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INNOTRACK

Integrated Project (IP)

Thematic Priority 6: Sustainable Development, Global Change and Ecosystems

D1.2.5 – Track segmentation

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PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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Glossary

Abbreviation/acronym	Description
Track Segment	A length of track that has the same geometry within it, but is different from neighbouring segments. Can be several 100's of metres in length.
Track Site (Monitored Site)	A section of track used for monitoring of rail wear, RCF etc. Usually less than 100 metres long and usually with same track characteristics.

1. Executive Summary

Railway track is an asset that is many thousands of kilometres long that require continuous maintenance to remain fit for purpose. This asset does not degrade at a continuous rate but is variable due to the difference in geometry, track structure and the loading conditions that different parts of the network are subjected to. Therefore to understand degradation and plan maintenance of the track it has to be broken down into smaller sections. Within the Innotrack project this has been carried out so that the sections are defined by their geometrical and loading characteristics; this is called Track Segmentation. Primary segmentation has been carried out using data provide by each IM from their track recording coach. This report details the analysis of the track recording coach data that has been carried out and the next steps to allow secondary segmentation to be carried out to understand the degradation of different segments of track.

2. Introduction

The railway infrastructure, although a continuous asset, does not degrade at a constant rate. This is due to the different track geometry and loading conditions of sections or “segments” of the track. To understand this degradation, work is being carried out within WP1.2 and WP4.1 to identify the range of track characteristics that exist within the networks of the participating infrastructure managers. This information will be used to identify the important cost drivers for the tracks hopefully allowing extrapolation to the network as a whole to understand the life cycle costs. The railway infrastructure managers involved in this study are as follows:

Company	Country	Total Network km	Segmented km
Network Rail (NR)	United Kingdom	19568	4600
ProRail	Netherlands	2776	230
Deutsche Bahn (DB)	Germany	34128	650
Banverket (BV)	Sweden	9957	217
Österreichische Bundesbahnen (ÖBB)	Austria	5702	505
Société Nationale des Chemins de fer Français (SNCF) *	France	29547	1559
Administrador de Infraestructuras Ferroviarias (ADIF)	Spain	12991	On Hold
České dráhy (CD)	Czech Republic	9491	On Hold

Table 1 - Summary of Participating Rail Networks

(Source: Railway Statistics Synopsis 2006, International Union of Railways [UIC], Paris, France)

This report details the work carried out by Corus in carrying out segmentation of selected tracks from data provided by each IM. The first step is to collect track geometry data from each of the companies providing a representative sample of the total network, the current distance that has been studied so far is given in Table 1. To facilitate this, companies were asked to provide data covering stretched of tens of kilometres and covering a range of traffic conditions. A standardised technique to use this data to generate a database of curves, transitions and tangents for each company is then applied. Having made this primary segmentation on the basis of radius/curvature, a secondary analysis is then applied to establish characteristic national variations of other track design parameters, this in combination with operational data such as line speed. Information on traffic volumes for the sections of track studied are then integrated into this and an analysis is made to quantify the impact on cost drivers reported by each company for use in establishing a rail degradation algorithm which in turn can be used to determine most cost effective rail replacement strategy. It should be noted that the ultimate model will make use of the segmentation analysis in combination with railway, metallurgical expertise and detailed results obtained from closely monitored test sites (D4.1.1, D4.1.2) which have been established for several years. A flow diagram of the segmentation process is given in Appendix 1.

The approach to establishing these characteristics is described in detail in this report. An overview of results and data processed at time of writing are also presented together with an indication of the next steps to be taken to define track geometry and use characteristics to be considered in the development of a rail degradation algorithm to help IM’s to select the most cost effective rail grade options.

3. Initial Analysis and Validation

3.1 Initial Data Evaluation and Validation

Files are received in a text format as recorded by the Track Recording vehicles in each of the Innotrack companies. The first step is to carry out a data audit. This usually reveals several questions and areas requiring confirmation, e.g. units, missing signals etc. An extract from such a data audit output is shown below.

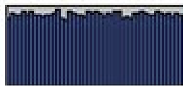
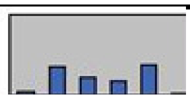
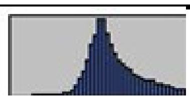
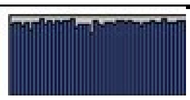
Field	Graph	Min	Max	Mean	Std. Dev	Unique	Valid
Record_Number		1	764402	--	--		764402
Line_Ref		--	--	--	--	8	764402
Cross_Level		-8.98	7.93	0	0.81		764097
Super_Elevation		-162.97	169.38	-0.07	69.29		764396
Curvature		-60.94	82	0.27	20.1		764402
Incline		-26.17	21.48	-0.12	10.26		764396
Track Gauge Deviation		-15.27	40.9	4.48	5.48		764389
Distance		22.75	192405	--	--		764402

Figure 1 - Example of Data Audit; Results are fed back to data provider as first step in Process

From the sample of fields included in Figure 1 it can be seen that descriptive statistics and a simple graphical representation help in the verification of the data. In particular, outlying and null (empty) values can be seen and the completeness of the data set evaluated. In this case there are over 760,000 measurement records. Where the field contains a flag or string with few representative values the number of unique values is reported as for Line_Ref in the above example. The exercise is useful also in verifying the units of measurement. It should be noted that the data files received from each company also included track quality measurements such as vertical alignment, twist etc. As these represent only a snapshot of the track stability however, they are not useful for this comparison approach. Investigation of the dynamics of track quality over periods of time are the subject of other work packages in Innotrack. The data which were used in the segmentation analysis are indicated in Appendix 1 which also shows the completeness (in terms of required data items) for each of the infrastructures.

In the case of invalid or missing values an appropriate strategy is selected, for example by interpolation.

3.2 Distance Discrepancies

Investigation of the distances between measurements reveals occasional gaps; these could result from processes associated with data extraction from the source database, or period where measurement was suspended, e.g. due to too low speed, a location correction made during the measurement process or a failure on board the measuring coach. Depending on the nature of the error, correction is made either through use of other sources of geometry data (e.g. other track recording vehicle runs) or by regeneration of the datum distance based on the nominal measurement interval, which typically differs between companies ranging from 0.16 to 0.25 metres. Normally a combination of these approaches is required. The original distances are retained in the file however so that later alignment of information on defects and maintenance can be achieved. An example of observed inter-measurement distances from files received is shown in Figure 2. These are mainly negative in this case due to the direction of travel for the particular run, and clustered around the nominal interval of 20cm. Very large discrepancies normally relate to isolated zero values or other errors which can be corrected manually. Other changes can relate to temporary loss of recordings or distance resets.

Value	Proportion	%	Count
-15		3.94	77304
-16		5.97	117107
-1633		0.0	1
-17		0.37	7350
-18		0.49	9556
-19		41.54	814661
-20		19.71	386619
-21		24.3	476517
-22		0.27	5203
-23		0.07	1299
-24		0.03	593
-25		0.06	1150
-26		0.04	764
-28		0.01	180
-29		0.02	392
-30		0.0	68
-31		0.0	48
-32		3.16	61962
-3309		0.0	1
-47		0.0	6
-48		0.0	32
0		0.02	448
11124570		0.0	1
16		0.0	1
30155056		0.0	1
3379602		0.0	1
3500303		0.0	1

Figure 2 - Example of distribution in measurement intervals in centimetres

3.3 Track Design Parameters

For the purpose of the proposed initial segmentation, the most important parameter is radius or curvature. In order to make a database of pan-European comparable track segmentations, it is important to have complete understanding of this parameter and the way in which it is calculated/derived. Normally the curvature data are presented either as a 'versine' based on a standard cord length, or as the reciprocal of radius multiplied by a factor. Both the approaches result in a value close or equal to zero in the case of a tangent tending to infinity as the radius becomes tighter. This approach makes the geometry data easier to handle as a continuous parameter results as shown in Figure 3.

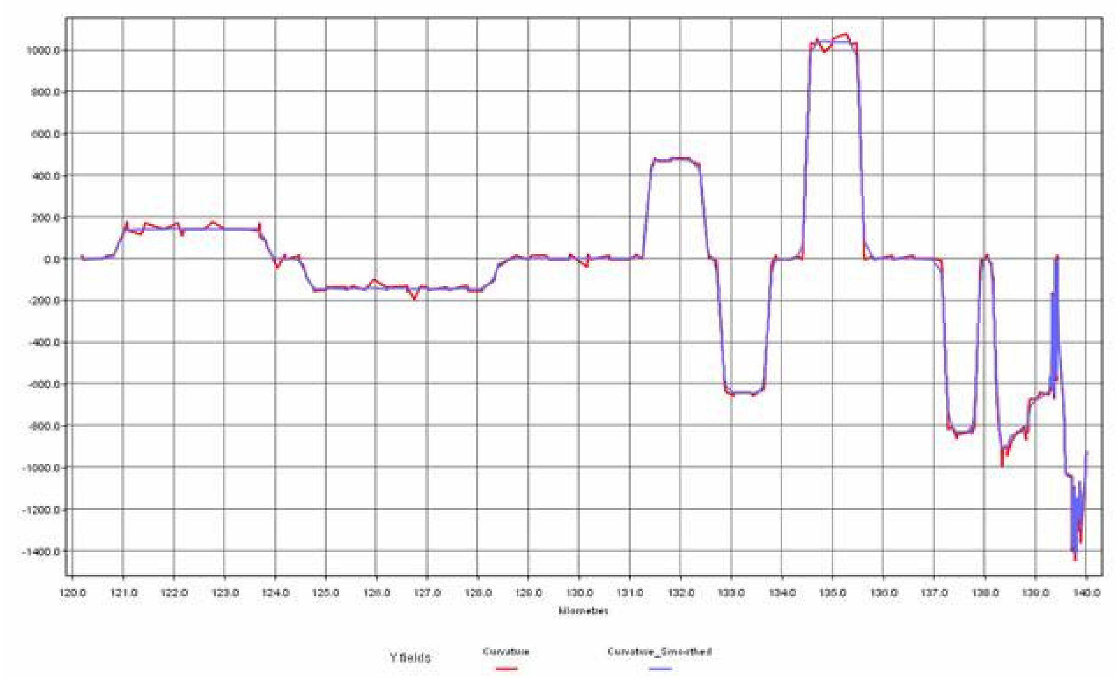


Figure 3 - Example of Curvature Signal (in this case 1/R x 100000)

The sample of track in Figure 3 shows the variation of curvature with distance. For the purposes of segmentation the curvature is smoothed as shown in the sample (blue trace) so that curves (sections with constant radius) can be isolated more easily ignoring higher frequency noise. This smoothing has been done using a rolling mean based on +/- 50 metres.

In the example, it can be seen that from a tangent (straight) section there is a transition to a curve (to left or right) which runs for approximately 3km before a transition back to a short stretch of tangent followed by a transition to curve in the opposite direction to the first. It was decided that for the purposes of segmentation however, segments would be determined on the basis of calculated radius. The corresponding representation for Figure 3 in terms of radius derived from the smoothed curvature signal is shown in Figure 4.

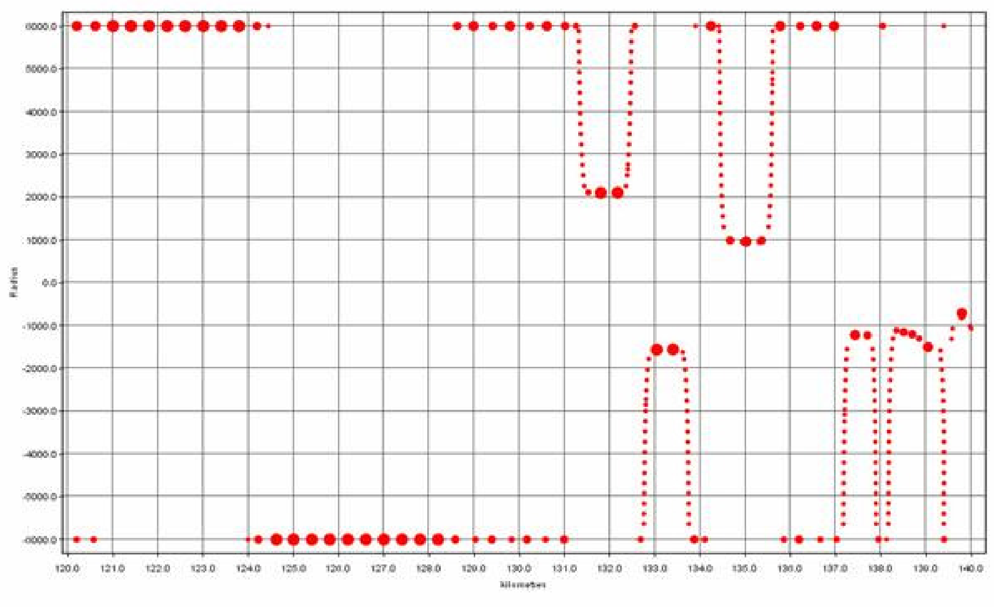


Figure 4 - Variation in Radius corresponding to section

The problems raised through use of the radius signal in this way are evident in that the radius for a tangent section would theoretically be infinite and also the sign of radius switches from negative to positive during a 'straight' section. To handle this, a standard ceiling of +/-6000 metres is applied when radius exceeds this. A typical distribution of actual radius between these limits is shown in Figure 5.

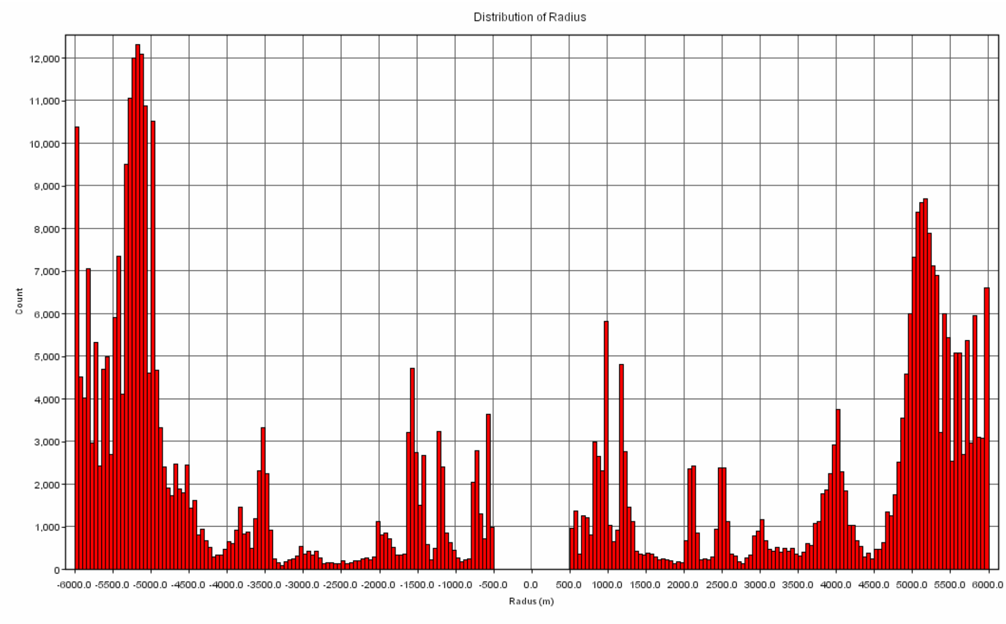


Figure 5 - Distribution of Radius within Tangent Boundaries.

As we are obtaining data from different countries, recorded using different track recording vehicles, a validation method is needed to give confidence that track designs can be compared. To do this, an algorithm is applied to convert the radius to the locus of the track to give a 'birds-eye' (aerial view) representation. By rotating this path such that the bearing between the start and end point matches that of the actual geography, a representation such as that shown in Figure 6 is obtained; Glasgow to Crewe in the UK Network Rail infrastructure. It can be seen that the computed path is very similar to the actual. To validate further, the 'crow flies' distance between the start and end points of the computed path is then computed and compared to the actual geographical value determine from latitude and longitude parameters. If the difference between computed and actual exceeds 2.5% then further investigation of the raw data is applied to verify the radius calculation and the inter-measurement distance,

In this way the computation of radius is validated and this method has been applied for all the data received.

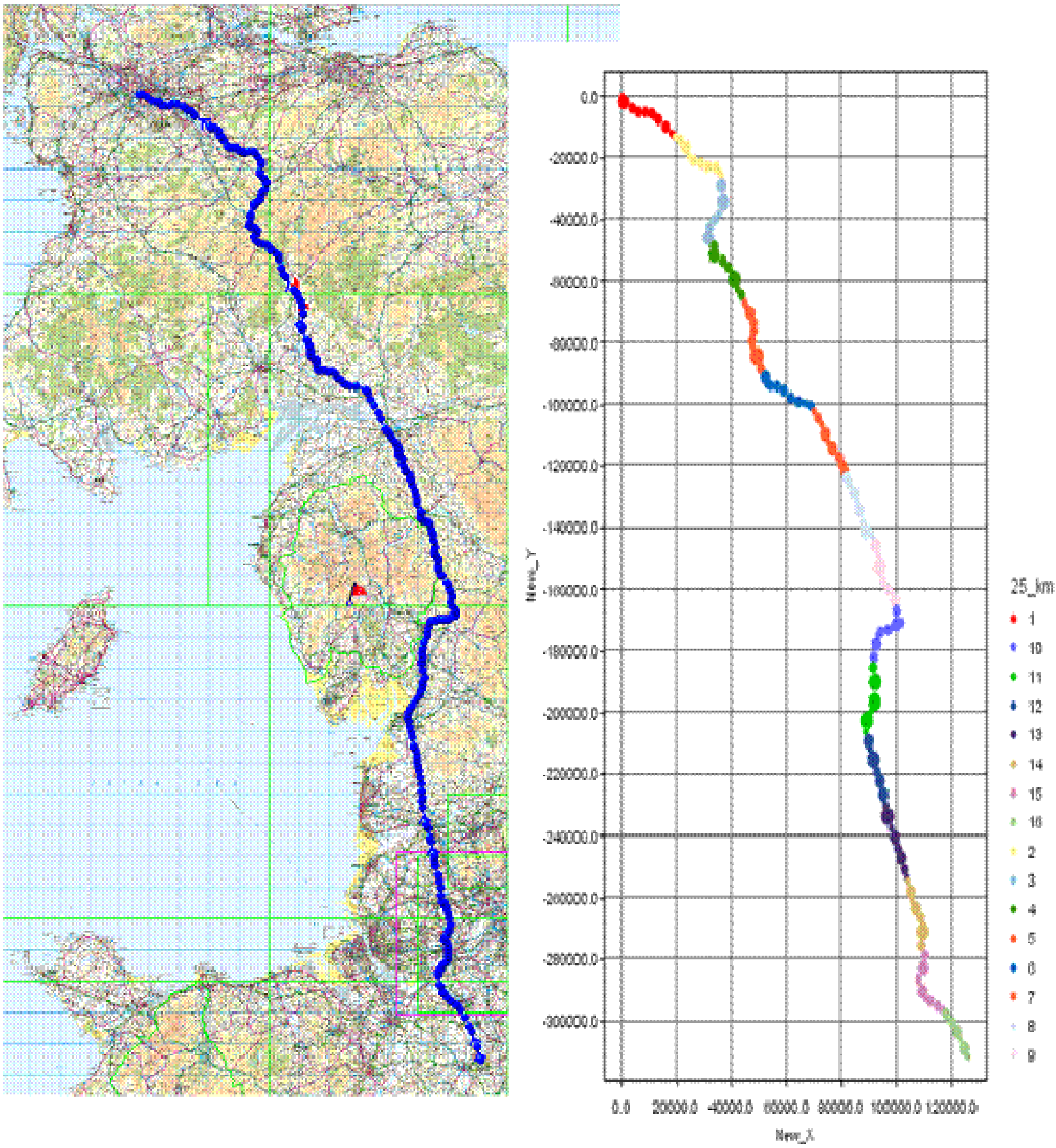


Figure 6 - Comparison of Path of Rail track computed from instantaneous radius compared with geographical data

4. Segmentation

The next step is to determine the start and end points of each curve and tangent section and the length of the connecting transition section. Automation of this process is complicated by residual noise on the signal which varies between the infrastructures. The first step is to calculate the change in instantaneous radius between each measurement; delta-radius. In theory where this is zero, the corresponding section of track will be a curve or tangent. In the case of a tangent however the noise is very high due to the high values of radius computed. Consequently, it was decided to apply a value of 6000 metres, above which a segment would be created and defined as tangent. Because of this notional definition of a tangent section the identification of the start or end of a transition out of/into a tangent section is straightforward. A similar change point between transition and curve is more difficult however. This is illustrated in the example in Figure 8 which shows how the raw delta-radius values around the ends of and throughout the curve.

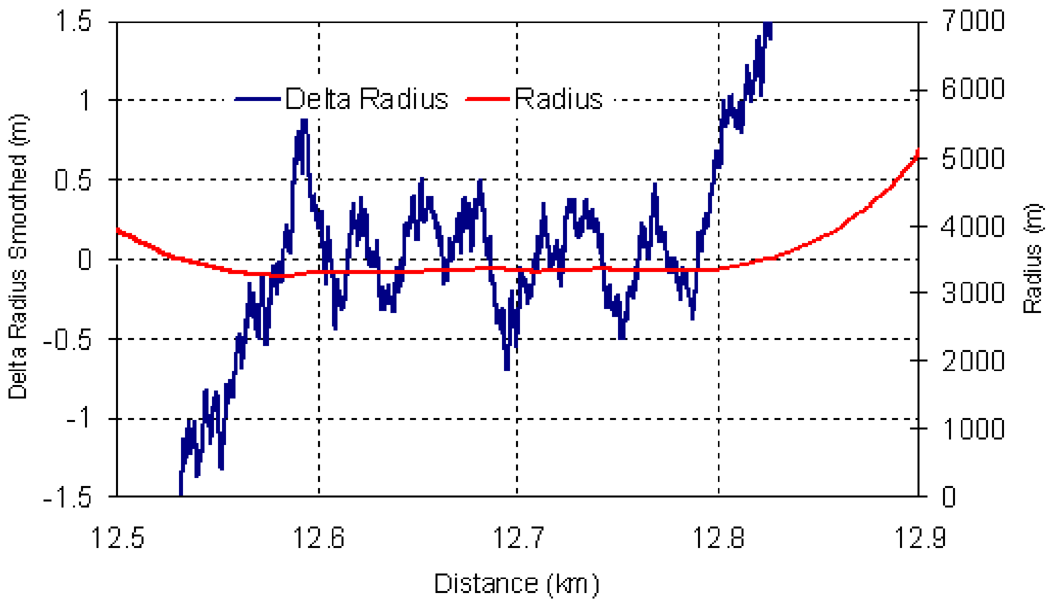


Figure 7 - Instantaneous change in Radius for a Curve of radius 3400 metres

The level of noise observed is often considerably more than seen in this example and automation of the process to select a start and end point where delta-radius is zero is challenging. To facilitate this, a further smoothing factor is applied to the delta-radius signal; it was found that smoothing on basis of +/- 25metres (to generate Rad_Trans_Smoothed) gave good results. The outcome of this treatment for the sample in Figure 7 is shown below.

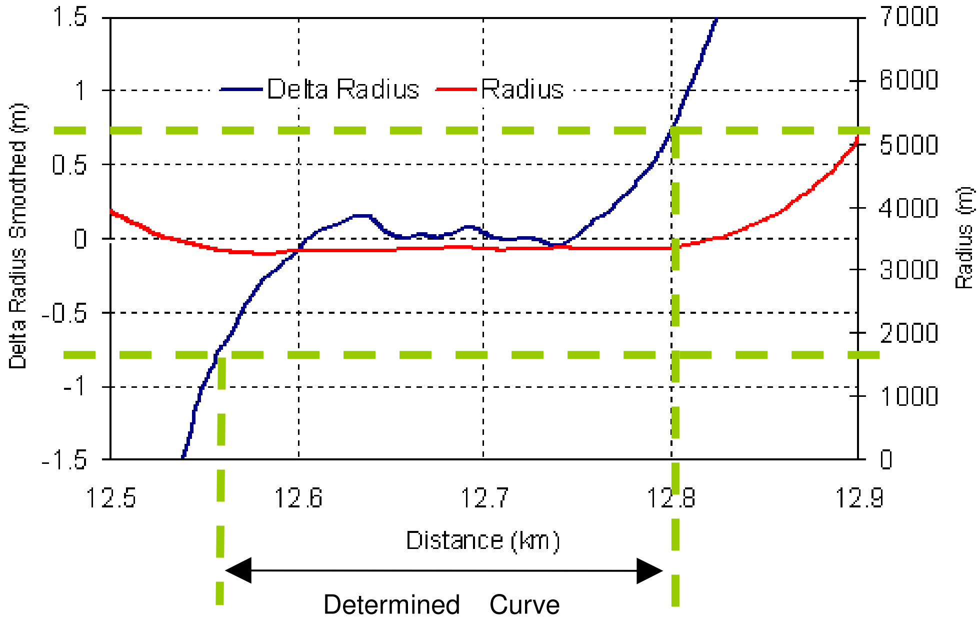


Figure 8 - Smoothing of Delta-Radius Signal (Rad_Trans_Smoothed)

Next, in order to automate the identification of a start and end point for the curve, upper and lower bands for delta_radius_smoothed (Trans_Lim) are set to +/- 0.75. The intersections of these limits with the delta_radius_smoothed curve then serve to define the start and end points, from which the segment length is determined (as demonstrated in Figure 8). The overall conditions for classification on the basis of these signals is described in Table 2.

Classification	**Condition**
1. Curves	absolute(Rad_Trans_Smoothed) <= 'Trans_Lim' and absolute(Radius) < 6000m
2. Transition Curves	absolute(Rad_Trans_Smoothed) > 'Trans_Lim' and absolute(Radius) < 6000m
3. Tangent	absolute(Radius) >= 6000m

Table 2 - Conditions applied in Classification of Track Type

This first pass carried out to describe the track in terms of the series of tangents, transitions and curves. A further pass is then made to aggregate small segments with neighbours such that the minimum segment size generated is 50 metres. In particular, the following characteristics are observed following the first pass.

There appears to be a large number of curves and transition curves between tangent sections, many more than would be expected. For most examples these can be combined into an entry and exit transitions with an intermediate single curve.

Following a long tangent section there are several transition curves which cross the various radius ranges to reach the following curved section. This is reasonable but it is better to define these as single transition segments with a maximum and minimum radius applying.

A curve should lie within one radius range but there are occasions where consecutive curves are identified in different radius ranges. This implies that the radius is close to the common boundary of the radius ranges. These segments can be combined into the 'majority' radius range.

There are occasional short curve or transition curve sections which correspond to high radii close to the 'Tangent' definition of 6km. These segments can be redefined as Tangents and then combined with neighbours.

To further consolidate the number of segments identified therefore, the following actions have been applied.

Method	Consolidation Steps
Standard based on 'Track Type' and 'Radius Bin'	1
Consolidation of consecutive Curves, Transition Curves and Tangents belong to same radius band.	2
A curve or transition curve which is less than 50 metres long and is close to a tangent value (Radius > 5.5km) shall be reclassified as a tangent	3
A short Transition Curve which is bordered by 2 curves shall be reclassified as a curve.	4
A short curve which is bordered by 2 transitions shall be reclassified as a Transition Curve	5

Statistics for all other design parameters included in the raw data files are then computed by aggregating data according to the final outcome of the above process. A sample of output from this exercise is shown below in Table 3 (tight curves in a 320km track sample). The table shows example statistics for the Cant parameter. A full listing of the data items supplied by each of the participating companies is presented in Appendix 1.

Segment_ID	Radius_Bins	Track_Type	Segment_Length (m)	Start (m)	Cant_Min	Cant_Max	Cant_Mean
14	(b) 0.3 <= Radius < 0.7 km	1. Curves	168.8	1009	-70	-48	-61.5
16	(b) 0.3 <= Radius < 0.7 km	1. Curves	171.8	1338	-115	-35	-63.6
102	(b) 0.3 <= Radius < 0.7 km	1. Curves	235.4	27971	119	135	127.1
476	(b) 0.3 <= Radius < 0.7 km	1. Curves	104.0	164887	-14	8	-1.0
937	(b) 0.3 <= Radius < 0.7 km	1. Curves	309.4	277772	138	158	151.8
1023	(b) 0.3 <= Radius < 0.7 km	1. Curves	219.0	309835	15	57	39.2

Table 3 - Sample of Segmentation analysis showing Curves in One Radius range for a track of over 309km length

By applying this methodology to the raw track recording vehicle data as supplied by each company therefore, a digital description characterising the geometry of each track with the minimum number of segments is generated. The highest level description concerns the distribution of track type, i.e. Tangent, Curve and Transition, for example as shown in Figure 9.

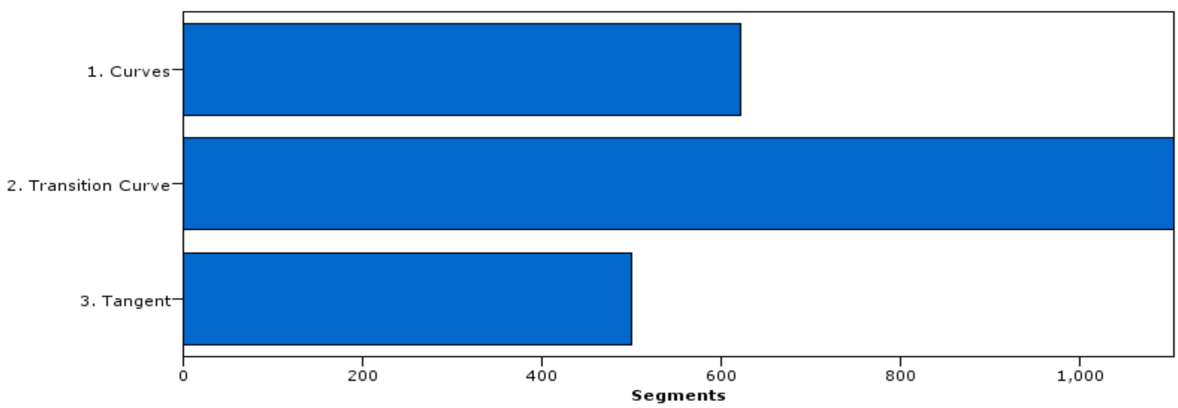


Figure 9 - Proportions of Track Type ('Count' here refers to number of segments in several thousand kilometres of track)

This is then broken down further to indicate the distribution of curves with respect to radius. For comparison purposes a standard set of radius ranges have been applied and the result relating to the above data is shown in Figure 10. It should be noted that transition curves actually have a continually varying radius (to connect a tangent to a curve or a curve to a curve) and so the classification in these cases is based on the modal value.

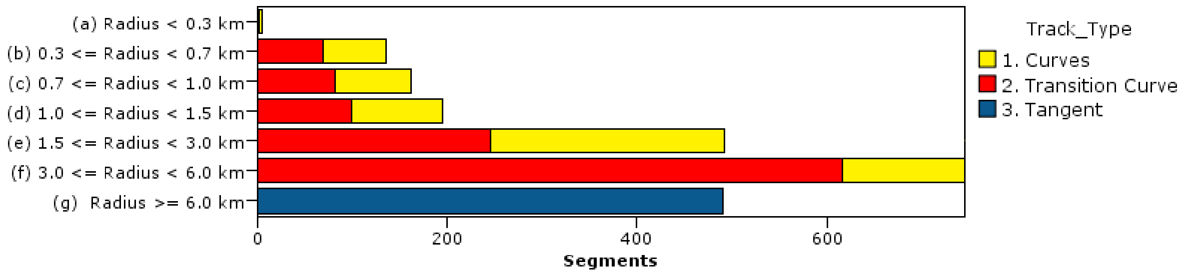


Figure 10 - Breakdown of Curve Types into Standard Radius Ranges

As each segment has an associated length, the total distance of curves of certain radius can easily be computed. An example is given in Table 4.

Track_Type	Radius_Bins	Total Length (m)	Average Segment Length (m)	Number of Segments
1. Curves	(a) Radius < 0.3 km	2010	287	7
1. Curves	(b) 0.3 <= Radius < 0.7 km	28348	220	129
1. Curves	(c) 0.7 <= Radius < 1.0 km	88879	380	234
1. Curves	(d) 1.0 <= Radius < 1.5 km	289046	499	579
1. Curves	(e) 1.5 <= Radius < 3.0 km	582782	381	1531
1. Curves	(f) 3.0 <= Radius < 6.0 km	206874	223	926
2. Transition Curve		895440	151	5934
3. Tangent	(g) Radius >= 6.0 km	2457769	956	2572

Table 4 - Example Distribution of Curves in terms of Radius Range

As mentioned previously, transition curves have been associated here with the most relevant radius range, i.e. the one applying for most of the transition length. To further describe the transition segments in a numerical manner, the incoming and outgoing radius are also recorded along with the length of the segment; one of these will often be a tangent however.

Each different curve or tangent segment in each bin in Table 4 would degrade in a manner identical to all other segments if a number of factors is constant between them. These factors include cant, traffic (amount, speed, axle load, vehicle type), rail grade, maintenance, previous curvature, structures, signals etc. Unfortunately all of these can be different for different segments therefore to fully understand degradation secondary segmentation is required to further refine the results.

5. Secondary Segmentation Based on Construction Features and Geometry

It can be seen from Table 3 that several segments are identified with similar geometry characteristics, but these can exhibit large differences in terms of the distribution of associated properties, illustrated in this case by the statistics for Cant. As mentioned previously, the segmentation analysis processes the data for all parameters provided in the IM data sets, to generate statistics for all geometry characteristics. These are then stored in an overall segmentation database for all the track samples considered. The secondary segmentation process examines the 'similar curves' across the different networks to find similar and dissimilar clusters corresponding to the patterns of these different geometry features. Thus the occurrence and reasons for significant differences between and within networks can be explored.

In addition, some of the data provided includes information about constructions associated with the railway track, for example the locations of stations, tunnels and switches. The location of this type of feature within a segment can be very influential to the anticipated behaviour also. Thus the position of the features relative to the entry and exit of the segment should be known and in some cases it may be appropriate to consider the feature as a segment in its own right, at least with regard to the definition of maintenance rules.

In order to fully implement this process of secondary segmentation further information is required from the infrastructure operators. Firstly further raw track geometry data is required from some companies to facilitate a meaningful analysis. Second, missing design information such as line speeds and cant deficiencies will be sought. When sufficiently large track data samples have been received from each of the railway companies, analyses will be made in conjunction with information about maintenance and defects, to compare and contrast characteristics across the networks.

The approach to be followed is illustrated in the following.

5.1 Geometry and Track Quality

The segmentation analysis facilitates the generation of overview statistics for all track geometry and quality parameters included in the data. This is illustrated in Table 5 which presents overview statistics for a sample of tight radius segments taken from different infrastructures.

The table shows in particular the variation in Cant (Super-Elevation) which is applied for this class of curve in different cases. This may reflect national standards but will also be influenced by the traffic mix for each parent track. The cant for a passenger line will normally be set higher than for freight or mixed traffic lines where a compromise between rail wear and passenger comfort must be struck. Some information on traffic type and volume is available for some of the data but this will be followed up further as a next step.

It is interesting also to investigate the variation in design geometry for transition and tangent segments. Figure 11 for example shows the distribution of cant for tangent segments for some of the countries. It can be seen as expected that this is usually zero but with a normal spread.

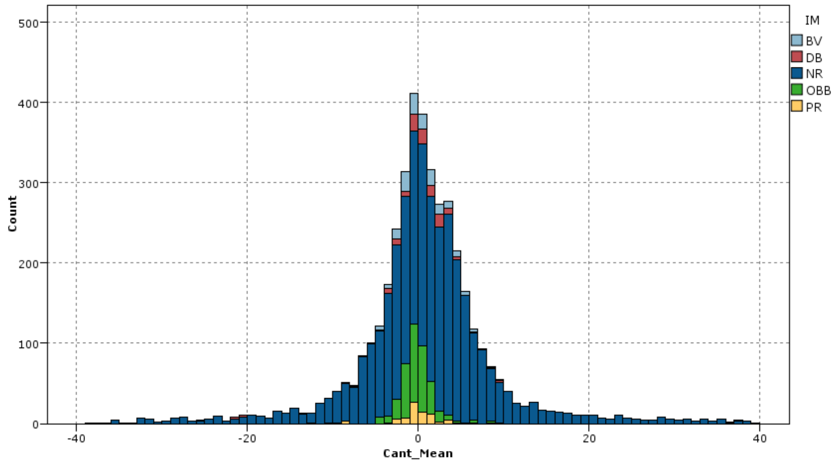


Figure 11 - Distribution of Cant for Tangent Track

Company	Segment Length (Metres)	Mean Radius (km)	Radius SD (km)	Gauge Deviation (mm)	Gauge Deviation SD	Cant Min (mm)	Cant Max (mm)	Mean Cant (mm)	Cant SD	Mean Cant Deficiency	Cant Deficiency SD	Line Speed (kmh)
BV	81.3	1.0	0.0	7.5	1.4	26.1	0.8				24.4	28.0
BV	150.8	1.0	0.0	6.7	1.2	-28.2	2.7				-34.0	-23.1
BV	311.9	1.0	0.0	5.8	1.5	-54.5	2.7				-61.5	-43.7
DB	250.4	1.0	0.0	11.3	1.0	134.1	2.9	86.9	3.6	140.0	120.5	137.5
DB	944.7	1.0	0.0	3.8	1.4	113.7	1.9	116.3	3.7	140.0	103.9	118.4
DB	950.1	1.0	0.0	3.3	1.2	-113.8	1.9	-115.7	3.7	140.0	-118.5	-104.2
NR	97.8	1.0	0.0	7.2	1.7	116.0	1.8	138.2	6.3		112.0	121.0
NR	154.2	1.0	0.0	12.0	2.2	-136.2	5.4	-175.8	14.2		-147.0	-122.0
NR	356.6	1.0	0.0	0.1	0.9	-154.1	3.4	-93.7	3.8		-163.0	-144.0
OBB	25.7	1.0	0.0	12.6	0.9	88.4	1.7				86.1	92.3
OBB	79.5	1.0	0.0	4.0	0.5	42.6	2.8				37.2	48.6
OBB	86.3	1.0	0.0	5.2	1.4	-49.0	1.0				-50.9	-46.8
PR	311.8	1.0	0.0	0.0	1.4	135.1	0.9	0.0	0.7	130.0	132.4	137.9
PR	617.3	1.0	0.0	0.0	3.4	-136.6	12.2	-0.1	1.2	130.0	-156.4	-90.4
PR	619.3	1.0	0.0	0.0	2.8	-147.9	11.5	-0.1	1.2	130.0	-163.8	-96.2

Table 5 - Sample statistics for four railways for 1km Radius Curves

In the case of tangent segments however it should be remembered that a lower limit on radius of 6km has been applied. In practice, relatively significant cant levels can be set for the lower ranges of radius within the resulting segments, especially if mainly carrying or dedicated to passenger traffic; as illustrated in Figure 12.

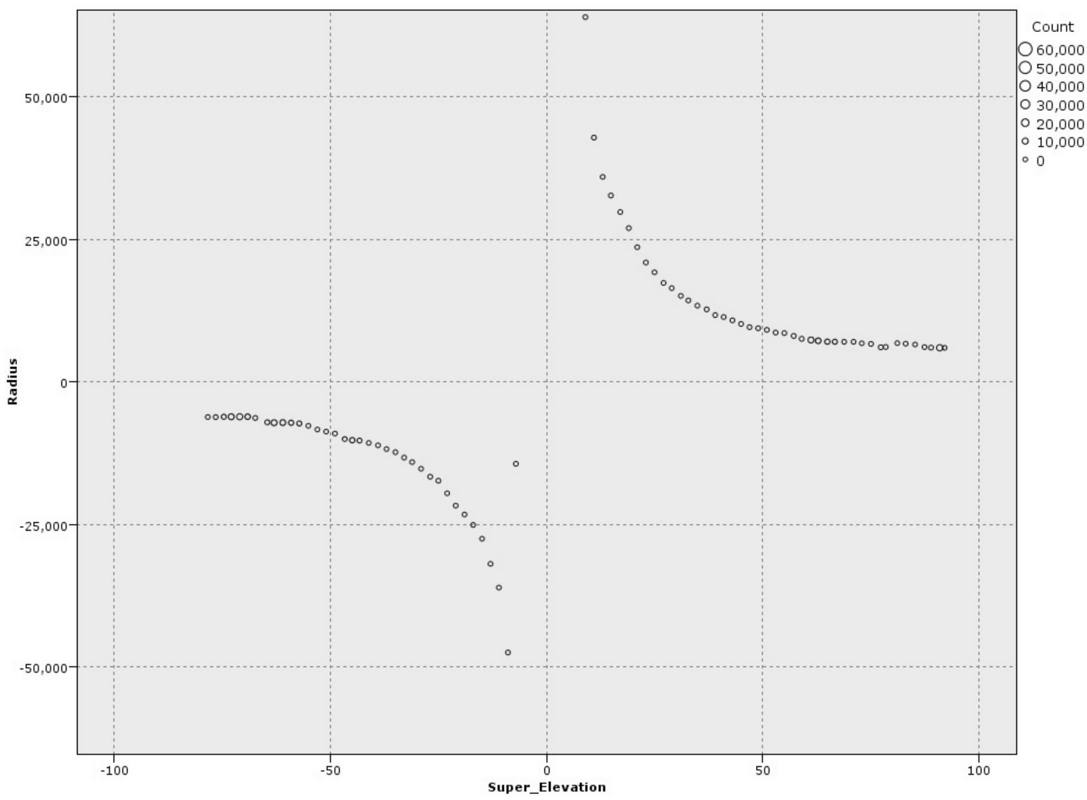


Figure 12 - Actual relationship between radius and Cant for a 'Tangent Segment'

In the case of transitions, these normally occur between a tangent section and a curve or between curves of different radius and thus have an ever changing radii. In these cases, the factors influencing rail wear may include parameters such as the maximum rate of change of radius (ROC) during the transition and where this occurs in relation to the entry and exit of the segment, or the radius into and out of the transition considered together with the transition segment length. The rate of change of radius for transition curves can affect the degradation of the rail for some distance after the transition curve as it can lead to vehicle instability and increased contact forces. Table 6 presents some examples statistics for transitions pertaining to one length of track.

Segment Number	Segment Length	Radius In (m)	Radius Out (m)	Radius Min (km)	Radius Max (km)	Radius Mean (km)	Cant Min	Cant Max	Cant Mean	Cant Deficiency Mean	Transition ROC
2.0	98.2	5992.3	1017.8	1.0	6.0	2.1	0.0	101.7	56.4	13.9	50.6
4.0	167.4	649.7	757.5	0.6	1.8	1.2	66.6	99.5	77.4	24.0	-0.6
6.0	182.7	906.6	5987.7	0.9	6.0	2.0	9.6	68.3	39.2	32.6	-27.8
8.0	161.4	-5992.6	-5994.6	2.8	6.0	3.7	-38.8	-13.5	-34.1	-108.8	0.0
10.0	52.4	-5973.9	-4667.2	4.7	6.0	5.1	-46.7	-43.4	-45.8	-50.7	-25.0
12.0	51.7	-4639.9	-5931.1	4.6	6.0	5.1	-45.2	-38.3	-41.3	-57.6	25.0
14.0	116.5	6006.3	3316.4	3.3	6.0	4.2	45.9	83.9	69.1	45.0	23.1
16.0	119.2	3354.7	5965.0	3.4	6.0	4.2	47.0	87.4	72.0	40.6	-21.9
18.0	118.3	6001.2	4097.4	4.1	6.0	4.8	73.8	109.5	93.2	94.6	16.1
20.0	118.6	4072.1	5960.4	4.1	6.0	4.8	77.9	112.6	97.0	92.4	-15.9
22.0	67.2	-6003.9	-5264.1	5.3	6.0	5.5	-85.4	-70.3	-79.5	-83.7	-11.0

Table 6 - Data Relating to Transitions

The table demonstrates for example, that the computation of a transition rate of change (ROC) based on difference between incoming and outgoing radius is often sufficient to describe the characteristics of a transition. This is not always the case however; for example in the table above, segment 8 has the same radius of approximately 6km (the cut off where tangent is assumed), but the minimum radius observed is just 2.8 km. This case probably results because the calculated intermediate curve length is very short and has been consolidated into neighbouring transitions. These ‘complex transitions can be recognised fom the relationship between the computed statistics for the segment.

5.2 Other Track Features

As discussed earlier, the incidence of track features along the length of the track will also be influential in terms of the parameters or a rail degradation model. In some cases features such as stations, tunnel, bridges and switches are digitally recorded in the Track Recording Vehicle data making these easy to incorporate into the segmentation analysis. In other cases ‘route description files’ are available which serve to describe the start and end points of different types of features on a distance basis which can be cross referenced to the track recording vehicle measurements. Figure 13 for example shows the number of switches within the different segments for a 320km length of track. It can be seen that in one case there are 20 switches present; this presentation does not give any indication of segment length however and for the case in question the segment is approximately 25 km in length, as can be seen in Figure 14 which shows number of switches against segment length.

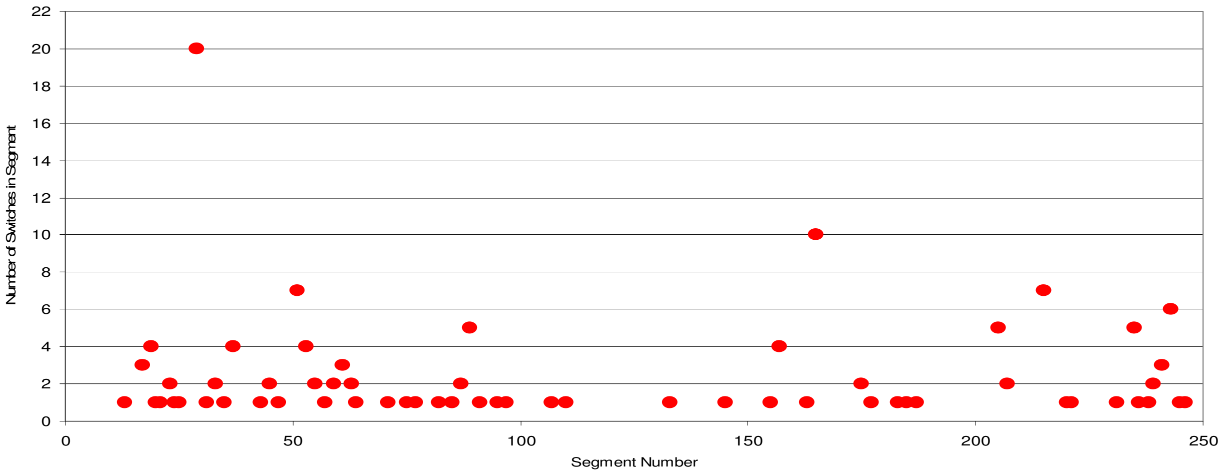


Figure 13 - Distribution of Switches within Segments

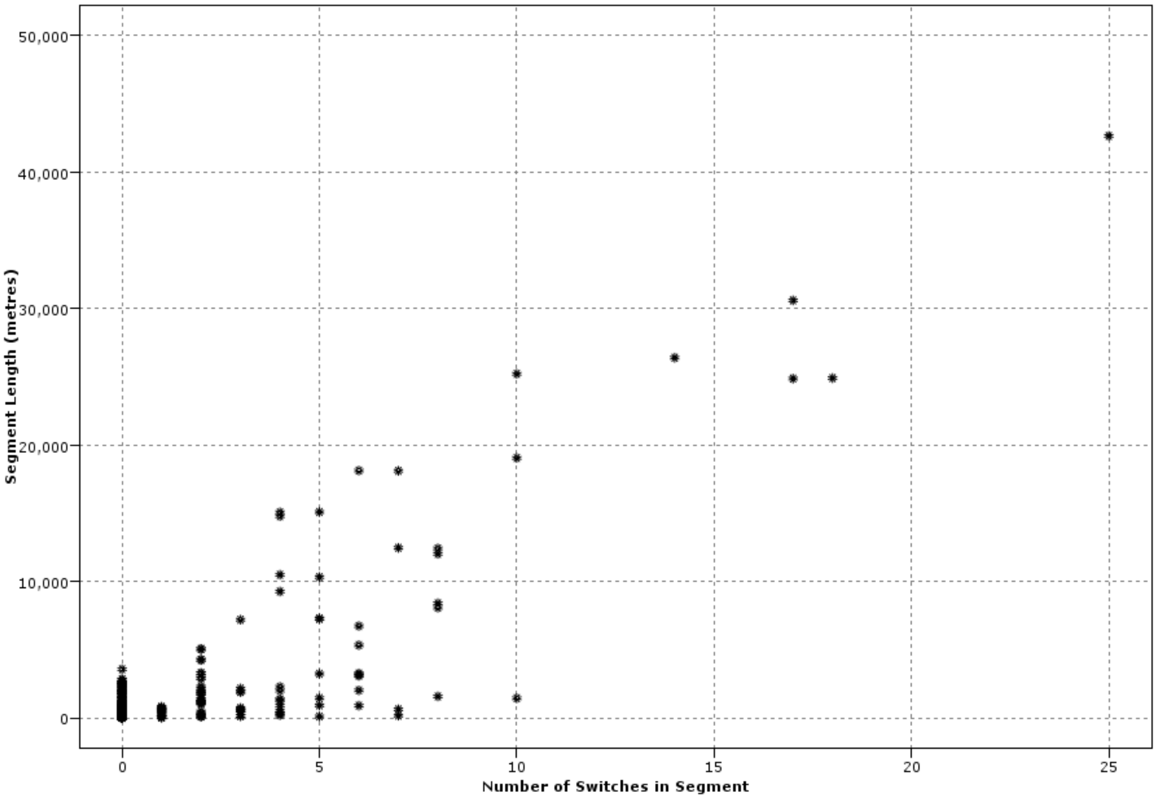


Figure 14 - Relationship between Number of Switches and Segment Length

Initially the approach taken in the primary segmentation is just to specify whether a station is present within a segment or not, or the number of switches within the segment. In secondary segmentation however, more sophisticated approaches may be required, for example to split segments into smaller ones with features at the boundaries.

6. Data Modelling Approaches

The ultimate objective of this approach is to create a model or series of algorithms which can be applied to define the probable life expectancy of rail given its geometry, material type, service conditions and maintenance regime. An essential characteristic of the data mining approach is the combination of data exploration and analysis with the human expertise in the domain. Thus a combined iterative approach is required. Figure 15 outlines the process being followed in this respect.

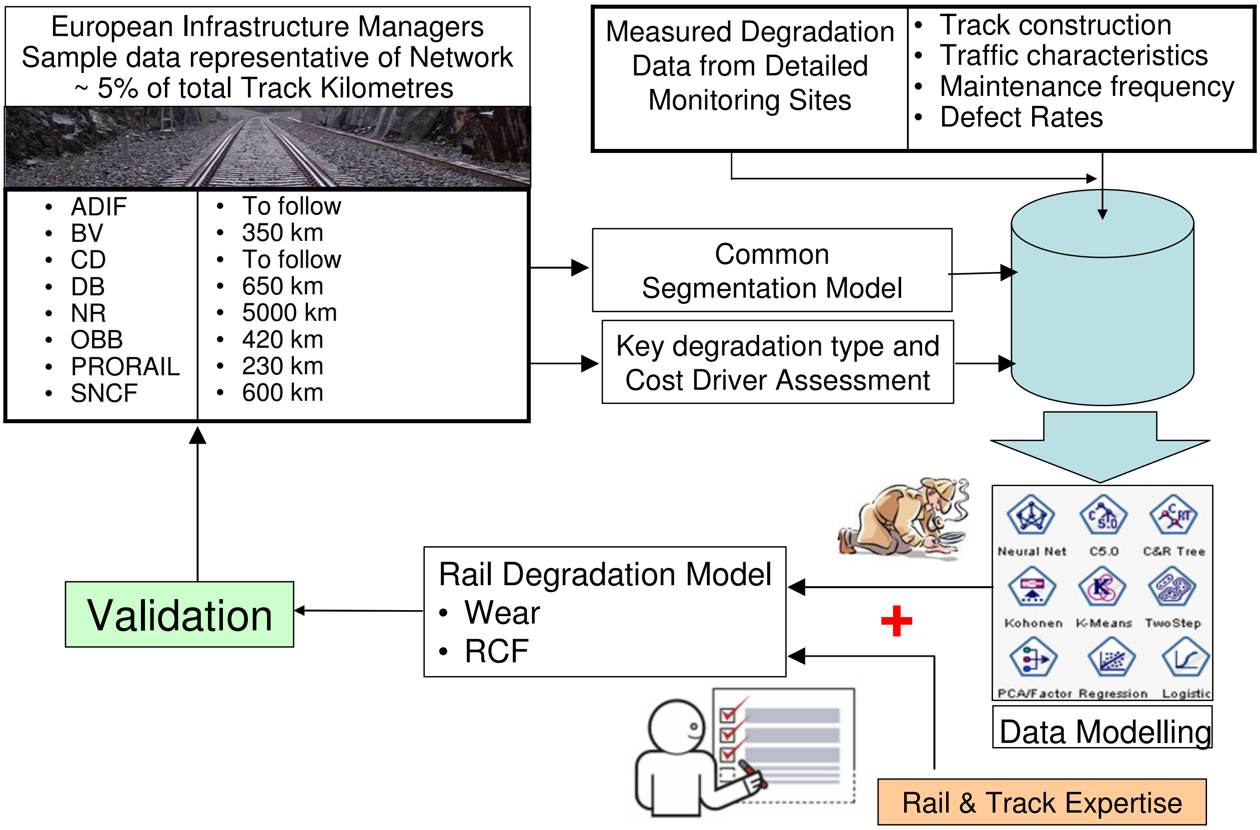


Figure 15 - Overall Approach for Deriving Rail Degradation Model

This report has described the approach being followed via the 'Common Segmentation Model' as indicated in the Figure. This provides the basis classification of railway tracks regardless of operator. To this we need to add qualitative and quantitative knowledge about degradation mechanisms and relative maintenance cost. This will come from three sources :

(a) The Infrastructure managers for each of the participating companies will be asked to advise for the track sections submitted, which specific areas cause most problems and the nature of these problems. It is recognised that there are some difficulties in this step as many of the companies have only a high level knowledge of maintenance history, this often being managed through a third party. A template has been designed to assist in the highlighting of track areas requiring most attention. This is included in the IM report example in Appendix 3.

(b) Over several years, Corus Rail and Voestalpine have operated several instrumented sites located in the UK, France, Germany and Austria. Regular inspections and measurements have been undertaken for these sites yielding a rich database of various degradation processes for a variety of track geometries and operating conditions.

(c) Rail and metallurgical expertise will be drawn upon to derive qualitative models for rail degradation incorporating a subjective but knowledge driven assessment of the relative impact of geometric and operating parameters on different modes of degradation.

Data modelling focussed on sources (a) and (b) will be carried out to uncover patterns within the data relating the segment geometric and operating parameters to degradation as reported by the operators and revealed through the detailed site monitoring. Techniques to be applied in this regard include regression (uni-variate and multi-variate), unsupervised clustering algorithms, neural networks and rule induction.

This will also serve to describe the relative strengths of the various relationships. These will then be applied to the qualitative models developed in conjunction with the experts (c). The original data submitted by the operators can then be used to validate the model and to develop methods for use in the field.

7. Annexes

7.1 Appendix 1 - The Segmentation Process

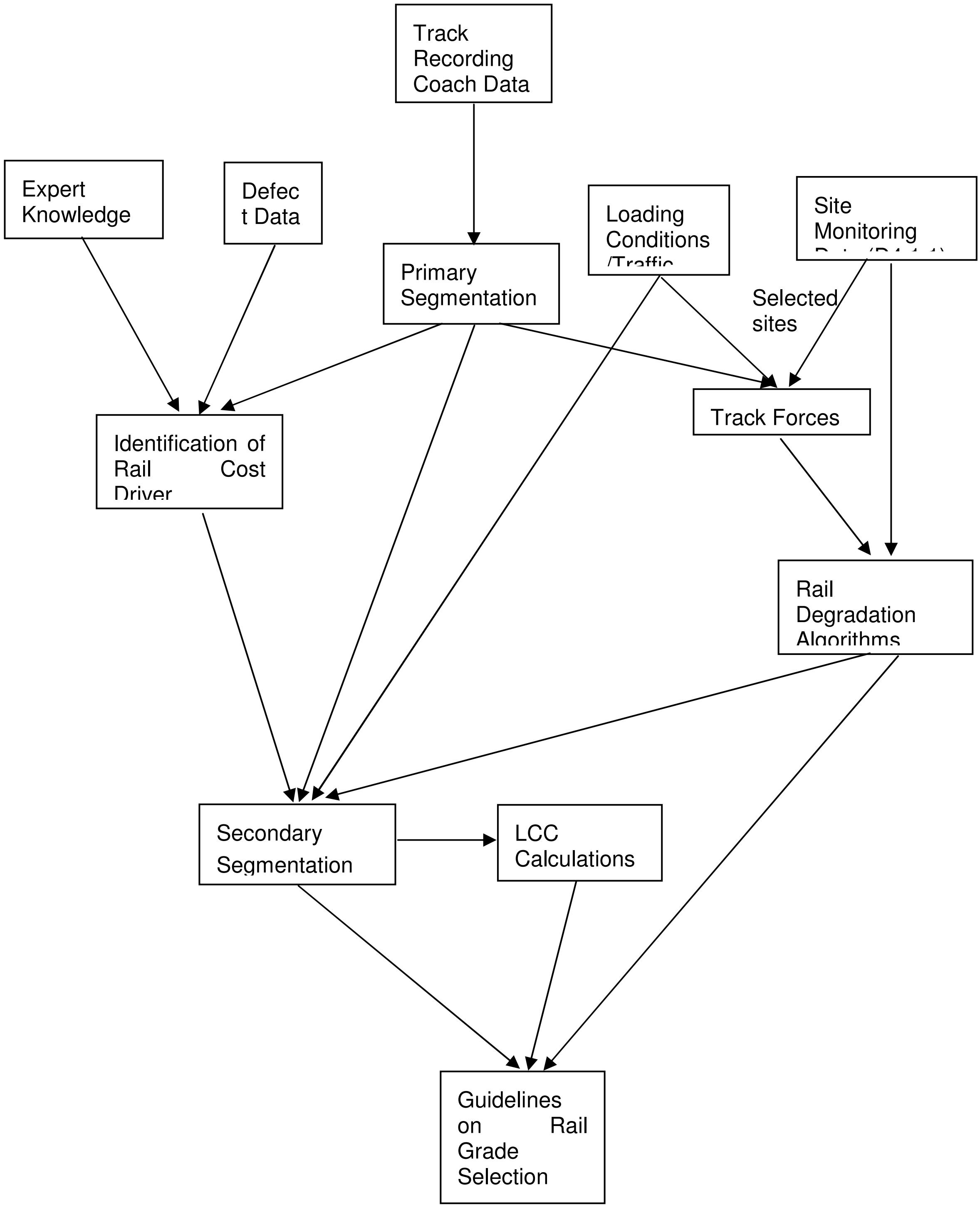


Figure 16 – Segmentation process

7.2 Appendix 2 - Data Fields

	DB	BV	OBB	PRORAIL	NR	SNCF
Segment_Number	√	√	√	√	√	√
Track_Type	√	√	√	√	√	√
Radius_Bins	√	√	√	√	√	√
Segment_Length	√	√	√	√	√	√
Distance_from	√	√	√	√	√	√
Distance_to	√	√	√	√	√	√
Radius_In	√	√	√	√	√	√
Radius_Out	√	√	√	√	√	√
Radius_Min	√	√	√	√	√	
Radius_Max	√	√	√	√	√	
Radius_Mean	√	√	√	√	√	√
Radius_SDev	√	√	√	√	√	
Gauge_Deviation_Min	√	√	√	√	√	√
Gauge_Deviation_Max	√	√	√	√	√	√
Gauge_Deviation_Mean	√	√	√	√	√	√
Gauge_Deviation_SDev	√	√	√	√	√	√
Cant_Min	√	√	√	√	√	
Cant_Max	√	√	√	√	√	
Cant_Mean	√	√	√	√	√	√
Cant_SDev	√	√	√	√	√	
Cant_Deficiency_Min	√			√	√	
Cant_Deficiency_Max	√			√	√	
Cant_Deficiency_Mean	√			√	√	
Cant_Deficiency_SDev	√			√	√	
Gradient_Min			√		√*	
Gradient_Max			√		√*	
Gradient_Mean			√		√*	
Gradient_SD			√		√*	
Altitude_Min			√		√	
Altitude_Max			√		√	
Altitude_Mean			√		√	
Altitude_Max			√		√	
Permitted_Line_Speed_Min	√			√		
Permitted_Line_Speed_Max	√			√		
Permitted_Line_Speed_Mean	√			√		
Permitted_Speed_SDev	√			√		
Cross_Level_Min			√			
Cross_Level_Max			√			
Cross_Level_Mean			√			
Cross_Level_Sdev			√			
Switches_Start_Sum	√				√*	
Switches_End_Sum	√				√*	
Railway_Stations_Start_Sum	√				√*	
Railway_Stations_End_Sum	√				√*	
Tunnels_Start_Sum	√				√*	
Tunnels_End_Sum	√				√*	
Bridges_Start_Sum	√				√*	
Bridges_End_Sum	√				√*	
Speed_Recording_Mean	√					√
Speed_Recording_Min	√					√
Speed_Recording_Max	√					√
Speed_Recording_SDev	√					√
FileName	√	√	√	√	√	√
IM	√	√	√	√	√	√
ELR_Code_In					√	
ELR_Code_Out					√	
Locn_Miles_In					√	
Locn_Miles_Out					√	
Locn_Yards_In					√	
Locn_Yards_Out					√	

√*	partial data available

Table 7 – Data fields

Note that additional data were provided by most of the companies relating to track quality measurements such as twist and vertical alignment.

In the case of Network Rail, the signal originally specified as cross-level as been taken as Cant.

For BV, DB and OBB the signal originally specified as Super Elevation as been taken as Cant

In case of OBB, a Cross-Level signal is included also but the distribution suggests this does not relate to Cant (Super Elevation)

Data received from SNCF is in a pre-segmented format meaning that the segmentation analysis can only be partially applied

7.3 Appendix 3 - Example IM Report

INNOTRACK

Track Segmentation – IM Report

ÖBB

DATE	22nd January 2008
ABSTRACT	Summary of results of analysis of Track Recording Coach Data received from ÖBB, Austria
AUTHOR, COMPANY	S. Thornton, Corus
WORKPACKAGE	SP4.1
CONFIDENTIALITY LEVEL	
FILING CODE	
RELATED ITEMS	

Introduction

The following two deliverables from SP4 require knowledge of the range of duty conditions that exist on the networks of the participating railways.

D4.1.2 Rail degradation algorithms: Derivation of degradation algorithms based on practical observation but backed with scientific understanding of the associated mechanisms.
D4.1.1 Definitive guidelines on the use of different rail grades according to duty conditions and based on RAMS and LCC principles.

Although it is acknowledged that duty conditions are a function of both track and vehicle characteristics, the scope of the work within WP4.1 is to identify the range of track characteristics that exist within the networks of participating IMs. The companies involved in this study are as follows (Source: Railway Statistics Synopsis 2006, International Union of Railways [UIC], Paris, France)

Company	**Country**	**Total Network - Route km**	**Segmented km**
Network Rail (NR)	United Kingdom	19568	4600
ProRail	Netherlands	2776	230
Deutsche Bahn (DB)	Germany	34128	650
Banverket	Sweden	9957	217
Österreichische Bundesbahnen (ÖBB)	Austria	5702	505
Société Nationale des Chemins de fer Français (SNCF)	France	29547	1559
Administrador de Infraestructuras Ferroviarias (ADIF)	Spain	12991	On Hold
České dráhy (CD)	Czech Republic	9491	On Hold

Table 1- Summary of Participating Rail Networks

The methodology of the study is to collect track geometry data from each of the companies providing a representative sample of approximately 5% of the total network. A standardised technique to use this data to generate a database of curves, transitions and tangents for each company is then applied. Having made this primary segmentation on basis of radius/curvature, a secondary analysis is then applied to establish characteristic national variations of other track design parameters, in combination with operational data such as line speed. Information on traffic volumes for the sections of track studied are then integrated into this and an analysis is made to quantify the impact on cost drivers reported by each company for use in establishing a rail degradation algorithm which in turn can be used to determine most cost effective rail replacement strategy. A flow diagram of the segmentation is given in Appendix 1 with a full explanation of the methodology applied in the segmentation analysis being reported elsewhere(1).

This report summarises the outcome of the segmentation analysis for data received from ÖBB (Österreichische Bundesbahnen). Table 1 presents an overview of data received from each of the participating companies showing the approximate length in kilometres of the national rail network, and the length of track covered by the track recording vehicle data received.

The next step is to collect information about cost driver segments within the submitted stretches of track, i.e. which areas are particularly susceptible to specific defects and what are the relative costs of maintaining these areas, relative the whole of the specific track, and relative to the complete network. A template proforma is provided in Appendix 3 to assist with this and the requirements are explained further in section 4 of this report.

Initial Analysis and Validation

Data was provided by OBB covering two rail tracks as described in Table 2.

Line Ref	Description	Length (km)
New_5841	Woergl - Zell am See - Salzburg	174.4km
New_5660	Salzburg - Linz – Vienna	250km

Table 2 – TRC Data Provided by OBB

The data items in the file are indicated in Appendix 2. Although a large number of data fields were included in the file, only those pertaining to design geometry are included in the segmentation analysis. Most of the others relate to dynamic track quality measurements and only represent a snap shot in this respect. The behaviour of track quality over time will of course be indicative of stability including the impact of traffic volume and support conditions but this aspect is the subject of other work packages within Innotrack.

Inter-Measurement Distance

In the case of the OBB data, the nominal inter-measurement distance is 25cm. There are occasional gaps in the data relating sometimes to periods where the track recording vehicle did not measure, e.g. because of too low or too high speed, but mostly corresponding to apparent resets in distance. An example of a step of approximately 265m in one of the data files is shown in Figure 1. These are rare however and are handled through generation of new distance basis which removes all the gaps but retains reference to the original distances.

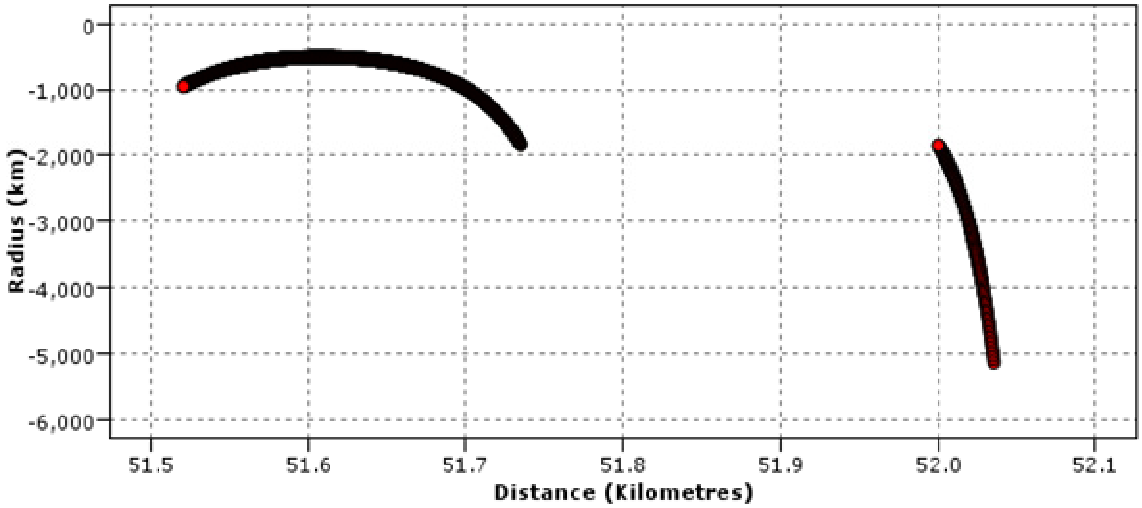


Figure 1 – Example of discontinuities in Distance recorded by track recording Vehicle

Validation of Radius Calculation

In order to make meaning full comparisons between track measurements made for different infrastructures, it is important to have good confidence that the radius upon which the segmentation is based, generates a good representation of the track layout. This is verified by application of an algorithm which derives the track path from the instantaneous radius calculations. Knowledge of the start and end points of the track section, combined with the bearing from start to end is then used to determine the geographical 'crow flies' distance between the two points. This can then be compared with this distance as calculated from the derived track path. An example for the longer of the two track consider (Salzburg to Vienna) is included below in Figure 2. In this case the error between computed and geographically determined is only 1.6%.

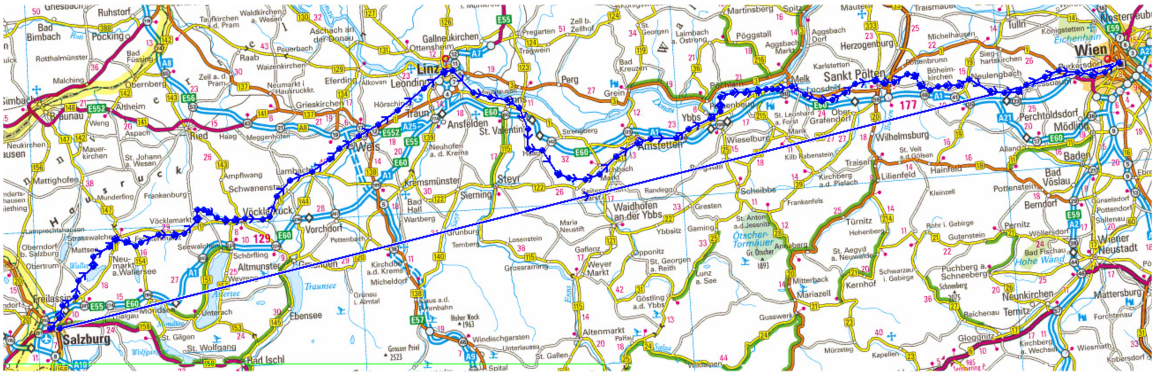


Figure 2a - Salzburg to Vienna : Bearing = 79°; Crow Flies Distance = 250

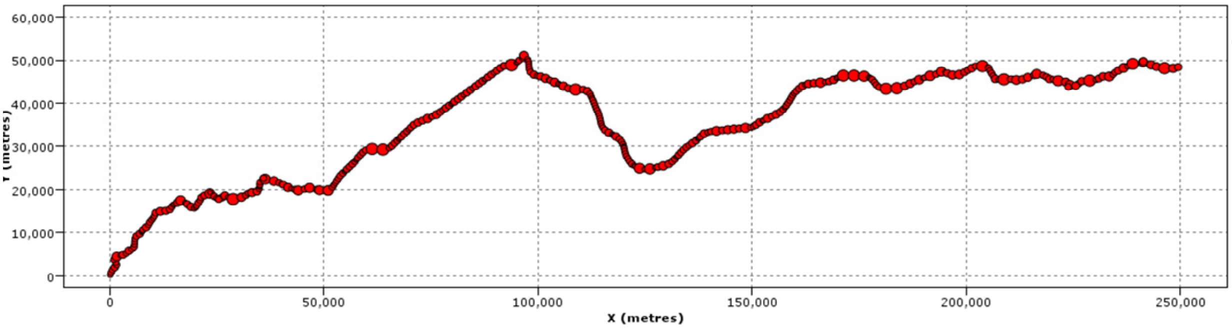


Figure 2b - Salzburg to Vienna : Computed Crow Flies Distance = 254m (error = 1.6%)

Segmentation Results

The 425km of Track data supplied by OBB was segmented according to the primary segmentation method(1). This resulted in a total of 1626 segments falling into ranges as follows:

Value	Proportion	%	Count
1. Curves		27.92	454
2. Transition Curve		50.0	813
3. Tangent		22.08	359

Table 3 – Proportions of Curves, Tangents and Transitions for OBB Data Sample

The relative proportions of track types for the two tracks considered are indicated in Table 4. This shows that the '5660' track (Salzburg to Vienna), has a higher proportion of tangent segments.

Track Type	Radius Ranges	Total Length (m)	Segments (No)
1. Curves	(a) Radius < 0.3 km	736	8
1. Curves	(b) 0.3 <= Radius < 0.7 km	53543	261
1. Curves	(c) 0.7 <= Radius < 1.0 km	18202	73
1. Curves	(d) 1.0 <= Radius < 1.5 km	10841	45
1. Curves	(e) 1.5 <= Radius < 3.0 km	16911	35
1. Curves	(f) 3.0 <= Radius < 6.0 km	27002	32
2. Transitions		136228	813
3. Tangent	(g) Radius >= 6.0 km	241532	359

Table 5 – Lengths and Types of Segments

Thus the segmentation analysis for the total data sample provided results in 1626 segments, 454 of which are curves. There are 8 curves within the tightest radius range (< 300m radius), 261 in the next range and so on. The assumption is made that this breakdown is indicative of the make up of the entire network although this may not be entirely accurate. In particular, the total length of track represented in the data sample submitted is only approximately 3.8% of the network total track length.

It should be noted that because of the way a tangent has been defined (radius > 6km), a transition segment will always connect a tangent to a curve or a curve to a curve. Thus the Radius Range associated with a transition could be taken according to the minimum value of radius, the maximum value, a mean, or some other function. In carrying out the segmentation, the ingoing and outgoing radius for each segment is determined together with mean, standard deviation, minimum and maximum. Table 6 shows some example statistics for transition segments arising from the primary segmentation process.

Segment_Number	Segment_Length (m)	Radius_In (m)	Radius_Out (m)
16	646	5973	-5845
240	726	6054	5783
606	659	617	-392
776	777	550	-337
824	652	-6035	5875

Table 6 – Radius and Length Statistics associated with Transition Segments

These statistics in conjunction with other parameters such as line speed will be used to find and cluster similar transitions from the same and other rail networks. In addition, alternative ways to characterise transitions segments will be explored in conjunction with the iterative process of combining maintenance and rail degradation knowledge into the data model. It can be seen that some of the examples in Table 6 appear relatively straightforward, e.g. where Radius_In and Radius_Out have absolute values greater than or close to 6000m then this is likely to be a transition between two tangent segments. Other examples show transitions between two curves. Care must be taken however as the segmentation process attempts to reduce the overall number of segments by combining small tangent and curve segments and this can result in segments which it could be said correspond to ‘complex transitions’. In Table 6 for example, segment number 776 in connects two small radius curves. Closer inspection of the raw data however reveals that there actually is a series of very short tangent and curve segments in between these as shown in Figure 3.

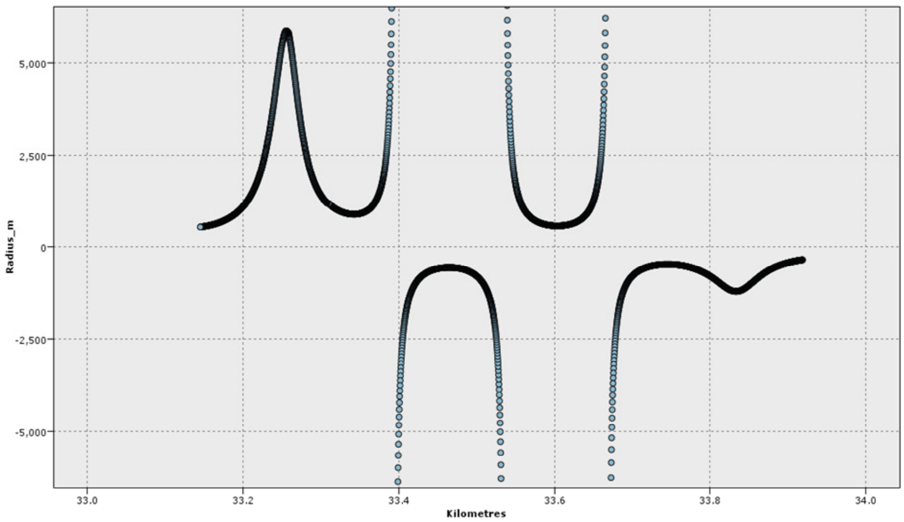


Figure 3 – Segment 776 : A Complex Transition

Clearly there are several further refinements which could be made to the segmentation analysis process, and the features derived to characterise different forms of segment. The data management infrastructure has been designed such that repeat analyses can be applied on a macro scale in the event of further data being received, or an alternative approach being deemed worthwhile.

Secondary Segmentation

Table 5 shows that several curves with similar characteristics (in terms of radius) exist within the network. These curves will be differentiated (or otherwise) however, by the other associated track design parameters, e.g. gradient, line speed, cant etc. In addition, the presence of constructions such as railways stations, tunnels, bridges and switches will also be influential on performance and life costs. In the case of ÖBB, no information about such constructions as yet been received but this can be incorporated if the data becomes available.

To explore the characteristics of the track more closely the variation of these other parameters with respect to radius. Figure 4 shows the distribution of mean radius for all curves; the allocation in terms of radius range is overlaid.

The distribution of cant (super elevation) for all the curves is shown in Figure 5.

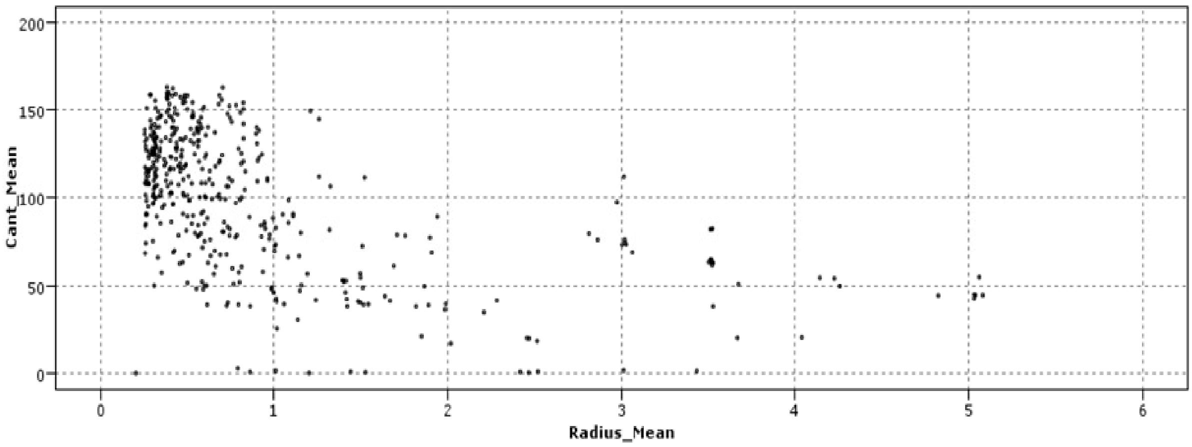


Figure 5 – Distribution of Cant for all curves

In the case of Tangent segments the mean cant is between 0 and 6mm. A more detailed secondary segmentation analysis can be carried out when missing design data have been provided.

Cost Driver Details

The next step in the analysis is to gather information from the Infrastructure Managers about the cost drivers for the submitted track samples. The objective here is to identify national and European-wide characteristics of rail degradation. This information will be combined with other relationships derived from detailed test site monitoring (D4.1.1) and expert knowledge to compose a rail degradation model(D4.1.2) which in turn will allow recommendations for the use of different available rail grades(D4.1.3). The process by which this will be undertaken is summarised in Appendix 1. The original data supplied by the participating rail network operators will then be applied to validate this model. Refinement of the model will then follow.

In order to guide the collection of the information from the infrastructure managers, a template form has been prepared and is attached as Appendix 3. This template requires completing with one line of the table for each key cost driver segment of the segmented line. Cost driver segments can be regarded as those that require much greater attention in terms of inspection and maintenance than is average for the line as a whole and therefore require a greater percentage of the budget. The information required for each cost driver segment are the key degradation mechanisms involved, any maintenance or inspection that is considered to be a drain on resources and an indication of the costs that the segment requires compared to the line as a whole. Location information such as the name of the track section and a distance from the standard reference location are required along with basic track parameter such as line speed, traffic and curvature. An example of some cost driver segments is also given in Appendix 3. In addition, a summary of the distribution of segments indicating variation in radius and cant is included in Appendix 4. Any other information that can be provided such as the type and location of defects over several years would also be useful if supplied in an electronic format (e.g. spreadsheet) as it can be merged into the segments to allow examination of relationships between defects and track geometry.

APPENDIX 1 – THE SEGMENTATION PROCESS

See Figure 16, Page 23.

APPENDIX 2 – DATA FIELDS (With Example Statistics)

Name	Description	Units	Missing values	Mean	SD	Min	Max	Valid
lfd Nr	enumerator			8832	783	7476	10188	2713
Datum	Date of Recording Coach Run	Date/Time		12/06/2007				2713
Strecke	line (for example: 2017A1)	String		2091A				2713
S1	line section (A=1,B=2,C=3,...)			1	0	1	1	2713
S2	line section (0,1,2,3,4,…)			0	0	0	0	2713
Fahrz	track measurement coach	String		250	0	250	250	2713
FRicht	direction measurement			-1	0	-1	-1	2713
FStell	direction measurement coach			-1	0	-1	-1	2713
Gleis	track			2	0	2	2	2713
KM	kilometer	km		233.90	19.58	200.00	267.80	2713
v	speed of track recording coach	km/h	999999	64.06	0.85	59.45	67.54	2713
seit_l	alignment (left)	mm	999999	-0.03	1.27	-4.96	6.13	2713
seit_r	alignment (right)	mm	999999	-0.02	1.46	-5.08	4.53	2713
seit_70_l	alignment (long wave, left)	mm	999999	-0.25	3.63	-12.54	12.62	2713
seit_70_r	alignment (long wave, right)	mm	999999	-0.25	3.47	-10.27	10.47	2713
hoeh_l	longitudinal level (left)	mm	999999	0.01	2.63	-14.57	11.02	2713
hoeh_r	longitudinal level (right)	mm	999999	0.01	2.46	-14.34	10.39	2713
hoeh_70_l	longitudinal level (long wave, left)	mm	999999	0.02	3.96	-22.58	12.85	2713
hoeh_70_r	longitudinal level (long wave, right)	mm	999999	-0.01	3.77	-20.86	12.73	2713
verw3	track twist (3-m basis)	%O	999999	0.46	2.46	-6.95	10.98	2707
verw5	track twist (5-m basis)	%O	999999	0.76	3.76	-8.98	16.80	2703
verw9	track twist (9-m basis)	%O	999999	1.37	6.12	-13.79	24.38	2695
verw16	track twist (16-m basis)	%O	999999	2.47	10.18	-22.07	32.27	2681
qhoeh	cross-level	mm	999999	0.00	1.05	-4.49	4.38	2713
ueberh	superelevation	mm	999999	17.23	43.11	-102.38	80.20	2713
kruemm	kurvature (chord 10m)	mm	999999	4.51	10.64	-23.71	20.04	2713
promill	incline	%O	999999	1.77	2.33	-0.39	6.25	2713
spur_app	track gauge (deviations from 1435mm)	mm	999999	2.50	4.75	-7.30	17.81	2713
riffel_l	axle box acceleration (left)	g [9.81m/s²]	999999	1.13	0.62	-0.16	8.55	2713
riffel_r	axle box acceleration (right)	g [9.81m/s²]	999999	1.00	0.96	-0.82	17.66	2713
kon_a1	equivalent conicity (deflection=1mm)	-	999999	0.41	0.34	0.01	1.33	128
kon_a2	equivalent conicity (deflection=2mm)	-	999999	0.44	0.34	0.01	1.44	128
kon_a3	equivalent conicity (deflection=3mm)	-	999999	0.49	0.36	0.02	2.01	2699
kon_a4	equivalent conicity (deflection=4mm)	-	999999	0.54	0.44	0.02	2.93	128
kon_a5	equivalent conicity (deflection=5mm)	-	999999	0.58	0.46	0.02	3.11	128
SpurKLD	track gauge (deviations from 1435mm)	mm	999999	1.89	5.21	-7.85	34.80	267
neig_l	rail gradient (left)	°	999999	1.70	1.09	-3.67	4.92	259
neig_r	rail gradient (right)	°	999999	1.97	1.03	-1.09	4.84	262
sart_	rail type (left)		-1	2.00	0.00	2.00	2.00	235
sart_	rail type (right)		-1	2.00	0.00	2.00	2.00	253
sa_l	side wear (left)		999999	0.67	0.63	-1.02	1.91	235
sa_r	side wear (right)		999999	0.46	0.58	-0.78	2.34	253
vglh_l	head loss (vertical and horizontal combined)	mm	999999	2.41	0.53	0.70	4.14	235
vglh_r	head loss (vertical and horizontal combined)	mm	999999	2.76	0.68	1.02	4.92	253
ha_l	head loss (vertical, left)	mm	999999	1.74	0.52	0.00	3.71	235
ha_r	head loss (vertical, right)	mm	999999	2.17	0.70	0.47	4.18	253
skuk_l	rail head (bottom, left)	mm	-1	-0.04	0.13	-0.63	0.66	235
skuk_r	rail head (bottom, right)	mm	-1	0.15	0.98	-1.33	8.59	253
dwx_l	head loss (area left)	cm²	-1	89.70	28.64	5.20	177.85	235
dwx_r	head loss (area right)	cm²	-1	106.71	35.74	1.91	210.27	244
ueb_l	lips (left)	mm	-1	0.04	0.07	0.00	0.39	235
ueb_r	lips (right)	mm	-1	0.19	1.27	0.00	10.90	253
lat	GPS latitude		-1	482.46	0.02	482.43	482.49	678
long	GPS longitude		-1	163.64	0.01	163.63	163.66	678
alt	GPS altidude		-1	210.66	0.45	209.60	211.10	678
DALBW3	rail surface (left)	mm	999999	0.01	0.02	0.00	0.35	2708
DARBW3	rail surface (right)	mm	999999	0.02	0.01	0.01	0.13	2713
spur_2	track gauge (deviations from 1435mm)	mm	999999	2.42	4.69	-7.27	17.34	2713
kon2_a3	equivalent conicity (deflection=3mm)	-	999999	0.47	0.40	0.01	1.98	244

APPENDIX 3 – COST DRIVER SEGMENTS TEMPLATE

Participating Company ________________________________ Representative Name ________________________________

Date ________________________________ E-Mail ________________________________

Line Reference ________________________________ Telephone ________________________________

Start Location ________________________ Reference KM ____________ Longitude ________ Latitude __________
End Location ________________________ Reference KM ____________ Longitude ________ Latitude __________
Total Track Distance ______ km Traffic Type (% Passenger) ______________ Traffic Vol ________ MGT/Year

Cost Driver Segment Details Sheet 1 of

Defects Coding (Defect classification from UIC 712R, 4th edition, 2002)

A - Wear (220)
D - Corrosion (134/154/234/254)
G - Switches and Crossings
J - Other Rail Defects [requiring replacement]
B - Rolling contact fatigue/Headchecks [RCF] (122/222)
E - Squats (227)
H - Wheelburns (125/225)
C - Corrugation (2201-2203)
F - Weld (4xx)
I - Track Quality (e.g. requiring regular tamping)

Section ref	km from	km to	Radius (m)	Line Speed (kmh)	Defect Identities (see legend) Enter 0 if not a problem, 1 if a light problem, 2 if moderate, 3 if severe										Cost Indicator (Continuous Scale Circle appropriate) 1 – Irrelevant Cost compared with overall 5 – A major proportion of the budget for the line
					A	B	C	D	E	F	G	H	I	J	
															1 -------- 2 -------- 3 -------- 4 -------- 5
Comments															
															1 -------- 2 -------- 3 -------- 4 -------- 5
Comments															

Participating Company ______________________________ Representative Name ______________________________

Date ______________________________ E-Mail ______________

Line Reference ______________________________ Telephone __________

Cost Driver Segment Details Sheet 2 of

Section ref	km from	km to	Radius (m)	Line Speed (kmh)	Defect Identities (see legend) Enter 0 if not a problem, 1 if a light problem, 2 if moderate, 3 if severe										Cost Indicator (Continuous Scale Circle appropriate) 1 – Irrelevant Cost compared with overall 5 – A major proportion of the budget for the line
					A	B	C	D	E	F	G	H	I	J	
															1 -------- 2 -------- 3 -------- 4 -------- 5
Comments															
															1 -------- 2 -------- 3 -------- 4 -------- 5
Comments															
															1 -------- 2 -------- 3 -------- 4 -------- 5
Comments															
															1 -------- 2 -------- 3 -------- 4 -------- 5
Comments															
															1 -------- 2 -------- 3 -------- 4 -------- 5
Comments															

Example

Participating Company North Western Railway Representative Name: Sir Topham Hat

Date 1/4/07 E-Mail TheFatController@nwr.co.ios

Line Reference Isle of Sodor Main Line Ref Code = MLN Telephone +666 123456

Start Location Tidmouth Reference KM 0 Longitude ______ Latitude ______

End Location Vicarstown Reference KM 33.5 Longitude ______ Latitude ______

Total Track Distance 35 km Traffic Type (% Passenger) 60 Traffic Vol 15 MGT/Year

Cost Driver Segment Details Sheet 1 of

Defects Coding (Defect classification from UIC 712R, 4th edition, 2002)

A - Wear (220)
D - Corrosion (134/154/234/254)
G - Switches and Crossings
J - Other Rail Defects [requiring replacement]
B - Rolling contact fatigue/Headchecks [RCF] (122/222)
E - Squats (227)
H - Wheelburns (125/225)
C - Corrugation (2201-2203)
F - Weld (4xx)
I - Track Quality (e.g. requiring regular tamping)

Section ref	km from	km to	Radius (m)	Line Speed (kmh)	Defect Identities (see legend) Enter 0 if not a problem, 1 if a light problem, 2 if moderate, 3 if severe										Cost Indicator (Continuous Scale Circle appropriate) 1 – Irrelevant Cost compared with overall 5 – A major proportion of the budget for the line
					A	B	C	D	E	F	G	H	I	J	
Knapsford Curve	5.25	5.5	1200	120	2	3	0	0	0	0	0	2	2	0	1 -------- 2 -------- 3 -------(4)-------- 5
Comments	Ground every 5 months for RCF, tamping every 3 months due to poor track geometry. Wheel burns near signal KP1254(5.4km)														
Crosby Tunnel	10	11	Tangent	160	0	0	2	3	1	0	0	0	0	0	1 -------- 2 -------(3)-------- 4 -------- 5
Comments	Corrosion damage to rail foot in tunnel requiring general replacement every 2 years as well as some rail breaks. Track geometry good														