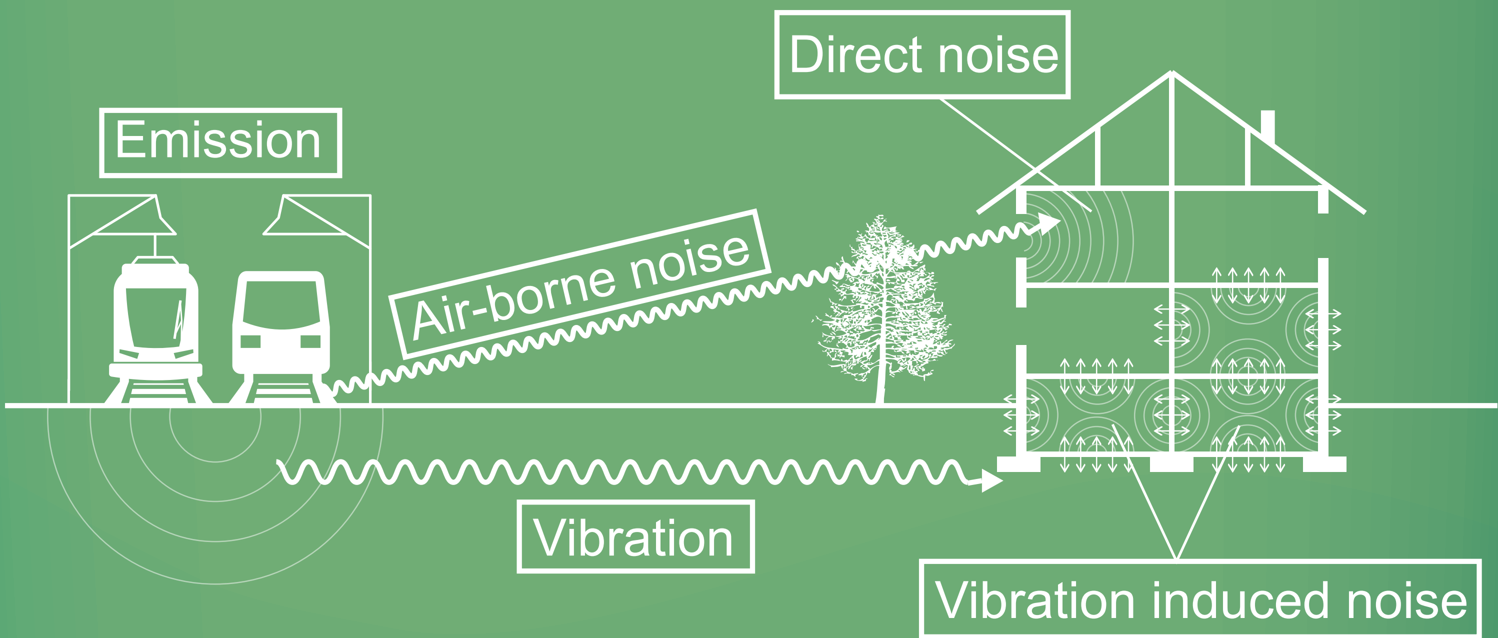
RIVAS - Vibrations: Ways out of the annoyance

Project co-funded by the European Commission

A summary of outcomes



rivas

SEVENTH FRAMEWORK PROGRAMME

Project co-funded by the European Commission

Introduction

Introduction

Since future transport requires a system that is able to move a lot more passengers and freight than it is today, a high-capacity, efficient, cost-effective and environmentally friendly transport system is necessary across Europe.

The Strategic Rail Research Agenda 2020[1] of the European Rail Research Advisory Council (ERRAC) expects rail transport to double . However, an increasing number of people living near railway lines are annoyed by noise and vibrations as side-effects of rail transport, hence it is necessary to find ways to reduce those effects. Thus over the three years of its duration, the RIVAS project tackled the challenge of developing and analysing vibration mitigation measures - under the patronage of the European Commission (FP 7). The 27 partners, placed under the coordination of the International Union of Railways (UIC), represent end-users such as infrastructure managers and train operating companies (ADIF, DB, RATP SBB, SNCF, Trafikverket), associations, manufacturers and suppliers (Alstom, Bombardier, EiffageRail, Keller, Lucchini, Pandrol, RailOne, Sateba), universities and research institutes (BAM, CEDEX, Chalmers University, CSTB, ISVR, KU Leuven) as well as consultants and associations (D2S, Satis, TÜV Rheinland, Vibratec, Prose).

The purpose of this document is to outline the most recent activities of each work package and present the latest developments in the field of mitigation measures to reduce vibrations near railway lines.

Figure 1: Structure of the RIVAS project

1 Strategic Rail Research Agenda 2020; European Rail Research Advisory Council, May 2007

WP1 Assessment and monitoring procedures

The work package supports the development of mitigation measures within the RIVAS project. To reach this aim, measuring procedures, calculation tools and routines to assess annoyance were provided allowing the comparison of results obtained by different partners.

To detect mitigation-measure efficiencies, advanced measuring protocols based on train pass-bys and artificial excitation were developed. By using a combined procedure, the vibration levels are measured in the test section and the reference section at a certain distance from the track before and after the installation of the mitigation measure to get optimal results (figure 2). In addition, measuring procedures were proposed to detect vehicle, track and soil parameters influencing the vibration reduction significantly. Especially the measurement of soil parameters was in the focus of the investigations.

Here, benchmark tests showed their influence on the efficiency e.g. for mitigation measures in the propagation path. For the exchange of data between the RIVAS partners, a database structure was provided.

For the final presentation of results, a procedure to assess the annoyance inside buildings based on four descriptors (two for vibrations and two for vibration-induced noise) with generalized exposure-response curves was proposed. Based on different ground-building combinations and typical hotspot configurations, the results for the mitigation measures developed were transferred to an annoyance reduction and presented with respect to their cost-benefit relation.

Based on the typical spread of relevant parameters, a virtual track to be used for the optimization of vehicle design will be proposed as well as calculation procedures.

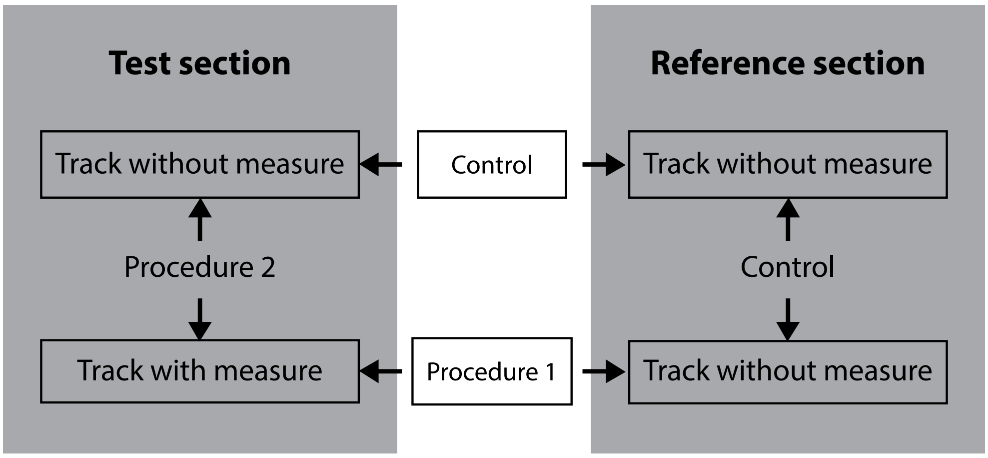


Figure 2: Illustration of the concept to assess the insertion loss of a mitigation measure. The control before the installation of the measure serves to verify that both sections are identical. The control of the reference section before and after the installation of the measure is to check that the conditions have not changed with time.

Conclusion

As a result of our investigations, the use of common measuring protocols was found to be substantial to obtain reliable and comparable results. Influencing parameters have to be detected and are especially needed for the transfer of results from one side to another. In addition, the procedure to calculate the annoyance reduction inside buildings can be used to find the best suited solutions. Virtual test tracks are considered to become an important tool for optimization of vehicle designs in the future.

Measurement procedure based on artificial excitation

For the detection of mitigation-measure efficiencies, a procedure based on vibration measurements during train pass-by was developed within the RIVAS project. But especially for testing the mitigation effect of resilient elements in the track, a measurement procedure with artificial excitation has significant advantages. First, the installation of a new mitigation measure at a test track is possible without performing the full homologation process. Second, installation costs are low because the mitigation measure has to be installed only for some meters instead of one hundred meters as required in the measuring protocol based on train pass-bys.

Therefore an alternative measurement method to detect mitigation-measure efficiencies by using artificial excitation was tested within RIVAS. As seen from previous investigations, the main problem is to include a preload on the track. Because the procedure has to be easy-to-handle, cost-efficient and simple to install and to uninstall in the track, an approach proposed by the engineering company "Ingenieurbüro Dr. Heiland" based on using two excavators for applying the preload was tested. For the vibration generation a special harmonic shaker was used to operate a vibration sweep over a frequency range of 0 – 110 Hz with nearly constant forces. To determine the influence of the preload on the impact of resilient elements, different load configurations can be investigated realized by different positions of the buckets. Figure 3 shows a picture of the experimental setup.

Figure 3: Shaker (blue) with two excavators on a straight track, picture distorted by a photography effect (Picture: Ingenieurbüro Dr. Heiland)

The mitigation-measure efficiency has to be obtained at a measuring position next to the track (e.g. at a distance of 8 m from the track center) at the sections with and without mitigation measure. The difference in the transfer motilities with and without mitigation measure leads to the insertion loss, a parameter of the efficiency. A first test of the experimental setup was done at an existing test site with two different types of under sleeper pads.

Keeping in mind that even at the test site with a length of some hundred meters, the soil parameters can vary considerably, a further test is needed to correct the influence of the soil parameters on the mitigation-measure efficiencies. Therefore, an excitation realized by a falling weight was applied on the ballast between two sleepers at the section with and without under sleeper pads. The measured transfer mobility can be used for corrections if needed. figure 4 shows the results for the insertion loss without and with correction for the test site used. Only with the soil correction, the isolation effect as expected from theory can be seen.

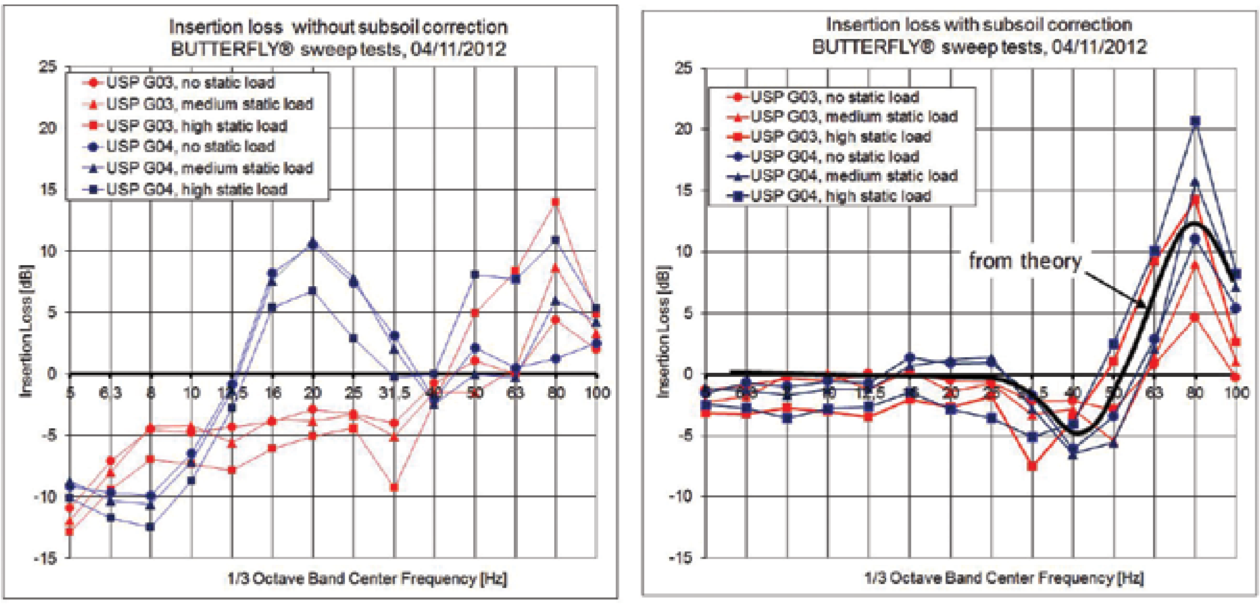


Figure 4: Mitigation-measure efficiencies without soil correction (left figure) and with soil correction (right figure). (Diagrams: Ingenieurbüro Dr. Heiland)

The experiment revealed a very important finding: the measured efficiency depends significantly on the preload. Moreover, the comparison between the efficiencies obtained during train pass-by and by artificial excitation show some deviations which are based on different track irregularities arising with and without under sleeper pads and on different forces influencing the parametric excitation. But it was concluded that the isolation behavior of different resilient elements in the track can be measured and compared with this method.

Mitigation measures at source WP2

The source of vibrations induced in the vicinity of track is the interaction force created at the wheel-rail contact point when a train passes on a track. This force is strongly influenced by the wheel and rail irregularities.

RIVAS Work package 2 has been investigating the vibration levels caused by wheel and track irregularities, in order to propose and discuss maintenance measures to reduce vibrations.

Indeed, vibrations are caused by irregularities in track evenness (longitudinal level, isolated defects, insulated joints, corrugation, etc), in track support stiffness, by parametric excitation (transition zones, hanging sleepers, etc) and by wheel irregularities (out-of-roundness, flats). A classification of the wheel and track defects with respect to vibration emission has been discussed through numerical simulations and measurements. In addition, a classification of the track and wheel defects within the European networks has been carried out regarding their contribution to vibration emission.

Measurements and simulations have shown that wheel out-of-roundness (OOR) can have a strong influence on the vibrations emitted by some categories of rolling stock. Track geometry defects with wavelengths lower than about 10 m have some influence on the low frequency vibration, but the parametric excitation has to be considered in addition. Isolated defects shorter than 3 m may generate significantly high free-field vibration. Dipped rails at welds and insulated rail joints can generate high wheel–rail impact loads with broad frequency content that lead to high vibration levels. More details regarding track irregularities are provided below.

Longitudinal level misalignments are defined as the mean value of vertical irregularities of the two rails. This type of misalignment is usually measured with specially equipped measuring cars. Longitudinal levels across European networks have been classified on the basis of ORE B176-curves (figure 5). This classification is used for the mapping of the simulation results.

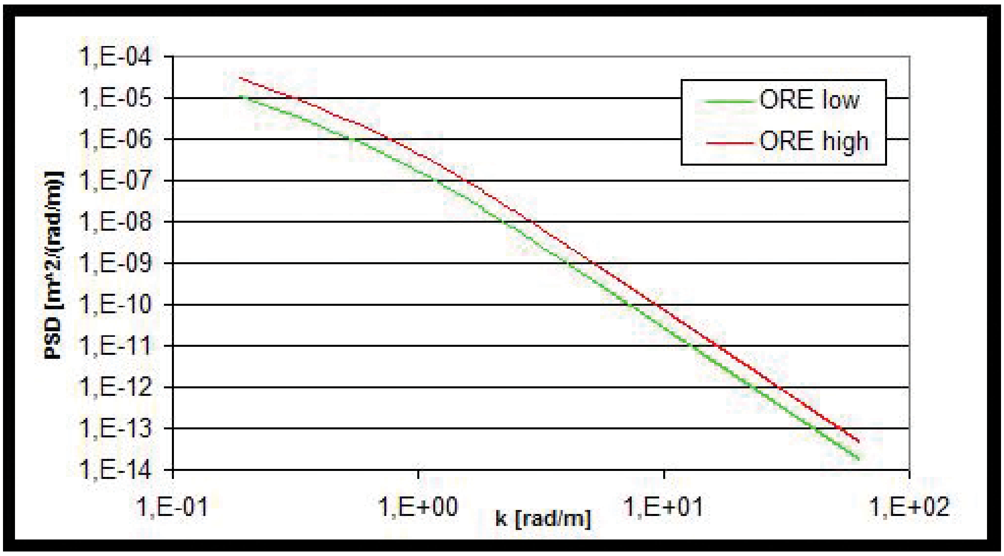
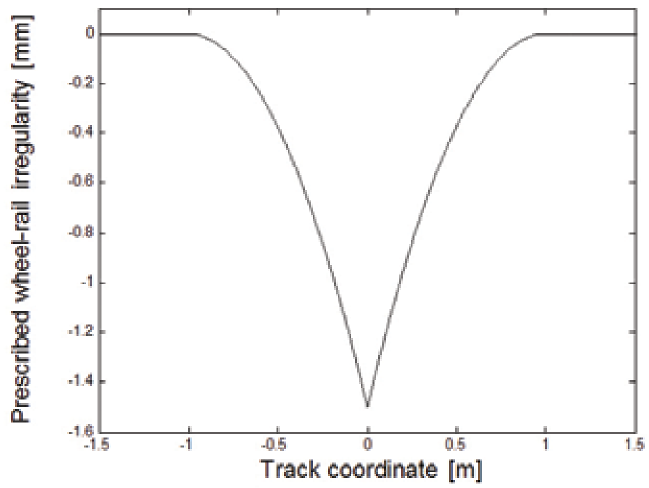


Figure 5: Track quality classes defined as single-sided Power Spectral Density of longitudinal level

Track stiffness variation measurement requires special equipment/measuring cars. Measuring track parameters in the loaded case (e.g. measuring longitudinal level misalignments with the help of measuring vehicles) usually leads to an inclusion of the influence of track stiffness variations in the measured data. Within RIVAS, stiffness distribution has been obtained from RSMV (Rolling Stiffness Measurement Vehicle) measurements. Additionally, distributions of track geometry defects on track with known stiffness variations, such as bridges were classified and generally show poorer geometry than on sections without obvious causes for stiffness variations.



Welding of rails in the field may result in a cusp-like discontinuity. Such discontinuities in the rail induce high-frequency vertical wheel–rail contact forces. Simulations carried out within RIVAS (figure 6) show that for dipped rail, large contributions to the dynamic contact force in the frequency interval 50 – 100 Hz are observed, and that the vibration level increases with an increasing dip depth.

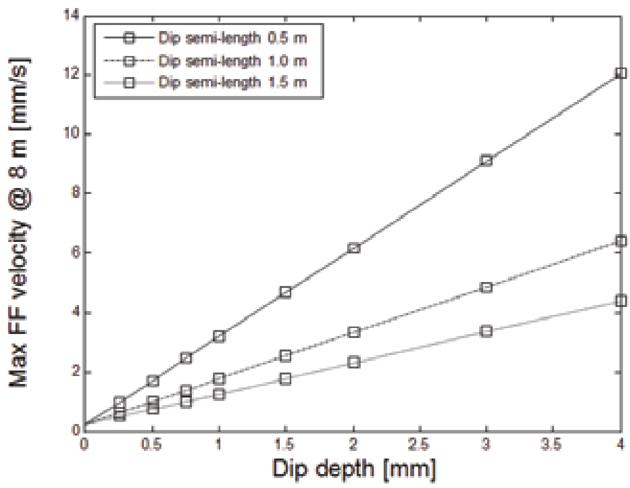
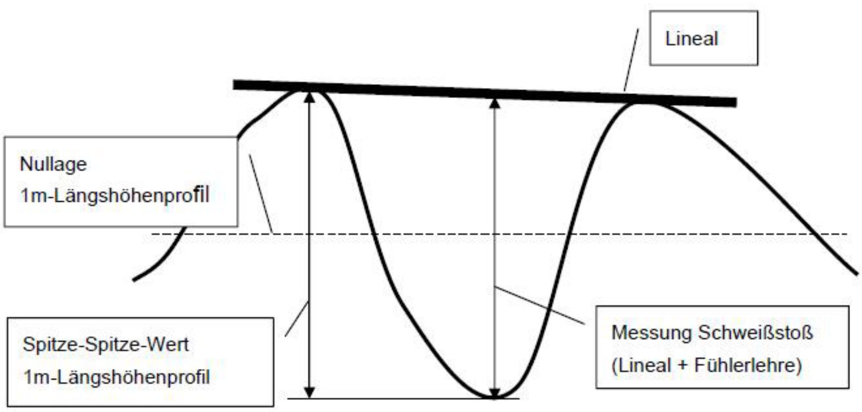


Figure 6:
(a) Prescribed wheel–rail irregularity due to dipped rail with depth 1.5 mm and semi-length 1.0 m.
(b) Influence of dip depth and dip semi-length on maximum vertical free field velocity at 8 m. (Vehicle model including one wheelset of an Y25 bogie, train speed 100 km/h, Lincent soil)



The measurements of these discontinuities are performed using trolley systems or rulers. The dip depth is defined by the maximum distance from a 1m-ruler to the dip (see figure 7), the width of the dip by the distance of the ruler points of support. The angle at the dip bottom can be derived from the angle between two best fit straight lines to the left and right of the minimum over a length of 250 mm. Classifications is made based on depth, semi-span length and rail misalignment, for joints.

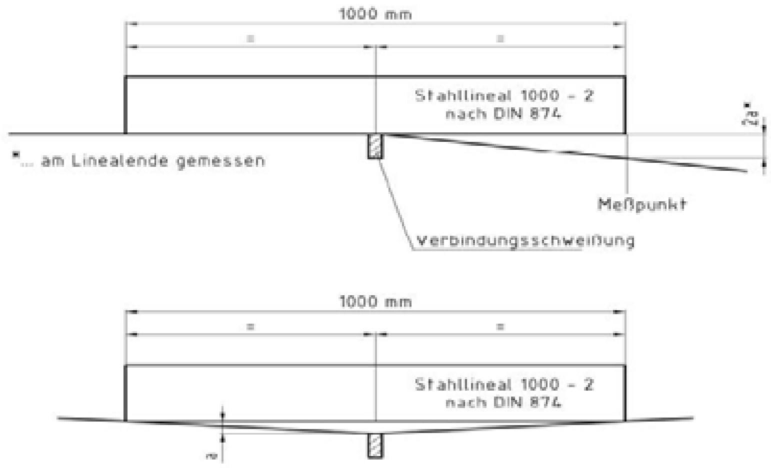


Figure 7: Determination of dip depth or cusp height of rail surface discontinuities (e.g. rail welds)

The gap width of a rail joint is typically 4 – 20 mm and the height difference (misalignment) between adjoining rails may be in the range of 0 – 2 mm. In addition, on each side of the joint, there may be a dip in the rail. Such defects induce low frequency vibrations, wider gaps creating higher vibration levels.

Finally, a ranking of the relative influence on the overall ground-borne vibration problem of the different types of track irregularities/track defects has been carried out based on the RMS-values at 8 m distance from the track simulated for all classes of track defects used. The frequency distributions of the contributing defects and defect occurrences on the networks have been used to weight the results.

The works regarding track defects tend to show that the longitudinal level misalignments with wavelengths of 0.6 m seem to be the type of track irregularities with the highest overall vibration impact on the network, although the highest vibration levels are found in the vicinity of welds and insulation joints, while wheel OOR are the main influencing factor regarding wheel irregularities. To this effect, it is proposed to introduce a new wavelength band containing wavelengths in the interval 0.5 – 3 m, not covered by typical track measurements today but within the capabilities of most of the IM measurement cars and tools.

Measurements are being performed to verify these findings and to quantify the proposed mitigation and they will be published by the end of the project. For more information, please refer to the RIVAS website.

Mitigation measures on track WP3

Track design optimization for ground vibration mitigation consists in reducing the global stiffness of the track. Several mitigation measures installed in the track can be used: ballast mat, under sleeper pads (USP) and very soft rail fastening systems.

Within RIVAS Work package 3, several track configurations have been considered to propose relevant mitigation measures:

- Soft under sleeper pads coupled with heavy sleepers have been optimized and specifically produced to be tested on track, for straight ballasted tracks;
- Soft rail pads have been optimized and specifically produced to be tested on track, for straight ballasted tracks;
- Soft under sleeper pads have been installed in curves to appraise their efficiency in terms of ground vibration reduction and their effect on track stability;
- Soft under sleeper pads have been installed on several switches to assess their effect on ground vibration;
- Soft under sleeper pads have been optimized and tested in a specific slab track system, the GETRAC system.

All these systems have been installed on track to be tested. The final results that will allow concluding on their mitigation impact and the collateral effects are under analysis.

Systems for the straight ballasted track

For the straight ballasted track, two different mitigation measures have been specifically worked out. Soft or very soft under sleeper pads under heavy sleepers allow decoupling the upper part of the track (rail + sleeper) with the lower part (ballast + sub-layers), “capturing” the energy in these upper layers and reducing therefore the mobility between the track and the free-field, as shown on figure 8 (a).

Rail fastening systems, that allow very soft rail pads to be used, imply an increase of the track receptance at the contact point. With a higher rail receptance, the resonance of the wheel-rail interaction force is shifted to the lower frequency ranges, reducing the interaction force for the frequencies above this resonance, as shown on figure 8 (b).

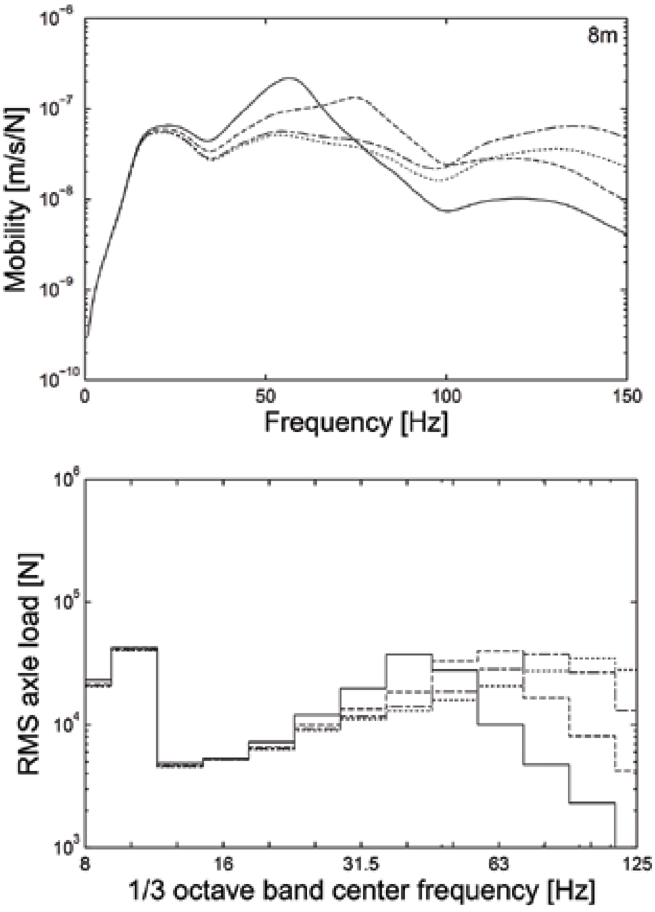


Figure 8:
(a) Mobility between the track and the free field at 8 m with an under sleeper pad stiffness of 50 MN/m (solid line), 100 MN/m (dashed line), 500 MN/m (dashdotted line) and no under sleeper pad (dotted line);
(b) one-third octave band RMS value of the third axle load of the AGC TER train with a rail pad stiffness of 25 MN/m (solid line), 60 MN/m (dashed line), 150 MN/m (dashdotted line) and 300 MN/m (dotted line).

Within the Work package 3, as a preliminary work a large numerical study taking into account several influent parameters such as rolling stock unsprung mass or ground stiffness, was carried out to enable optimizing track design. It showed that ground stiffness has a minor impact on the efficiency of both of these mitigation measures. Then according to the results of this numerical parametric study, prototypes have been developed and tested in laboratory before being installed in scale 1:1 test rig or on commercial track.

The soft under sleeper pads installation has been designed with the use of heavy sleepers: this system allows decoupling the upper part of the track (rail + sleeper) with the lower part (ballast + sub-layers), “capturing” the energy in these upper layers and reducing therefore the mobility between the track and the free field. The heavy sleepers, with a larger contact area between the sleeper and the ballast, allow keeping a reasonable rail deflexion at the contact point, even with very soft under sleeper pads. Different combinations of soft or very soft under sleeper pads and heavy and wide sleepers (b) have been tested on the Eiffage Rail Test Rig in Herne during spring 2013 as described in figure 9 (a), with a dedicated excitation system, see figure 3 of the Work package 1 section. Several data were measured such as ground vibration velocity at 8 m and 16 m, sleeper vibration velocity, rail deflection, ground characteristics… All measurement results were analysed to have a global overview of {soft USP + heavy/wide sleeper} influence on track dynamic behaviour and ground vibration generation.

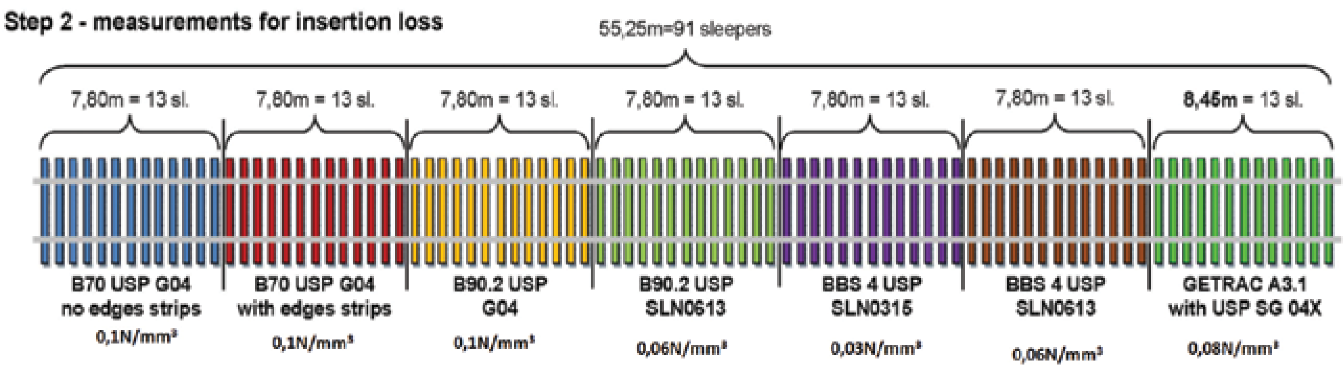


Figure 9 (a): Test track arrangement in Eiffage Rail workshop in Herne

Figure 9 (b): wide sleeper BBS4

The second mitigation measure consists in reducing the railpads stiffness. Therefore, dedicated fastening systems that can support very soft railpads have been developed, with a dedicated sleeper. One of these systems, called DFC Valiant, is a fastening system with two resilient layers as shown on figure 10, left: a rubber pad (a) is placed between the sleeper and a cast-iron baseplate (b) on which the rail is mounted through a FASTCLIP system including a classic rail pad (c). A wide range of stiffness can be achieved with the DFC Valiant by using different rail-pad/baseplate-pad combinations.

Before being installed on a commercial track, these fastening systems were characterized with dedicated lab tests.

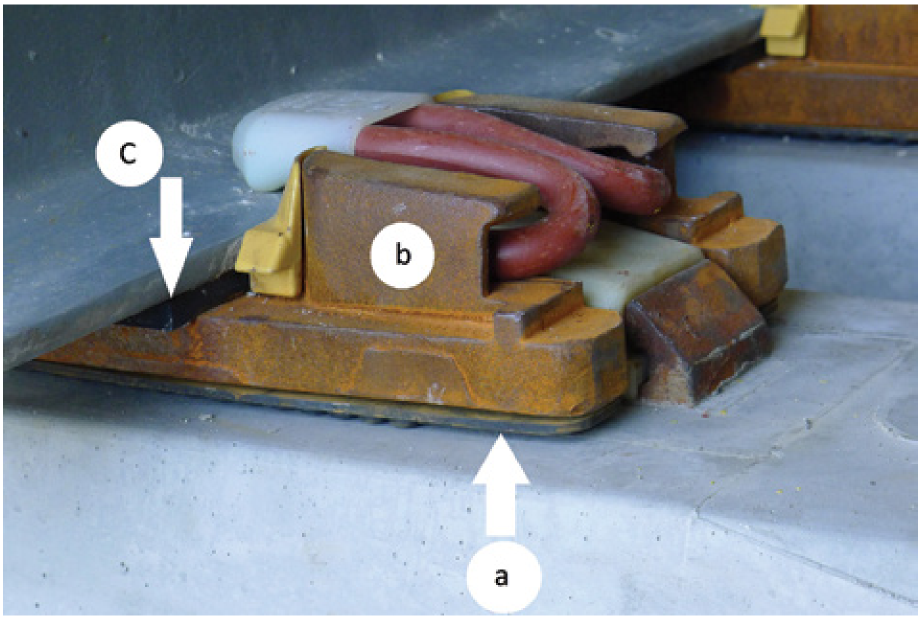


Figure 10: DFC system

These tests have allowed assessing the global stiffness of the all system {ballast + sleeper + fastening system + rail} under a realistic load: an excitation at 5 Hz around 60 kN (+/- 10 per cent). The following results were obtained: 560 MN/m for the reference system, 85 MN/m for the DFC. Numerical simulations were then performed with these estimated stiffness. The computed Insertion Losses at 8 m from the track, indicate that the DFC system will be efficient (IL up to 10 dB) for frequencies above 60 Hz.

Insertion loss measurements will be performed after installation of the DFC on a commercial track in autumn 2013 on a Freight corridor in the East of France. They will allow concluding on the DFC efficiency, confirming or questioning the lab tests relevancy for mitigation measures characterization.

Within Work package 3, different mitigation measures in track were tested, for several track configurations such as straight ballasted track, curve, turnout and slab track. All these measures are based on the modification of the track compliance (and therefore the wheel-rail interaction force) and the track transfer function (the response of the track to the vibration transmission). Their installations and tests in commercial track and/or scale 1 rig allow their efficiency to be appraised in realistic conditions of use.

Mitigation measures on transmission / propagation WP4

RIVAS Work package 4 focuses on vibration reduction technologies in the transmission path, either under or next to the track. In the frequency range of railway vibration, the top layer of soil plays an important role which is often neglected. It leads to a "cut-on frequency" above which a steep rise in the vibration transmission spectrum occurs. A key approach is therefore to take the layered ground structure into account or alter its effect to form barriers to propagation.

Options that were studied within the project include trenches, buried wall barriers, subgrade stiffening, horizontally layered wave-impeding blocks, and heavy masses at the soil surface. Open trenches and buried wall barriers will hinder the transmission of waves in the soil (figure 11). Similarly, heavy masses next to the track can block or reflect the ground-borne vibrations. Subgrade stiffening is often applied under railway tracks on soft soils to limit settlements or track displacements. It also reduces ground-borne vibration levels due to the increase in the effective stiffness of the soil beneath the track. The inclusion of wave impeding blocks under the track increases the cut-on frequency of the waves propagating in the top layer of soil. Because the layered ground structure plays an important role, all options are studied numerically for different ground types to establish the circumstances in which they are efficient.

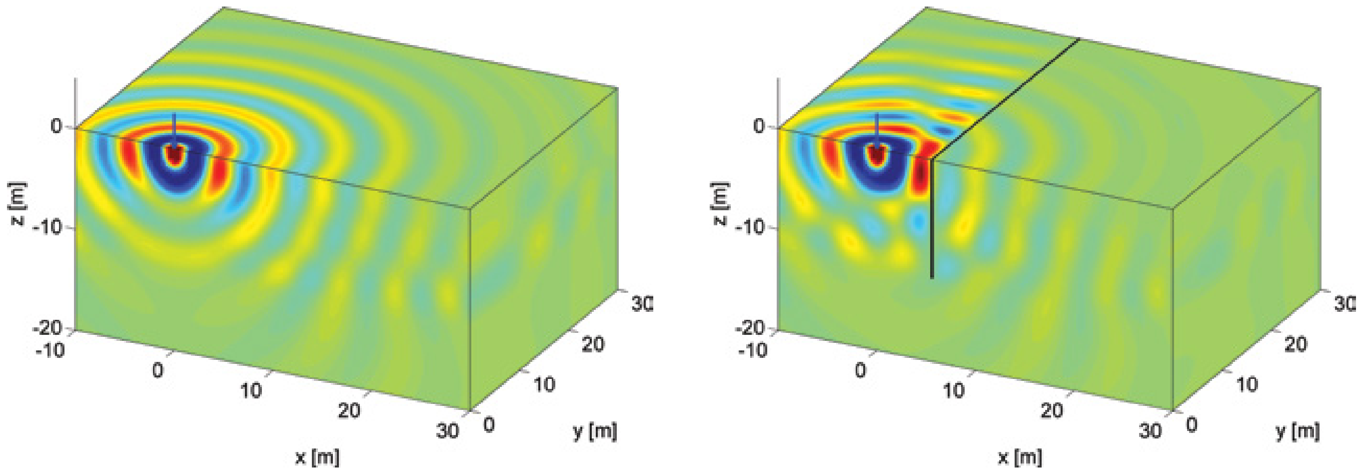


Figure 11: Ground vibrations without (left) and with (right) a buried wall barrier

To consolidate the results of the parametric study, three field tests were considered within the project: soil stiffening next to the track in alluvial conditions in Spain, a trench barrier in Switzerland, and a sheet piling wall as a wave barrier in Sweden.

Sheet piling wall in Sweden

The field test in Sweden is located in Furet in the southwest of Sweden along the West Coast Line between Gothenburg and Lund. A sheet piling wall designed and constructed by Trafikverket is subjected to a program of measurements and theoretical analysis within the framework of RIVAS.

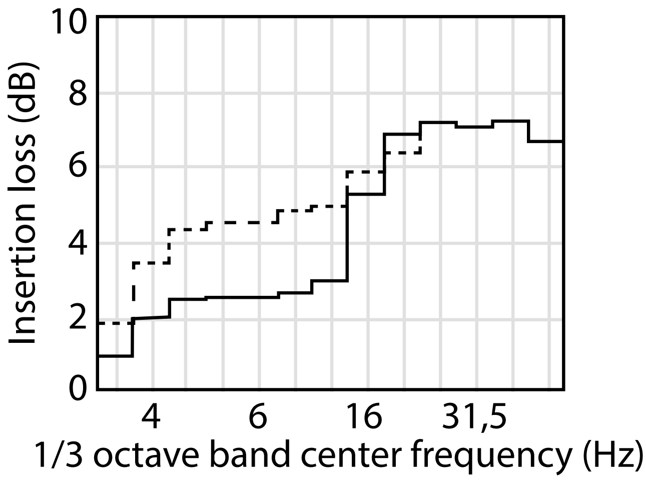


Figure 13: Calculated insertion loss at a distance of 16 m from the track for a 12 m (solid line) and a 18 m (dashed line) deep sheet pile wall

Figure 12: Installation of the sheet pile wall in Furet (Sweden)

Vibration problems at the site were reported to the Swedish Railway Administration. Indeed, the soft soil in Furet leads to high vibration levels in several buildings close to the track. The highest levels are measured in the frequency range of 4 – 5 Hz. A first attempt to mitigate vibration has been made in 2006. Under sleeper pads have been placed at the track closest to the buildings. At the same time the ballast of the other track has been exchanged and leveling of both tracks has been carried out. Unfortunately measurements performed after these measures showed insufficient vibration mitigation. Therefore it was decided to use a sheet piling wall as a method to further reduce the low frequency vibrations at the site.

Sheet piles are commonly used as retaining walls in geotechnical applications. Design calculations have indicated that sheet piles can also reduce ground-borne vibration. A sheet piling wall with a length of 100 m was installed next to the track behind the existing noise barrier in November 2011 (figure 12). The depth of the sheet piles is 12 m with every fourth pile extended to 18 m. These large depths are necessary to reduce the vibrations at very low frequencies (figure 13). Measurements after installation of the sheet pile wall have showed sufficient reduction of vibration levels in the exposed buildings, except for a small house with wooden structure at approximately 40 m distance from the track.

Comparison between measurement results for train passages before and after installation of the sheet pile wall indicate a significant reduction in vertical vibration levels at the soil surface behind the sheet pile wall. The effectiveness is higher closer to the wall where the maximum vibration levels are reduced by about 50 per cent. At 32 m the maximum levels are reduced by about 30 per cent while at 64 m from the track center, no reduction in maximum vibration levels is seen. It is also important to note that the construction of the sheet pile wall did not lead to an increase in vibration levels at the other side of the track.

The trends observed in the measurements are confirmed by theoretical analysis. Numerical simulations show that a sheet pile wall can act as an effective wave impeding barrier. The effectiveness of the wall however strongly depends on the characteristics of the soil. The design of a mitigation measure on the transmission path is therefore case specific and requires the knowledge of the soil layering and relevant soil parameters. Stiff buried wall barriers like the sheet pile wall will be more effective at sites with a relatively soft soil.

The results of the parametric study and the field tests are brought together in a design guide identifying a set of guidelines on the possible effectiveness of the mitigation measures in different soil types. The guidelines contain information on engineering design constraints, practicability, costs and social issues to form a technology assessment of the different mitigation methods on the transmission path.

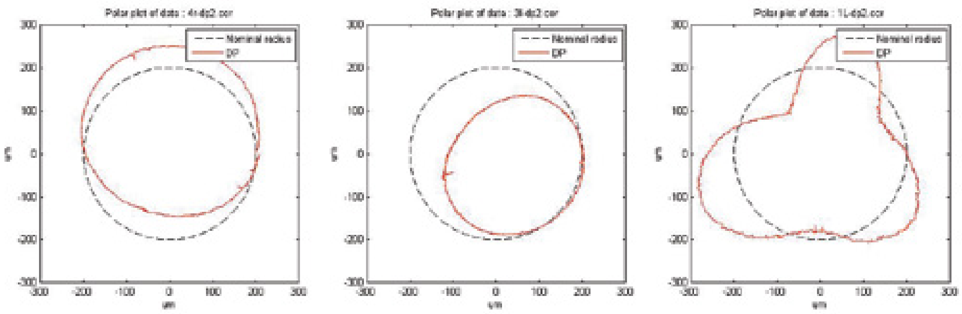
Mitigation measures on vehicles WP5

The fifth and final technical work package within RIVAS was dedicated to the influence of rolling stock on ground-borne vibration. More specifically it investigated how properties of vehicle design, such as unsprung mass, suspension stiffness and axle spacing contributed to the excitation of ground-borne vibration. Furthermore work package 5 has been aimed at understanding the excitation of vibration caused by out-of-round wheels and to quantify this effect in relation to other excitation mechanisms related to the track.

Based on numerical models of vehicle, track and ground, parametric studies have been performed to assess the influence of an alternative vehicle design on the ground-borne vibration; not only for one specific case but considering a wide variation of ground conditions. In general, it is concluded that the influences of the carbody mass and the bogie mass are small on vibration that propagates to larger distances from the track. The secondary suspension comes into play at very low frequencies where other mechanisms related to the soil are often dominant. The primary suspension stiffness and in particular the unsprung mass are the two vehicle parameters showing the most significant influence on the vibration level. A modification of the primary suspension stiffness leads to a shift of some of the vehicle resonances and is hence a narrow-band effect which is sensitive to variations in ground conditions. The potential of lowering the vibration level by reducing the unsprung mass is however a broad-band effect which is less sensitive to particular ground conditions and hence has proven to be most promising.

Focus – key results

Simulations of ground-borne vibration excited by freight and passenger trains have identified the unsprung mass (dominated by the wheelset mass) to be the single most important parameter of the vehicle design. While the total mass (static axle load) of the vehicle primarily influences the quasi-static excitation of vibration in the vicinity of the track, the unsprung mass has a strong influence on the dynamic part of the excitation which gives rise to vibration that propagate away from the track. The origin of the dynamic excitation is found in the wheel and rail irregularities which to some extent are present on all wheels and rails. New wheels featuring low levels of out-of-roundness when leaving production may, during operation, develop into wheels with severe out-of-roundness caused by non-homogeneous wear, plastic deformation and rolling contact fatigue cracking. Figure 14 shows three types of wheel out-of-roundness observed on a test train used within the RIVAS project. These are the first three orders of out-of-roundness which may excite high levels of ground-borne vibration.



(a) (b) (c)

Figure 14 :The first three orders of wheel out-of-roundness measured on freight wagons: a) eccentricity (order 1), b) ovality (order 2) and c) polygon of order 3.

Measurement campaigns within RIVAS have shown that the expected positive effect by e.g. a low unsprung mass is difficult to identify when studying vehicles with wheels in different conditions. The wheel irregularities mask the effect of other parameters confirming the importance of considering the influence of the wheel condition. In order to assess the effectiveness of a reduced out-of-roundness and a lower unsprung mass, simulations have been performed with different levels of track irregularities, out-of-round wheels and unsprung mass. Input data for the simulations were prepared by studying measurements of out-of-roundness for different types of wheels. The results show that the out-of-roundness of a wheel in average condition may add up to 3 dB to the overall vibration level while an increase of up to 5 dB is seen in a single frequency band. For a wheel in poor condition the increase is about 5 dB on the overall level and up to 15 dB in a single frequency band.

Figure 15 shows one example of the simulation results. Four different vehicle designs are studied in combination with having wheels in good and poor condition. The results show that the reduction of the unsprung mass by 50 per cent leads to a broad-band reduction of 6 dB. Furthermore it can be seen that the potential reductions due to low unsprung mass and wheels in good conditions are in the same order of magnitude. The improvement achieved by vehicle design changes may therefore be completely lost if the level of out-of-roundness is not kept sufficiently low. Since the size of the unsprung mass is closely related to the vehicle and drive concept, which is governed by requirements of comfort, safety and reliability apart from requirement on ground-borne vibration emissions, a 50 per cent reduction of unsprung mass should be considered as a large reduction difficult to achieve in practice. In order to reduce the ground-borne vibration levels, the design of new vehicles should aim at lowering the unsprung mass. This must however not compromise the wheel resistance against wear and the development of out-of-roundness. Vehicles already in service need to be maintained in order to avoid high levels of out-of-roundness, and it is necessary to gain a better understanding of the mechanisms causing out-of-roundness.

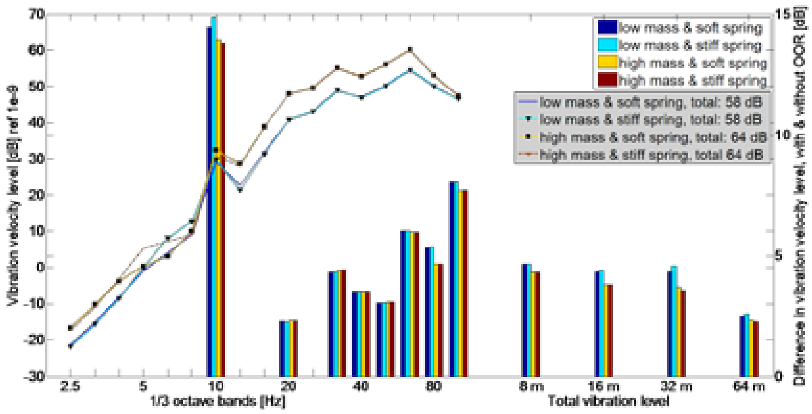


Figure 15: Vibration spectra at 8 m from the track at the site of Lincent, Belgium. Wheel-rail excitation by the ISO 3095 track and a wheel in poor condition. Four different vehicle designs with high and low levels of unsprung mass and primary suspension stiffness. The bar diagram shows the increase in vibration level caused by OOR in 1/3 octave bands at 8 m and for the total level at 8, 16, 32 and 64 m from the track. First published in Notes on Numerical Fluid Dynamics and Multidisciplinary Design, Springer, 2014.

The work carried out within RIVAS Work package 5 has resulted in a good understanding of the vehicle influence on ground-borne vibration. A reduction in vibration level can be achieved by lowering the vehicle unsprung mass of new vehicles. However the first action to take in order to reduce the excitation of vibration already today is to improve wheel maintenance and to prevent the growth of wheel out-of-roundness.

Conclusion

Within the frame of the EU FP7 project "Railway induced vibration abatement solutions (RIVAS)", a holistic approach to ground borne vibration due to railway traffic was adopted, with the aim of reducing annoyance of lineside residents. Mitigation measures studied apply to rail vehicle design, rolling stock maintenance, track design, track maintenance, subgrade engineering, and the transmission path within the railway infrastructure. Numerical modeling, allowing for elaborate parametric studies, was supported by field tests for verification and validation of predicted vibration reduction.

Results from the project have clearly shown that the effectiveness of vibration mitigation measures are highly depending on the type of train and train speed, the type of track, the soil conditions and even the type of buildings next to the track. These characteristics therefore need to be taken into account when selecting an appropriate vibration mitigation measure. In the final phase of the project, focus of the work goes to the writing of practical design guides, in order to facilitate implementation of vibration mitigation methods studied within the frame of the project.

The design guides, as well as all other public deliverables will be made available on the project's website **www.rivas-project.eu** by the end of the year 2013 when the project comes to a conclusion.

Partners

- Union Internationale des Chemins de fer
- Union des Industries Ferroviaires Européennes
- Administrador de Infraestructuras ferroviarias
- Trafikverket, Swedish National Rail Administration
- Deutsche Bahn AG
- Régie Autonome des transports Parisiens
- Schweizerische Bundesbahnen SBB
- Societé Nationale des Chemins de Fer Français
- Bundesanstalt für Materialforschung- und prüfung
- Chalmers Tekniska Hoegskola AB
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- Dynamics, Structures and Systems International – D2S
- Sound Advice in Technology, Innovation and Strategy – SATIS
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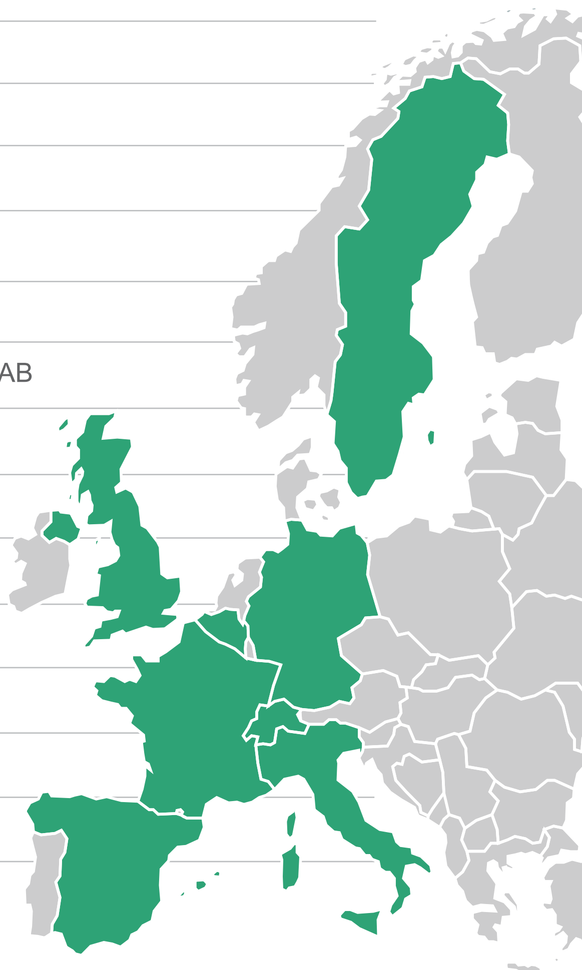

Project co-funded
by the European Commission

For more information please visit the website **www.rivas-project.eu**

Conception: UIC Communications Department | November 2013 | Project coordinator: Wolfgang Behr (UIC)
Editorial coordination: Andrea Demadonna (UNIFE) / Isabelle De Keyzer (UIC) | Design: Marina Grzanka | Photo credit: © Fotolia

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