	8.4 Special vehicles	8.5 Stationary Tests	8.6 Simulation, Extension of acceptance	8.7 Track Loading	8.8 Ride Characteristics
HS (DE)	X	X		X	X		X	**X**
SZ (DE)	**X**	X				**X**		
MW (SE)		**X**	X	X		X		
BE (UK)			**X**			X		
PD (FR)		X	X	**X**			X	
AC (UK)	X	X			**X**	X		X
JS (AT)		X	X		X	X	**X**	
VB (FR)		X				X		
AB (FR)					X			
VB (DE)		X				X		
JC (FR)		X						
OC (FR)							X	
RD (FR)								X
HG (NO)		X	X				X	
AH (AT)		X	X				X	
TH (CZ)					X			X
M J (UK)				X				
AK (AT)						X		
TK (DE)		X	X		X			X
RK (DE)					X	X		X
NK (IT)			X			X		
DL (FR)		X			X		X	

Bold **X** means group leader Normal X means group member	8.1 Editing	8.2 Test Conditions	8.3 Track Quality, Contact Conditions	8.4 Special vehicles	8.5 Stationary Tests	8.6 Simulation, Extension of acceptance	8.7 Track Loading	8.8 Ride Characteristics
JÖ (SE)							X	
MO (UK)					X			X
OP (CH)		X	X		X	X		
UR (CH)		X					X	
AS (CH)		X						
RW (UK)		X		X				
MZ (DE)			X		X		X	

3 Changes to the scope

3.1 Scope extension

The standard was further developed from a pure collection of test specifications to a description of the process for assessment of running characteristics. In addition, it also contains specifications on an informative basis not necessarily to be used for the acceptance process.

The new process also includes the use of simulations. The requirements were further developed starting from the requirements specified in UIC 518:2009 and EN 15827 and refined in discussions inside WG 10 and its relating subgroups and in a second step by the DynoTRAIN research project.

The scope was extended to freight vehicles with nominal static vertical wheelset forces up to 250 kN (previously handled in EN 15687). Also the inclusion of vehicles intended for operation with cant deficiencies above 165 mm (previously handled in EN 15686) was covered by the new requirement to specify the combination of admissible speed and admissible cant deficiency. Additionally the loading conditions for the assessment have been defined more precisely.

Further a hint to a set of recommended values for admissible cant deficiencies to be chosen for broad international approval was included. It replaces the fixed requirements made for conventional vehicles in the previous version of the standard.

In order to close the open points in the Rolling Stock TSIs about track geometric quality and the achievability of the combination of the specified test conditions during on-track tests, the concept of defined target test conditions and the assessment of achieved test results against target test conditions was developed.

Further, it needed to be stated that the standard also contains quantities and dependencies that are not directly used for acceptance purposes, but for example for purposes of validation of simulation models or determination of operating conditions outside the reference conditions.

3.2 Limitation

In order to prevent misuse of the standard for non-railway and non-standard gauge vehicles, it was better described what needs to be considered when using it “by analogy” for such vehicles.

To clarify the limits of the scope, it was stated that the strength of the vehicle and mounted parts, passengers and train crew vibration exposure, comfort, load security and effects of cross wind are out of the scope of this standard – as well as the quantification of track deterioration or track fatigue.

3.3 Clarification

It was found that the old wording needed clarification: "Testing for acceptance of vehicles is based on some reference conditions of track. If these are not respected on certain lines, appropriate measures will be taken (speed modifications, additional tests, etc.)."

The discussion in WG 10 showed that it was not possible to specify the underlying reference conditions by exact boundaries. The only way for clarification was to:

— state that all vehicles which were successfully assessed are able to be operated on tracks complying with EN 13803;

— describe the current state of the art in order to allow the EIM (European Infrastructure Managers) to continue to use their implemented process for operation under demanding track conditions in the future (for example on lines with curve radii below 250 m).

This includes two notes explaining why vehicles can also be operated safely outside the target test conditions. A third note clarifies that the methods of this standard may also be applied to determine operating rules under infrastructure conditions that are more severe than the target test conditions.

In this context, it was also stated that the document contains target test conditions for the geometric track quality, as they have been adjusted compared to the previous version of the standard.

As the target test conditions for stability testing were changed with respect of the target conditions of the TEN (Trans European Network), it was necessary to clarify, that the equivalent conicity to be included in the stability assessment might be higher in some national systems for the time being before the infrastructure target conditions are met. In this context, it was found necessary to state in a note that such national requirements do not necessarily have to include the maximum occurring values of equivalent conicity. This makes it possible to find practical test conditions and it reflects also testing at overspeed and that vehicles assessed as stable are in most cases far below the limit values.

3.4 Shifted to other sections

The allowances

— to deviate from the rules laid down if evidence can be furnished that safety is at least the equivalent to that ensured by complying with these rules and

— of variations from the defined conditions as specified by the article 7.1 of Directive 91/440 of EC which were stated in the scope of the 2005 version are now described more detailed in a separate clause (4). It is now stated that in case of deviations, these shall be reported, explained and taken into account when assessing the safety.

4 Fault modes

4.1 What was changed?

The explicit requirement on testing with deflated air springs was removed.

A new subclause 5.2.2 "Fault modes" and a new subclause in Annex T (Simulation of on-track tests), T.2.5 (Investigation of dynamic behaviour in case of fault modes) was introduced.

4.2 Why was it changed?

When testing with deflated air springs was introduced in UIC 518, air springs were a relative novelty in railway vehicles. Since then much experience has been gained and they are now very common and it was felt inappropriate to specify a test for the specific fault mode of deflated air springs, while many other possible fault modes were overlooked, such as faulty yaw dampers or failing active components.

In EN 14363:2005 faulty yaw dampers were also specifically mentioned in parallel to deflated air springs. A more open approach was also indicated in EN 14363:2005, this idea is further developed in the present revision of EN 14363.

It was therefore appropriate to further develop the writing in EN 14363:2005 and require a similar – more open – methodology for dynamics assessment. It is impossible in a standard like EN 14363 to foresee every possible relevant fault mode to assess since these will differ from vehicle to vehicle. Also, the technical development makes it necessary to adopt a methodology that can be used for future systems not known today.

It was not clear in EN 14363:2005 at what speed fault modes were to be tested, also not what test extent to apply. Therefore, a large variation of testing practice has evolved from country to country making it more difficult to follow a principle of testing in one country for acceptance in many.

With the introduction of simulations, it was also necessary to define under what conditions simulations can be used to assess fault modes.

Some important principles were clarified:

— Due to probability reasons, assessment of a fault mode is limited to running safety parameters, speed up to V_{adm} and cant deficiency up to I_{adm}.

— Independent fault modes shall be tested/ simulated independently, unless the analysis points out the combined fault is necessary to be assessed.

— The safety factor λ does not need to be derived for fault modes, see U.2.

4.3 Comments raised in the CRM process and how they were addressed

In the comment phase there were discussions, not on the principles but on the writing to make it clear yet open enough for its purpose.

The comments revealed concerns that the new approach would lead to requirements for additional testing which was not the intention. The intention was only to provide a framework to assess the relevant fault modes which may not be the same for each and every vehicle type.

To handle these concerns, modifications were made, where one of the most important changes was to clarify that potentially catastrophic failures of conventional mechanical parts are managed by the design and maintenance regime of the vehicle, and hence do not need to be additionally assessed.

5 Load conditions for testing

There were a number of different references to loading condition which were not consistent and clearly enough specified in the 2005 edition. It was concluded that for clarity, loading definitions used in EN 15663 would be the reference load cases, but where the loading conditions specified in EN 15663 are inappropriate then details for specific loading cases will be given where these apply. This is particularly the case with extreme loads. Testing in the context of EN 14363 does not relate to extreme cases, nor has it been used in the corresponding tests prior to the introduction of EN 14363 in European rail administrations. As a result, the test loading conditions to be used apply the relevant normal loading for the operation of the tested vehicle.

Another aspect was that extreme conditions could lead to outliers in the statistical sample that cannot be handled by the statistical approach of EN 14363.

Further it was agreed that the load cases to be used for stationary and on-track testing should be as consistent as possible and that for some tests not all of the load conditions need to be investigated.

For long distance and high speed trains without obligatory seat reservation it was found inadequate to test them only with occupied seats. Therefore, the load case “Design mass in working order” was adjusted by taking into account 2 P/m^2 in standing areas. It was found that this was already state of the art.

SNCF members of WG 10 explained, that vehicles for RER in Paris were always tested in a loaded condition taking into account up to 700 kg/m^2 in standing areas, referring to EN 15663:2009, 6.2. WG 10 decided that in future and if necessary, such a case should be handled as a notified national technical rule (NNTR). This will remove the possibility of uncertainty about when extreme loads are required to be considered and under which circumstances they are to be applied.

For handling the necessary fuel consumption during testing, some practical rules were specified, assuming that they will not be used to influence test results systematically. For locomotives, that normally have big fuel tanks, it was taken into account that measured values of track loading might vary too much if the full range of fuel consumption is used during testing. Therefore, the acceptable range was restricted to the upper third.

Another practical rule was created to specify the handling of loads that can be collected and/or distributed or spread along the railway track during operation.

The definitions of the load cases “empty” and “loaded” were concentrated in subclause 5.3.2 giving common rules for all tests described in EN 14363.

6 First stage assessment

6.1 General

In the 2005 edition, this topic was covered by Clause 4 'Stationary tests'. Concern was expressed that since some of the tests specified in the chapter were not in fact stationary but included movement of the test vehicle the title could therefore cause some confusion. As a result the title became the subject of much discussion, a suggestion to change the name to 'quasi-static tests' was rejected because this could also cause confusion since the term 'quasi-static' does not translate from English directly into other languages. As a result, the title of the clause was changed to 'first stage assessment' to reflect that generally the assessments that are identified in this chapter are carried out on a vehicle before the on-track testing is carried out.

The term assessment has been adopted to recognise that it is not always necessary to carry out physical tests to demonstrate the performance of a vehicle. In certain circumstances that are defined in the text of the clause, other means of demonstration of the performance is possible.

6.2 Safety against derailment on twisted track

Before the introduction of internationally accepted approval, the various approvals were carried out by each national authority. This process was generally carried out by the national railway. There was concern that a proper definition of the testing conditions did not exist, e.g. details such as tolerances on track gauge, track curvature etc. This was particularly so with the inclusion of additional institutions, who had not previously carried out these tests but were now permitted to perform the testing. A definition of the test conditions was therefore required. After inquiries with the railway test bodies, where they still existed, it became clear that there was no definitive definition of the test conditions that had historically been carried out, either arising from the UIC tests or for national requirements. In addition, the tests carried out in the past did not include records of the actual test conditions of the track, such as track gauge, deviations from the 'nominal' values of track curvature or installed cant. As a result the current text does not define limits to be applied, but does require the track conditions to be recorded in the future. When sufficient data are available, it is the intention to specify limits that shall be applied that are both practical and relevant.

There was some confusion about the compatibility of the test conditions for each of the three test methods in the 2005 edition, the coefficient of friction was not consistent between the methods. The reason for the difference could not be determined although the three methods all derive from the original work carried out within the ERRI B55 project. As a result of the possible misinterpretation, it has been made clear that each method shall be considered separately.

As with the definition of track condition, investigations were carried out to determine the signal processing that had been applied to data recordings in the past. No information could be found about what processing was applied and so nothing could be specified with any confidence, again the processing that is applied in future test is required to be recorded with the intention that when sufficient data is available requirements will be formulated.

Method 1 as defined in the 2005 edition has caused some confusion. The requirements included a double requirement, with both the Y/Q limit and the flange climb wheel lift limit Δz, specified as acceptance criteria. This has been changed by removing the Y/Q limit with the Δz remaining as the acceptance requirement. However, the requirement is to record the Y/Q value during the tests, although this is not an acceptance criterion.

With current techniques it is not credible to analyse the interface conditions that influence the Δz value with certainty and so it is not permitted to carry out analysis of any changes to a vehicle that could affect Δz value. As a result any vehicle that differs from the tested vehicle shall be retested.

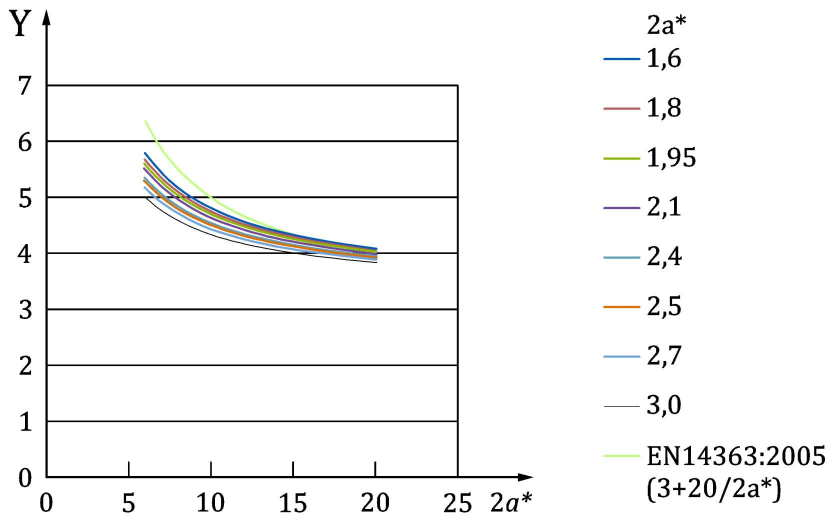
However, it is possible by using the recorded Y/Q values to analyse both the originally tested vehicle's performance and the performance of a vehicle that has undergone a change to the significant parameters of a vehicle using the method 2 criteria.

Method 2 now recognises that in the event of a change to a significant parameter of a vehicle (such as change in vertical stiffness) a vehicle type that has been previously accepted using method 2 can now be analysed to assess the effect of the change. The analysis can be made by comparing the performance of the original vehicle with that of the changed vehicle.

Method 3 In the 2005 edition, the twist criteria for the test was intended to be identical to that used in method 1, to maintain a consistent test condition. This resulted in a different test condition compared to the original criteria for method 3 which is defined in the GB RSSB document GM RT 2141.

A comment (GB 792) proposed to relax the bogie test twist of method 3 from 7 ‰ to 6,67 ‰ in order to be consistent with the origin of the requirement (GM/RT 2141, issue 3). A detailed analysis showed, that the original application of GM/RT 2141, issue 3, leads to a vehicle twist depending also on the bogie wheel base $2a^{+}$:

$$g_{GMRT}^{*} = 3{,}33‰ + \frac{3{,}33‰ \cdot \left(6m - 2a^{+}\right)}{2a^{*}}$$



Key

Y vehicle test twist in mm/m

2a* running gear distance in m

Figure 1 — Vehicle test twist as a function of vehicle dimensions

As this is lower than or roughly equal as the vehicle test twist specified in EN 14363:2005 (see Diagram) $g^*_{EN} = 3‰ + 20\,\text{mm} / 2a^*$, it was decided, to keep the vehicle test twist specification from EN 14363:2005 in combination with the slightly relaxed bogie test twist from GM/RT 2141 as it was proposed by the comment. Compared to the twist conditions of method 1 and method 2 this test condition remains roughly equal or more demanding, depending on the geometry of the vehicle to be tested.

To fit the two curves for bogie twist and vehicle twist, the limitation for the application of 6,67 ‰ needed to be increased from 5 m to 5,45 m.

6.3 Safety against derailment under longitudinal compressive forces in S-shaped curves

The tests referenced in this chapter, and detailed in EN 15839, reflect the requirements developed in the UIC leaflet 530-2. The reference has been changed from UIC 530-2 to EN 15839 and EN 14033-1 for special vehicles.

6.4 Evaluation of the torsional coefficient of a car body

This evaluation has been included since it is relevant to the tests for safety against derailment under longitudinal compressive forces in S-shaped curves and some of the tests for safety against derailment on twisted track. It was derived from ERRI B12/DT 135, Annex E and was refined in order to remove the influence of the roll moment from the results.

6.5 Determination of displacement characteristics

This chapter replaced the subclause 4.3 “Sway characteristics” in EN 14363:2005. This replacement and the inclusion of this evaluation has been made in conjunction with CEN/TC 256 WG 32, at their request. This evaluation is included because the tests described are generally performed when the other tests described in the First Stage Assessment are carried out. Only the tests are described, the data obtained is used in the processes of EN 15273. Details have been removed from the main text and placed in Annex D of the revised EN.

The term “flexibility coefficient” has replaced “roll coefficient” to relate directly to the EN 15273 series.

6.6 Loading of the diverging branch of a switch

For some railways the determination of a vehicle's performance is required when negotiating a diverging branch. The characteristics of the track at a diverging branch differ between countries and as a result it is not possible to define testing or acceptance criteria. Nevertheless, a methodology has been agreed for the process to be followed when there is a need to determine the performance when negotiating this track feature. Much of the work in developing the technique was carried out by DB but the limit values that were established during this work relates only to the DB situation. For other situations where the features of a diverging branch differ from the DB case, it would be necessary to carry out specific studies to determine specific limits for that case.

The following provides background about the work carried out by DB in determining the assessment of vehicles negotiating DB switches.

Switch Test (6.5 and Annex F)

A test which determines the loading on the turnout branch in switches was not specified in EN°14363:2005. However, it was mentioned in the scope that this is an open point and a future inclusion of turnout runs in switches with $R \leq 190$ m in the normal and simplified measurement method is possible if test conditions will be fixed after further investigations.

In UIC 518:2009 test conditions have been specified in chapter 6.1.6 and Appendix N. These test conditions are adopted and incorporated in this revision, chapter 6.5 and Annex F. It has to be mentioned that no requirements for the assessment of the vehicle behaviour in switches and crossings are specified in this revision of EN 14363. Annex F is informative and presents a methodology for a consistent approach.

After an increase of rail failures in switch blades, see Figure 2, Deutsche Bahn carried out fatigue tests of switch blades in order to determine the fatigue limit at the most critical section (fixed end of the switch blade). With the help of Finite Element calculations the maximum permissible Y and Q forces were determined in order to respect the fatigue stress limit.

Key

1 broken switch blade causes a high risk of derailment

Figure 2 — Broken switch blade in a switch (diamond crossing) with R = 190 m

6.7 Running safety in curved crossings for vehicles with small wheels

There is no international requirement for the assessment of the passage of a vehicle with small wheels as defined in this revision of EN 14363. The methodology given in Annex E is derived from earlier work carried out by ERRI (see UIC 510-2) but is presented only as a possible means of carrying out an assessment.

Some clarifications of the methodology were done, clarifying e.g. that when measuring angle of attack and lateral force it is necessary to measure these before a possible hit of the crossing nose and also that the reference diameter is for the minimum wheel diameter (worn). In UIC 510-2 it was assumed that the lateral forces are measured using H-force measurements. Criteria have now been introduced also when using instrumented (load measuring) wheelsets. An option to replace a missing assessment quantity (angle of attack or lateral force) has been specified. A continuous formula instead of discrete values for flange height defining allowed dispensation from test has been introduced.

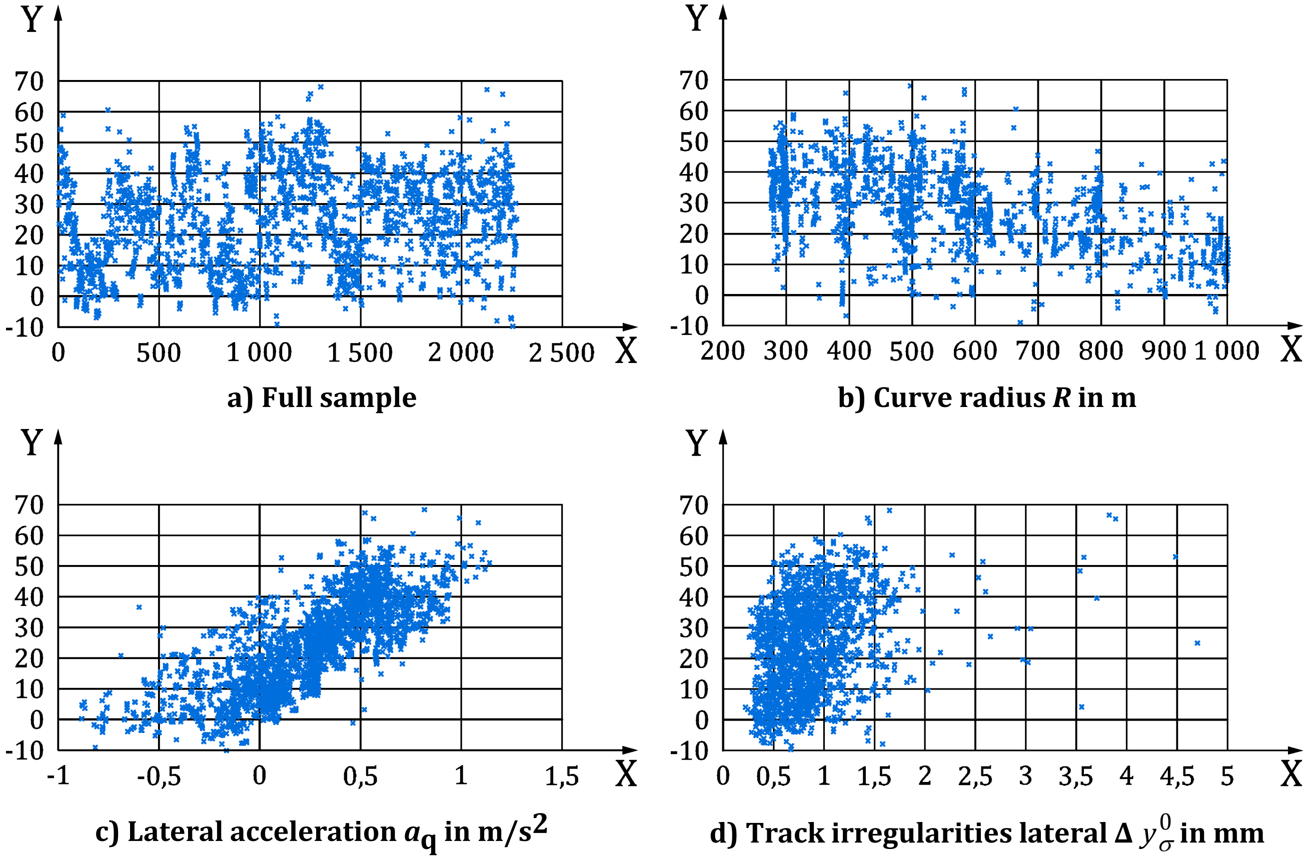
7 Statistical analysis and multiple regression

7.1 Background

For the assessment of on-track test results EN 14363 uses a statistical approach. Tests are done on a small part of the future field of application and statistical methods are applied in order to estimate or predict the highest future values of the assessment quantities. These estimated maximum values are compared to the limit values.

7.2 Relationship of assessment parameters and input variables

Motivation and justification for this approach can be explained by Figure 3. It shows results from tests done with the loco 120 within DynoTRAIN. The 0,15 % or 99,85 % values (depending on the curve direction) of ΣY in curved track sections are plotted. The left diagram is the full sample of all constant radius curve sections, plotted against the sample number. The other diagrams indicate the influence of several input quantities. The expected main input parameters are speed, curvature, cant deficiency, track irregularities, contact geometry parameters and wheel-rail friction. In total, values from 2 274 sections are available, which all have different curve radii, track irregularities and have been operated with different uncompensated lateral accelerations. There are also differences in the wheel-rail contact conditions as well as in the wheel-rail friction. The relationship of ΣY to some of them is indicated in the other diagrams of Figure 3.



Key

Y	assessment quantity ΣY_{max} in kN
a)	X = sample nr.
b)	X = curve radius R in m
c)	X = uncompensated lateral acceleration a_{q} in m/s^2
d)	X = standard deviation $\Delta\, y_{\sigma}^{0}$ in mm

Figure 3 — Values of ΣY in curved sections, DynoTRAIN Loco 120, leading position

In the upper right one ΣY is plotted against curve radius in the respective section. There seems to be a clear tendency that forces decrease if curve radius increases. But it has to be kept in mind that this diagram shows not only the influence of the curve radius, but includes also the influence of the other influencing or input parameters. The influence of two others is shown in the two other diagrams, uncompensated acceleration in the lower left and track irregularities in the lower right one. As parameter for track geometry the standard deviation of the band-pass filtered alignment (outer rail) is used.

There seems to be a clear tendency that forces increase, if the uncompensated lateral acceleration increases. For track irregularities we see not that clear tendency, although forces seem to increase with increasing standard deviation of alignment.

Looking at these results (which are typical for most results from on-track tests), we conclude that the vehicle response consist of some parts which depend in a more or less deterministic way on input parameters, such as curve radius or cant deficiency. The results include additional influences, which could depend on unknown or un-measurable parameters or are the consequence of the stochastic character of the vehicle response.

7.3 Assessment methods

The question is how to conclude, from the test results, the future behaviour of the vehicle in every condition of input parameters to be considered. There are a number of ways to do this.

One possibility is to measure the full network and assess the behaviour by comparing the values to limit values. De facto, this is an assessment of the highest value found. So assessment takes only one situation into account. If this situation changes, the result will change also, and the status of the network changes always, due to deterioration, maintenance, new lines, etc. The results contain an element of random behaviour and therefore, for a specific test run, the limit value may or may not be respected. For larger networks or interoperable rolling stock the approach of testing on the entire network is unachievable.

Another possibility is to identify the critical situations and measure the vehicle response there. This may be done on a specially built test track (as e.g. the test ring in Pueblo, USA from AAR/TTCI), or some selected pieces of service track. This approach requires to identify and quantify the desired critical situations and to build and maintain these features in the test track. Another main disadvantage is, that it depends very much on the vehicle design, which situations (e.g. speed, cant deficiency, curvature, track irregularities and their combinations) are critical for a vehicle and which are not. As the assessment is usually done by comparing the measured values with limit values, there is also the problem of the random nature of the vehicle response. Experience in the USA was in some cases, that vehicles passed the tests and derailed in situations, where the conditions were assumed to be significantly less critical than those in the tests.

EN 14363 uses a different approach: Because of the random nature of the vehicle reactions and in order to limit the amount of tests, statistical methods are used.

7.4 Assessment by statistical methods in EN 14363

7.4.1 General

The principle is to model the measured parameters and use this statistical model to predict the range of future values. The upper range of the predicted values is then assessed against the limit value.

In EN 14363:2005 two statistical methods are mentioned:

— one-dimensional method;

— two dimensional method (or simple regression).

In the new version additionally the multiple regression method has been introduced.

Mathematically spoken, all three methods are regression methods, where the data are modelled using no input parameter (one-dimensional method), one input parameter (two-dimensional method with cant deficiency as input parameter) or more input parameters (multiple regression).

7.4.2 One-dimensional method

EN 14363:2005 gives a formula for calculating the estimated maximum of the assessment parameters for running safety:

$$Y(PA)_{\max} = \bar{y} + k s_{\mathrm{y}} \quad (1)$$

with $\bar{y}$ as the mean value of the sample, s_y as the standard deviation and

$k = 3$ for running safety parameters;

$k = 2{,}2$ for other parameters.

This is a simplification of the formula resulting from regression model with no input parameter ("intercept only model") as [1]

$$Y(PA)_{\max} = \overline{y} + t(PA, f)\left(1 + \frac{1}{N}\right)s_{\mathrm{y}} \quad (2)$$

with N as the sample size (number of sections, $f = N$-1 as the degree of freedom, PA the significance level of the Student t-distribution (confidence level), which is 99 % for running safety parameters and 95 % for the other parameters.

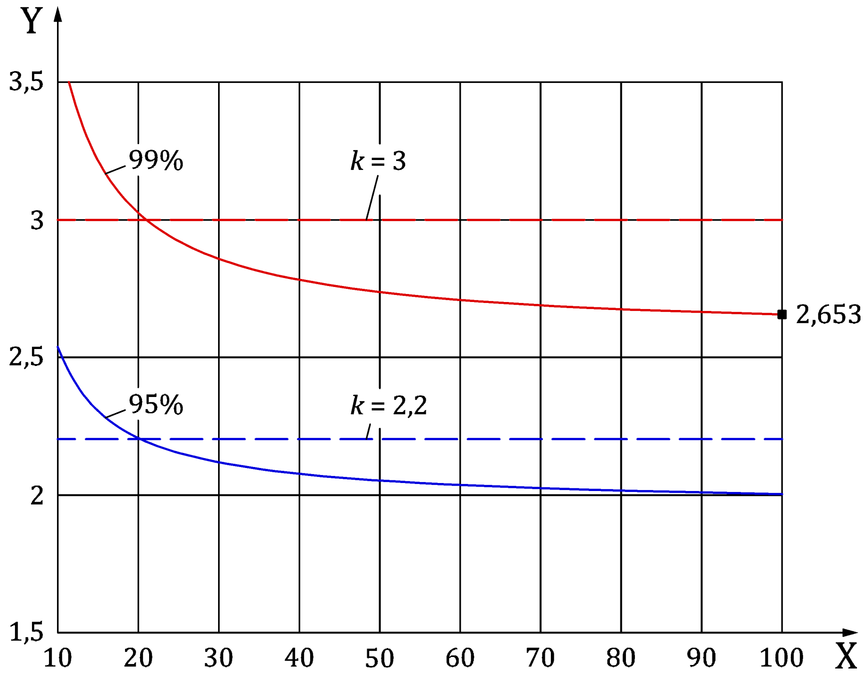
This can be derived assuming that

$$y_i = \beta_0 + e_i = \overline{y} + e_i \quad (3)$$

with e_i as difference to the regression, here the mean. e_i is called residuum or statistical error. ${s_{\mathrm{y}}}^2$ is an estimation of the variance of the errors.

As Formula (1) is a simplification of the exact Formula (2) we can compare. In Figure 4 the coefficients *k* from Formula (1) are compared with those from Formula (2). Below a sample size *N* = 20 the values from the simplified formula are lower than those from the exact formula. This is not relevant because the minimum sample size is 25. At a sample size of 25 the exact formula gives 2,908 8 instead of 3,0 (confidence level 99 %). At a sample size of *N* = 100 the result is 2,65 and the value converges to 2,575 8 at very large samples.

In the revised EN 14363 the exact formula has been introduced.



Key

X number of samples

Y *t*(*PA*,*f*)*(1 + 1/*N*) or *k*

Figure 4 — Comparison of simplified formula for one-dimensional method in EN 14363 and the exact formula

EN 14363:2005 required a minimum number of sections of $N >= 25$ (50 for test zone 3). UIC 518:2009 allows also the use of a smaller number of sections between 15 and 24 (49). In these cases UIC 518:2009 uses Figure 4 by defining a higher value of the student factor $t(PA)$.

Studies within DynoTRAIN showed that the latter approach may lead to unreliable results, because with a small number of sections the regression assumptions are unlikely to be respected. Other changes implemented in EN 14363:2016 make it easier to reach the required number of sections. Therefore the scale factors from UIC 518:2009 have not been adopted.

The one-dimensional method has a number of limitations. If the output variable includes a deterministic dependency to an input, this variation is modelled as a statistical error. This can be demonstrated by the following example: Here a sample has been created, with varying cant deficiency a_q, which is normal distributed. A deterministic relationship between the output ΣY and the input a_q is assumed as

$$\Sigma Y / \Sigma Y_{lim} = -0{,}31667 + 0{,}83333 a_q \tag{4}$$

The uncompensated lateral acceleration a_q has been varied, assuming normal distribution with a mean value

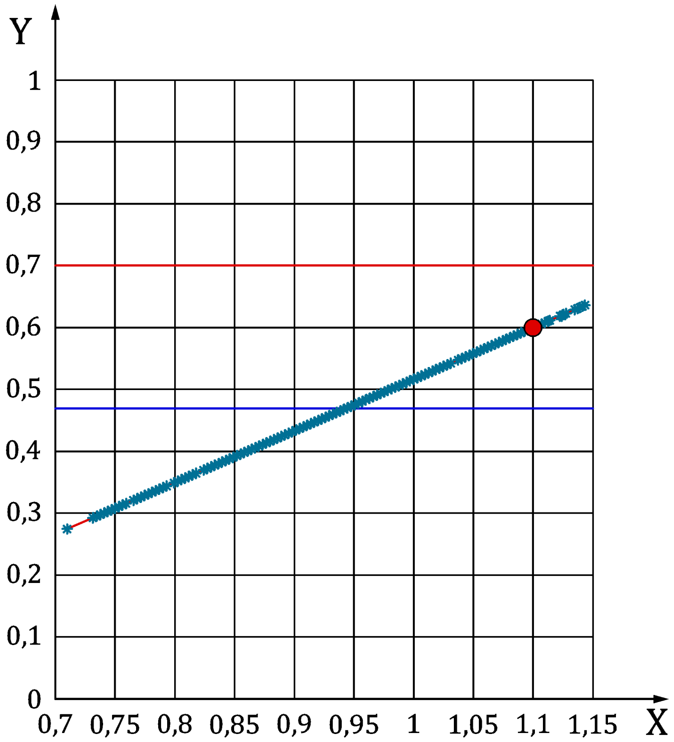
$$mean\left(a_q\right) = 0{,}945$$

and a standard deviation

$$std\left(a_q\right) = 0{,}1 .$$

The values are then limited to the range between 0,7 m/s^2 and 1,15 m/s^2, as defined in EN 14363.

In Figure 5 the sample is plotted against the cant deficiency. The estimated maximum value using Formula (1) is 0,697 and is plotted as a red line, the blue line is the mean value. The estimated maximum value is higher than all “measured” values, and significantly higher than the values resulting from the two-dimensional method, which is 0,6 (indicated by the red circle).



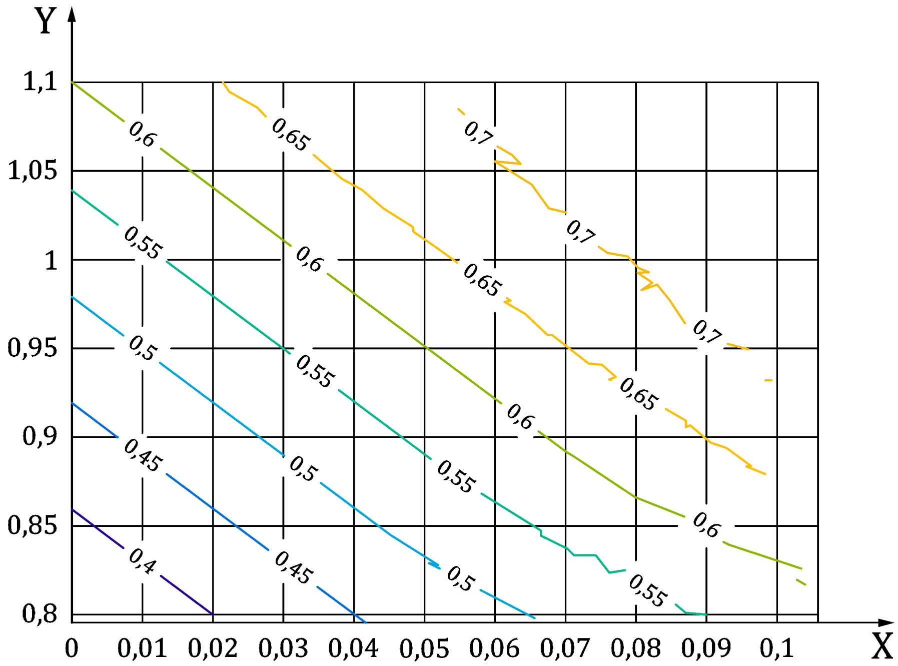
Key

X lateral uncompensated acceleration $a_{q,mean}$ in m/s^2

Y quotient $\Sigma Y / \Sigma Y_{lim}$

Figure 5 — Estimated maximum value using one-dimensional method on a purely deterministic sample

The next limitation is that the result depends on the “design” of the sample. This applies especially if there are strong dependencies on input variables. If for instance the response increases strongly with cant deficiency, then a higher estimated maximum value will result, if the cant deficiencies in the sample are higher. This can also be demonstrated with the example using Formula (4). The mean and the standard deviation of the uncompensated acceleration a_q has been varied and normal distributed samples of a_q have been calculated. The uncompensated lateral acceleration has been restricted to the range $0{,}7 \cdots 1{,}15\,m/s^2$, therefore the distribution at higher means and standard deviations diverges slightly from the normal distribution.



Key

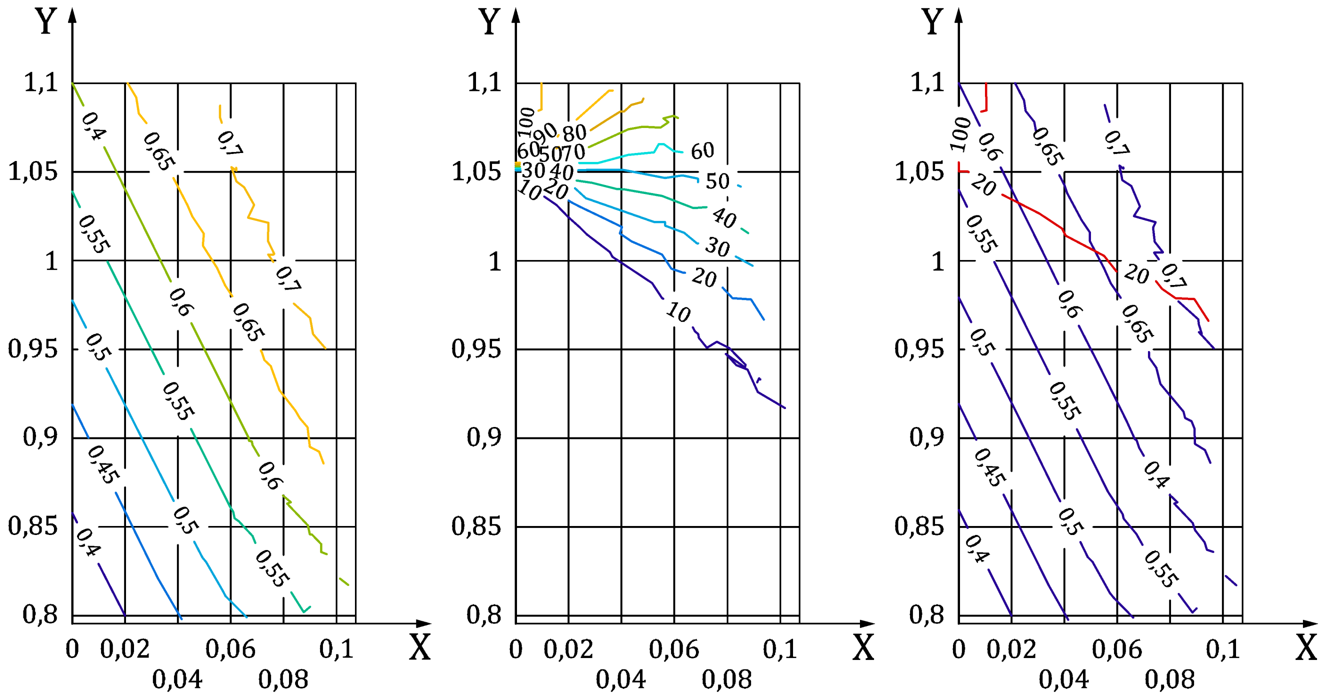
X standard deviation of uncompensated lateral acceleration a_q in m/s^2

Y mean value of uncompensated lateral acceleration a_q in m/s^2

Figure 6 — Maximum estimated values of the quotient ΣY / ΣY_{lim} depending on mean and standard deviation of the input

Figure 6 shows the resulting estimated maximum values with varying mean and standard deviation of the input a_q. If the sample of the input parameters is at lower values, the estimated maximum value is significantly lower than the "correct" value of 0,6 from the two-dimensional method. If the mean is at 1,1 (which is the value where the two-dimensional method determines the estimated maximum value) the results depends on the variance of the input. With no variance we get 0,6, with increasing variance the estimated maximum values increases as discussed above in the context of Figure 5.

EN 14363 handles this problem by requiring that more than 20 % of the sections shall have an uncompensated lateral acceleration between 1,05 and 1,15 m/s^2. In Figure 7 the percentage in this range is shown in the middle diagram and together with the estimated maximum values in the right diagram. Now the estimated maximum values are mostly higher than 0,6 and the result is quite well controlled.



a) Estimated maximum value of the quotient $\Sigma Y / \Sigma Y_{lim}$

b) Percentage of values with a_q between 1,05 m/s² and 1,15 m/s² in %

c) Estimated maximum value of the quotient $\Sigma Y / \Sigma Y_{lim}$, percentage of values with a_q between 1,05 m/s² and 1,15 m/s² in %

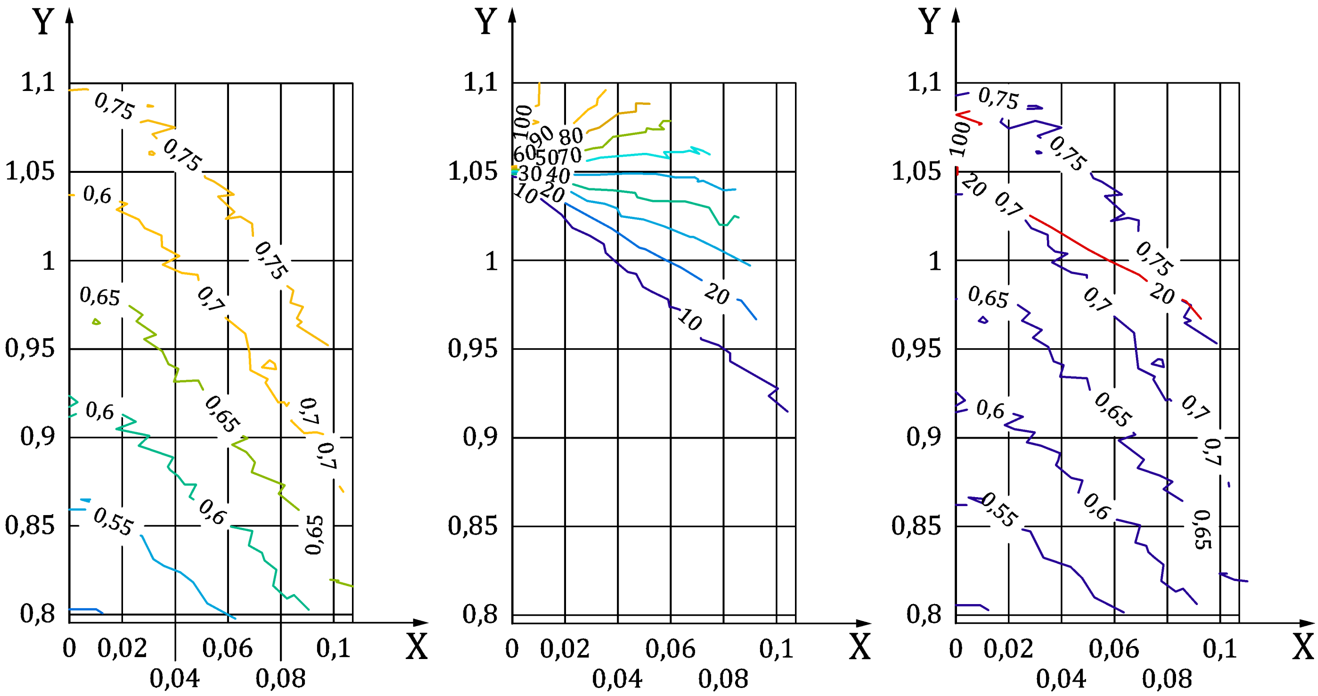
Key

X standard deviation of uncompensated lateral acceleration a_q in m/s²

Y mean value of uncompensated lateral acceleration a_q in m/s²

Figure 7 — Maximum estimated values depending on mean and standard deviation of the input and percentage of values with uncompensated lateral acceleration between 1,05 m/s² and 1,15 m/s²

If a random statistical error is introduced in Formula (4) the relations change. Figure 8 shows the result if a normal distributed statistical error with a mean equal to zero, a standard deviation of 0,01 is included.



a) Estimated maximum value of the quotient $\Sigma Y / \Sigma Y_{\text{lim}}$

b) Percentage of values with a_q between 1,05 m/s² and 1,15 m/s² in %

c) Estimated maximum value, percentage of the quotient $\Sigma Y / \Sigma Y_{\text{lim}}$

Key

X standard deviation of uncompensated lateral acceleration a_q in m/s²

Y mean value of uncompensated lateral acceleration a_q in m/s²

Figure 8 — Maximum estimated values of the quotient $\Sigma Y / \Sigma Y_{\text{lim}}$ depending on mean and standard deviation of the input and percentage of values with uncompensated lateral acceleration between 1,05 m/s² and 1,15 m/s², model including a statistical error

So we may sum up that the one-dimensional method only gives correct results, if the input parameters (or parameters influencing the assessment quantities) have a small spread and are centred around the value where the highest response parameters occur. In EN 14363 this is ensured by limitations of the test conditions.

The main input parameters are speed, curvature, cant deficiency, track irregularities, contact geometry parameters and wheel-rail friction. EN 14363:2005 includes requirements on all these parameters.

— Speed, which is a relevant parameter for test zone 1 (straight track) is limited to a small range $1{,}1 V_{\text{adm}} \pm 5 \text{km} / \text{h}$.

— Cant deficiency, which is a relevant parameter in curved tracks is limited to the range $(0{,}7 \cdots 1{,}15) cd_{adm}$ with the additional requirement that a defined percentage (> 20 % for one-dimensional method) of test sections have to be in the range $(1{,}05 \cdots 1{,}15) cd_{\text{adm}}$.

— The influence of curvature is covered by separating the analysis into three zones: Zone 4 with radii between 250 m and 400 m, zone 3 with radii between 400 m and 600 m and zone 2, those sections in curves where speed is in the range $(0{,}95 \cdots 1{,}15)V_{\text{adm}}$ and cant deficiency is in the $(0{,}7 \cdots 1{,}15)cd_{\text{adm}}$. The according curve radii depend on the admissible speed V_{adm}. Within test zone 3 and 4 the mean radius of all sections has to be within a defined range.

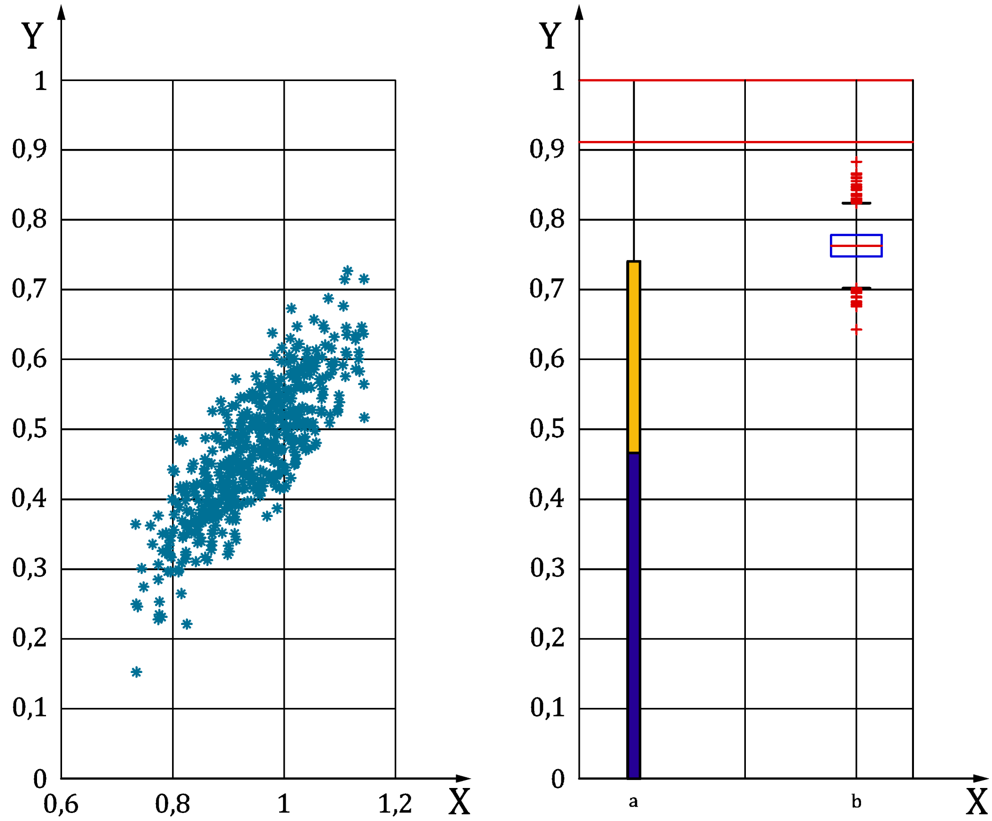
— Track irregularities are controlled by requiring a defined distribution for the standard deviations of alignment and longitudinal level ($50\ \% \leq QN1, 10\ \% > QN2$).

— Contact geometry is controlled by requiring tests on tracks with 1:20 and with 1:40 rail inclination and a limitation of equivalent conicity in case of unstable behaviour.

— Spread and influence of friction is controlled by requiring tests to be done only on dry rails.

This approach is correct and gives at first valuable results, if the underlying regression assumptions are respected. To derive Formula (2) one has to assume that the statistical errors are normal distributed [1]. One problem of restricting the sample by rigid conditions on the input parameters is that often a lot of sections have to be eliminated and samples become small. Such samples are very sensitive to deviations from normal distribution, which may distort the result. And there is no control of this necessary selection or elimination process.

The problem is demonstrated also with the synthetic data used above. A sample is created using a mean of 0,9 and a standard deviation of 0,1 for the a_{q}-sample. The scatter of the output is plotted in Figure 9 against the cant deficiency. In the right diagram the estimated maximum value of this sample is plotted as bar. From the sample 65 observations are in the range between 1,05 m/s^2 and 1,15 m/s^2. This is 13 %, which is less than the required 20 %. So some sections have to be removed, it is also allowed to use less sections. It is only required to use 25 sections in minimum. If this is done randomly, different estimated maximum values are calculated, which are plotted in the boxplot.



Key

X lateral uncompensated acceleration a_q in m/s^2

Y quotient $\Sigma Y/\Sigma Y_{lim}$

a full sample

b all samples

Figure 9 — Output (quotient $\Sigma Y/\Sigma Y_{lim}$) versus uncompensated lateral acceleration and estimated maximum values from one-dimensional analysis

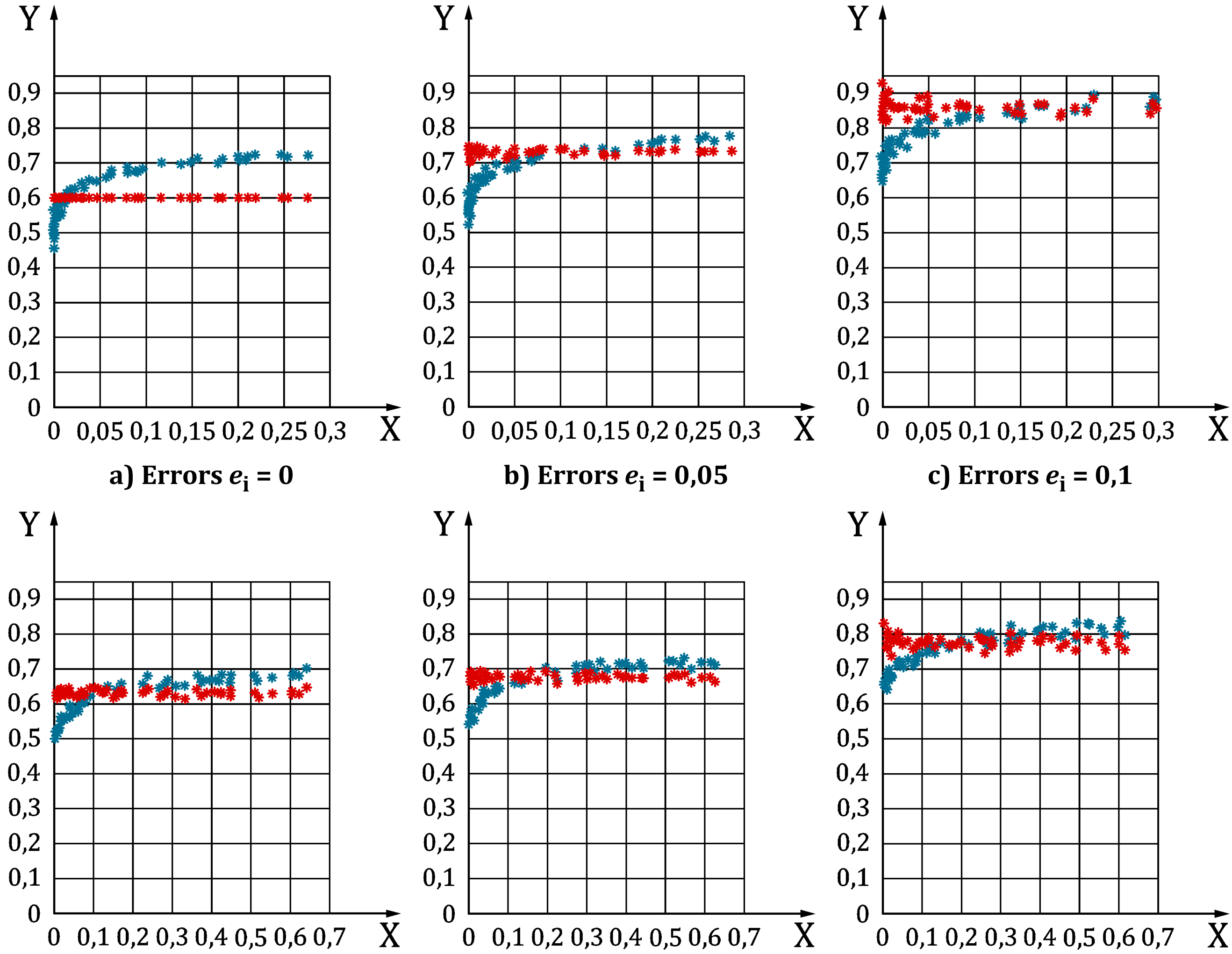
7.4.3 Two-dimensional method

The two-dimensional method models the influence of cant deficiency using a linear regression. The following formula applies:

$$y_i = \beta_0 + \beta_1 a_{qi} + e_i \tag{5}$$

Here three parameters have to be estimated, the intercept β_0, the regression coefficient β_1 and the errors e_i. In difference to the one-dimensional method, a certain variation or spread of the input parameter cant deficiency is needed in order to achieve a good estimation of the dependency.

In the "synthetic example" discussed above (created with Formula (4)), the result of the two-dimensional method is also shown in Figure 5. As this example is fully deterministic there is no statistical error in this model and the result is the exact deterministic value. In the following figure this is studied further. In the upper row data are analysed, where only the influence of the uncompensated lateral acceleration is considered according to Formula (4). Estimated maximum values are calculated with the one-dimensional and the two-dimensional method and plotted against the portion of sections in the upper range of uncompensated lateral acceleration. 0,2 corresponds to the required 20 %. The figure clearly illustrates that this requirement is necessary if the one-dimensional method is used, but it is unnecessary, if the influence of cant deficiency is included in the regression model, which is the case in the two-dimensional method. Differences are high in the deterministic case, with increasing statistical errors the differences reduce.



a) Errors e_i = 0 **b) Errors e_i = 0,05** **c) Errors e_i = 0,1**

d) Errors e_i = 0 **e) Errors e_i = 0,05** **f) Errors e_i = 0,1**

Key

X portion of values with uncompensated lateral accelerations between 1,05 m/s^2 and 1,15 m/s^2

Y estimated max. value of the quotient $\Sigma Y / \Sigma Y_{lim}$

* (blue) 1-dim

* (red) 2-dim

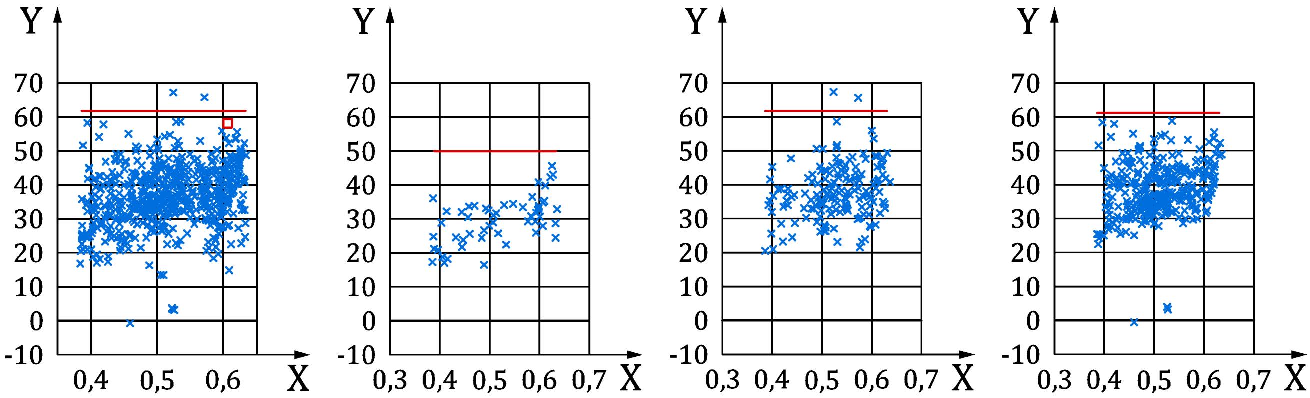
Figure 10 — Estimated maximum values of the quotient $\Sigma Y/\Sigma Y_{lim}$. Upper row (a, b, c): Output depends on uncompensated lateral acceleration. Lower row (d, e, f): Output depends on uncompensated lateral acceleration, radius and track irregularities

In the lower row the following dependency of the output has been used:

$$\Sigma Y / \Sigma Y_{lim} = -1{,}3167 + \frac{222{,}22}{R} + 0{,}83333 a_{\mathrm{q}} + 167\, \Delta y_{\sigma}^{0} + e \qquad (6)$$

The additional deterministic variation due to the change of radius and track irregularities, acts like an additional statistical error. As shown above, this leads to higher estimated maximum values as the deterministic effect is modelled statistically.
EN 14363 tries to overcome this problem in the case of curve radius by dividing the sample into three smaller samples (test zones 2, 3, 4).

This can be demonstrated using the data which have been already shown in Figure 3. In Figure 11 in the left column the data of the full curvature range is plotted against uncompensated lateral acceleration. In column 2, 3 and 4 the data from test zone 2, 3 and 4 are plotted. In the upper row the estimated maximum values are calculated using the one-dimensional method (the line is calculated with k = 3 for the standard deviation, the square represents the value calculated with the correct formula which gives a lower value for the student-t factor for the large sample), in the lower diagram the simple regression as used in the two-dimensional method is applied.

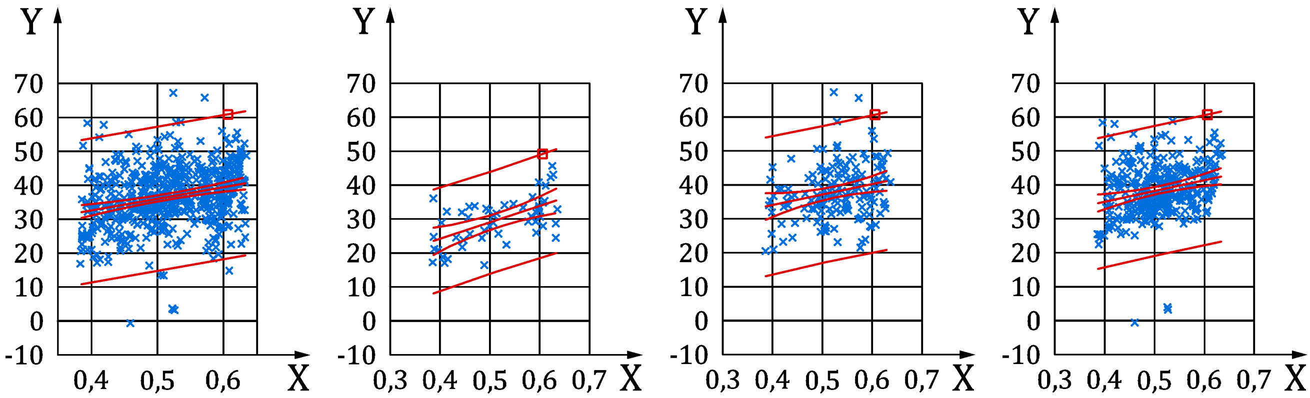


a) Full sample, 1-dim $\sum Y\,max = 61{,}7$ **kN/ 58,2 kN**

b) Zone 2, 1-dim $\sum Y\,max = 49{,}7$ **kN**

c) Zone 3, 1-dim $\sum Y\,max = 61{,}6$ **kN**

d) Zone 4, 1-dim $\sum Y\,max = 61{,}1$ **kN**



e) Full sample, 2-dim $\sum Y\,max = 60{,}5$ **kN**

f) Zone 2, 2-dim $\sum Y\,max = 48{,}8$ **kN**

g) Zone 3, 2-dim $\sum Y\,max = 60{,}3$ **kN**

h) Zone 4, 2-dim $\sum Y\,max = 60{,}4$ **kN**

Key

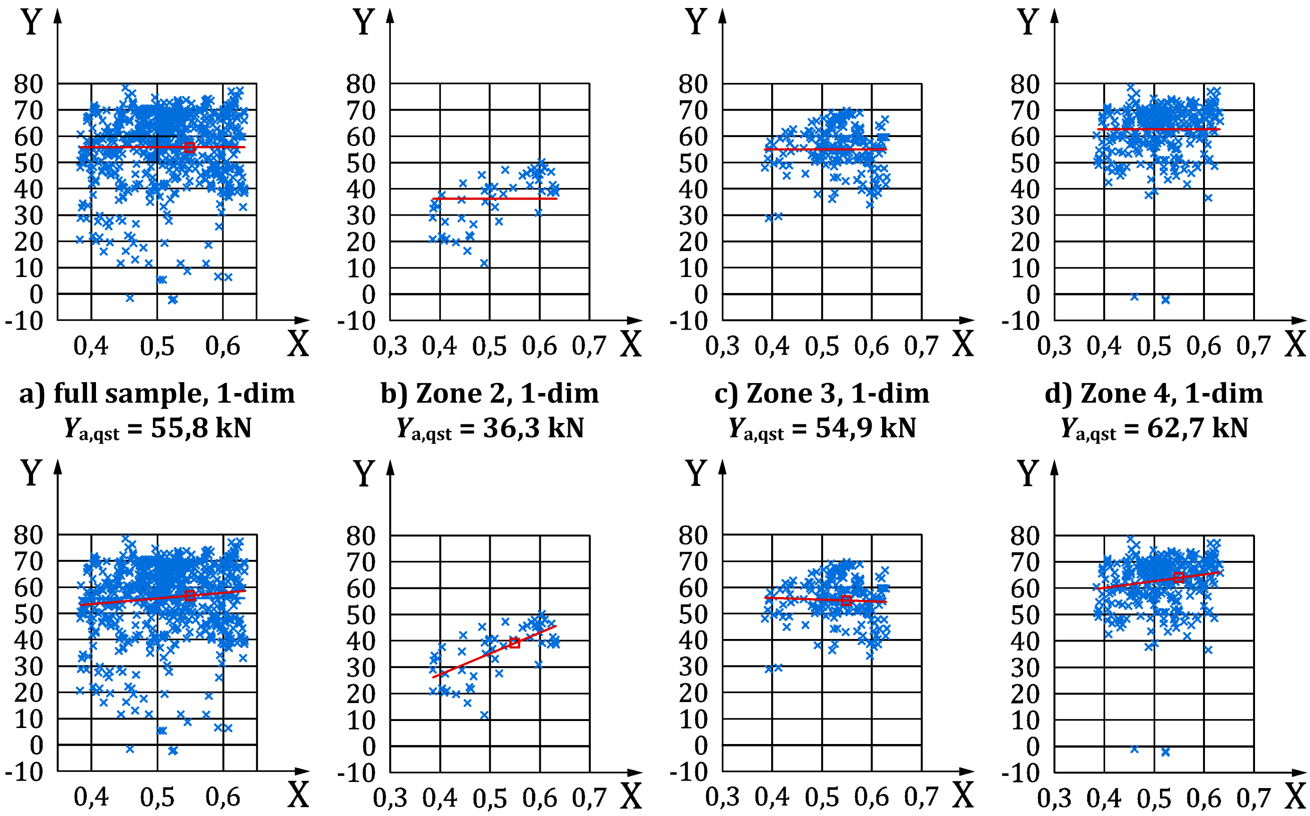
X uncompensated lateral acceleration a_{q} in m/s^2

Y ΣY_{max} in kN

Figure 11 — Analysis of ΣY_{max} data in the 3 test zones

In the case of one-dimensional analysis the full sample gives slightly higher values, but the difference is very small. In the case of two-dimensional analysis the difference is negligible. Only test zone 2 differs with significantly lower values. This is connected with the fact, that this analysis had to be carried out with a relatively low speed $v_{adm} = 120\,km/h$, otherwise not enough sections would have been available.

For this assessment quantity the separation in the three test zones seems to be unnecessary. This is different for Y_{qst}, as shown in the next figure.



a) full sample, 1-dim **$Y_{a,qst}$ = 55,8 kN**

b) Zone 2, 1-dim **$Y_{a,qst}$ = 36,3 kN**

c) Zone 3, 1-dim **$Y_{a,qst}$ = 54,9 kN**

d) Zone 4, 1-dim **$Y_{a,qst}$ = 62,7 kN**

e) full sample, 2-dim **$Y_{a,qst}$ = 56,6 kN**

f) Zone 2, 2-dim **$Y_{a,qst}$ = 38,9 kN**

g) Zone 3, 2-dim **$Y_{a,qst}$ = 54,8 kN**

h) Zone 4, 2-dim **$Y_{a,qst}$ = 63,3 kN**

Key

X uncompensated lateral acceleration

Y Y (50%) in kN

Figure 12 — Analysis of Y_{qst} in the three test zones and in all curves

There are two reasons: First, here the mean value is assessed. This causes that low values in the sample reduce the estimated value. This is a very different situation than in the case of ΣY, where the maximum value is estimated. This leads to the situation, that the full sample gives 10 % lower values than test zone 4. Second, there is a rather strong dependency of Y_{qst} on the curve radius, which is not considered in the two statistical methods. This leads to a wide spread of the results and the big statistical error has no influence as only the mean is assessed.

The curve radius is controlled in EN 14363 by requiring the mean curve radius to be between 280 m and 350 m in test zone 4. In the example the mean of Y_{qst} changes by 8 kN between 350 m and 280 m curve radius. This led to the method in UIC 518:2009 [2], where the limit value is adapted to the mean curve radius of the tests according to

$$\left(Y_{\text{qst}}\right)_{lim} = \left(30 + \frac{10500}{R_{\text{m}}}\right) \text{kN} \tag{7}$$

The factor in the numerator of the quotient has been derived from regression analysis, where the curvature has also been included. This is a form of multiple regression with more than one input parameter.

As mentioned above, the important regression assumption for the one-dimensional method is that the statistical errors are normally distributed. In the case of two-dimensional analysis there are a number of additional assumptions and requirements, which are discussed later.

7.4.4 Multiple regression

Multiple regression is a regression analysis with more than one input variable. The general form used in the revised EN 14363 is:

$$y_i = \beta_0 + \beta_1 x_1 + \ldots + \beta_{\text{p}} x_{\text{p}} + e_i \tag{8}$$

with the following input parameters x_i:

Test zone “straight track”: Speed V, track geometry TQ_σ

Test zone “curves”:

— Speed V, cant deficiency I, track geometry TQ_σ (assessment in large radius curves);

— curvature $1/R$, cant deficiency I, track geometry TQ_σ.

Which track geometry parameter has to be applied, depends on the assessment parameter:

$$TQ_\sigma = \Delta y_\sigma^0 \; for \, Y, \Sigma Y, \frac{Y}{Q}, T, T_x, H, \ddot{y}, \ddot{y}^{+}, \ddot{y}^{*}$$

$$TQ_\sigma = \Delta z_\sigma^0 \; for \, Q, \ddot{z}^{*} \tag{9}$$

In difference to the one-dimensional method the analysis should include a wide range of the input parameters. Together with a high number of included sections, this enables a good estimation of the regression parameters.

If the one-dimensional method is used, the test conditions have to be centred at the “target values”. These are those conditions (of the influencing parameters) where the assessment is done. Usually these are the values of the input parameters where a high vehicle response is expected and defined as reference conditions.

If multiple regression is used, assessment has to be done by examining the predicted response at the target values or in a defined range of the input parameters. The same applies to the two-dimensional method with cant deficiency as the only input parameter.

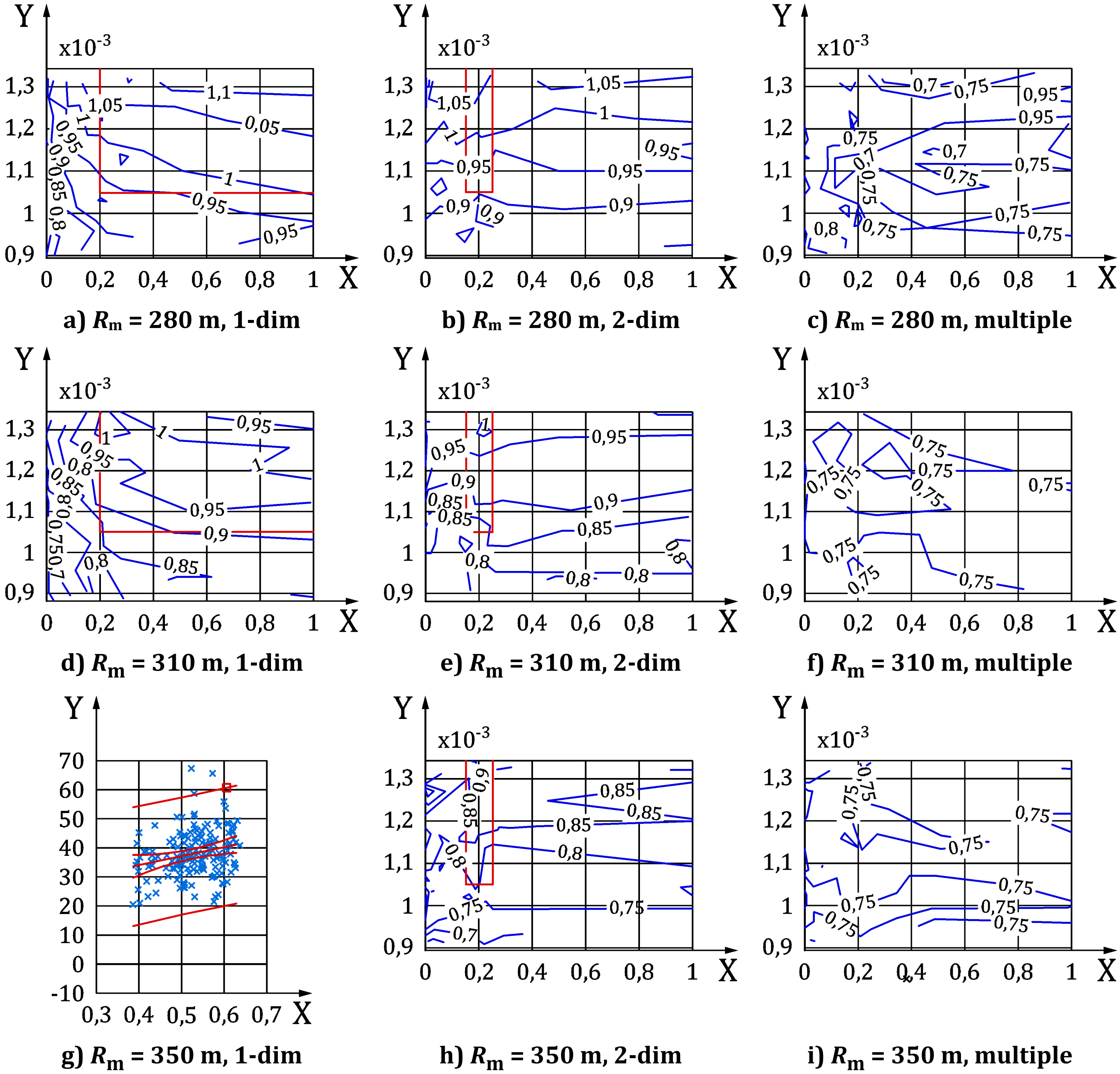
Again the synthetic example is used to demonstrate the multiple regression. The following formula has been used:

$$\Sigma Y / \Sigma Y_{lim} = -1{,}6667 + \frac{222{,}22}{R} + 0{,}83333 a_{\text{q}} + 500 \, \Delta y_\sigma^0 + e \tag{10}$$

The standard deviation of the normal distributed error e is 0,15. The mean of the three input parameters has been varied, for R and a_q the standard deviation has been adjusted so that the sample is within the ranges $250 \ldots 400\,\text{m}$ and $0{,}7 \ldots 1{,}15\,\text{m}/\text{s}^2$.

Figure 13 shows the estimated maximum values of the various samples and the three methods. In the first row the mean curve radius is approximately 280 m. In the second row the mean radius is 310 m, in the third row it is 350 m. The first column gives the results for the one-dimensional method, the second column for the two-dimensional method and the third row for the multiple regression. In red the range of required portion at high cant deficiency and 90 % value of track irregularities is plotted.

The multiple regression always gives results around 0,75, independent of the values of the input parameters. The results from the two other methods depend on the actual values of all three input variables. As the multiple regression estimates the sample exactly on the target values of the input parameters, the results of the other methods are only equal, if the mean of the input parameters corresponds to the target values.



Key

X portion of values with a_q between 1,05 m/s^2 and 1,15 m/s^2

Y 90% value of the standard deviation of alignment Δy_{σ}^{0} in m

Figure 13 — Estimated maximum values of the quotient ΣY / ΣY_{lim} of various samples

The figure also demonstrates one of multiple regression's advantages, which is that the results are more or less independent from the distribution of the input parameters samples. The other main advantage is that the full available data can be used, it is not necessary to remove data in order to fulfil all requirements on the input parameters.

The presentation of the results of the multiple regression is not described in the EN 14363 yet. Therefore a possible way of presentation is given in Annex A.

7.5 Regression assumptions

All three methods are regression methods which rely on some important assumptions. When these assumptions are violated the results do not hold and an application of them may lead to serious error. The most significant regression assumptions and associated problems are [1], [3].

— Specification errors

The relevant input variables have to be included, otherwise the regression coefficients of the included variables will become unreliable or wrong as they are biased estimates of the true ones. The validity of the assumed function, e.g. linear function has to be given.

— Normality and independence of the errors

The errors $e_1, e_2, \ldots, e_n$ are assumed to be both independently and identically distributed normal random variables each with a mean of zero and a common variance s_y^2.

This implies four assumptions: The errors have a normal distribution, they have a mean of zero, they have a constant variance (heterogeneity or the heteroscedasticity problem) and they are independent to each other (autocorrelation problem).

— Assumptions about input (independent) variables

The input values $x_{1j}, x_{2j}, \ldots, x_{nj}; j = 1,2, \ldots, p$, are measured without error. Errors in the measurement will affect the residual variance, the multiple correlation coefficient, and the individual estimates of the regression coefficients.

The input variables $\boldsymbol{X_1}, \boldsymbol{X_2}, \ldots, \boldsymbol{X_p}$, are assumed to be linearly independent of each other. This assumption is needed to guarantee the uniqueness of the least squares solution. If this assumption is violated, the problem is referred to as the collinearity problem.

— Assumptions about the output values (observations):

All observations are equally reliable and have approximately an equal role in determining the regression results and in influencing conclusions.

Identification and correction techniques

A simple and effective method for detecting model deficiencies in regression analysis is the examination of residual plots using standardised residuals. Residual plots will identify serious violations in one or more of the standard assumptions when they exist. The analysis of residuals may lead to suggestions of structure or point to information in the data that might be missed or overlooked if the analysis is based only on summary statistics. An assessment of graphical presentations of residuals may often be the most useful part of the regression analysis.

High leverage points and outliers should also be studied in detail.

Correction of specification errors:

Typical corrections are transformations (e.g. use $1/R$ instead of R), nonlinear models using interaction terms or with high order polynominal terms. If important independent variables are missing, the correction measure is to include them, unless they are collinear with already included variables.

Non-Normality and heterogeneous variances of residuals:

Transformations of the dependent variable and possibly some of input variables can solve the problem. More complex methods are the “weighted least square” technique, the “generalised least square” method or the “generalised linear models”.

Influential points and outliers:

Outliers in the output variable should be removed, but only if there is a clear indication of measurement or analysis errors. The influence of outliers and influential points will become smaller if the sample size is increased. The usual technique to solve problems with outliers and influential points is the technique called “robust regression”.

Collinearity

Collinearity between cant deficiency and curvature can be avoided by a careful planning of the tests. There is a natural collinearity between speed and track geometry (better track geometry at higher speeds). Again test planning can help by including lower speeds on lines for higher speeds with better track geometry. Generally also the increase of sample size reduces possible problems with collinearity. It can also be helpful to combine two or more variables that are highly correlated or delete one of the variables that are highly correlated. An alternative method is ridge regression and also other special high-level techniques are available for collinear data.

Measurement errors on the input variables

They should be avoided as much as possible. Most of the predictors used in the assessment of running characteristics are measured sufficiently exact (speed, cant deficiency, curvature). In the case of track geometry it should be kept in mind, that not only the measurement has to be as exact as possible, but also the mapping to the test sections. Special analysis of the measured track geometry for the tests according EN 14363 can avoid problems with measurement errors in the regression.

8 Recalculation of *Y/Q* (7.6.2.2.5)

8.1 What was changed

When the maximum estimated value of $(Y/Q)_{a,max}$ obtained using the standard evaluation process exceeds the limit value (or does not provide $\lambda \geq 1,1$), an alternative evaluation is allowed, based on the following deviations from the standard process:

— alternative test zone made up of all track sections with 300 m ≤ R ≤ 500 m
(instead of 400 m ≤ R ≤ 600 m for zone 3 and 250 m ≤ R < 400 m for zone 4);

— in the first stage of statistical processing (per section), use h_1 = 2,5 % and h_2 = 97,5 %
(instead of h_1 = 0,15 % and h_2 = 99,85 %);

— in the second stage of statistical processing (per test zone), use *PA* = 95,0 %
(instead of k = 3 or PA = 99,0 %);

— the mean curve radius shall be in the range 350 m ≤ R_m ≤ 400 m
(instead of 450 m ≤ R_m ≤ 550 m for zone 3 and 280 m ≤ R_m ≤ 350 m for zone 4).

The result of this alternative evaluation can be used for vehicle assessment and calculation of λ for any vehicle type.

8.2 Why was it changed

A few articulated container carrier wagons were submitted to on-line tests in 2005 in Germany and failed, running empty, to comply with the limit value $(Y/Q)_{\text{lim}} = 0{,}8$. However, similar wagons had been used for many years throughout Europe without special reports of derailments.

This is why a UIC Experts Group was set up in January 2006, in order to organise investigations (including on-line tests) comparing these new wagons with other series (of similar design or not) considered as safe, due to a long experience in service, but possibly as critical in terms of (Y/Q).

The idea was to investigate the relevance of the current $(Y/Q)_{\text{lim}} = 0{,}8$ criterion, and maybe propose another limit value and/or another criterion to characterise safety against derailment.

The outcome of this work (carried out in 2006 and 2007) can be summarised as follows:

— both sets of wagons ("new" and "historic") showed very similar results in terms of (Y/Q) and subsequently a similar risk level, assumed to be acceptable based on service experience, although the maximum estimated values of (Y/Q) were around 1,0;

— this led to a review of what the requirement was, when the older wagons were accepted; it was found, that when the $(Y/Q)_{\text{lim}} = 0{,}8$ criterion was proposed by ORE C 138 committee, the evaluation was based on different statistical conditions than those now specified in UIC leaflet 518 and EN 14363;

— for both sets of wagons, shifting from "UIC 518" to "C 138" data processing conditions reduced the estimated maximum values of (Y/Q) by around 20 %. So, values in the range of 1,0 to 1,1 obtained during the test campaign were reduced to the range 0,80 to 0,85;

— however, it was felt relevant to keep a similar statistical process for all safety quantities, this is why (instead of simply increasing the limit value from 0,8 to 1,0) it was proposed to offer a possibility of recalculation using the "C 138" process, in case of failure with the usual process. This was included in the 2009 issue of UIC 518, and transferred into EN 14363 and is applicable to all vehicle types.

8.3 Any references to useful background

All background information can be found in the final report of the UIC Experts Group:

UIC B 12/RP 76 (September 2008)

Y/Q LIMIT VALUE - Study into the suitability of a Y/Q limit value of 0,8 for empty wagons

This is also summarised in part 1.3 of the Technical report of UIC leaflet 518 revision group.

8.4 What were the options, what was rejected and why?

Analysing the results obtained on the 5 tested wagons, the UIC Experts group had also considered the option of keeping the $(Y/Q)_{\text{a,max}}$ evaluation process unchanged, while moving its limit value to 1,0. Indeed, the results consistently showed that a test resulting in a maximum estimated value of 0,8 using the "C 138" process (original acceptance condition) will result in a value around 1,0 using the standard procedure of UIC 518.

The aim was to preserve the consistency of UIC 518, by specifying the same statistical evaluation for all safety quantities.

This idea was not retained (at this stage), because the group lacked information about:

— other types of running gear (all the wagons tested were fitted with Y25 bogies),

— other types of vehicles (locomotives, passenger vehicles…).

Indeed, the equivalence between “0,8 with C 138 procedure” and “1,0 with UIC 518 procedure” may be valid for freight wagons with Y25 bogies, and not for other vehicles or running gears.

This is why UIC 518 revision group proposed to set up a data base of all available test results, analysed with both procedures, in order to gather information on a wider extent before making a decision. This data base is still to be initiated, but we can already mention the results achieved in the frame of UIC “Y/Q group”, which are reported in the following table together with DynoTRAIN data (to be confirmed) and some data provided by the members of WG 10. Any additional contribution to this table is welcome.

Table 1 — Y/Q test results - Evolution of maximum estimated value of $(Y/Q)_a$ according to the processing conditions for recalculation of Y/Q

Vehicle	Type	Eval.	P0 (t)	TZ 3	TZ 4	TZ4mod	Diff Abs.	Red.
UIC wagon 1	Artic. 6-axle container wagon, WS 1 tare	D, 1-dim	4.77	0.84	0.93	0.75	-0.18	-19%
		F, 1-dim		0.78	1.05	0.80	-0.25	-24%
		D, 2-dim		0.75	0.83	0.76	-0.07	-8%
		F, 2-dim		0.71	0.91	0.81	-0.1	-11%
	Artic. 6-axle container wagon, WS 3 tare	D, 1-dim	5.04	0.71	0.86	0.66	-0.2	-23%
		F, 1-dim		0.81	1.00	0.75	-0.25	-25%
		D, 2-dim		0.82	0.85	0.70	-0.15	-18%
		F, 2-dim		0.72	0.88	0.76	-0.12	-14%
UIC wagon 2	Artic. 6-axle container wagon, WS 1 tare	D, 1-dim	3.96	0.85	0.96	0.78	-0.18	-19%
		F, 1-dim		0.84	1.08	0.83	-0.25	-23%
		D, 2-dim		0.78	0.86	0.79	-0.07	-8%
		F, 2-dim		0.79	0.95	0.84	-0.11	-12%
	Artic. 6-axle container wagon, WS 3 tare	D, 1-dim	4.20	0.75	0.80	0.65	-0.15	-19%
		F, 1-dim		0.76	0.97	0.72	-0.25	-26%
		D, 2-dim		0.67	0.74	0.68	-0.06	-8%
		F, 2-dim		0.70	0.86	0.73	-0.13	-15%
UIC wagon 3	Artic. 6-axle container wagon, WS 1 tare	D, 1-dim	4.16	0.85	0.96	0.76	-0.2	-21%
		F, 1-dim		0.86	1.02	0.77	-0.25	-25%
		D, 2-dim		0.79	0.87	0.78	-0.09	-10%
		F, 2-dim		0.80	0.90	0.79	-0.11	-12%
	Artic. 6-axle container wagon, WS 3 tare	D, 1-dim	4.12	0.93	0.89	0.70	-0.19	-21%
		F, 1-dim		0.85	1.05	0.76	-0.29	-28%
		D, 2-dim		0.80	0.82	0.72	-0.1	-12%
		F, 2-dim		0.79	0.92	0.79	-0.13	-14%
UIC wagon 4	4-axle container wagon, WS 1 tare	D, 1-dim	5.26	0.91	0.99	0.80	-0.19	-19%
		F, 1-dim		0.86	1.09	0.82	-0.27	-25%
		D, 2-dim		0.83	0.90	0.83	-0.07	-8%
		F, 2-dim		0.79	0.96	0.82	-0.14	-15%
	4-axle container wagon, WS 3 tare	D, 1-dim	4.53	0.72	0.85	0.67	-0.18	-21%
		F, 1-dim		0.78	1.04	0.75	-0.29	-28%
		D, 2-dim		0.63	0.76	0.7	-0.06	-8%
		F, 2-dim		0.70	0.90	0.75	-0.15	-17%
UIC wagon 5	4-axle tank wagon, WS 1 tare	D, 1-dim	5.24	0.78	0.87	0.69	-0.18	-21%
		F, 1-dim		0.97	0.98	0.74	-0.24	-24%
		D, 2-dim		0.70	0.81	0.72	-0.09	-11%
		F, 2-dim		0.80	0.88	0.74	-0.14	-16%
	4-axle tank wagon, WS 3 tare	D, 1-dim	5.26	0.73	0.76	0.63	-0.13	-17%
		F, 1-dim		0.80	0.97	0.72	-0.25	-26%
		D, 2-dim		0.68	0.69	0.65	-0.04	-6%
		F, 2-dim		0.74	0.86	0.73	-0.13	-15%
Freight wagon 1	4-axle container wagon, WS 1, tare	1-dim	4.4	0.88	0.97	0.88	-0.09	-9%
	4-axle container wagon, WS 3, tare	1-dim	4.4	0.94	0.86	0.77	-0.09	-10%
Freight wagon 2	2x2 axle wagon, WS 1, tare	1-dim	8.00	0.54	0.79	0.56	-0.23	-29%
Freight wagon 2	2x2 axle wagon, WS 3, tare	1-dim	7.20	0.68	0.92	0.81	-0.11	-12%
Freight wagon 2	2x2 axle wagon, WS 1, loaded	1-dim	16.50	0.43	0.70	0.53	-0.17	-24%
Freight wagon 2	2x2 axle wagon, WS 3, loaded	1-dim	15.70	0.63	0.78	0.76	-0.02	-3%
Special vehicle 1	8 axle wagon, WS 1, tare		10.54	0.61	0.72	0.62	-0.1	-14%
	8 axle wagon, WS 5, tare		9.62	0.66	0.74	0.66	-0.08	-11%
	8 axle wagon, WS 1, loaded		20.12	0.50	0.67	0.59	-0.08	-12%
	8 axle wagon, WS 5, loaded		18.96	0.44	0.53	0.47	-0.06	-11%
Locomotive 1	4-axle Loco	2-dim	21.25	0.65	0.74	0.63	-0.11	-15%
Locomotive 2	4-axle Loco	2-dim	21.25	0.69	0.70	0.62	-0.08	-11%
Locomotive 3	4-axle Loco	2-dim	22.00	0.60	0.66	0.59	-0.07	-11%
Locomotive 4	3-axle Loco	2-dim	22.50	0.60	0.62	0.57	-0.05	-8%
EMU 1	EMU WS 1, infl, empty	1-dim	14.54	0.6	0.68	0.63	-0.05	-7%
EMU 1	EMU WS 3, infl, empty	1-dim	13.09	0.47	0.55	0.49	-0.06	-11%
EMU 1	EMU WS 5, infl, empty	1-dim	13.84	0.53	0.60	0.55	-0.05	-9%
EMU 1	EMU WS 1, defl, empty	1-dim	14.54	0.66	0.69	0.64	-0.05	-7%
EMU 1	EMU WS 3, defl, empty	1-dim	13.09	0.58	0.63	0.58	-0.05	-8%
EMU 1	EMU WS 5, defl, empty	1-dim	13.84	0.66	0.71	0.65	-0.06	-8%

Dynotrain veh. 1	4-axle Loco, WS1	1-dim	21.73		**0.81**	**0.74**	-0.07	**-9%**
		2-dim	21.73		**0.78**	**0.71**	-0.08	**-10%**
	4-axle Loco, WS3	1-dim	20.46		**0.64**	**0.57**	-0.08	**-12%**
		2-dim	20.46		**0.63**	**0.57**	-0.06	**-10%**
Dynotrain veh. 2	4-axle passenger coach, WS1	1-dim	9.91		**0.76**	**0.65**	-0.11	**-15%**
		2-dim	9.91		**0.75**	**0.63**	-0.12	**-15%**
	4-axle passenger coach, WS3	1-dim	10.21		**0.73**	**0.60**	-0.14	**-19%**
		2-dim	10.21		**0.73**	**0.60**	-0.13	**-18%**
Dynotrain veh. 3	4-axle wagon empty, WS1	1-dim	4.90		**1.01**	**0.90**	-0.10	**-10%**
		2-dim	4.90		**1.02**	**0.95**	-0.07	**-7%**
	4-axle wagon empty, WS3	1-dim	4.76		**1.10**	**0.75**	-0.35	**-32%**
		2-dim	4.76		**1.12**	**0.82**	-0.30	**-27%**
Dynotrain veh. 4	4-axle wagon loaded, WS1	1-dim	21.63		**0.79**	**0.65**	-0.14	**-18%**
		2-dim	21.63		**0.77**	**0.64**	-0.14	**-18%**
	4-axle wagon loaded, WS3	1-dim	22.76		**0.78**	**0.60**	-0.19	**-24%**
		2-dim	22.76		**0.79**	**0.59**	-0.20	**-26%**
Dynotrain veh. 5	2-axle wagon empty, WS1	1-dim	5.84		**0.76**	**0.67**	-0.10	**-13%**
		2-dim	5.84		**0.77**	**0.72**	-0.04	**-6%**
	2-axle wagon empty, WS3	1-dim	6.49		**0.87**	**0.68**	-0.18	**-21%**
		2-dim	6.49		**0.89**	**0.55**	-0.33	**-38%**

NOTE The assessment of the DynoTRAIN data has been performed at a_q = 0,55 m/s^2 (+10 %).

9 Track loading parameters

In order to allow a more sophisticated assessment of track loading especially in cases where limit values are exceeded, but also for quantification of effects related to track damage, new quantities were specified for evaluation without limit values in order to gain experience by collection of measured data.

These quantities are described in detail together with the background inside the standard (see 7.5.3 and Annex J).

10 Rail surface damage quantity T_{qst}

10.1 What was changed

A new damage quantity T_{qst}, has been established by regression using simulated forces and simulated T_γ. In order to avoid the dependence of axle load T_γ is normalised to the vertical wheel force before the regression against the normalised lateral and longitudinal forces is made.

The formulation of the rail surface damage quantity consists of formulae in (1) and (2) in 9.4, derived for the outer wheel of the leading axles of each bogie or wheelset group. T_{qst} is a quasi-static parameter that depends on the quasi-static values of the T_X, Y and Q forces.

10.2 Why was it changed

One of the most important infrastructure cost drivers is RCF and wear of rails. These are also connected with the wheel maintenance costs. There is no assessment criterion that directly assesses this.

However, one purpose of controlling the lateral and vertical wheel forces (Y and Q) is to limit the fatigue risk of rails. Originating from work carried out by ORE C138 a limitation of these parameters in general – and the lateral quasi-static force (Y_{qst}) in particular – have somewhat implicitly also been considered a measure for controlling the wear of rails; therefore sometimes argued to remain in the standard. But both vehicle dynamic simulations and results from real measurements show that the magnitude of lateral force varies largely with actual friction and contact conditions – often unknown and un-controllable in testing procedures. Although the force level may be high, the rail surface damage (RSD) resulting from it may be moderate due to the low friction itself. This can lead to a situation where the test results may vary largely within the range for allowed test conditions.

It is also known that the correlation between RSD and Y_{qst} sometimes is very poor. This further reduces the usefulness of Y_{qst} as an indicator.

Work was carried out to find a parameter that is:

— measurable;

— reflects RCF and wear.

10.3 Approach

Both the wear and RCF damage mechanisms have been given a lot of attention in the railway sector for the last decades (GB and others) and a lot of the models arising rely on the so-called T_γ -parameter (being a measure of the friction energy loss in the wheel-rail interface per unit of travelled distance).

These models are based on a substantial theoretical frame work, and also verified and calibrated against real railway networks and in-service vehicles. The major drawback with these models is, however, that the input data is not easily measured nor controlled. It is required to have well defined computer simulation tools and methodologies at hand.

T_γ can be expressed as:

$$T_\gamma = F_\xi \cdot v_\xi + F_\eta \cdot v_\eta$$

where

F_ξ	is the longitudinal creepage force;
v_ξ	is the longitudinal creepage;
F_η	is the lateral/vertical creepage force;
v_η	is the lateral/vertical creepage.

It may be objected that also the spin moment and the spin creepage should be included to represent the total dissipated energy in the contact patch but since

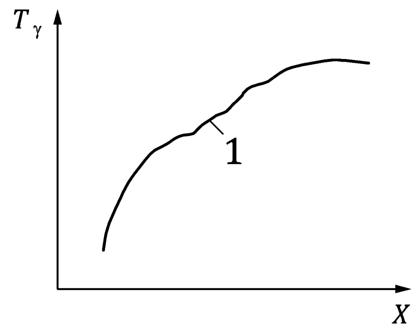
— T_γ is a widely accepted parameter and

— the product between spin creepage and spin moment generally will play a significant role only in large radii curves where the total dissipated energy and also T_γ is small and

— T_γ is relevant when making relative comparisons

it has been chosen to use only T_γ.

Therefore a simulation study was executed to find a parameter that will reflect T_γ, see Figure 14. This parameter was initially denoted Vehicle Curving Performance (VCP). So the idea was to find a function VCP=f(T_γ) and T_γ = g(test conditions, wheel rail contact conditions, operating parameters, ...). The aim was to find a simplified relation so that T_γ = f(X) where X could be Y_{qst}, $T_{x,qst}$ or other measurable parameters, or with other words, finding.



Key

X measurable quantities X

T_γ „non-measurable“, VCP ($T\gamma$)

1 transfer function F(X)

Figure 14 — Approach

From parametric simulation it is found that $T_\gamma \sim T_{qst}$=f(T_X,Y,Q) which is much less dependent on friction and geometric contact conditions.

Introducing T_{qst} and associated limit values more clearly shows the connection between track loading parameters and damage modes in track.

10.4 Derivation and definition of T_{qst}

A more complete description of how T_{qst} was derived can be found in [4].

Generally, T_{qst} may be written on the form:

$$T_{qst} = Q_{qst} \cdot \left[b_1 f_{i,j}^2 + b_2 f_{i,j} + b_3 \right]$$

where $f_{i,j}$ is defined as

$$f_{i,j} = \left(\frac{Y}{Q} \right)_{i,j\,qst} + a \cdot \left(\frac{T_X}{Q} \right)_{i,j\,qst}$$

for the different wheelsets (i) and wheels (j). Note that filtering shall be made before dividing with Q (to avoid division by zero).

The coefficients a, b_k (k=1, 2, 3) are the result of multiple regression analysis and part of the calibration procedure.

Simulations were carried out using:

— Various wheel/rail profile combinations.

— Various coefficients of friction.

— A number of vehicle types, both passenger and freight vehicles as well as radial steering and not radial steering vehicles.

Given by the formulation of T_{qst}, the following forces between wheel and rail are required:

1) guiding force Y, lateral measuring direction;

2) wheel force Q, vertical measuring direction;

3) wheel force T_X, longitudinal measuring direction.

It was found that the best fit between (see Figure 15) T_γ and T_{qst} was found using the following formulae:

$$T_{qst} = \frac{Q_{qst}}{10000} \cdot \left[330 \cdot f^2 - 62 \cdot f + 4 \right] \quad (11)$$

$$f = \frac{Y_{qst}}{Q_{qst}} + 0{,}62 \cdot \frac{\left| T_{x,qst} \right|}{Q_{qst}} \quad (12)$$

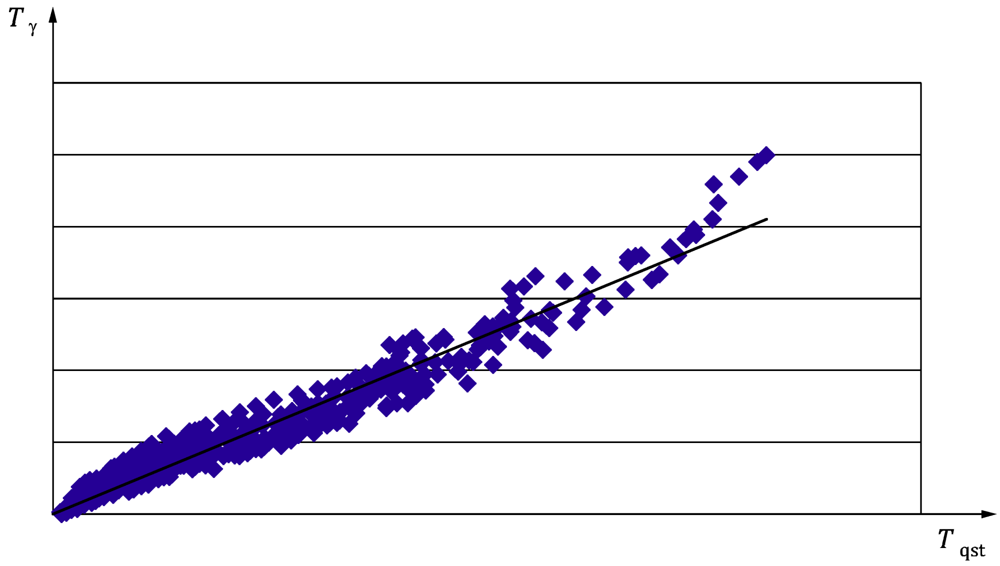


Figure 15 — Correlation between T_γ and T_{qst} ($y = 1{,}0 \cdot x + 0{,}0$)

10.5 Measurable quantities

To ensure that the new criterion would not pose any problems for test centres currently using force measuring wheelsets it was asked whether or not they would be able to measure T_{qst}.

The question was asked to 14 test centres and the answers were as follows:

Yes – 6 centres

We do not use or produce instrumented wheelsets – 2 test centres

No answer given – 5 test centres

We are not able to today but will be when it becomes necessary – 1 test centre

10.6 Limit values

Since no or very limited experience in using T_{qst} exists it was agreed in the group of specialists not to state any limit values at this early stage. To gain experience for future revisions it was agreed to require that T_{qst} shall be documented in case $T_{x,qst}$ is measured.

10.7 Verification from tests

Since it is difficult to measure the creepage it is also difficult to measure T_γ. However, DB Systemtechnik has carried out measurements that suggest that it is possible to achieve a reasonable qualitative relation between T_{qst} and T_γ.

11 Replacing of limit values of ride characteristics by informative guidance for assessment

11.1 General

When the review of EN 14363 started, the TSI requirements referred only to running safety and track loading as defined in EN 14363:2005. From the legal point of view, there was no need to investigate running characteristics of a vehicle. Further the background for the assessment quantities $y..^*_{q,max}$, $z..^*_{q,max}$, $y..^*_{q,rms}$, $z..^*_{q,rms}$ was not clear and it was not possible to decide, if and under which circumstances values above the limit values were acceptable. Existing vehicles (except passenger vehicles in normal order) did not always fulfil the requirements.

It was in question if the stated purposes "influence on passengers", "loading safety" and "strength of the vehicle and its mounted parts" are not really covered by the assessment quantities with their frequency ranges and limits. Furthermore other rules dealing with these purposes used other quantities and assumptions.

A look back showed that the limit values were used at the beginning in Germany as "preliminary values". The Max-limits had their origin at the elevator industry due to a lack of an appropriate state of the art in the railway sector. Rms values were used to replace the old Wz-method before running safety criteria were developed. Max- and Rms-values were at first evaluated with completely different filter- and evaluation methods at the beginning. Especially vehicles with air springs in deflated condition and many freight wagons with established running gear could often not fully comply with these limit values when the measured data were filtered and evaluated according to UIC 518.

WG 10 investigated, if the Max- and Rms-limit values of ride characteristics were useful to control some issues of safety or comfort. The following points were considered:

— **Fixation of payload** is regulated by RIV loading rules. They are based on experience with existing vehicles and roller-rig tests. Depending on the kind of payload, different quantities and frequency ranges were taken into account to develop the loading rules. As this topic is not a question of vehicle track interaction alone, this question cannot be handled in WG 10.

— The **strength of the vehicle and its mounted parts** is in the scope of WG 2. This working group stated, that the accelerations according to EN 14363 are not suitable for the assessment of strength, because they contain no information about quasi-static accelerations and spans of accelerations.

— **Riding comfort** for passenger vehicles was already covered by EN 12299.

— Limits and methods for the **health of the train crew** are described in Physical Agents (Vibration) Directive 2002/44/EC referring to ISO 2631 and ISO 5349. The accelerations (vibration) experienced by workers (train crew) in an 8 h period are limited by the Directive: The assessment process differs completely from the ride characteristics approach.

— **Passenger safety** was only related to accidents and their consequences. Such a scenario sets obviously higher requirements for luggage storage and seats than a normal train operation (including degraded operating conditions).

At the end it was clear, that the limit values had no clear purpose, especially as for the simplified measurement method other limits and another evaluation process was developed in the meantime.

It remained a “bad feeling” in the group to remove the evaluation of car body accelerations completely for the normal measuring method. It was reminded, that there was a long tradition before the introduction of instrumented wheelsets to accept vehicles only on the basis on measurements of accelerations (e.g. Wz values).

As a consequence of the fact that TSI does not use ride characteristics as acceptance criterion, it was finally decided not to set explicit limits in EN 14363. On the other hand, it was found, that the level of maximum acceleration in the vehicle body is necessary to describe the running behaviour of a vehicle. Therefore the quantities and the evaluation method for the max-values remained in the standard. The Rms- values were removed completely, as the database of available results was very small and the limits were less reasonable than for the Max-values. Now it is required to report the measured maximum values from the on-track tests in order to allow further assessment by experts if necessary for other purposes than legal acceptance. In Annex L for some vehicle types typical values that were found in several test reports of the past are stated as guidance. For freight wagons it is additionally indicated, that in case of excess of the stated typical values, additional investigations to demonstrate the loading safety under the intended conditions of operation and track quality are needed, as the RIV-loading rules are based on the behaviour of established freight wagons.

11.2 Removing limit values for quasi-static lateral acceleration

The background for the assessment quantity “Lateral quasi-static acceleration on car body” $\ddot{y}^*_{\text{qst}}$ was not clear. $\ddot{y}^*_{\text{qst}}$

First it was found from discussions with former members of WG 10, that the limit was originally created for two purposes:

— limitation of lateral acceleration of tilting trains operated without working tilting mechanism (1,5 m/s²);

— limitation of lateral acceleration for staff working in dining cars (1,5 m/s²).

For freight wagons it wasn’t possible to find the reason for the limitation. It was suggested that it might have been related to the fixation of payload.

A study showed, that the intended control of the quasi-static car body accelerations for normal vehicles is ensured by control of operating conditions together with the roll coefficient, which needs to be determined anyway for gauging purposes. Further, it was found that under normal operating conditions, the limitations given by the standard assumptions for gauging according to EN 15273 (and panto/catenary contact in case of electric vehicles) are more restrictive than the old limit values. In special cases (for example vehicles intended for operation with high cant deficiencies, operating conditions in failure mode are anyway controlled by definition of conventional operating conditions. It is not necessary to check this limitation by measurements during on-track testing.

Another case of Swedish X2000 locomotives (operated without tilting at cant deficiencies up to 275 mm with a sitting driver) showed, that a large excess of the present limit can be acceptable.

For freight wagons the sway coefficient is defined only by the deflection of the suspension. The clearance of the side bearers are not included and respected separately in the gauging procedure. The influence of the side bearers is small (0,14 m/s²) and the normal sway coefficients are normally very low (around 0,15). This would lead to a quasi-static body acceleration of 1,14 m/s². This means that it is normally not possible to exceed the limit. This is also the experience.

At the end it was concluded, that it is sufficient to control operating conditions by limitation of the uncompensated lateral acceleration only and the limit value was removed. The assessment quantity remained in standard to support the simplified method for evaluation of the flexibility coefficient s specified in Annex D of EN 14363:2005.

11.3 Revision of accelerometer positions in the car body of freight vehicles

It was found that in UIC 518 and in EN 14363 different requirements were made for the exact measuring position of accelerometers in the car body of a freight wagon.

While in UIC 518 it was required to place accelerometers at the end of the vehicle at the level of the centre of gravity, the EN required to place them above the bogies on the floor. UIC 518 further required to place additional accelerometers on the floor of the upper deck in double deck vehicles.

It is necessary to understand that the position of these accelerometers is also related to the evaluation of running safety in the simplified measuring methods.

WG 10 decided to use the definition of EN 14363, as the position above the running gear (expression used instead of bogie to include also 2-axle wagons) and on the floor reflects better the wheel/rail forces which should be controlled by the running safety parameters.

It was recommended to also measure accelerations in the centre of the vehicle body of long vehicles and double deck vehicles where major acceleration levels could be observed, to allow the assessment of unusual bending of the vehicle body if necessary.

12 Track geometric quality and coordination with WG 28

12.1 Background

Experience from testing bodies and rolling stock suppliers indicated that it was not practical to find test sections meeting all of the requirements of EN 14363:2005 or UIC 518:2009 for speed, curve radius, cant deficiency and track geometric quality. The track quality QN1 and QN2 values, which were intended to be target values for the 50th and 90th percentiles, appeared to be not representative of what was usually found on most European networks.

As a consequence, in some cases test planning aimed at “trying to approach these target conditions”, while in other cases they were simply forgotten about (“this is not feasible, so why should we try?”). This resulted in diverging ways of testing, and discrepancies in the acceptance practices in Europe.

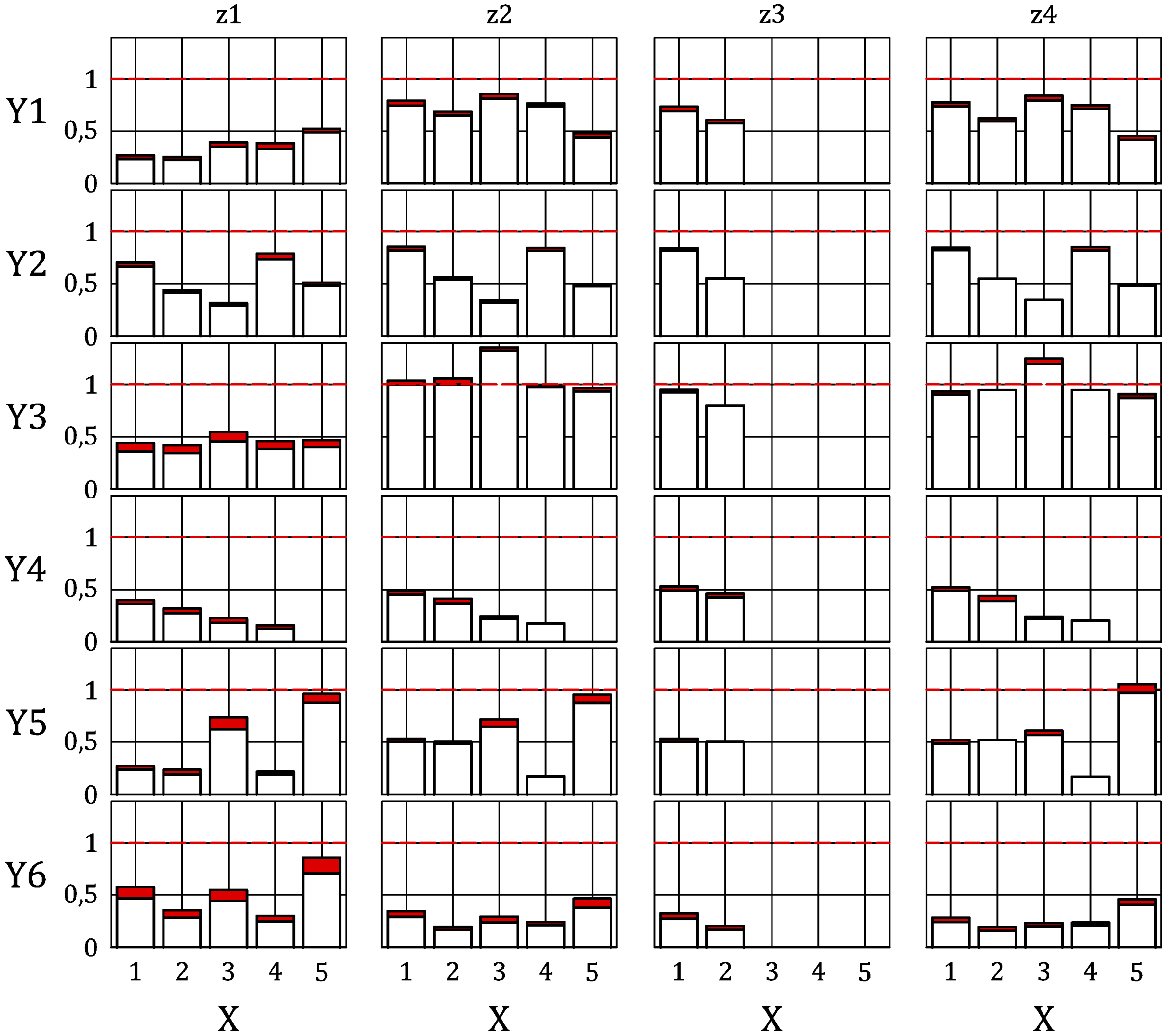
This aspect was considered by the Joint Survey group of WG 10 and WG 28 (see 12.2).

There was also concern that the main parameters used (standard deviations of alignment – σAL and longitudinal level - σLL) may be inappropriate, due to a poor correlation with the dynamic assessment quantities. This aspect was considered during the EU funded (7th Framework) project DynoTRAIN (see 12.3).

DynoTRAIN also investigated the sensitivity of the vehicle assessment quantities to the track geometric quality and the use of multiple regression analysis (see 7.4.4).

Before going into details of the motivation it is important to remember the nature of the statistical evaluation method being used in EN 14363. As the maximum vehicle reaction at a certain point of a line is clearly dependent on a maximum disturbance but also on the phase shift when entering the point together with the shape of the disturbance, it is not possible to define a worst track disturbance for testing the vehicle. This would also vary from vehicle type to vehicle type. Therefore the approach of vehicle testing in EN 14363 is to collect data in a wide range of track conditions to make an estimate of the future maximum value using a statistical approach.

Within project DynoTRAIN the influence from track geometry quality on the test results was studied. For an illustration, see the figure below showing the estimated maximum values of five different vehicles (the different bars in each figure, denoted v1, v2, v3, v4 and v5) in the four test zones (the different columns of figures denoted z1, z2, z3 and z4); the estimated maximum values are normalised with relevant limit values. The red bars show the influence from changing the track geometry from the lower to the upper boundary of class D. It can be clearly seen that the sensitivity of the test results to the track quality standard deviation within this track quality range is weak.



Key

X vehicle

Y1 $\Sigma Y_{max} / \Sigma Y_{max,lim}$

Y2 $Q_{max} / Q_{max,lim}$

Y3 $(Y/Q)_{max} / (Y/Q)_{max,lim}$

Y4 $\ddot{y}^{+}_{S,max}/\ddot{y}^{+}_{S,max,lim}$

Y5 $\ddot{y}^{*}_{S,max}/\ddot{y}^{*}_{S,max,lim}$

Y6 $\ddot{z}^{*}_{S,max}/\ddot{z}^{*}_{S,max,lim}$

Figure 16 — Influence of geometric track quality on test results

This may seem counter-intuitive but there is a good reason for this. The representation of the track quality, both in EN 14363 as well as in EN 13848-6 is based on standard deviations of the track quality.

However, there are many other properties of the track quality that are of importance for the vehicle response. Important properties are, not necessarily limited to: single defect magnitude, shape of the track faults (for instance wavelength contents), favourable or unfavourable phase shifts between lateral and vertical track faults. Therefore the vehicle response on two track sections with the same track quality standard deviation may vary considerably. Due to this in a statistical analysis there is normally a variation that can only be partly explained by the track quality standard deviation. As visualised in the figure above it was found that when the tested track quality is increased from the bottom end (70 %-value) to the top end (90 %-value) of interval D the assessment quantity increase is generally small.

12.2 Joint Survey Group WG 10 / WG 28

In 2010 WG 28, who were working on EN 13848-6, identified that there was a gap between the expectations and descriptions of track geometric quality from the Infrastructure and Rolling Stock points of view (Reference [6]). WG 28 therefore proposed a Joint Survey Group with WG 10 and this was set up by CEN/TC 256 resolution 053/2010 (Reference [7]) to:

— make a survey of requirements and expectations from both sides, Rolling Stock and Infrastructure;

— describe and analyse possible methods that can be used in the future for assessing track geometry quality – methods that might take into account vehicle reactions and might address the differences between WG 10 and WG 28;

— identify whether it would be possible to provide a common method agreed by all parties and leading to a common assessment of track geometry;

— in case of a positive answer, to give recommendations on how to build this common method.

An important input to this group was a large survey of existing track qualities in Europe (13 networks) undertaken by WG 28 (Reference [9]) which classified the results for five speed classes, more or less consistent with the ranges used in EN 14363 to specify test tracks quality. This again showed a very large variety of conditions throughout Europe, especially on “slow speed lines” ($V \leq 80$ km/h) which, however, are outside the usual vehicle test field. This gave:

— the 50 % and 90 % values of standard deviations (wavelength range D1) for longitudinal level and lateral alignment, classified per speed range and country;

— the overall European cumulative frequency distributions of longitudinal level and lateral alignment, classified per speed range and allowing a quick comparison of “real” 50 % and 90 % values with QN1 and QN2 values respectively.

EN 13848-6 includes, for each of the 5 speed classes mentioned above, classification of track quality into 5 track quality classes (TQC) A - B - C - D - E (from the best to the worst track quality). For each speed class, these TQC are defined separately for alignment and for longitudinal level (minimum and maximum values of σAL and σLL).

WG 10 also provided data (reference [10]) on the typical values (50^{th} and 90^{th} percentiles of σAL and σLL) observed during vehicle tests performed in Europe over the recent years, for various test speeds. This showed a rather wide scatter between the networks and allowed comparison with EN 14363:2005 QN1 and QN2 values.

An example synthesis of the two sets of data for the 160 km/h condition is given in reference [11].

The survey group had four meetings between October 2010 and August 2011 and the conclusions are given in (reference [8]).

The results were also presented to the ERA DYN WP meeting on 15 September 2011.

12.3 DynoTRAIN project

Work Package 2 of DynoTRAIN (reference [3]) investigated alternative methods for assessing track geometric quality that might be more closely correlated to measures of vehicle behaviour.

The dynamic performance of a vehicle is assessed using 3 types of estimated values, derived from measured forces and/or accelerations: quasi static, rms and maximum values.

From a physical point of view, quasi static values, used for track fatigue and running behaviour, are obviously independent of track quality.

For rms values, used for running behaviour only, it is reasonable to assume that a description of track geometry based on standard deviations is adequate (rms = standard deviation when the quasi static part of the signal is eliminated, which is the case here).

For maximum values (used for safety, track fatigue and running behaviour), which are the most important and critical, correlation with standard deviations of track irregularities is much less obvious: maximum estimated values of dynamic signals over a whole test zone are calculated from single values which are more or less the maximum values of each signal over each individual track section, and it is reasonable to expect these values to be more closely related to local maximum track defects than to global standard deviations of track quality on the whole track section.

This is why the use of peak values of track defects (maximum mean to peak values of alignment or longitudinal level) was suggested as an alternative to the use of standard deviations. In the frame of WG 10 SG 8 as well as the DynoTRAIN project, various studies were performed, using data from different networks and tested vehicles, in order to investigate correlation between the dynamic parameters (99,85 % values on every track section) and:

— standard deviations of track defects (alignment and longitudinal level);

— peak values of track defects (alignment and longitudinal level);

— alternative parameters describing track quality (for DynoTRAIN project only).

Although the original idea looked relevant and promising, these studies failed to identify a better way to describe geometric quality of test tracks. Correlation of dynamic parameters with standard deviations of alignment and longitudinal level over the corresponding track sections was always found as good as (and often better than) correlation with local peak values or any alternative description of track quality.

This is why, considering the experience gathered with standard deviations, their simplicity of use and the “universal availability” of this mode of description, it has been felt relevant to retain it for the present revision of EN 14363.

12.4 Use of 50 % and / or 90 % levels

Assuming it was logical that the upper part of track quality distributions (“bad track”) should be represented in the samples, a study considered the need to be more or less prescriptive about the remaining part of these distributions: do we need to specify anything for the 50th percentile, or something equivalent to qualify the lower and intermediate parts of the distributions?

A statistical exercise was performed in 2011 on some real cases (real locomotive and EMU test data), which showed that the estimated values were not so much affected when the original sample of track sections was reduced (in various ways) to adjust the 50th percentile while the 90th percentile remained unchanged. WG 10 therefore concluded that it was enough to specify target values for the 90th percentiles, without any specific requirement on the remaining part of the distributions.

12.5 Changes from EN 14363:2005 and UIC 518:2009

Based upon the studies described above, WG 10 decided to:

— continue to specify test track quality using the existing parameters σAL and σLL;

— use only the 90th percentiles as the influence of 50th percentiles was shown to be not so important;

— specify that the 90th percentiles of distributions of σAL and σLL shall fall within TQC 'D' defined in EN 13848-6 for the corresponding speed range.

Specified in this way, the level of track quality required for vehicle tests is more consistent with real track quality on most European networks, and is now both “achievable” (tests can be done properly) and “representative” (vehicles tested according to this specification should face no rejection in other European networks). This does not mean the vehicles will never see worse operating conditions, as stated in SG final report (reference [8]):

“The SG members acknowledge the fact that, regarding track geometric quality, there will always be discrepancies between the values specified in EN 14363 for vehicles acceptance (test conditions), the values specified in track maintenance standards and the real values experienced by the vehicles in service (operating conditions).

In spite of these differences, it is assumed - and confirmed by experience - that the vehicles tested in compliance with EN 14363 (with the test track quality conditions achievable in practice) can be operated safely on the lines maintained in accordance with existing track maintenance standards:

— up to a certain level of track deterioration, these vehicles can be operated at their design speed and cant deficiency values;

— beyond this level, the general operating rules (for example speed and/or cant deficiency restrictions) applied by the Infrastructure Manager ensure running safety of all vehicles.

Hence the changes in the EN 14363 include:

— target values for 50th percentiles of distributions (of σAL and σLL) have been removed;

— target values for 90th percentiles of distributions (of σAL and σLL) have been changed.

There are no specific requirements on track gauge as a measure of track geometry as this is only important when contributing to the wheel-rail contact conditions.

Most of the information related to Track Geometric Quality has been collected in Annex M, with some additional background in Annex N.

12.6 Speed range used for Track Quality assessment

It is made clearer that track quality relevant to V_{adm} should be used for Zone 2 and that the speed range 80 km/h to 120 km/h should be used for Zones 3 and 4. For vehicles tested on high-speed lines with $V_{adm} \geq 250$ km/h it is also required to test additionally on slower speed lines (from 160 km/h to 230 km/h) with a relevant test speed.

The speed ranges in Annex M are generally consistent with those in EN 13848-6 except that the range 160 km/h to 230 km/h has been divided into two (160-200 and 200-230) in EN 14363 as this reflects the maintenance practice on many networks. Many vehicles are tested for 200 km/h and it is important to have the correct track geometry for this case. To permit a track geometry suitable for 230 km/h for such vehicles would not be consistent.

12.7 Wavelength Ranges

Table M1 has been added to recognise that the wavelength range D1 (3 m to 25 m) is not sufficient to cover the required inputs, particularly at higher speeds. No mandatory values are set for track geometry in wavelength range D2 or D3, as this data is not yet available from most networks. However for a reference speed > 160 km/h it is required to report the values for range D2 and for speeds > 230 km/h it is recommended to also report the values from D3.

12.8 Requirements in different zones

The requirement on track quality in test zone 1, straight track, has been removed as the vehicle reaction is less dependent on track quality and the margins to the limit value are much higher. If the vehicle is tested at maximum speed in combination with a high cant deficiency in test zone 2 respecting the requirements for track quality, the worst case is covered.

The sensitivity analysis carried out using the data from DynoTRAIN, and other available data supports this conclusion. For stability testing, where limit values may be approached in straight track, track quality is not the relevant influencing parameter.

12.9 Topics discussed but not changed

Track quality for speeds ≤ 80 km/h

From the results of their survey, WG 28 were keen to include requirements for testing on worse track quality than required in the test zones 1-4 which only include quality representative of lines with speeds > 80 km/h. However, in the timescale of this revision, no data was available on the locations and other properties (speed, curve radius, cant deficiency) of track sections with geometric quality levels representative for speeds ≤ 80 km/h and therefore no practical test could be developed for this condition. This topic has been noted for further study before a future revision of EN 14363. This is likely to require a further survey of the networks and may include data not yet available in databases.

Exclusion of track sections with discrete defects above QN3.

No new information is available on the actual range of discrete defects on the different networks and therefore the values of QN3 from EN 14363:2005 have not been changed. These are shown in Table M4. Permitting the removal of these sections avoids a distortion of the statistical process by ‘outliers’.

13 Contact conditions

13.1 Equivalent conicity

13.1.1 Summary of requirements of EN°14363:2005

A definition of equivalent conicity tan γ_e is given in 3.10.4. The equivalent conicity is a function of the lateral wheelset amplitude y, for the mandatory requirements the equivalent conicity tan γ_e is assessed at y = ±3 mm. It is also stated that an extensive evaluation of the tan γ_e in a range of 1 mm ≤ y ≤ 8 mm may be necessary to clarify any questions relating to the running behaviour.

In 5.4.3.3, 5.4.4.4 and 5.4.4.5 requirements on the wheel profile, on the rail inclination and on the rail profiles were specified. Since the evolution of the wear of wheel profiles of new developed vehicles is not known beforehand, on-track tests are conducted with new wheel profiles. After the acceptance of the vehicle a further study shall demonstrate that the highest value of equivalent conicity of the worn wheels does not exceed the test value by more than 50 % or 0,05, whichever is the smaller.

For vehicles intended for unrestricted international operation the test condition shall cover rail inclination of 1:20 and 1:40. In addition the test sections shall respect values of equivalent conicity given in Table 7. However, because in some countries the vehicles have to negotiate track sections with higher equivalent conicity values than the values described in Table 7, the national authorities require stability tests in these sections.

13.1.2 Summary of requirements of UIC Leaflet 518:2009

A study of the UIC Vehicle Track Interaction group about the distribution of the track conicity in several European countries showed that the mean value of the equivalent conicity for the track (with worn rails and theoretical wheel profiles) is about tan γ_e = 0,2 and not dependent on the rail inclination. Therefore UIC 518 requires that the equivalent conicity should be distributed between 0,15 and 0,25 for a minimum of 50 % of the track sections. In contrast to EN 14363:2005, the equivalent conicity shall be calculated at a lateral wheelset movement y between ±2 mm and ±4 mm.

Since low body motions may be encountered for very low equivalent conicities tan γ_e < 0,05, on-track tests should include sections with values of equivalent conicity below 0,05.

13.1.3 Changes in EN 14363:2016

The test conditions specified in UIC 518:2009 were used as a starting point for the specification of the requirements regarding the contact geometry wheelset/track. The requirement to achieve the equivalent conicity distributed between 0,15 and 0,25 for a minimum of 50 % of the track sections together with the requirements for the distribution of the radial steering index values would on one hand require to equip the test trains with a costly measuring system, and on other hand restrict the number of test sections which fulfil all test condition requirements and are thus suited for the evaluation.

The discussions about the pros and cons resulted in the agreement, that the only important requirement regarding the contact geometry wheelset/track which is relevant for the result of vehicle acceptance test is the equivalent conicity value during the stability test in test zone 1. This minimum requirement reduces the required amount of rail profile measurements and can be checked also using manual measurements of rail profiles if no other possibilities are available.

The possibility to ensure the required wheel/rail contact geometry and the procedure for the evaluation of equivalent conicity value had been discussed and examples of assessments evaluated, particularly regarding:

— Wheel profile to be used during the testing to fulfil the requirement regarding the equivalent conicity.

— Effect of averaging the equivalent conicity over 100 m of track distance: Should it be sliding mean over 100 m, or the mean value of the sliding means over the whole test section, or the maximum value of the sliding means over the whole test section?

— Effect of the wheelset amplitude used for the determination of equivalent conicity value: Should it be amplitude of y = 2 mm, y = 3 mm, y = 4 mm, y = min [$(TG\text{-}SR\text{-}1)/2$; 4 mm], or the maximum value reached between y = 2 mm and y = min [$(TG\text{-}SR\text{-}1)/2$; 4 mm]?

The specification of the requirements regarding the wheel profile to be used during the testing turned out to be difficult, because a high conicity is required for the stability test, while an average conicity value of about 0,2 is required for other tests. Finally, it was agreed that the testing should be carried out using wheel profiles providing the contact geometry conditions wheelset/track representative of normal service. As the running stability is tested separately according to revised EN 14363, the high conicity for the running stability test can be covered by selecting suitable sections of track with high conicity. Alternatively, the required high conicity condition for the stability test can be achieved by a modification of the wheel profile on a running gear without instrumented wheelsets while keeping the normal profiles on the instrumented wheelsets.

Note l to Table 2 covers the situation where wheel profiles are maintained within very narrow limits in a way that the range of equivalent conicities in service is also narrow. In this case it is only necessary to test in this narrow range.

The discussions regarding the evaluation of equivalent conicity resulted in the specifications stated in Annexes O and P. The agreed requirements for manual and automatic rail profile measurements to demonstrate the compliance with the target test conditions are described in Annex O.

The requirements for the evaluation of equivalent conicity including the specification of lateral wheelset amplitude y for assessing the tan γ_e function are given in Annex P. The amplitude y of lateral wheelset displacement is dependent on the lateral clearance between wheelset and track. This is in line with the requirements in TSI Loc & Pas and TSI Infrastructure. The evaluation over 100 m was agreed to conduct as the sliding mean over 100 m, using a step equal to the spacing between rail profile measurements.

The changes regarding the required equivalent conicity values in the revised EN 14363 were necessary for two reasons. On one hand, investigations conducted by UIC and DynoTRAIN showed [1, 2], that the majority of the contact conditions are similar in European countries and does not require additional tests. On the other hand, the result of the DynoTRAIN project has already been included in the TSI Loc & Pas and the requirements in the standard should be consistent with the TSI Loc & Pas.

Hence, the limit curve of equivalent conicity (red line in Figure 17) was adopted from TSI Loc & Pas for the target test conditions given in Table 2 of EN 14363:2016. If the target test conditions are met, additional tests on different rail inclinations and a study about the evolution of wear of the wheel profile are no longer necessary.

13.2 Background information about investigations carried out in the DynoTRAIN project

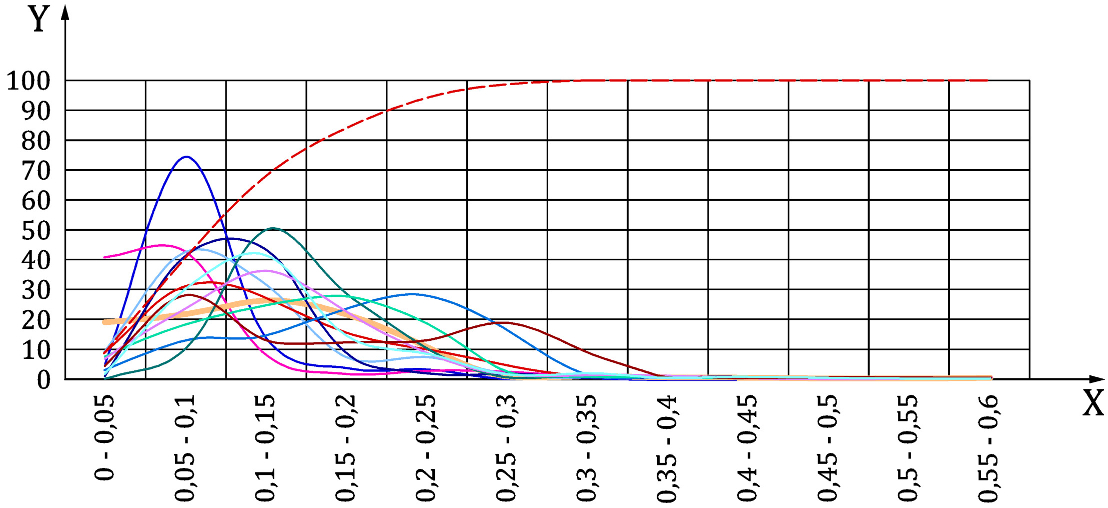
The objectives of the EU funded DynoTRAIN project were to close the open points (track geometry and contact conditions) in the TSIs. In the framework of the DynoTRAIN project, rail profile measurements were conducted in Germany, France, Italy and Switzerland with a vehicle based optical measurement device. In addition the project partners provided rail profile measurements of track sections which were considered as representative of their network. Table 2 shows the summary of the investigation in terms of equivalent conicity of the tracks for each country [13]. The values represent the 50 %, 95 % and 99 % value of equivalent conicity ($y = 3$ mm) of the frequency distribution dependent on the permitted line speed. The result of the UIC study is confirmed except for Italy where the values of equivalent conicity for the track are very low. The corresponding wheel profile (S1002 or EPS) is indicated for each country. It should be noted that the wheel tread section of the EPS profile is identical to the GB P8 profile and will therefore give the same values for equivalent conicity as the P8.

Table 2 — 50 %, 95 % and 99 % value of equivalent conicity (*y* = 3 mm) of the track in different countries [13]

	Germany			France			GB		
	Equivalent conicity S1002			Equivalent conicity S1002			Equivalent conicity EPS		
Speed class [km/h]	**50 %**	**95 %**	**99 %**	**50 %**	**95 %**	**99 %**	**50 %**	**95 %**	**99 %**
0–120	**0,15**	**0,60**	**0,90**	**0,10**	**0,25**	**0,45**	**/**	**/**	**/**
120–160	**0,15**	**0,50**	**0,85**	**0,10**	**0,15**	**0,25**	**0,15**	**0,20**	**0,25**
160–230	**0,15**	**0,30**	**0,60**	**0,10**	**0,35**	**0,55**	**0,10**	**0,15**	**0,20**
> 230	**0,10**	**0,20**	**0,30**	**/**	**/**	**/**	**/**	**/**	**/**

	Italy			Switzerland		
	Equivalent conicity S1002			Equivalent conicity S1002		
Speed class [km/h]	**50 %**	**95 %**	**99 %**	**50 %**	**95 %**	**99 %**
0–120	**< 0,05**	**0,15**	**0,20**	**0,20**	**0,45**	**0,65**
120–160	**< 0,05**	**0,15**	**0,20**	**0,20**	**0,30**	**0,50**
160–230	**< 0,05**	**0,10**	**0,15**	**/**	**/**	**/**
> 230	**< 0,05**	**< 0,05**	**0,05**	**/**	**/**	**/**

The project partners provided measured wheel profiles too. The wheel profiles are divided in wheels operating on rails with an inclination of 1/20 and wheels operating on rails with an inclination of 1/40. In Figure 17 the frequency distributions of equivalent conicity of all investigated wheel profiles are depicted [13]. The thick lines in the diagrams represent the mean value of each conicity class and the corresponding dashed lines the cumulative curves of the mean values. The figures in brackets in the legend represent the numbers of measured wheelset profiles.



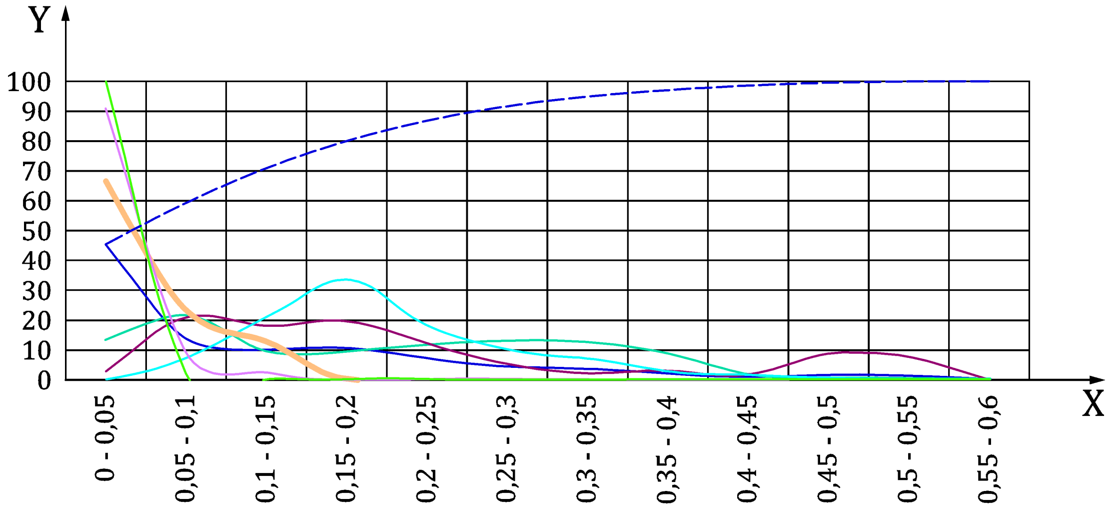
Key

mean (53512) | mean cumulated | ICE1 (25508) | ICET (11433)
ICE3 (10759) | ICE2 (2767) | 1016 (1523) | LINT41 (613)
ET440 (311) | RailJet (244) | BR185 (190) | Talent (110)
BR152 (54)

X equivalent conicity at y = 3 mm

Y frequency in %

Figure 17a — Frequency distribution of equivalent conicity of wheelsets (track gauge TG = 1 435 mm) wheels operating om 1/40 rails



Key

mean (18232) | mean cumulated | ETR600 (617) | Mark3 (520)
EMU_UK (176) | TGV (418) | Wagon (57) | Loco_FR (44)

X equivalent conicity at y = 3 mm

Y frequency in %

Figure 17b — Frequency distribution of equivalent conicity of wheelsets (track gauge TG = 1 435mm) wheels operating on 1/20 rails [13]

Representative samples of wheel and rail profiles were chosen for each speed category in order to calculate the equivalent conicity in a worn – worn condition. Table 3 summarises the results [13]. The maximum and minimum values of different percentiles of equivalent conicity in a worn-worn condition are given. Only the real case is considered, namely wheels operating on 1/40 rails combined with German rail profiles and wheels operating on 1/20 rails combined with French and GB rail profiles respectively. The letters in brackets indicate the corresponding country (F = France, G = Germany, GB = Great Britain). It is worth to mention that, even for a worn-worn condition, the mean equivalent conicity values are in the range between 0,1 and 0,25 which is similar to the UIC study and confirms the requirement in UIC Leaflet 518:2009.

Table 3 — Minimum and maximum values of different percentiles of equivalent conicity in dependence on speed in a worn-worn condition

	50 % value		**95 % value**		**99 % value**		**99,7 % value**	
Speed class [km/h]	**Min**	**max**	**min**	**max**	**min**	**max**	**min**	**max**
0–120	**0,15 (F)**	**0,22 (G)**	**0,33 (F)**	**0,48 (G)**	**0,42 (F)**	**0,58 (G)**	**0,45 (F)**	**0,62 (G)**
120–160	**0,11 (GB)**	**0,22 (G)**	**0,33 (GB)**	**0,44 (G)**	**0,43 (F)**	**0,57 (G)**	**0,44 (GB)**	**0,58 (G)**
160–220	**0,09 (GB)**	**0,21 (F)**	**0,23 (GB)**	**0,43 (F)**	**0,30 (GB)**	**0,52 (F)**	**0,32 (GB)**	**0,60 (F)**
> 220	**/**	**0,16 (G)**	**/**	**0,33 (G)**	**/**	**0,39 (G)**	**/**	**0,42 (G)**

Italian rail profiles were not used because the equivalent conicities for the track with the reference wheel profile S1002 are too small in order to obtain meaningful results.

Based on the above values Figure 18 shows the 95th percentiles of equivalent conicity for worn wheels and rails together with the limits of TSI Infrastructure and TSI Loc&Pas. In addition the limits given in EN 14363:2005 and UIC 518:2009 for combined wheel-rail conicity required in acceptance tests are plotted too. For the TSI Loc&Pas, the starting point was the limit curve of UIC 518:2009, which was slightly modified in order to comply with the limit values of TSI Infrastructure.

The limit values given in EN 14363:2005 seem a little bit too high for speeds up to 140 km/h, because they are above the 95th percentile of Germany and much higher than the 95th percentile of France. Hence, it might be hard to find test sections for a stability test in France which meet the requirements of this standard.

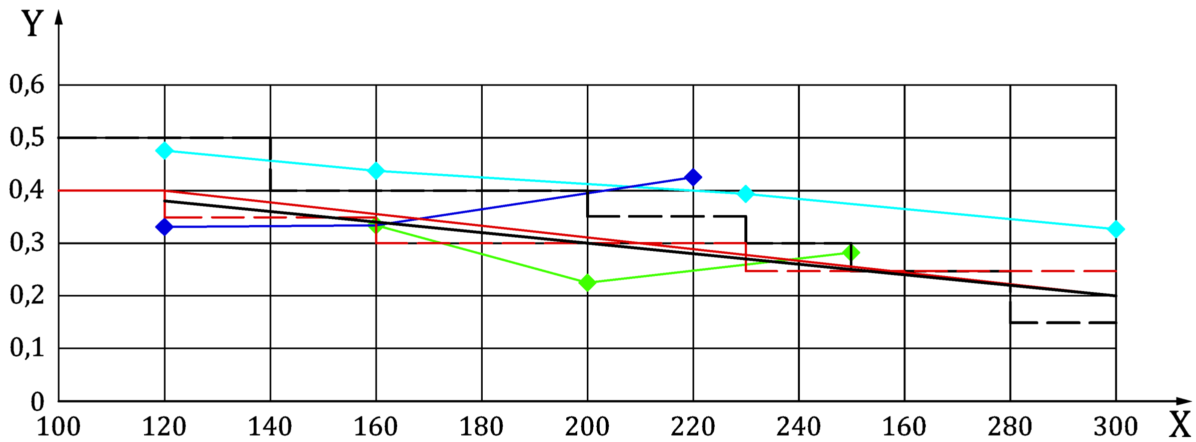
The assessment of the equivalent conicity at the amplitude at $y = \pm 3$ mm was also discussed. In order to show the differences the following equivalent conicities were calculated for a huge number of rail profiles:

— $(\tan \gamma_e)_{mid}$: the value for $y = (2\text{ mm} + y_{max})/2$;

— $(\tan \gamma_e)_{max}$: the maximum reached between $y = 2$ mm and $y = y_{max}$;

— $(\tan \gamma_e)_{3mm}$: the value for $y = 3$ mm.

where y_{max} is either 4 mm, or 2 mm or $(TG\text{-}SR - 1)/2$, depending on the lateral clearance of the wheelset. The frequency distribution between the equivalent conicity at $y = 3$ mm and $y = y_{mid}$ showed a negligible difference.

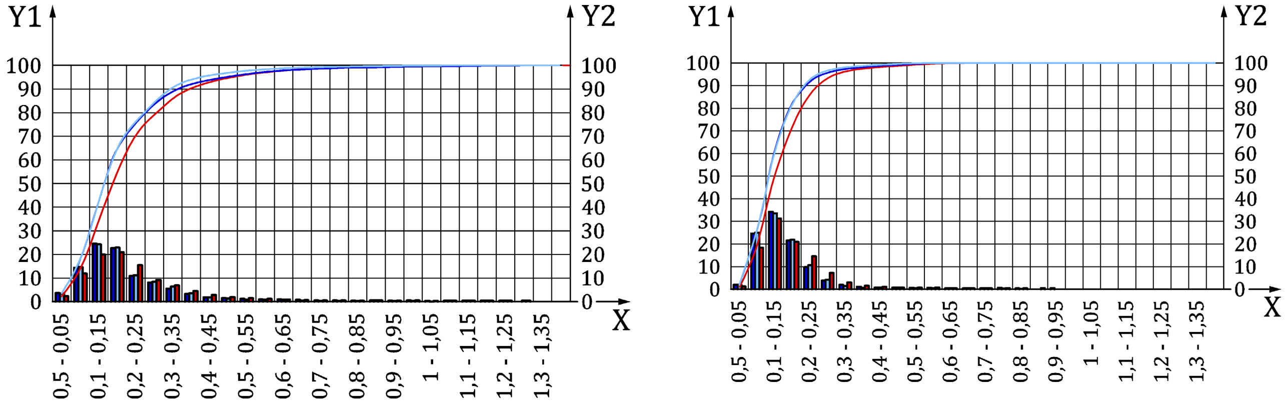


Key

	1/40 wheels in Germany (95% value of worn-worn condition)
	1/20 wheels in France (95% value of worn-worn condition)
	1/20 wheels in GB (95% value of worn-worn condition)
	EN 14363:2005 (track sections above max. limit could de descarded)
	UIC 518:2009 (min. limit for stability assessment)
	TSI Infra (limit for track, if instabilities are reported)
	TSI Loc&Pas (min. limit for stability assessment)
X	upper speed class limit in km/h
Y	equivalent conicity

Figure 18 — 95 % values of equivalent conicity for the three networks and limits given in TSI, EN 14363:2005 and UIC 518:2009

Furthermore it is worth to note that in very few cases the equivalent conicity was higher at $y = y_{mid}$ than the equivalent conicity on the borders ($y = 2$ mm or $y = y_{max}$). Figure 19 shows the distribution of equivalent conicity for the above mentioned lateral wheelset displacements. In the left diagram measured rail profiles in speed category 120 to 160 km/h were used, in the right diagram rail profiles in speed category 160 km/h to 230 km/h.



a) Rail profile 120 km/h < v ≤ 160 km/h combined with wheel profile S 1002

b) Rail profile 160 km/h < v ≤ 230 km/h combined with wheel profile S 1002

Key

(dark blue line)	$\gamma_{e,3\,mm}$
(light blue line)	$\gamma_{e,mid}$
(red line)	$\gamma_{e,max}$
X	equivalent conicity
Y1	frequency in %
Y2	cumulation in %

Figure 19 — Conicity distribution for rail profiles at different lateral wheelset amplitudes for two speed categories

In order to be compliant with the TSI, the equivalent conicity is assessed at the following lateral amplitudes *y*:

$$y = 3\,\text{mm}, \qquad \text{if } (TG - SR) \geq 7\,\text{mm}$$

$$y = \left(\frac{(TG - SR) - 1}{2}\right), \qquad \text{if } 5\,\text{mm} \leq (TG - SR) < 7\,\text{mm}$$

$$y = 2\,\text{mm}, \qquad \text{if } (TG - SR) < 5\,\text{mm}$$

where *TG* is the track gauge and *SR* is the distance between the active faces of a wheelset.

13.3 Radial steering index (RSI)

13.3.1 Summary of requirements of EN°14363:2005

There are no requirements in EN 14363:2005 regarding the RSI.

13.3.2 Summary of requirements of UIC Leaflet 518:2009

The radial steering index q_E was introduced in UIC Leaflet 518:2009 in order to assess the steering capability in small radius curves. UIC Leaflet 518:2009 states that for low radius curves (250 m ≤ R ≤ 600 m) the radial steering index q_E shall be ≥ 1 for 30 % of the track sections and < 1 for 30 % of the track sections.

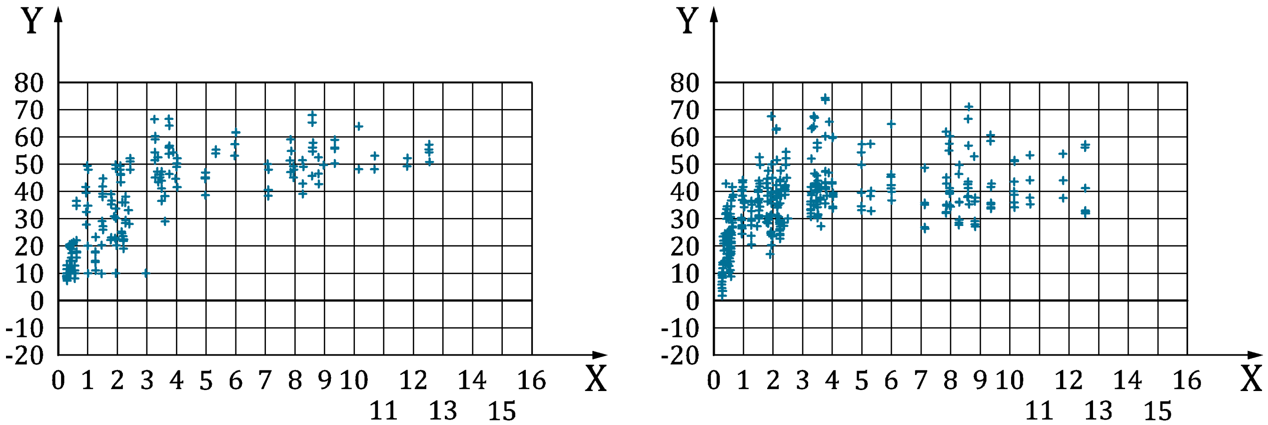
If the test conditions meet the requirements of Chapter 6.2.3 (contact conditions) in combination with the provisions given in Chapters 6.1.4 and 6.1.5, tests on different rail inclinations (between 1/40 and 1/20) are no longer required.

13.3.3 Changes in EN°14363:2016

The RSI is in an informative Annex Q introduced in this version. No requirements on the RSI are specified.

13.3.4 Background information about the radial steering index

Sufficient information about the theory is given in Q.1 of Annex Q in EN 14363:2016. Investigations by Deutsche Bahn AG showed a reasonable dependency of the lateral quasi-static guiding forces of the outer wheel on the radial steering index q_E, see [14]. In this study different bogie types in different countries were examined. If the contact geometry in curves is in a proper condition the quasi-static lateral guiding forces are low. On the other hand, high quasi-static guidance forces are expected if the contact geometry is in a bad condition. Figure 20 shows the quasi-static guiding forces of the outer wheel dependent on the radial steering index q_E for a bogie with a flexible (left) and stiff (right) wheelset mounting.



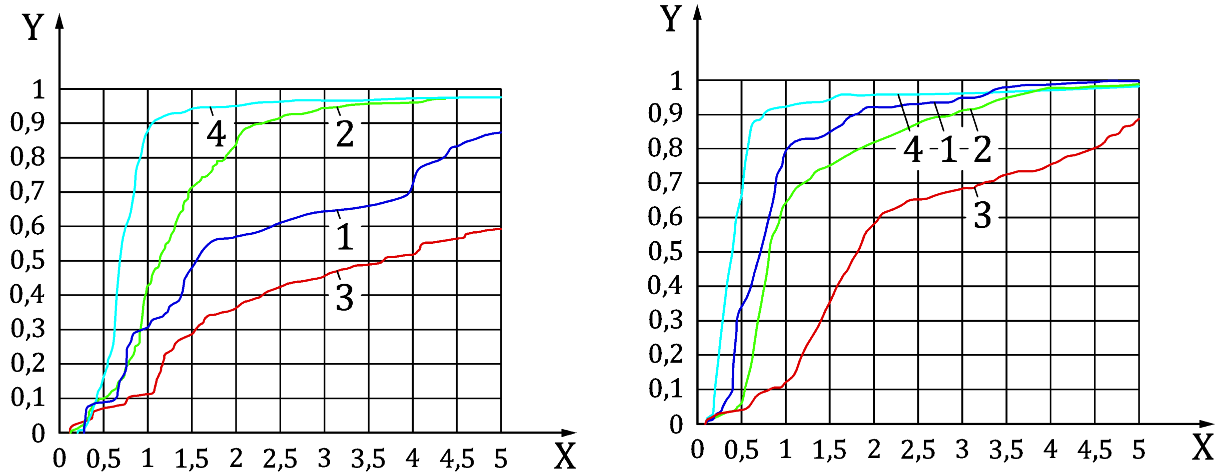
Key

X Y_{12} in kN - on the outer side of the curve

Y radial steering index q_E

Figure 20 — Quasistatic guiding forces Y_{12} of a bogie with a flexible wheelset mounting (left diagram) and with stiff wheelset mounting (right diagram) [14]

In the DynoTRAIN project the radial steering index q_E was evaluated for the test lines. Since the curvature of the test lines was measured with the track recording car the radial steering index was calculated for all mean rail profiles over 100 m in curves. Figure 21 shows the cumulative frequency curves of the radial steering index for the test lines in Germany, France, Italy and Switzerland for curves in test zone 3 and 4. In Italy and Switzerland the test lines have to be selected carefully in order to meet the requirements of UIC leaflet 518:2009, because it is hard to find sections with $q_E < 1$ in Italy and vice versa in Switzerland.



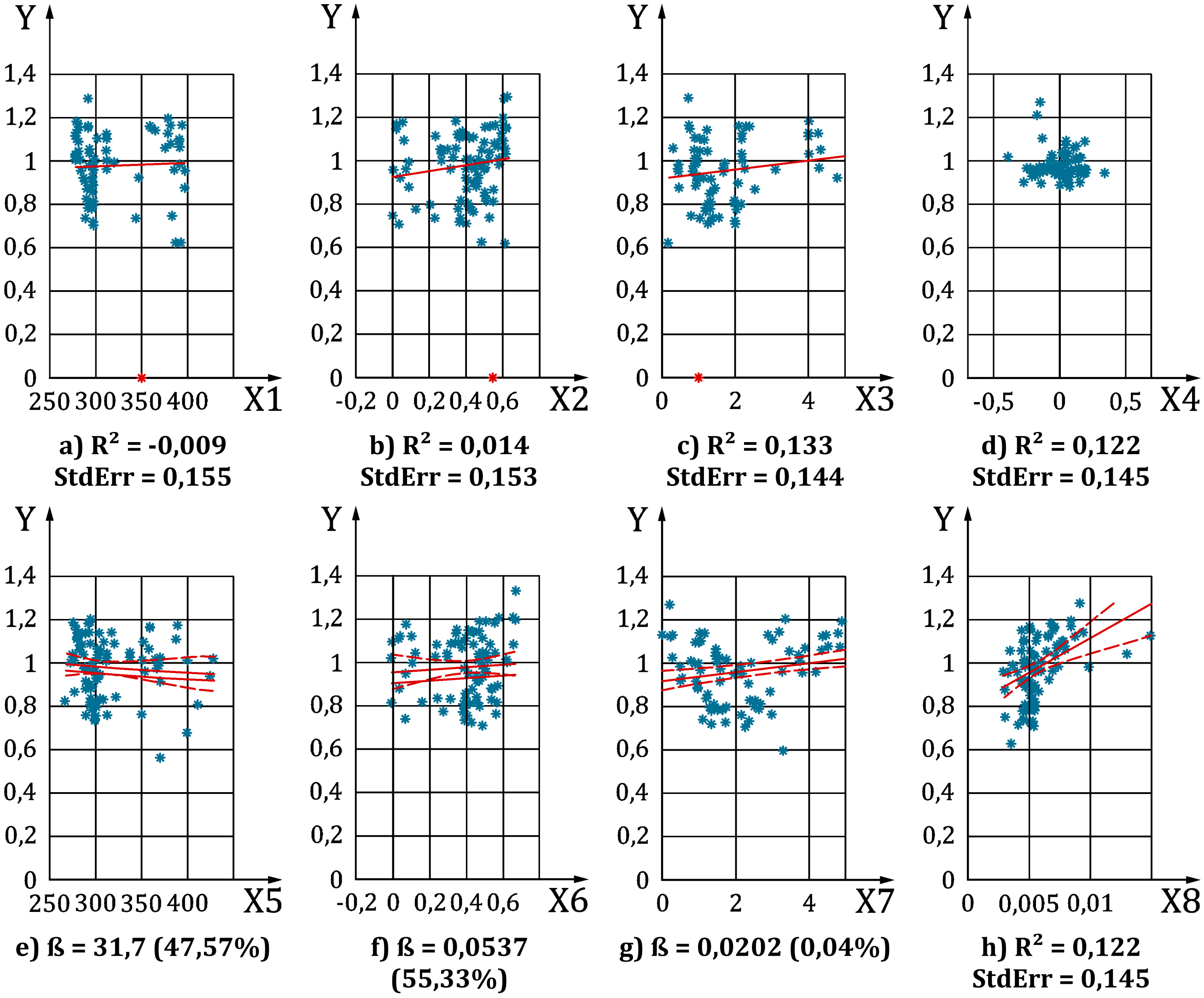
Key

X cumulative distribution

Y radial steering index q_E

Figure 21 — Frequency distribution of radial steering index for different countries in test zones 3 (right) and 4 (left)

In addition, the dependency of the lateral quasi-static Force Y_{qst} on the RSI q_E was analysed statistically for the loco BR120 and for the loaded freight wagons in small radius curves. A negligible dependency was found for all investigated vehicles. Figure 22 shows the regression analysis of the loco BR120. The input parameters are the curve radius R, the uncompensated lateral acceleration a_q and the RSI q_E. The correlation coefficient (R^2 = 0,133) is rather small for q_E.



Key

X1 adjusted R in m

X2 adjusted $a_{q,mean}$ in m/s^2

X3 adjusted TCGA$q_{E,mean}$

X4 residuals

X5 adjusted R

X6 adjusted $a_{q,\ mean}$ in m/s^2

X7 adjusted TCGA$q_{E,mean}$

X8 adjusted whole model

Y Y_{qst} / $Y_{qst,lim}$

Figure 22 — Regression analysis on Y_{qst} / $Y_{qst,lim}$, for loco BR 120 in zone 4 with radial steering index q_E as additional predictor

14 Special vehicles

The definition of special vehicles was revised to clarify, in which cases the related simplifications are reasonable to be used. Where applicable, a reference was made to the standards handled in CEN/TC 256 WG 5 (see EN 14363:2005, 3.15). The same definition is used in EN 15528.

It was found that in many cases requirements for special vehicles were missing in the 2005 revision. On the other hand it was possible to accept some of the simplifications specified for special vehicles also for other vehicles. At the end it was possible to harmonise the test conditions to a high degree.

In order to focus the main text to normal cases, the remaining differences related to on-track testing are now separately specified in Annex S, where it is also required to consider special vehicles in a first step as belonging to the class “Locomotive”, “Passenger Coach”, Multiple Unit” or “Freight Wagon” in order to derive the general requirements for the assessment (see 7.1 and Annex S.2).

As a result of few accidents it was found, that a general permission for the use of the simplified measurement method (as allowed in the 2005 issue) is not adequate; sometimes very sophisticated arrangements of wheelsets or special design features do not allow assessing running safety without measurement of wheel-rail contact forces (see Annex S.2). In these cases the restriction to test zones 1 and 2 makes no sense (see Annex S.3).

According to the previous version of EN 14363:2005, 5.4.4.4 it was possible to restrict testing of special vehicles to one network with only one rail inclination in cases where the test results of running safety remained below 85 % of the limit values. According to 7.3.1 of the revised EN 14363 testing with two rail inclinations is generally no longer required without any reduction of limit values, as it was found that the influence of rail inclination is not relevant due to the large variety of real contact conditions in all networks (for background information see also 13.1.3 and 13.2 of this report). Therefore test results of running safety of special vehicles no longer have to comply with reduced limit values in case of testing with only one rail inclination.

Another result of the discussions was, that testing under the extremes of equivalent conicity needs to be included in the on-track testing: Some sections with very low conicities ($\tan \gamma_e < 0,05$) and a gauge clearance ($TG\text{-}SR$) ≥ 7 mm have to be included in test zone 1 and stability testing has to be performed on at least 3 100 m long sections with the maximum conicity the vehicle is tested for. As stability is strongly non-linear with the speed, it was found, that a dispensation from these requirements for special vehicles would not be appropriate and that it was not possible to define a reduction factor for the limit values of running stability for cases where the maximum tested conicity is not controlled. Therefore in future it is necessary to determine information about the extreme conicities also for special vehicle’s on-track testing, see 13.1.3 for more information on contact condition.

It is noted that Note l of Table 2 of EN 14363:2005 states:

“If lower in-service values of equivalent conicity are ensured by the characteristics of the network and the maintenance regime of the wheelsets, stability testing may be performed for these lower maximum equivalent conicities. This shall be documented.”

This can for example apply to the case of vehicles with coned wheel profiles and short turning intervals in order to ensure a predefined limited range of equivalent conicities in service.

It was found, that special vehicles often have a payload or consumables that lead to a significantly smaller variation of vehicle mass compared to freight vehicles. Specifying one load case for testing was suggested and the use of the parameter range defined for dispensation of on-track tests to cover the full range of possible vehicle masses. This approach was found too strict for special vehicles, as the parameter tables allow also modification of other parameters. Therefore a larger than the normal range was found applicable and this will restrict on-track testing of most special vehicles to one load case, see Annex S.4.

Regarding safety against derailment on twisted track of special vehicles which are allocated to freight stock, a hint was added as a note to 6.1.1, that ORE-B55, RP 8 contains a lot of models and parameters that can be used to describe a reference vehicle in order to allow the related proof by calculation for many applications. For special vehicles to be operated in degraded working track, the additional requirements are specified in EN 14033-2. This is explained in a note in 6.1.1.

In 6.2, which is related to safety against derailment under longitudinal compressive forces in S-shaped curves, it is stated, that a specification of possible dispensation from testing according to EN 15839 is given in EN 14033-1.

15 Simulation

15.1 General

The main input documents of the simulation annex were UIC 518:2009 [1, 2] and drafts of EN 15827 ("PTA Bogie"). Those inputs were extensively discussed, so that the Annex T "Simulations" reflects the experience of the experts of SG 8.6 of WG 10, who were responsible for this annex. Furthermore, inputs from the DynoTRAIN project were included during the finalisation of this annex.

The following topics were identified for the evaluation in SG 8.6 of WG 10:

— 01 Model validation,

— 02 Description of fields of application,

— 03 Specification of track data measurement,

— 04 Track data for simulation,

— 05 Implementation of simulations of stationary tests,

— 06 Process of application of simulation.

The topics "03 Specification of track data measurement" and "04 Track data for simulation" were merged during the negotiations to one topic and are documented below in the chapter "Input data for simulation".

The topic "05 Implementation of simulations of stationary tests" was discussed in SG 8.6. It was decided that the application of calculation to replace the stationary tests should be handled in the subgroup dealing with the stationary tests. Thus, the topics of SG 8.6 were finally restricted to simulations of on-track tests and the title of the annex was modified accordingly. The reasons for this decision were:

— The requirements on the model validation are different:

  — It is not useful and reliable to require an extensive validation of the vehicle model by comparison with on-track tests if the model should be used only for the calculation of stationary tests.

  — On the other hand, the validation by comparison with stationary tests does not provide sufficient evidence that the vehicle model is well suited for the simulation of on-track tests.

— Different models can be necessary for the simulation of on-track tests and stationary tests due to differences between quasi-static and dynamic parameters.

The topic "06 Process of application of simulation" was handled in relation to the application fields and is therefore described below in the chapter dealing with this topic.

The discussions and conclusions from SG 8.6 of WG 10 are described using the following structure:

1) Model validation,

2) Fields and conditions for application of simulation,

3) Input data for simulation.

The Annex T “Simulation of on-track tests” of EN 14363 supersedes the Annex G of EN 15827:2011 which is also dealing with simulation.

15.2 Model validation

15.2.1 Principle of model validation

SG 8.6 members agreed with the conclusion used during the preparation of UIC 518:2009; that it is not necessary to undertake validation or benchmarking of the computer software. If a rigorous validation is carried out of the specific vehicle model then it is not credible that good comparison could be obtained with software that was not suitable.

According to the opinion of some SG 8.6 members, the validation method described in UIC 518:2009 is too complex, costly and too difficult to fulfil. The application of simulations would thus be restricted due to high cost of model validation, which would significantly reduce the potential for cost reduction by replacing some tests by simulations. Moreover, the strict requirement of the usage of measured track layout and track irregularity data was stated as a barrier in using simulations.

The following different principles of validation were proposed and discussed:

— Using other (estimated) track irregularities;

— Using a reference track according to UIC 518;

— Validation oriented on the most critical criterion with the lowest margin (e.g. *Y*-force in tight curve);

— Validation in relation to the process the model will be used for; the validation without measured track irregularities should be possible if the model is used only to calculate the differences between the original and new (modified) vehicle, and those differences are added to the measured values of the original vehicle.

The last proposal was considered in the discussion about the application fields, but not in regard to the validation. The other proposals were refused. SG 8.6 agreed that the model validation should be based on comparison of measurement with simulation using actual measured track irregularities.

15.2.2 Evaluations to carry out model validation

The validation as described in UIC 518:2009 should cover:

— comparison with static, laboratory and slow speed tests where applicable,

— frequency responses and PSDs from on-track tests,

— time history responses from on-track tests,

— analysis following the UIC 518 procedure.

The validation method described in UIC 518:2009 was understood by some members as that a complete on-track test according to EN 14363 [3] has to be simulated and the statistical evaluation of both measurement and simulation compared and assessed to get the vehicle model validated. This would require very large investigations and result in very high costs. Moreover, the required input data like the track irregularities are often limited or not available. Some group members thus proposed to simplify the validation methodology. The members involved in the development of UIC 518:2009 explained that the intention of the validation methodology described in UIC 518:2009 was not to require the simulation of a complete on track test. The comparison of statistical evaluation and of the estimated percentiles was included as an example only. This motivated the group members to provide proposals for a more detailed specification of the comparisons to be carried out for the model validation as described below in the chapter dealing with fields for application of simulations.

The quantitative **validation criteria and limits** for the maximum deviation between simulation and measurement were discussed and limits were proposed for the stationary test as well as for the on-track test (Table T.1). The values given for wheel-loads and load distribution are taken from experience in UK as already used in UIC 518:2009. Regarding the on-track test, SG 8.6 agreed on the proposed limits for the validation of $Y_{\text{a, qst}}$ and $Q_{\text{a, qst}}$, but no limits could be agreed for other quantities.

15.2.3 Independent review

During the development of UIC 518:2009, a use of an independent review of the comparison between the results from tests and simulations was agreed as the most appropriate method. This topic was extensively discussed during the preparation of EN 14363 revision. Some SG 8.6 members proposed that the review by an independent reviewer should be omitted, because the draft now includes Table T.1 with quantitative validation criteria and limits for the maximum deviation between simulation and measurement.

Another argument against the independent review was a possible subjectivity of the assessment result because the expert's knowledge and experience performing the independent review is not specified. Based on this discussion, the requirements on the independent reviewer as well as the process of the assessment and on the documentation of the independent review were described in more detail. Additionally a flow chart illustrating the process was added (Figure T.1).

15.2.4 Validation proposal from DynoTRAIN

The project DynoTRAIN was carried out parallel with the preparation of the revised EN 14363. The model validation was the content of Work Package 5 (WP5) of DynoTRAIN. The results of this WP provided in the Output Document (Final Deliverable of WP5) [18] describe a new method for the validation of vehicle models in context of vehicle acceptance.

The investigations carried out in DynoTRAIN WP5 with the aim to develop this validation method are described more in detail in [18, 19 and 20]. They represent unique activities of testing, simulations, comparisons with measurements and evaluations. The on-track measurements included several vehicles, tested using 10 force measuring wheelsets in four European countries in a test train equipped with simultaneous recording of track irregularities and rail profiles. The simulations were performed using several vehicle models, built with the use of different simulation tools by different partners. The comparisons between simulation and measurement were conducted in a large number of simulations using a set of the same test sections. The results were assessed by three different validation approaches: By comparisons based on values according to EN 14363, by subjective engineering judgement and by using computable measures, so called validation metrics. The final validation proposal is based on comparisons between simulation and measurement evaluated by analogy with EN 14363. The assessment of agreement between simulation and measurement in frequency domain carried out in the framework of DynoTRAIN did not provide any useful input and is thus not included in the final validation proposal.

The proposed model validation criteria and limits are based on 12 quantities evaluated by analogy with EN 14363, covering the quasi-static and dynamic wheel/rail force measurements and vertical as well as lateral vehicle body accelerations. For each quantity, a set of at least 24 comparisons between simulation and measurement are evaluated using values based on EN 14363 from at least 12 sections. The agreement between simulation and measurement is assessed comparing the mean value and standard deviation for a set of differences between simulated and measured values of each quantity with the corresponding validation limit. The proposed method represents an overall assessment of a large number of data which is impossible to carry out by using engineering judgement, as it is not practically possible to display, check and document the approval of such a large number of plots.

A proposal to add this method as a possible validation method was provided during the enquiry. The method was then included in to the EN 14363 revision as Validation Method 2, while the original validation method was named Validation Method 1. Because of the large set of compared data and the explicit numerical validation criteria, no independent review is required when using Method 2. The vehicle model fulfilling the specified criteria and limits is validated for simulation of the complete range of vehicle assessment using the normal measurement method. The flow chart displaying the model validation process (Figure T.1) was adapted accordingly to show the procedure using Method 1 (with review) and Method 2 (without review).

15.2.5 Efficiency of the usage of stationary tests

In the framework of DynoTRAIN WP5 also the efficiency of the comparisons and model adjustments using stationary tests on the results of the on-track tests simulations were evaluated. These comparisons neither confirmed nor denied the positive effect of the stationary tests. Sometimes the results were better but sometimes worse after the model adjustment by the stationary tests.

This showed that the importance of the comparisons with the stationary tests should not be overestimated. Based on this DynoTRAIN result, a comment was provided in the enquiry to modify the mandatory requirement in prEN 14363:2013 [17] regarding the comparison with the stationary tests if they are available. SG 8.6 agreed to change this requirement from mandatory to recommendation.

15.3 Fields and conditions for application of simulation

15.3.1 Introduction

The areas for the application of numerical simulation are specified in UIC 518:2009 as follows:

— Approval of vehicles following modifications;

— Approval of new vehicles by comparison with an already approved vehicle (base design);

— Supplement the range of test conditions when the full range of conditions has not been covered (e.g. full range of curve radii, speeds, cant deficiency etc.).

Based on the discussions in the SG 8.6, two additional application cases were identified:

— Investigation of dynamic behaviour in case of faults;

— Investigation of dynamic behaviour in case of tracks different to the tested track.

The application field of tracks different to test track was finally excluded as this regards the network access requirements and not the vehicle acceptance.

15.3.2 Definitions of reference and modified vehicle

The discussions about the application fields identified a need to specify exactly the terms used.

The term “base design” was agreed to be replaced by the term **reference vehicle**. It was agreed that the reference vehicle is a vehicle that has been tested and approved according EN 14363 or an equivalent standard, i.e. a vehicle approved using simulations cannot be a reference vehicle. This definition was included in Clause 3 “Terms and definitions”.

Furthermore, a need was identified to specify what a modified vehicle is. It was agreed to define the modified vehicle as a vehicle that has been previously accepted in accordance with EN 14363 or an equivalent standard and then undergone engineering change. The **engineering change** was agreed to be defined as a change to the design of the vehicle that potentially varies the performance of the vehicle, when evaluated according to this standard. The definition of engineering change was also included in Clause 3 “Terms and definitions”.

Discussing the definition of the “base design”, it was agreed that it is not reasonable to specify exactly the “base design” in the chapter “Terms and definitions”. Instead, this application case was described as the assessment of a new vehicle by comparison with an already approved vehicle and limited to cases when vehicles are being introduced with a range of different types within the fleet and vehicles that are similar to the reference vehicle. Furthermore, a verbal explanation of the allowed changes to components and vehicle parameters was included in a note to support the understanding of the possibility to apply this case.

15.3.3 Scope of permitted modifications

UIC 518:2009 defines the scope of permitted modifications as a percentage of parameters of the original vehicle. The discussion about the application fields of simulation in SG8.6 started with a possibility to enlarge the percentage of parameter change compared to the scope in UIC 518:2009. However, the discussions showed that there is no knowledge which would allow to specify the suited range of parameter variation. The experience from the use of simulations shows that the simulation provides plausible results in a large range of parameter variation. Thus, the simulation results of a vehicle model which has been rigorously validated, can be considered as reliable in a large range of parameter variation. The effect of the parameter change on the running dynamics behaviour of the vehicle is more relevant than the actual change of the parameter. The SG 8.6 members supported this view and agreed to allow the use of simulations for vehicle acceptance if their results demonstrate an improvement against the original vehicle or if they show a sufficient margin to the limit values.

SG 8.6 supported the proposal that simulations can be applied for a modified vehicle also in case of exceeding the safety limits during the acceptance tests, if the simulation demonstrates an improvement and fulfilment of criteria for the modified vehicle.

This new specification of the range of the application field of simulations in the vehicle acceptance context represents a fundamental change. It means that the allowance of the application of simulation cannot be identified in advance; it can be only confirmed based on the results of the simulation. On the other hand, the possible application field is much wider and is not restricted to the case when the reference vehicle fulfilled all criteria during the acceptance test, or fulfilled them with a certain margin to the limit values.

The discussions about the practical application of this new methodology showed that the criteria to be fulfilled using simulation cannot be specified identically for all application fields, because they are related not only to the application field but also to acceptance test results of the reference vehicle as well as to the process of application of simulation and comparison with measurement. Therefore, these conditions and criteria of applications are explained together with the application fields.

15.3.4 Requirements regarding the modification of a validated model

UIC 518:2009 requires limited tests on the actual modified vehicle to confirm that the modifications have been correctly applied in the vehicle model. It was recognised by the SG 8.6 members, that this requirement increases the cost and thus reduces the potential of the application of simulations instead of physical testing. SG 8.6 agreed that no tests are required when applying simulations, but confirmed the importance of a correct application of modifications in the vehicle model. This resulted in a requirement for an independent confirmation and documentation that the modifications have been correctly applied to the model.

15.3.5 Evaluation of estimated values

Based on the discussions about the principle of the model validation (see above), a new option was agreed for the evaluation of the estimated values which is based on a relative assessment using a combination of simulations and previous on-track tests. The vehicle acceptance is then based on the measurement results of the reference vehicle and the simulation is only used to evaluate the differences between the reference and the new vehicle. Because the main input for the assessment is in this case provided by the measurement, it was agreed that the evaluation of the estimated values to be compared with limit values is in this case not necessary for the complete test according to this standard. Instead, the simulated dynamic behaviour of the tested vehicle as well as the new or modified vehicle is compared under identical boundary conditions on at least 3 sections of each test zone. For every required assessment quantity, the simulation results for both new or modified vehicle and the tested vehicle have to be evaluated. The new or modified vehicle's estimated value for the assessment quantity is calculated by adding the average difference of the compared sections from one test zone to the estimated value from the test report of the tested vehicle. This new estimated value has to be compared to the limit value.

Thus, the evaluation of the estimated values which have to be compared with the limit values for the vehicle acceptance can be provided by two alternatives:

— statistical evaluation according to conditions specified for testing, which requires simulations of the complete on-track test (Chapter T.5.1.2) or simulations of the conditions which were not met during the test (Chapter T.5.1.3);

— relative assessment using a combination of simulation and previous on-track test (Chapter T.5.1.4).

15.3.6 Application field: Extension of the range of test conditions

This application field originates from UIC 518:2009. The data from the on-track test measurements should be extended with the results from simulations for the test conditions which were not satisfied during the test. Some SG 8.6 members as well as later comments in the CRM process did not support this application, because there is no experience with such use of simulations and thus no evidence that this application will provide an assessment of the same or better safety level than other assessments using measured data only. Moreover, the proposed combination of some sections from measurements and some sections from simulations in one statistical data set can provide incorrect results as the data may have different statistical properties. This comment was refused with the argument that this application field may be important and necessary in some cases. To reduce the risk of combining the data from measurement and simulation with different statistical properties, a note was introduced with a recommendation to check the heterogeneity and constant variance of both simulation and measurement.

The data from simulation and measurement are combined into one data set and handled on the same way as the measured data. Therefore, there is only one possibility for the evaluation of the estimated values which have to be compared with the limit values, i.e. the same evaluation as for measurements.

15.3.7 Application field: Approval of vehicle modification

The following procedure was agreed when applying the simulations for the acceptance assessment of modified vehicles. The simulations have to be carried out for all test zones to demonstrate that the performance of the new vehicle is consistent when compared to the previously tested vehicle. This requirement should confirm that the modification did not completely change the running dynamics performance of the vehicle and thus the validated model is still suited for simulations. The model of the modified vehicle is then used for simulation and the results are compared with limit values for vehicle acceptance.

SG 8.6 members agreed that simulation can be used also when a vehicle has been tested and found to exceed some of the limit values. It is permitted to use simulation to demonstrate that the modifications to the vehicle improve the behaviour sufficiently to meet the limits. In this case, the SG 8.6 members agreed to introduce a request for a margin of 10 % to the running safety limit values. No margin is required for other criteria, but it was agreed that all values have to remain below the limit and not to increase by more than 1/3 of the previous margin to the limit value.

15.3.8 Application field: Approval of new vehicles by comparison with a reference vehicle

The approval of new vehicles by comparison with already approved vehicles of similar ("base") design was agreed to be an important application field, because the number of vehicles of different types within the fleet as well as a use of "vehicle platforms" are continuously increasing.

SG 8.6 members agreed that the fulfilment of a safety margin $\lambda \geq 1,1$ as required in UIC 518:2009 is not necessary for the assessment of the reference vehicle for application of simulations for the acceptance of a similar vehicle.

The vehicle similar to the reference vehicle can be approved using numerical simulation if it demonstrates that the performance of the new vehicle is consistent when compared to the reference vehicle. If the change to the dynamic performance results in:

— an increase in any assessment value compared to the reference vehicle,

— and/or a fundamental change in the frequency and/or amplitudes of the dynamic response,

then a full review has to be carried out. This review should compare the changes to the dynamic response(s) of the new vehicle compared to the reference vehicle on at least 3 sections of each test zone. The vehicle approval using simulations is accepted, if this comparison demonstrates that:

— the assessment values for running safety from simulations do not increase by more than 1/3 of the previous margin to the limit values,

— and at the same time the values for track loading from simulations do not increase by more than 2/3 of the previous margin to the limit values.

15.3.9 Application field: Investigation of dynamic behaviour in case of fault modes

The simulation of vehicle running dynamics behaviour in case of fault modes was agreed as a new possible application field. This application field has not been discussed in detail and no requirements were specified besides that the vehicle model has to be used within its range of validity.

15.4 Input data for simulation

15.4.1 Introduction

UIC 518:2009, Appendix J, contains a description of the range of input conditions for numerical simulations. These conditions were reviewed and modifications discussed, see below.

15.4.2 Track layout

UIC 518:2009 states that the simulation should be carried out using the real track layout. Some SG 8.6 members opposed that this is not often practically applicable. The track layout (curvature, cant, curve transition) can be adequately modelled using the tabulated input data, which is commonly used and which is often the only possible solution. The discussion about this point resulted to the conclusion that this should be understood as either measured layout (curvature, cant, …) or "book" track layout regularly checked and confirmed to be correct.

15.4.3 Track irregularity data

The SG 8.6 discussed which measuring systems are suitable to deliver proper track data, in which way have the data to be processed for simulation, and if scaling or manipulation of measured track data and use of artificial track irregularity data generated from power spectral density should be allowed or not.

SG 8.6. confirmed that the track data used shall have its origin in real track recordings normally performed with an inertial measuring system. The track irregularity data shall represent the full three dimensional track, including vertical alignment, cross level, lateral alignment and track gauge. For the validation of the model the track geometric irregularities shall be sufficient to excite the vehicle suspension in all directions and shall include some track at both ends of the quality range.

SG 8.6 confirmed acceptance of the common practice to separate track irregularities from design geometry in recordings, and afterwards superimpose these in simulations.

The group discussed the requirements on the accuracy of the track measuring systems. The members recognised that it is not reasonable to require specific measurements for simulation purposes. Thus, it was agreed to refer to the corresponding standards EN 13848-1 regarding the measurement accuracy and EN 13484-2 regarding the measuring systems. A recommendation for a higher track measurement accuracy than in the requirement according to EN 138484-1 was introduced in a note.

15.4.4 Frequency / wavelength content

With respect to the statistical processing and the limit values to be valid for simulations the output needs to cover the same frequency range as for the test results. The corresponding requirements on the input track geometry data from UIC 518:2009 have been discussed. It was agreed to require that wavelength contents of the measured track irregularity data, when taken in combination with the vehicle speed, shall at least correspond to an excitation frequency in the range of 0,4 Hz to 20 Hz.

15.4.5 Requirements for variation in input conditions

UIC 518:2009 requires to use a certain variation of the input conditions to provide variations similar to on-track tests, in particular:

— Variation of the wheel/rail friction coefficient,

— Variation of running speed.

Some SG 8.6 members were of the opinion that such variations are not necessary. They argued that stochastic variations are not applied in simulations during the vehicle design and development, and that there is no evidence about any negative impact on the simulation results or about the deviations between simulation and measurement caused by missing stochastic variation.

The distribution of wheel/rail friction coefficient proposed in UIC 518:2009 (a single sided normal distribution from 0,36 with standard deviation of 0,075) is not necessarily present during the on-track tests. The requirements regarding the wheel/rail friction coefficient during the on-track tests are much more general, and the wheel/rail friction coefficient cannot be exactly measured.

Furthermore, the vehicle speed is often almost constant during each test when using modern traction vehicles with exact speed control.

Nevertheless, the variation of input conditions similarly to physical testing is considered as important. SG 8.6 finally agreed to mention the requirement for the variation of the input as a recommendation.

16 Extension of acceptance (Annex U)

The extension of acceptance of a vehicle is based on the principles of EN 14363:2005 and UIC 518:2009. Contrary to EN 14363:2005, where the information concerning the extension of acceptance was spread over the whole Clause 5, the aim now was to condense the information and put it into a separate Annex. The only remaining text in the main part of EN 14363 is the hint in subclause 7.1 that the extension is possible, using partial on-track tests or simulation. Annex U deals with the partial on-track test and the possibility of test dispensation. The flowchart in Figure U.1 gives the process to determine the minimum requirements for testing for the extension of approval. The allowed parameter changes in Tables 1, 3 and 11 from EN 14363:2005 are now combined in Table U.1. The reason for this change is, to make the whole document more readable and to avoid double information. The left part of the table gives the parameters to be looked at, grouped by operational, vehicle and running gear parameters. The centre part gives the allowed range of change for each parameter for the two vehicle groups (freight stock or locos, multiple units and passenger coaches), either for test dispensation or for the use of the simplified method. In the right part, the required test extent for a partial on-track test is stated.

Some new parameters were introduced in the table, or have been changed compared with EN 14363:2005 as follows:

— Virtual centre of gravity for vehicle with I_{adm} > 165 mm, taken from EN 15686;

— Moment of inertia of vehicle body is now separated for bogie and non-bogie vehicles according to UIC 518:2009;

— The possible variation of the unsprung mass was changed to from −5 % to −100 %, because no negative effects are to be expected;

— The unsprung mass, primary suspended mass and secondary suspended mass are now regarded as running gear parameters. That means the secondary suspended mass is not the carbody mass, but the mass which the running gear supports;

— Sum of nominal static vertical wheelset forces per running gear, if the vehicle has no secondary suspension level: This parameter replaces the part in brackets for primary suspended mass in EN 14363:2005 (total mass if vehicle has no secondary suspension level);

— The primary and secondary stiffness are replaced by the ratios of stiffness and its loads which means that the eigenfrequency is to be kept within a certain range;

— The allowed change in secondary lateral damping has been widened to a range of ±30 % following a comment in the CRM.

A new process is defined in U.3.2 which describes the possibility to extend the range of parameter change, if more than one vehicle has been tested. The extension of the range is possible, because the confidence with the use of interpolation is higher than in the extrapolation which is applied if only one vehicle is tested.

Additionally there is now the possibility to approve a vehicle with the simplified method despite the fact that it normally shall be approved with the normal method. This is the case if the vehicle is in the same test train as the vehicles equipped with measuring wheelsets and the acceleration level is comparable. In the past this procedure has already been applied for articulated trains and multiple units as it is not practicable and not necessary to equip every vehicle in the train with measuring wheelsets.

Another major change compared to EN 14363:2005 concerns the possibility of partial testing. EN 14363:2005, Table 1 defines the range for a parameter change for which a partial test is allowed. Outside this range a partial test is not applicable. It was found that this approach sometimes lead to unnecessary limitations on the use of the reduced test extent.

In the new version of EN 14363 a separation is made between the range of parameter change and the test extent so that a partial test can be applied even if the change of the parameter is outside the given range. Testing outside the given range may require use of the normal method (with reduced test extent), see flowchart Figure U.1 of the revised EN 14363. If more than one parameter is changed then a combination of required test extents will be required. The test extent is given in Table U.1 for the separate parameters. This procedure is consistent with the latest edition of UIC 518 and all previous versions at least since the second edition of 1999.

If the λ is less than 1,1, it is now still possible to get a dispensation from testing, if the change of the parameter in question is sufficiently small. Details for that process are given in Annex U.1.

If the initial approval was based on the normal method, a simplified method can still be applied for the extension of the approval under certain circumstances, even if the acceleration was above the limit value in the initial approval. Details are given in U.5.

17 Topics discussed but postponed for future revisions

17.1 General

Some of the topics discussed below may be handled for the next revision while others may need more research and discussions before being solved.

17.2 Y/Q

DE 546:

The estimated maximum value of Y/Q depends strongly on the friction conditions. A normalisation of the test results is suggested. Preferred alternative to the "C138" evaluation it is proposed to allow the following (…).

It was proposed to correct the individual values of Y/Q on sections where high friction is observed.

This comment was not accepted. It was found, that no target value for friction can be agreed for a safety related quantity for this revision.

This is noted, to discuss again Y/Q for next revision.

17.3 T_{qst}

The rail surface damage quantity T_{qst} is introduced in 7.5.3. Limited experience from using T_{qst} exists no limit values were introduced. Though it would have been possible to use the limit value for Y_{qst} and derive an equivalent limit for T_{qst}, this approach was considered too risky. At the next revision of EN 14363, hopefully more experience have been gained and limit values can be agreed on.

17.4 B_{qst} and B_{max}

The combined rail loading quantity B_{qst} and B_{max} are introduced in 7.5.3. For the same reason as for T_{qst} no limit values were introduced.

17.5 $Y_{a,max}$

The maximum guiding force $Y_{a,max}$ is introduced in 7.5.3. For the same reason as for T_{qst} no limit values were introduced.

17.6 Introduction of high frequency contents to the Q-force limits

The high frequency contributions of the vertical wheel forces are primarily important for the superstructure of the track (and also for wheels, bearings and axles of the vehicle). In this context higher frequencies are those in the range of 20 Hz to 200 Hz.

In EN 14363:2005, only up to 20 Hz frequency contents is considered for the dynamic Q-forces. With other limit values taking into account the higher frequencies, a vehicle with a low Q-force contribution in the frequency range from 20 Hz to 200 Hz could for instance be allowed to increase the axle load or to be operated at higher cant deficiency. This could hence be commercially beneficial for the entire rail system.

In EN 14363:2005, the limit value for the 20 Hz filtered Q-force is speed dependent so that vehicles with higher speed have a stricter limit value. It can be suspected that the reason for this is “hidden” high frequency contributions and therefore this dependency may be removed. Also, the limitation of axle load for HS vehicles may be discussed again following an introduction of limit values considering also high frequency Q-forces.

A simulation study was carried out to identify the influencing factors on the high frequency Q forces. It was found that the unsprung mass of wheelsets and speed are the most important ones. A possible idea for how to evaluate the Q forces incorporating the high frequency parts was presented. It was also stated that more studies are needed before a firm proposal can be made. In the upcoming revision of EN 14363 it will be discussed whether or not high frequency Q forces will be part of it.

Further studies could be:

— further simulation studies to be carried out by other organisations than the only one presented;

— study of test results existing where high frequency Q-forces were measured on the vehicle or in the track;

— from these studies creating a feasible model including measurements of Q-forces with a frequency content of up to and including 20 Hz and adding a component based on basic vehicle data, e.g. unsprung mass of wheelsets and vehicle speed.

17.7 Track geometry

Background for the assessment of track geometry based on standard deviation is given in 12.3. If there is any new information available this topic might be reviewed again.

17.8 Compatibility with track conditions outside the test conditions

It was noted that on some lines the condition falls far out of the reference conditions, primarily concerning equivalent conicity and curvature. It was also noted that the tracks on such lines, the mechanical strength was not such that vehicles barely complying with the limit values of EN 14363 could be tolerated.

In analogy with e.g. line classification and axle load and axle distribution of vehicles it was proposed to introduce something called “Interaction Compatibility”.

It was noted that such deviations shall be handled by national rules. But it was also identified a need for:

— Investigation on vehicles to quantify running behaviour on lines with a geometric track quality representative of lines with an admissible speed ≤ 80 km/h and

— Investigations on vehicles to quantify running behaviour in curve radii below 250 m.

Work Item proposals have been handed in to CEN on this.

17.9 WHEEL RAIL Geometric contact conditions

Refer to chapter about Wheel Rail Geometric Contact Conditions as well as the revision work of EN 15302, WG 10 / SG 2.

17.10 Cyclic top

'Cyclic Top' describes a particular type of track geometry with a sequence of vertical track irregularities where each individual feature (usually a dip in the track top) is within the allowable limits but the cyclic nature of the input can lead to resonant behaviour as a vehicle passes over the track. The level of response will depend on the spacing of the dips, the speed of the train and the natural frequency and damping of the vehicle suspension. In the worst case the resonant response can be so severe that 'bounce' or 'pitch' of the vehicle suspension leads to complete loss of vertical load on one or more wheels with consequent risk of derailment. As these derailments have occurred at not low train speeds the potential for serious consequences is considerable.

This type of track defect is very difficult to detect without specific criteria and is not easy to observe.

There are a number of factors that increase the risk of this problem:

— Spacing of the dips that is similar to vehicle wheelset or bogie spacing (for example sections of jointed rail of 18 m length combined with 9 m wheelbase wagons);

— Low damping in certain load conditions (for example two-stage suspensions around the change-over load position);

— Repeated response of similar vehicles at the same location tends to cause an increase in amplitude of the track defects;

— Potential for running long distances with single wagons derailed, damage to track and potential for collision with other vehicles / bridges, stations etc.

GB awareness of this issue over many years has developed a process to analyse track geometry measurements using a cycle counting algorithm, within a wavelength range. The results of this are then incorporated in the track maintenance planning. This works well for the types of vehicles generally operated on the GB network but might need to be modified for other networks.

The traditional GB process for vehicle testing, described in GMRT 2141, used a peak-counting analysis process which could give an indication of under-damped vehicle behaviour but this relied on the vehicle being tested in the particular loading and speed combination over track which provides such inputs. Use of simulations was considered but this was not pursued as a full, validated dynamic model of the vehicle would be required and these do not generally exist for the most at risk vehicles (freight wagons). Further work is needed to consider how assessment of this risk can practically be incorporated into European vehicle approval processes.

17.11 Over-speed and over Cant deficiency testing

The tendency is that it is becoming more difficult to get permit to test at over-speed or excess cant deficiency. This was briefly discussed and led to a reduction of the required over-speed for HS vehicles but will need more consideration for future revisions.

17.12 General points

— Remove the word "acceptance" from the whole standard: EBA thinks acceptance is a task for higher level documents;

— Discuss the need for measuring wheelsets for high speed vehicles.

18 Influence of the revision of EN 14363 on current TSIs

18.1 General

WG 10 prepared a letter that was sent from TC 256 to ERA suggesting changes to be made to the RST TSIs after publication of the new EN 14363. This letter is attached in this chapter. It is the starting point for ERA to modify the TSIs respectively. It is necessary to understand that these modifications will be made under the responsibility of ERA and therefore might be different from these proposed solutions.

18.2 Letter to ERA

A letter with the following content has been sent to ERA:

Brussels 2015-05-04

JPC R Corr 271 Adjustment of the references to standards following the publication of EN 14363:2015 into TSIs Loc & Pas and WAG when existing

Dear Sirs,

I am writing you formally to clarify what has already been discussed at the occasion of several meetings between the Convenor of CEN/TC 256 WG 10 and the relevant desk officers in the ERA.

EN 14363:2015 'Railway applications - Testing and Simulation for the acceptance of running characteristics of railway vehicles - Running Behaviour and stationary tests' is a major revision of EN 14363 dating back from 2005 and is probably one of the most important standard for interoperability.

With the recent publication of EN 16235:2013, the revised EN 14363:2015 and the amended EN 15839:2012, the TSI's Loc & Pas and WAG can be modified in the coming versions of the two TSIs as described in Annex 1 to this letter.

We remain of course available for any clarification ERA desk officers may need.

Yours sincerely,

CCMC

18.3 Annex 1 to letter to ERA

Commission Regulation (EU) No 1302/2014 of 18th November 2014 (TSI Loc&Pas)

The references in **Annex J.1** should be changed:

— Index 16: EN 14363:2015, relevant cl (1)),

— Index 17: EN 14363:2015, 7.5,

— Index 18: to be deleted,

— Index 19: EN 14363:2015, 7.5,

— Index 83: EN 14363:2015, 4, 5, 6.1,

— Index 84: EN 14363:2015, 4, 5, 7.

At the same time, the Technical Document **ERA/TD/2012-17/INT** should be withdrawn and deleted from **Appendix J-2., Index 2**.

In 4.2.3.4.1 (2) the text "and in the specification referenced in Appendix J-1, index 16" should be deleted

In 4.2.3.4.2 (3) the reference to the "Technical Document referred in Appendix J-2, index 2" should be replaced by a reference to EN 14363:2015, Clause 7

In 4.2.3.4.2 (4) the text "and in the specification referenced in Appendix J-1, index 16" should be deleted

In 4.2.3.4.2 (5) the text "index 16 with the modifications as set out in the technical document referenced in Appendix J-2, index 2" should be deleted.

In 4.2.3.4.2.1 (1) the text "and additionally for trains intended to be operated with a cant deficiencies

> 165 mm in the specification referenced in Appendix J-1, index 18, with the modifications as set out in the technical document referenced in Appendix J-2, index 2." should be deleted.

In 4.2.3.4.2.2 (1) the text "with the modifications as set out in the technical document referenced in Appendix J-2, index 2" should be deleted.

In 6.2.3.3 (1) the text "as amended by the technical document referenced in Appendix J.2, index 2." should be deleted.

In 6.2.3.4 (1) the text "The conditions for the assessment in accordance with the specification referenced in Appendix J-1, index 84 shall be amended as per technical document referenced in Appendix J-2, index 2." should be deleted.

In 6.2.3.6 the reference to "the technical document referenced in Appendix J-2, index 2" should be replaced by a reference to EN 14363:2015, Annexes O and P.

In 7.3.2.4 the reference to "EN 14363:2005, 4.1.3.4.1" should be replaced by "EN 14363:2015, 6.1.5.3.1" after consultation of UK experts committee.

In 7.3.2.5 "ERA/TD/2012-17/INT" should be deleted in the headline.

In 7.2.3.5 – specific case Spain, the sentence "The limit value shall be evaluated in accordance with ERA/TD/2012-17/INT except for the formula in 4.3.11.2 should be replaced by "For the normalization of the estimated value to the radius R_m = 350 m according to EN 14363:2015, 7.6.3.2.6

(2), the formula "$Y_{a,nf,qst} = Y_{a,f,qs} - (10\,500\ m / R_m - 30)\ kN$" shall be replaced by "$Y_{a,nf,qst} = Y_{a,f,qst} - (11\,550\ m / R_m - 33)\ kN$".

In 7.2.3.5 – specific case Spain, the sentence "In addition the cant deficiency threshold to be considered for applying the EN 15686:2010 shall be 190 mm." should be replaced by "In addition the cant deficiency threshold to be considered in EN 14363:2015 for evaluation of the overturning parameter ***k*** in 7.5.2, 7.6.3.2.7, Table 4 and Table 5 and for the specific application of the parameter change Table U.1 according to the footnotes h, I, j, and o shall be 190 mm instead of 165 mm."

In 7.2.3.5 – specific case Spain, it might also be necessary to adapt the list of I_{adm} values of ETCS-train categories given in Annex H. This shall be checked with Spanish CCS experts.

In 7.2.3.5 – specific case Spain, it might also be necessary to adapt the cant deficiency threshold for application of the simplified measuring method in Table 1 of EN 14363. This shall be checked with Spanish running dynamics experts.

In 7.2.3.5 – specific case United Kingdom (Great Britain) ('P') the reference to "EN 14363 and ERA/TD/2012-17/INT" should be replaced by a reference only to "EN 14363"

ERA/TD/2012-17/INT should be withdrawn

ERA/GUI/07-2011/INT Guide for Application of TSI LOC&PAS (V2.00) from 01 January 2015

For Clause 2.4 the following modifications are proposed:

— In the point related to 4.2.3.4.2 "Running dynamic behaviour",

    — The text in the first box should be adapted to the modified text of the TSI;

    - The box related to TD 2012-17 should be deleted;
    - The first paragraph should be modified / reduced: "The rolling stock may have to be tested for several combinations of admissible speed and cant deficiency (combinations to be selected by the applicant) for their running dynamic behaviour in accordance with EN 14363. This technical specification covers also tilting systems."
    - The second and the third paragraph should be deleted;
    - In the seventh paragraph (related to speeds above 300 km/h) the references to "TD" in the first and last line should be replaced by a reference to EN 14363;

- In the point related to 4.2.3.4.3.2 "In-service values of wheelset equivalent conicity",
    - The last paragraph the reference to "TD-2012-17 Clause 4.3.6" should be replaced by "in Table 2 of EN 14363:2015 (Line: Requirements for wheel/rail contact)".

Commission Regulation (EU) No 321/2013 of 13th March 2013 (TSI WAG)

In 4.2.3.5.2 the text "Clause 5 of EN 14363:2005" should be replaced by "Clauses 4, 5 and 7 of EN 14363:2015"

6.1.2.1 should be modified as follows:

"The demonstration of conformity for the running gear is set out in EN 16235.

Units equipped with an established running gear as described in EN 16235:2013, Clause 6 are presumed to be in conformity with the relevant requirement provided that the running gears are operated within their established area of use.

The assessment of the bogie frame strength shall be based on 6.2 of EN 13749:2011."

In 6.2.2.2 the text

"The demonstration of conformity shall be carried out either in accordance with:

- the procedure defined in 4.1 of EN 14363:2005, or
- the method given in 4.2 of EN 15839:2012 by using the pre-calculation for standardised solutions."

should be replaced by

"The demonstration of conformity shall be carried out in accordance with Clauses 4, 5 and 6.1 of EN 14363:2015".

In 6.2.2.3 (1st paragr.) the reference to "Clause 5 of EN 14363:2005" should be replaced by Clauses 4, 5 and 7 of EN 14363:2015"

In 6.2.2.3 the 2nd paragraph "As an alternative to perform on-track tests on two different rail inclinations, as set out in 5.4.4.4 in EN 14363:2005, it is permitted to perform tests on only one rail inclination if it is demonstrated that the tests cover the range of contact conditions as defined in Appendix B, Clause 1.1." should be deleted.

In 6.2.2.3 the 3nd paragraph "When an on-track test with normal measuring method is required the unit shall be assessed against the limit values set out in B.1.2 and B.1.3." should be deleted.

In 6.2.2.3 (4th paragraph) the reference to Clause 5 of EN 14363:2005" should be replaced by "Clauses 4, 5 and 7 of EN 14363:2005"

In 6.2.2.3 the 5th paragraph

“The required test conditions for on-track tests, as set out in EN 14363:2005, are not always fully achievable concerning

— track geometric quality, and

— combinations of speed, curvature, cant deficiency.

In cases this is not fully achievable the demonstration of conformity is an open point.” should be deleted.

In 6.2.2.3 the text “Simulations - Alternatively, under the conditions stated in 9.3 of EN 15827:2011, a simulation may replace the above mentioned on-track tests.” should be deleted.

In 7.1.2 (a) the first sentence should be modified as follows:

“The running dynamic behaviour of the unit shall have been assessed as set out in EN 14363:2015 (points 4, 5 and 7).”

In 7.3.2.3 the reference to “EN 14363:2005, 4.1.3.4.1” should be replaced by “EN 14363:2015, 6.1.5.3.1” after consultation of UK experts committee.

In 7.3.2.3 the reference to “EN 14363:2005, 4.1.3.4.1” should be replaced by “EN 14363:2015, 6.1.5.3.1” after consultation of UK experts committee.

In 7.2.3.4 for the 1668 mm countries (Spain, Portugal?) a specific case should be introduced: “For the normalization of the estimated value to the radius R_m = 350 m according to EN 14363:2015, 7.6.3.2.6 (2), the formula “$Y_{a,nf,qst} = Y_{a,f,qst} - (10\,500 \text{ m} / R_m - 30)$ kN” shall be replaced by “$Y_{a,nf,qst} = Y_{a,f,qst} - (11\,550 \text{ m} / R_m - 33)$ kN”

In Table A.1 the second line “Test conditions for on-track tests as set out in the EN 14363 are not always achievable ….” should be deleted.

Appendix B should be deleted completely. It was already replaced by TD 2013-01 through commission regulation 1236/2013.

Appendix C.8 should refer to the amended version of EN 15839.

In Appendix D, line 6.2.2.2 “EN 14363:2005, 4.1” should be replaced by “EN 14363:2015, Clauses 4, 5 and 6.1).

In Appendix D, line 6.2.2.2 “EN 15839:2012” should be deleted.

In Appendix D, line 4.2.3.5.2 “EN 14363:2005, Clause 5” should be replaced by “EN 14363:2015, Clauses 4, 5 and 7”.

In Appendix D, line 6.2.2.3 / 6.1.2.2.1

“EN 14363:2005, Clause 5” should be replaced by “EN 14363:2015, Clauses 4, 5 and 7” “EN 15687:2010, 5.3.2.2” should be deleted.

“EN 15827:2011, 9.3” should be deleted.

In Appendix D, line 6.1.2.1 (“Running dynamic behaviour” and “Running gear”) “Content of prEN 16235 included in Appendix B of this TSI” should be replaced by “EN 16235:2013”.

In Appendix D, line “Tests concerning long. compressive forces (C.8)” should refer to the amended version of EN 15839.

All references to ERA/TD2013-01/INT (introduced by Commission Regulation (EU) 1236/2013) should be deleted.

ERA/TD2013-01/INT should be withdrawn.

ERA/GUI/07-2011/INT Guide for Application of the CR WAG TSI from 15th April 2013

In subclause 2.4

— the reference to points 4.2.3.5.1 and 6.2.2.2 should be deleted;

— point 2.4.8 should be deleted;

— the reference to points 4.2.3.5.2 and 6.2.2.3 should be deleted;

— In point 2.4.9 Figure 6 should be modified:

  — In the third line the boxes "tests" and "simulations" should be combined and the text should be modified to "assessment of tests, dispensation conditions or simulations (EN 14363)";

  — The hints to Annex B below the "Tests"-box should be deleted;

  — In the "Qualification of running gear box" the reference to "(App B.2)" should be replaced by a reference to "(EN 16235)";

  — In the "Established running gear box" the reference to "(list in 6.1.2.1)" should be deleted, the reference to "(EN 16235)" should remain there.

— Point 2.4.10 should be deleted;

— Point 2.4.11 should be deleted;

— Figure 7 should be deleted;

— Point 2.4.12 should be deleted;

— Figure 8 should be deleted;

— Point 2.4.13 can be deleted, but maybe it would be helpful for clarification to keep it.

In sublause 2.5

— Under point 5.3.1: "Running gear":

  — The box referring to rail inclination should be deleted o point 2.5.3 should be deleted;

  — Point 2.5.4 should be deleted or modified to "EN 14363 and therefore also EN 16235 require testing for a specified minimum equivalent conicity. It is possible to qualify a running gear also for higher equivalent conicities in order to be compliant with existing NNTR's in this field. Therefore reporting of the combination of speed and max. equivalent conicity is required";

  — Point 2.5.5 should be deleted;

  — Point 2.5.6 should be deleted.

In Appendix 1 in the last line "Longitudinal Compressive forces" reference should be made to the amended version of EN 15839.

Annex A
(informative)

Guideline for presentation of results from multiple regression

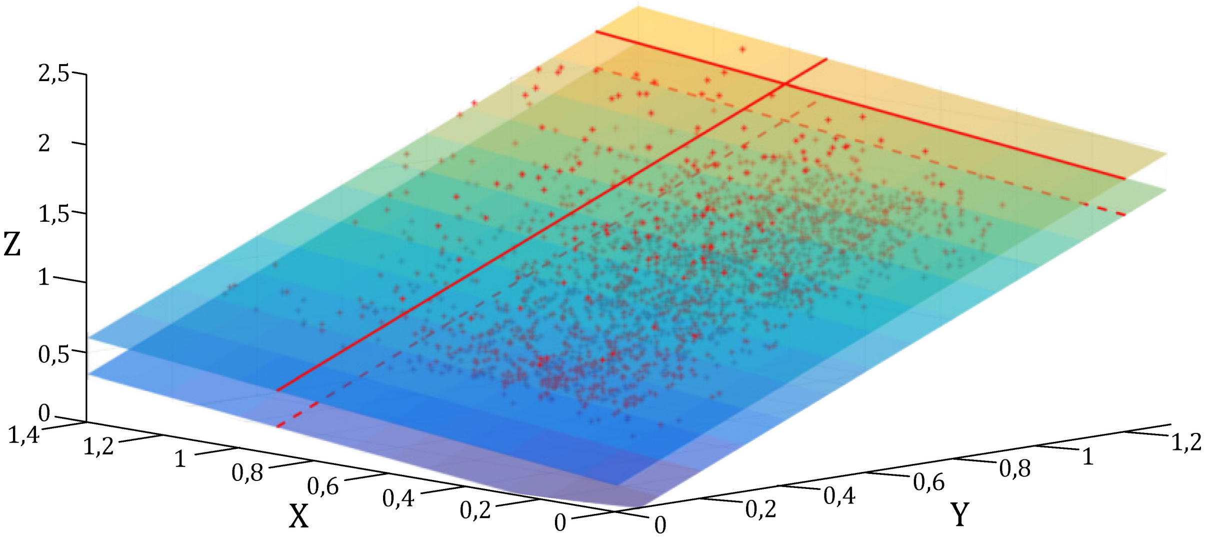
A.1 Introduction and purpose

EN 14363:2016 introduces with the multiple regression a new method for statistical analysis of test data. To facilitate the review and approval of test reports it is helpful if the data are presented in a similar way. This guideline gives principles and an example to present the data and results from multiple regression.

A.2 Principles

The aim is to present the results on one page for each assessment quantity and vehicle status (for example load condition and running direction).

All percentiles of the assessment quantity are shown related to the defined influencing parameters and together with the cross section of the regression plane and the prediction surface defined by the target values of the test conditions (i.e. by setting all, except the plotted influencing parameters, to their respective target values).



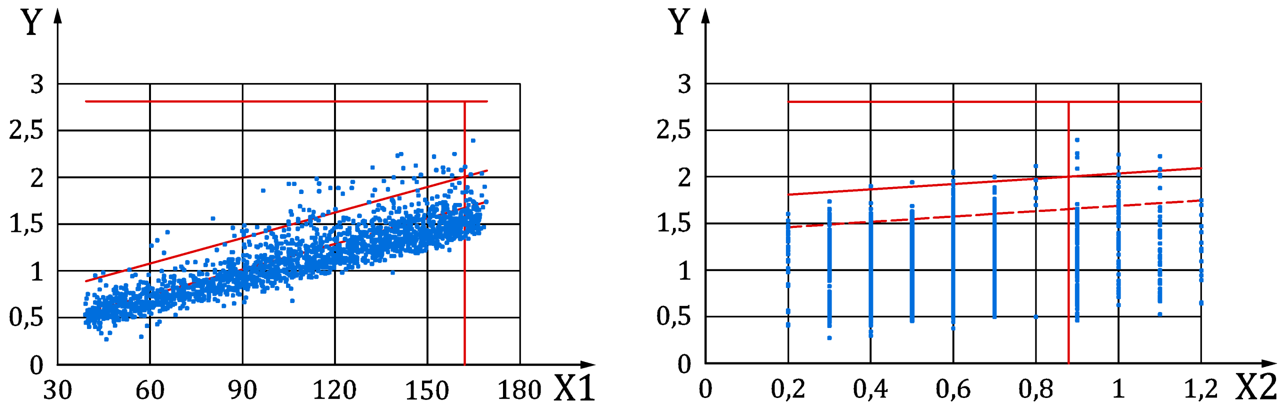
Key

X influencing parameter 2

Y influencing parameter 1

Z assessment parameter

Figure A.1 — Percentiles of assessment parameter, regression plane (lower surface) and prediction surface (upper surface) against two influencing parameters, cross section lines at the target positions



Test zone x: (2229 samples)

Key

X1 influencing parameter 1

X2 influencing parameter 2

Y assessment parameter

Figure A.2 — Percentiles of an assessment quantity against two influencing parameters with cross sections

Figures A.1 and A.2 illustrate this for two influencing parameters.

Figure A.1 shows the percentiles in a 3-dimensional diagram. The lower plane is the related regression plane, the upper surface is the prediction surface, used to determine the estimated maximum value. The shown cross sections indicate the target values of the two influencing parameters.

Figure A.2 illustrates the cross sections in a two dimensional view together with all percentiles. The dashed lines are the cross section lines with the regression plane, the solid line above is the cross section line of the prediction surface (used to determine the estimated maximum value). The vertical line indicates the chosen target value of the influencing parameter.

As defined in the standard, two data sets of percentiles are used: One for test zone 1 and one for the three test zones in curves. EN 14363:2016 defines in Table R.2 also three sets of independent parameters (for test zone 1, 2 and for both test zones 3 and 4 together). The related target values for the four test zones are defined Table 2 of EN 14363:2016. The data set for curves is assessed with two sets of independent parameters (one for test zone 2 and one for test zones 3 and 4) and three sets of target values (one for each test zone).

Percentiles from transition curves are presented against the speed.

The limit value, the number of sections included in the analysis, the related regression coefficient (a) and the estimated value are stated together with graphical presentation.

A.3 Example

Figure A.3 shows an example of a graphical representation of the results for one assessment quantity (here $\ddot{y}_S^*$), one running direction and one vehicle status.

The first line shows the results of test zone 1 and of the transition curves.

1) The first diagram shows the percentiles plotted against speed. The diagram includes the cross section line of the regression plane at the target value of track geometry quality (red dashed line)

and the cross section line of the prediction surface at the target value of track geometry quality (red line). The vertical line indicates the target value for the independent parameter speed (*V*). The horizontal line indicates the limit value of the assessment quantity ($\ddot{y}_S^*$) in test zone 1. Above the diagram, the number of sections (here: 4062) is stated. The slope of the cross section of the regression plane is given below the diagram (here a = 0,001 27).

2) The second diagram shows the same percentiles against the other influencing parameter, here lateral track geometry quality $\left(\Delta y_\sigma^0\right)$. It includes, in the same way as the first diagram, the cross section lines for the regression plane, the prediction surface, the target value of track geometry quality and the limit value for the assessment quantity ($\ddot{y}_{S,lim}^*$) in test zone 1. In this example the estimated value $Y(PA)_{max} = 0,598\ m/s^2$ is stated above the diagram. Again, below the diagram the slope of the cross section of the regression plane is given (here a = 0,305).

3) The third diagram shows all percentiles in transition curves against speed together with a horizontal line showing the limit value for reference.

In the second to the fourth line, the results of test zone 2, 3 and 4 (curves) are presented.

4) The data are presented in same way as in the first two diagrams of the first line.

5) Here three influencing parameters apply, which are different for test zone 2 ($V, I, \Delta y_\sigma^0$) and for test zones 3 and 4 ($I, R, \Delta y_\sigma^0$).

6) The shown percentiles in all diagrams of the three lines are the same.

7) It is possible to show the results of test zone 3 and 4 in one line of figures, as the same percentiles and influencing parameters are used. This requires then to show the two different target values for curve radius. There may be then two different sets of cross section lines of the prediction surface and limit values in the diagrams.

Interpretation of the diagrams:

The cross section lines of the prediction give the estimated maximum value if <u>one</u> target value is changed. If for example it is desired to estimate the behaviour at a different track quality target value, the resulting value can be obtained from the diagram by reading the value of the prediction line at the new target value.

The presented cross section lines are not the same as the regression line and the upper confidence interval of a two dimensional analysis (simple regression) made for the same percentiles.

It is not possible to combine the influence of more than one parameter in these diagrams. For such a case a new application of the regression formulas with new target values has to be done.

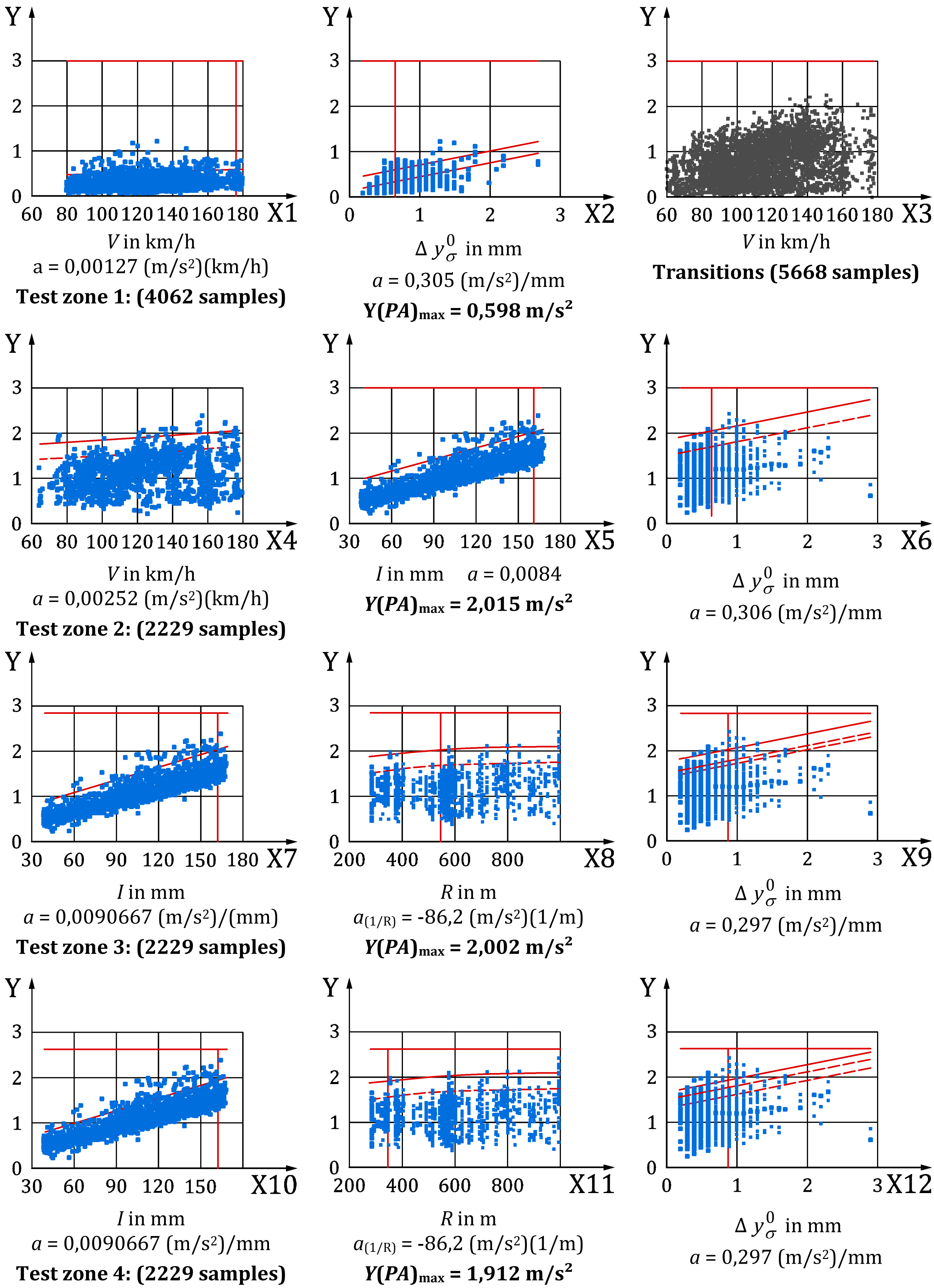


Figure A.3 — Example of presentation of multiple regression results

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