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Harmonised **A**ccurate and **R**eliable **M**ethods for the EU Directive on the Assessment and Management **O**f Environmental Noise

FINAL TECHNICAL REPORT
Final

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Approval by the Coordination Committee

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SUMMARY

The Harmonoise project has produced methods for the prediction of environmental noise levels caused by road and railway traffic. These methods are intended to become the harmonized methods for noise mapping in all EU Member States. The methods are developed to predict the noise levels in terms of L_{den} and L_{night}, which are the harmonized noise indicators according to the Environmental Noise Directive 2002/49/EC.

By de-coupling the description of the source from the description of noise propagation, the Harmonoise project provides the basis for a generic noise propagation model, which has been validated within the project for surface transport sources (road and railway noise), but which can in principle be extended for other noise sources.

The rail and road sources are described by separate generating mechanisms, defined as sub-sources. For road noise this has resulted in a separate description of the rolling noise and propulsion noise, whereas for railways the sources have been divided into rolling, traction and aerodynamic noise.
This is a big advantage when, in the second stage of the European Noise Directive, it comes to the production of Noise Action Plans. The chosen source description will allow for an efficient simulation of certain source mitigation measures.

Measurement data from road and rail traffic have been collected during an extensive measurement campaign at selected locations in Europe to demonstrate the validity of the Harmonoise methods. The Reference method, which consists of a set of advanced sound propagation models, gives a more theoretical description of propagation effects and parameters. The model is used to validate the Engineering methods, in which the source models are coupled to the so-called point-to-point propagation model, which allows for time-efficient computations, to yield L_{den} and L_{night}.
It was considered a main priority in the Harmonoise project to improve the description of weather conditions and their influence on sound propagation. A description of sound propagation through a turbulent or layered atmosphere has led to short-term noise levels for 25 meteorological classes.

An important advantage of the Harmonoise methods compared to other existing methods is the fact that the level of accuracy will mainly depend on the accuracy of the chosen input parameters. This makes the methods suitable for mapping purposes, where usually less detailed information about source and mapping area is required or available, but also for detailed computations in case of noise assessment studies.

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1. Project overview

1.1 Main achievements

1.1.1 New methods

The Harmonoise project has produced methods for the prediction of environmental noise levels caused by road and railway traffic which are intended to become the harmonized methods for noise mapping in all EU Member States. The methods are developed to predict the noise levels in terms of L_{den} and L_{night} (the harmonized noise indicators according to the Environmental Noise Directive 2002/49/EC) with an accuracy that is better than the methods currently used. The full accuracy however depends on the availability and accuracy of detailed input data.

The methods are valid for any regional climate in Europe, provided that the long term weather behaviour can be described in terms of the frequency of occurrence of certain meteorological classes that have been defined in the project.

1.1.2 Ready for action planning

The methods make a clear distinction between the description of the sources on the one hand and the description of the sound propagation on the other. As a consequence, the sound propagation model is a generic model that could be used for other sources than road and rail traffic.

Road and rail noise sources are described as sets of point sources, each with its own position, third octave band sound power level and directivity, which depend on the operating conditions of the source. In doing so, measures can be included in the calculation of the sound power of a point source. In this way the efficiency of certain mitigation methods, which affect only part of the noise generation (e.g. quiet tyres), can be predicted.

1.1.3 Validated methods

A set of scientific methods has been selected, after thorough testing of various alternatives, that are considered capable of predicting the “real” environmental noise levels L_{den} and L_{night} in simplified cases. The results of these so-called Reference methods have been used to validate the new methods. In addition to that, experimental results have been collected in long term field surveys. A standardised database format has been developed, including both noise data and meteorological data, for future reference and possible extension by other researchers. In general good agreement has been found between the Engineering methods, the Reference methods and the measurements; where the agreement was poor, explanations could be found that can help future researchers in improving the set-up of their experiments.

1.1.4 Dissemination and acceptance

During the project, numerous communications with the end users have been arranged. The scientific world was informed at conferences and seminars, including special sessions at Euronoise 2003 in Naples, at Internoise 2004 in Prague and a final Harmonoise conference in Rhodes (October 2004). Regular contact was established with the Working Group on the Assessment of the Exposure to Noise (WG-AEN), with its members recruited from different end-user groups. Authorities responsible for noise mapping where contacted by the Consortium members in many different member states. Finally, the web site www.harmonoise.org provided information, including many downloadable documents, almost from the start of the project. Every three months electronic newsletters were went to civil servants and other future users like consultants, specialists, scientists, etc.

1.1.5 Implementation and standardization

The technical result of the project is a set of algorithms and rules for outdoor noise prediction. It is expected that a process of standardisation, see section 4.6, would enhance the rapid introduction of the methods by all Member States. National peculiarities, such as specific vehicle types or fleet compositions, may have to be introduced into the methods by individual Member State if necessary. It is this process of implementation that needs to be carried out to guarantee that the Harmonoise methods will indeed be the harmonized methods for noise mapping and action planning in 2012, as envisaged in the European Noise Directive.

1.2 The consortium's composition

The Consortium carrying out the project consisted of 19 partners from 9 different Member States. One party joint the Consortium after the project started and contributed without EC funding. The size of the Consortium and its geographical spread allowed easy access to existing methods in many different countries and adds to its credibility and acceptance by authorities and scientists in these countries. The Harmonoise consortium profited specifically from recent developments in noise prediction techniques in France and in the Nordic countries, both of which were sufficiently represented in the consortium.

The Consortium is presented in the following Table 1.

Participant No.	Participant short name	Participant Legal Name	Country code
1	AEA	AEA Technology Rail BV	NL
2	TNO	Netherlands Organisation for Applied Scientific Research	NL
3	SP	SP Sveriges Provnings- och Forskningsinstitut Aktiebolag (SP)	S
4	DGMR	DGMR, Consulting Engineers	NL
5	DeBakom	DeBakom Gesellschaft für sensorische Messtechnik mbH	D
6	DB	Deutsche Bahn AG	D
7	DLR	Deutsches Zentrum für Luft- und Raumfahrt e.V.	D
8	M+P	M+P raadgevende ingenieurs bv	NL
9	TRL	Transport Research Laboratory	UK
10	SNCF	Société Nationale des Chemins de fer Français SNCF	F
11	CSTB	Centre Scientifique et Technique du Bâtiment	F
12	LCPC	Laboratoire Central des Ponts et Chaussées	F
13	Autostrade	Autostrade per l'Italia	I
14	ARPAT	Agenzia Regionale per la Protezione Ambientale della Toscana (ARPAT)	I
15	DELTA	DELTA Danish Electronics, Light and Acoustics	DK
16	Kilde	Kilde Akustikk AS	N
17	VTI	Statens väg- och transportforskningsinstitut (VTI)	S
18	TUG	Politechnica Gdansk	PL
19	JRC	Joint Research Centre, Institute for Health and Consumer Protection (IHCP)	I
20	Sintef	Sintef group	N

1.3 Role of the partners involved

1.3.1 Main partners

The role of the participants in the project has been as follows:

- **AEA Technology Rail bv**, Co-ordinator, responsible for the overall project management and links with the European Commission (Work Package 7). In Work Package 1.2 on railway noise sources responsible for the description of rolling noise in dependence of wheel and track roughness, which emerged from the STAIRRS project. This links also provided new approaches with respect to measurement methods aiming at separation of vehicle and track contribution in rail bound sources. In Work Package 5 responsible for the content management of the project web site and in general for dissemination issues, among others through numerous presentations and lectures. AEA will be one of the partners organising the final conference. In Work Package 6 definition of the end user group and the enquiries collected from them.
- **TNO Institute of Applied Physics**, as a work package leader of Work Package 2 responsible for the assessment of Reference methods, the selection of a final set of preferred Reference methods (by applying the methods to many case studies), and the application of these Reference methods to the results of the field experiments (Work Package 4). In Work Package 1.1 on road traffic sources responsible for the application of advanced imaging techniques for source localisation. Contributions to Work Package 1.2 on rail sources with respect to measurement methods
- **SP Sveriges Provnings- och Forskningsinstitut Aktiebolag (**Swedish National Testing and Research Institute**)**, as a work package leader of Work Package 1 on noise source modelling and at the same time Task Leader for task 1.1. on road sources, responsible for the overall description of these sources in physical terms, depending on operating conditions. Building on their experience in road source modelling for the improved Nordic method. SP's expertise in rail source modelling, sound propagation and general prediction methods is also used in WP 1.2, 2 and 3 respectively.
- **DGMR consulting engineers**, as a work package leader of Work Package 3 on the Engineering method, DGMR was responsible for the development of the Engineering method, building on existing methods and the new insights that were gained in the Work Packages on source description and the Reference model. DGMR was also responsible for the comparison between the Engineering method and the results of the field experiments. As one of the leading companies in Europe building and supplying software for various noise prediction models, DGMR will be involved in the implementation of the methods, together with their partner Bruël and Kjaer.
- **DeBAKOM**, **Gesellschaft für sensorische Messtechnik mbH, as a** work package leader of Work Package 4 on experimental data collection and validation, DeBakom has been responsible for the selection of suitable measurement sites, for the definition of the database structure for storage of measured data, and for automated background noise correction in unattended measurement equipment.
- **DB**, **Deutsche Bahn AG,** has contributed in Work Package 1.2 to the definition of track influence to noise creation of railway vehicles, with a special focus in rail roughness and riding behaviour,
- **DLR**, **Deutsches Zentrum für Luft- und Raumfahrt**, as an expert in meteorology DLR was responsible for the definition of meteorological classes in as far as these can be considered relevant for noise propagation. DLR provided specific

expertise in this field both for Work Package 2, 3 and 4, and contributed to the dissemination of the results in supplying papers to various occasions.

- **M+P consulting engineers**, contributed to the work in Work Package 1.1 (road source description) particularly with respect to tyre/road noise and power train noise. M+P supplied results from many measurements for better insight into the source description for road vehicles. M+P was responsible for the link with the ROTRANOMO project on urban traffic noise modelling.
- **Transport Research Laboratory**, experts in road vehicle noise, contributed to the work in Work Package 1.1 in carrying out specific source measurements for source localisation and source behaviour under different operating conditions.
- **SNCF**, **Société National des Chemins de fer Français SNCF**, as a work package leader of Work Package 1.2 responsible for the description of rail sources, especially working out the distribution over the different generating mechanisms, i.e. rolling noise, traction noise and aerodynamic noise. SNCF was responsible for defining the structure of a database that could contain all the source information for railway vehicles throughout Europe. SNCF organised a special Harmonoise workshop on railway sources with specialists in the field. SNCF was responsible for the link with DEUFRAKO projects.
- **CSTB**, **Centre Scientifique et Technique du Bâtiment**, responsible for the assessment and development of the Reference methods (in collaboration with TNO), for the drafting of the P2P model and the Engineering method (in collaboration with DGMR), based on their experience with the French methods for road traffic and railway noise. CSTB supplied the infrastructure for the Harmonoise website, including a document management system.
- **LCPC**, **Laboratoire Central des Ponts et Chaussées**, contributed to the collection of experimental data in several measurement campaigns and developed innovative methods for the experimental assessment of ground absorptive properties.
- **Autostrade per l'Italia,** contributed to the description of road noise sources in carrying out specific measurement on a test section of road, focused to assess the directivity of road vehicle sources under various operating conditions. Link with SILVIA and SIRUUS projects.
- **Arpat**, **Agienzia Regionale per la Protezione Ambientale della Toscana**, contributed to the collection of experimental data in several measurement campaigns and was responsible for the analysis and presentation of the results of these campaigns. Arpat organised a conference on the effect of different physical agents working on the environment, where the Harmonoise project could be presented to an Italian audience. Arpat is one of the partners responsible for organising the final conference.
- **Delta**, **Danish Electronics, Light and Acoustics**, contributed to Work Packages on source description as well as sound propagation, mainly building on their long year experience in developing the Nordic model,
- **Kilde Akustikk AS**, contributed to Work Package 1.2 on rail sources, in supplying existing data on Nordic trains to the work package and in setting up the overall approach in that work package.
- **VTI, Statens väg- och transportforskningsinstitut (Swedish Road and Transport Research Institute)**, a leading expert in tyre/road noise, contributed significantly in Work Package 1.1 on road noise sources, proposing different vehicle and road surface categories to be taken into account, and carrying out noise measurements in collaboration with Politechnica Gdansk,
- **Politechnica Gdansk**, an expert in modelling and measurement of road vehicles, carried out measurements under specific operating conditions, such as wet road

surface, and also measurement on a test rig to assess the directional behaviour of road noise sources,

- **JRC, Joint Research Centre, Institute for Health and Consumer Protection**, contributed to Work Package 4 in participating in various measurement campaigns and elaborating the results. JRC has been one of the parties who organised the final conference.
- **SINTEF,** expert in sound propagation outdoors, joint the project almost one year after the start and contributed to Work Packages 2 and 3 in assessing and developing the Reference model and the Engineering method.
- **TUG,** has been involved in tyre/road noise research since 1978. Over 25 years of tyre/road noise research resulted in accumulation of knowledge, experience and specialized equipment. When we applied for the HARMONOISE project, Poland was still waiting to be a full scale EU member. Poland is starting some big projects related to the road building and we would like to use best possible prediction tools. The best way to gain the knowledge is to make it together with other partners. We try to utilize this knowledge both in national Polish projects, and in SILVIA and IMAGINE.

1.3.2 Subcontractors

Two parties were engaged as subcontractors to individual partners of the above consortium, viz.

- Progetti e Servizi working for Autostrade per l'Italia for the purpose of specialised measurements, using multiple microphone techniques for directivity assessment, and
- Systemhaus – solution for research GmbH, working for DLR for the purpose of IT-support in managing large amounts of data

2. Project objectives

2.1 Introduction

In 2003, the European Directive on the Assessment and Management of Environmental Noise (2002/49/EC) was accepted by the Parliament and the Council. According to this Directive, Member States will be responsible for the production of strategic noise maps to be sent to the European Commission. Among others, these maps will cover major motorways and railways. The Commission acknowledges lack of harmonised methods of sufficient accuracy for the prediction and assessment of noise from roads, railways and industrial sites. For the first series of noise mapping, to be concluded in 2007, Member States are allowed to apply their own national prediction methods (under certain conditions), or the so-called Interim methods defined by the Commission as an alternative, but for the next mapping operation, in 2012, harmonised methods will have to be used. A main objective of the Harmonoise project was to provide such harmonised, new prediction methods for environmental noise from roads and railways, which can meet the requirements of the Directive in that they are more accurate, more reliable and, on that basis, enjoy a general international acceptance from future users throughout the Community.

2.2 The Goals of the Harmonoise project

2.2.1 General

“Better acceptance through better performance”, that is what could be identified as the main goal for the Harmonoise project. In the proposal phase as well as during the project, the main points have been identified that contribute to “a better performance”. They are presented in the following graph.

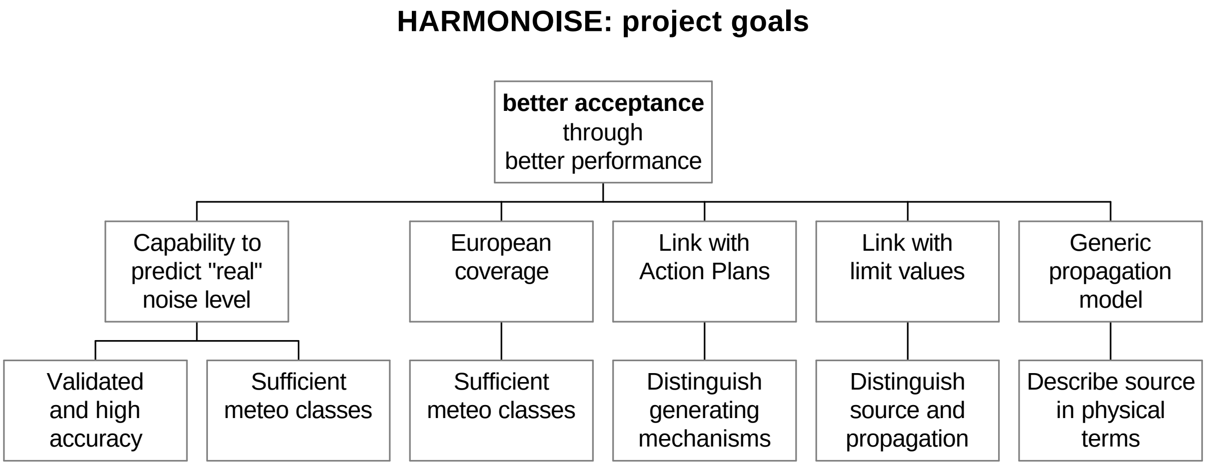

Figure 1: Summary of the project goals for Harmonoise

The individual items are treated in the following paragraphs. It may seem surprising that obvious performance criteria such as ‘ease of use’ or ‘limited computer processing time’ have not been made subject of this project goal, even though this may be high on the list of some of the end users. These criteria have been considered, but were thought to be ranked of lower priority because computer power has significantly improved and will continue to improve over the coming years. Ease of use is often a matter of software architecture rather than method.

2.2.2 Validated and high accuracy

A general comment often heard during the project was that the aim of high accuracy could only be achieved at the cost of unreasonably large efforts in collecting highly detailed input parameters. No doubt the accuracy of the result is highly dependent on the accuracy of the input data. Averaging input data may make life easier but will unavoidably affect the accuracy of the end result. It is the conviction of the Consortium that guidelines must be developed, both on a European level and a national level, on what accuracy is required at every application of the methods. Whenever a lower accuracy is thought to be acceptable for the application under concern, the user can apply a lower level of detail for the input data, i.e. use average or default values.

> *Example:*
> *The road surface has a large influence on the generation of tyre road noise in traffic noise prediction. In the HARMONOISE project, road surface correction factors have been defined for many different road surfaces. When mapping a great length of road, it requires a lot of effort to assess the actual quality of the road surface – even measurement trailers may be involved to collect that data. When the mapping is carried out to assess the total number of annoyed people, it may be sufficient to assess the* **average** *road surface quality over the complete stretch of road in order to assess the total number of annoyed people with sufficient accuracy.*
> *On the other hand, when preparing action plans, it may be relevant to assess the exact locations where the road surface quality is poor, in order to be able to quantify the costs and the efficiency of a mitigation measure that involves improving the road surface quality.*

In the proposal for the Harmonoise project, the following ambition levels have been defined – in terms of standard deviation, even though this refers to the accuracy[1] of the methods (See 2.2.3):

- up to 1 dB standard deviation for distances up to 100 m between source and receiver,
- up to 2 dB standard deviation for distances up to 2000 m in flat surroundings,
- up to 5 dB standard deviation for distances up to 2000 m in hilly surroundings,
- and up to 5 dB standard deviation in urban areas

2.2.3 Capability to predict the “real” noise level

The accuracy of the methods to be developed was almost the only criterion that has been presented to the consortium by the European Commission before the start of the project. The accuracy is defined here - in conformity with the general interpretation -

[1] for "accuracy" see e.g. Guide to the Expression of Uncertainty in Measurement, ISO

as the degree of conformity of a calculated value to its reference value[2]. It should be stressed here that, surprisingly, this is not a very significant criterion for authorities and political decision makers. In interpreting the results of noise mapping and action planning, reproducibility[3] seems to be of higher importance, as it leads to higher clarity, equality of judgment and transparency in political consequences of a calculated value. In this respect it is typical that most decision makers appear to be worried about the fact that the Harmonoise methods will lead to results *different* from the results of previous methods (and may thus require different political action), than the fact that the Harmonoise results are *more accurate* than previous results. In this respect it would be very difficult to satisfy the needs of both politicians and scientists.

2.2.4 Sufficient meteo classes

The harmonized indicator L_{den} is the yearly average noise level, averaged over the three periods of the 24 hour day, i.e. the day (12 hours), the evening (4 hours) and the night (8 hours). The distinction in 3 periods relates to three levels of activity in average social behaviour, i.e. work (incl. study, housekeeping), relaxation and sleep. The three time periods may coincide with three meteorological periods, where for instance wind speeds are generally higher during the day and temperature inversion is more frequent during the night. It was considered a main priority in the Harmonoise project to improve the description of weather conditions and their influence on sound propagation, because the state-of-the-art methods for noise prediction do not fully account for these effects.

2.2.5 Other propagation effects

Once the influence of weather conditions on the sound propagation has been improved, the other phenomena involved in sound propagation over large distance are of lower importance. The ground effect which is highly relevant for sources close to the ground, is described sufficiently accurately by the method of Delany and Bazley, see chapter 3.

Another important phenomenon affecting the sound propagation is the screening and reflections by barriers and building blocks. This is the main propagation effect in urban areas, where weather effects tend to be completely distorted and the approach of meteorological classes would no longer work. It would be unrealistic to expect the Harmonoise project to come up with methods for noise levels in dense urban areas of comparable accuracy as the methods for open space. Nevertheless, it is the firm believe of the consortium that in urban areas the physics of sound propagation, as described by the Harmonoise methods, do not differ from the physics in open space. The real challenge is to assess input data, such as temperature and wind profiles, reflection and diffraction coefficients and impedances, that would enable an accurate noise prediction.

[2] As opposed to “precision” which is defined as the degree of mutual agreement among a series of individual results; often, but not necessarily, expressed by the standard deviation

[3] Reproducibility here meaning: with respect to a set of independent tools of the same design, the ability of these tools to produce the same value or result, given the same input conditions and operating in the same environment.

Other sound propagation phenomena, such as energy absorption in humid air or scattering in vegetation are less significant and/or better defined so that there was no obvious scope for improvement of existing methods.

2.2.6 Separation of source and propagation

By describing the source term in more general, physical terms the Harmonoise project intended to provide a better link between two main political goals of the EC:

- on the one hand to monitor the extend of environmental noise annoyance throughout the EC and to stimulate (or to enforce) that counteractive measures be developed and carried out by local authorities,
- and on the other hand to control and reduce the noise creation of a wide variety of noise sources by stating noise creation limits.

Thirdly, by de-coupling the description of the source from the description of noise propagation, the Harmonoise project intends to provide the basis for a generic noise propagation model, which have been validated within the project for road and railway noise, but which can be used without change for any other noise sources, e.g. aircraft noise, ship noise, recreational noise and industrial noise. In fact, that is the subject of another project in the 6th Framework program, called IMAGINE, which will develop harmonized methods for aviation and industrial noise on the basis of the Harmonoise generic propagation models.

2.2.7 Distinction in generating mechanisms within the source

Finally, the source description in Harmonoise largely follows the distinction in generating mechanisms within the source defined as sub-sources. This is a big advantage when, in the second stage of the European Noise Directive, it comes to the production of Noise Action Plans. The chosen source description will easily allow the users of the method to simulate the efficiency of certain mitigation measures without much additional effort.

Example:
In railway noise, rolling noise, traction noise and aerodynamic noise are contributing to the overall noise creation. Rolling noise is generated by the roughness of rail and wheels. Controlling the track roughness may have a noticeable effect for rail vehicles with smooth wheels, whereas for trains with rough wheels the effect is negligible. The source descriptions in the HARMONOISE methods allow quick and easy assessment of the efficiency of such a measure, not only on a single vehicle level but also for a mixed traffic with smooth wheel trains and rough wheel trains. This then allows cost benefit studies in terms of e.g. invested money against reduced annoyance, a work that would lie at the basis of Noise Action Plans.

2.2.8 Economic development and scientific and technological prospects

Once the system of noise prediction methods is in place it will be used e.g. for the purpose of noise mapping. Mapping activities will be compulsory for agglomerations of substantial size (250,000 inhabitants first, 100,000 in a second stage) as well as for all major railways and roads in Europe. The total cost of initial noise mapping for agglomerations was estimated to amount to 50 to 75 million Euro. A slightly smaller amount will be involved in the mapping activities for railways and roads outside the agglomerations.

The partners in the consortium will profit in different ways. Having participated in the Harmonoise project gives them an advance in making strategic noise maps and action plans. Also partners might be involved in other activities on the prediction of noise levels. Some partners also want to be involved in the development and commercialisation of dedicated software. Others may want to engage in the training and coaching of end users. And some of the partners will become end-user themselves, using the software developed by others. Finally it is expected that further scientific development will take place, as it has recently started in the follow-up project IMAGINE.

3. Approach

3.1 Overall structure of the project

The overall structure of the project and the links between the 4 technical Work Packages is presented in the following figure.

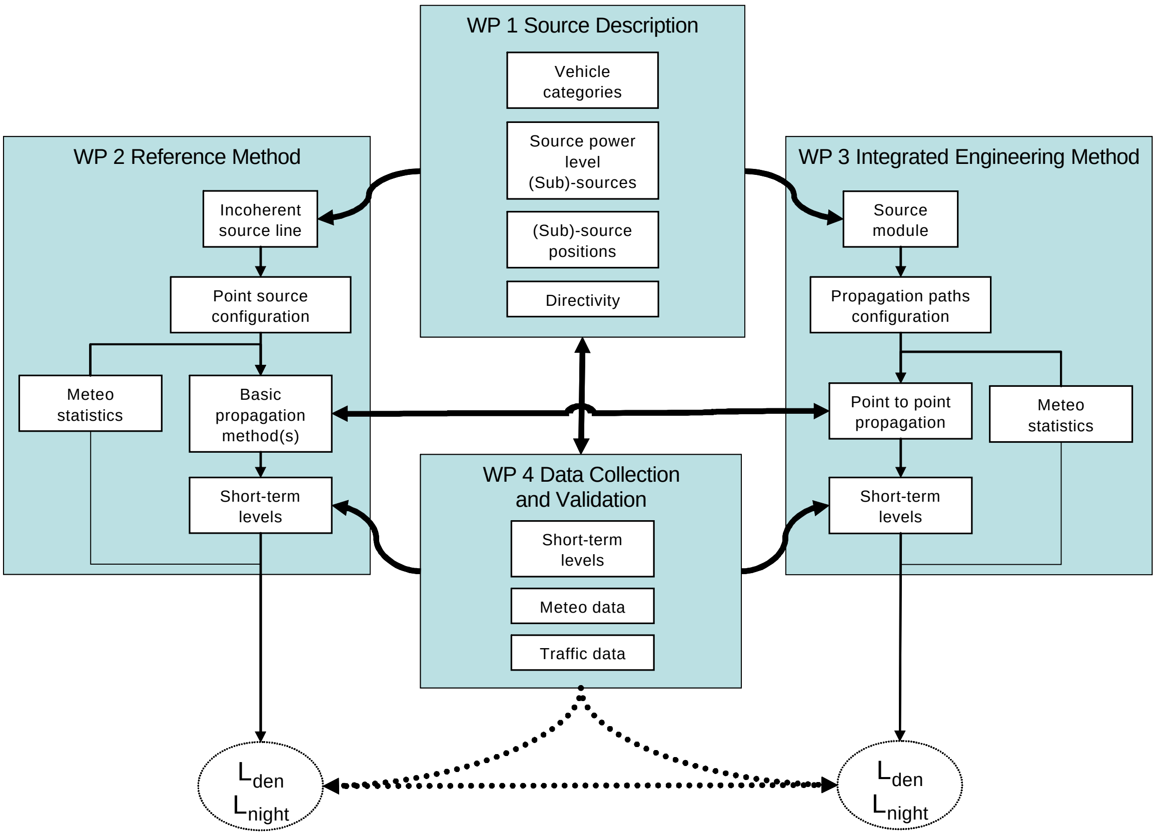

Figure 2: Overall project structure in 4 technical Work Packages

The figure clearly illustrates the links between the different work packages. The main result of the project is the Engineering method [4], where the method is thought to include and combine different *methods* of simulation. The Engineering method is also indicated as "integrated" as it combines the findings of the source description and the propagation description. Still, the source description and the propagation remain independent components of the Engineering method.

In the engineering model the source models are coupled to the point-to-point sound propagation model to yield L_{den} and L_{night}

[4] A model is defined here as an abstract and often simplified conceptual representation of the workings of a system in the real world, which includes mathematical or logical objects and relations representing the objects and relations in the real world system and constructed for the purpose of explaining the workings of the system or predicting its behaviour under hypothetical conditions.

3.1.1 The Reference model versus the Engineering method

The sound propagation is described by both the Engineering method of Work Package 3 and by the Reference model of Work Package 2. Both models can operate with the same source model, but the propagation modelling methods will differ substantially. The Engineering method is intended for everyday use whereas the Reference model will serve as a calibration base for the Engineering method. The Engineering method will be the most suitable for modeling complex geometries, but cannot take into account the complex description of the atmosphere. The engineering model uses a simplified description of the atmosphere in terms of a limited number of representative classes. As such, the Engineering Model only intends to predict the propagation as a long time averaged value over many similar situations. The Reference model will be designed to achieve the highest possible accuracy, without too much concessions to flexibility of use or short computation times.

This has the disadvantage that the Reference model will only produce results in fairly simple geometrical situations (e.g. infinitely long stretches of road with infinitely long barriers, i.e. simple geometry with complex meteorology). It means that the validation between Work Package 2 and Work Package 3 can only be limited to such cases.

3.1.2 Engineering method

The core of the engineering method is a point-to-point model, i.e. only one point source and one receiver position is treated at the time and the contribution from the different point sources is assessed one after another. The point to point calculation is made for a single meteorological situation. The contribution of all relevant sub-sources is added, and then the calculation is repeated for other meteorological classes. In the end, by weighting the results per meteorological class with the frequency of occurrence of that class, the long term average level per period of the day is computed. Then the three periods of the day are added together (for L_{den} assessment) into a single value taking into account the penalties for evening and night time period. The resulting engineering method should be flexible in such a way that it can be used for noise mapping, requiring a higher speed of computations and (presumably) less detailed input data, but also for noise assessment studies, with more detailed computations.

The acoustic properties of the ground are described using the fairly simple one parameter impedance model of Delaney & Bazley. That model has been shown to work very well in most cases. Using this impedance the ground effect is calculated using analytical point source sound propagation theory. The difficult mathematical functions are solved using the Chien & Soroka approach. Impedance jumps in the propagation path are dealt with using a Fresnel zone approach to weight the effect of the different impedance areas.

3.1.3 Reference model

From the evaluation it was concluded that the linearised Eulerian model and the Parabolic Equation (PE) model are preferable on the aspects of accuracy and applicability. At present the Euler model demands too much computational effort. The same applies to the 3-dimensional version of the PE method. Therefore the 2-

dimensional version of the PE method was chosen as the general basis for the Reference model. As the PE method cannot handle large elevation angles and complex geometries, it can be replaced in the source region by the straight ray model or the boundary element method (BEM) in cases where refraction by meteorological gradients can be neglected. In those cases the straight ray and the BEM model will be coupled to the PE model to take care of the propagation outside the source region, where the influence of an inhomogeneous atmosphere will be relevant. This coupling can be realized by computing the complex sound pressure for a vertical stack of intermediate receiving points and using these sound pressure values as a starting vector for a PE model simulation.
This choice of possible models enables a variety of geometries in the source region. Reflections between vertical surfaces can be taken into account by carrying out computations in several propagation planes and summing the contributions in the receiving point. Outside the source region the permissible geometrical and geographical variability is governed by the modeling possibilities of the PE model. In this region the model can handle one shielding obstacle of rectangular cross section, a terrain profile with a maximum local slope of 30 degrees and one or more ground impedance transitions. Because of the 2D approximation used, all propagation elements must be infinitely long, except for the source length which may have a finite length and a curved shape.

3.1.4 Meteorological description

The noise propagation is highly affected by the weather conditions. Under downwind conditions (wind blowing from the source to the receiver point) the noise levels tend to be significantly higher than under transverse wind or upwind conditions. Temperature gradients in the atmosphere, humidity and wind speed may also play a role. For this reason, in most legislative regulations it is stated that the assessed noise levels shall be representative for the long term average situation, i.e. both the source condition and the weather conditions shall reflect the average situation for a long term (e.g. one year or more).
Every meteorological condition is represented for each propagation direction by one effective sound speed profile that approximates the actual sound speed profile for this condition and direction. Meteorological influences over longer periods can be computed by using a weighted combination of all effective sound speed profiles for each propagation direction.

3.1.5 Sound propagation in urban areas

Special attention is required for urban situations. The noise source parameters are usually less constant than in open space (speed variations, transient driving). The propagation computation is governed by a large variation of local wind profiles, often defined by building orientations (street canyons). The complex geometries with small and large obstacles, surfaces, and many edges will require much computation effort. The primary tool for noise mapping in practice will be the Harmonoise Engineering method. The accuracy of the results of the engineering method is assessed by the comparison with results of measurements and of simulations with the Reference model. In the case of urban areas, however, both these assessment methods are non-trivial. Measured data from urban areas will generally include a large number extraneous noise events (that cannot be attributed to traffic), which must be removed

from the records. Due to the fluctuating nature of urban sound, automated removal will be problematic, while manual removal requires (continuous) visual information from the receiver and source area.
Therefore, in principal, validation against the Reference model would be more appropriate. Before the actual start of the Harmonoise project the possibilities to incorporate sound propagation in urban areas with various building configurations was studied in a literature research project. The conclusion of this research was that no methods for mathematical-physical modeling of sound propagation in urban configurations could be found in literature and that the only solutions seemed to be empirical or statistical approaches to the problem. This conclusion was confirmed after the extensive survey of the state of the art of modeling methods in the field of mathematical physical modeling.
The only model that would be capable of producing firmly theoretically based modeling results for urban configurations would be the Euler model. Unfortunately the Euler model requires too long computation times to be feasible in the near future. However on the long run, this modeling method might be the ultimate solution for reference modeling methods .
Editorial note: a technical report from WP3 about how to apply the Engineering model in urban situations will come available in January 2005. The calculations have been finished, but the report is only in early draft.

3.1.6 Validation of the Reference and Engineering Method

As described above, the Reference model will consist of a toolbox of state-of-the-art sound propagation models. To demonstrate the validity of the model, it should be validated through comparison with measurement data from road and rail traffic. Meteorological data together with ground impedances will be collected. The meteorological quantities and the ground impedances are used as input in the sound propagation calculations with the Reference model. The sound levels measured at the microphone position closest to the source can be used to assess the sound power level of the source. These half hour noise levels will be integrated into an equivalent noise level. This is the basis for comparison with both the Engineering method and the Reference model.

The final result of the project then is a validated set of Engineering methods for the prediction of environmental noise – in terms of L_{den} and L_{night} - from road and rail traffic under a wide range of different operating conditions and practically in any climate.

3.2 Approach to source description

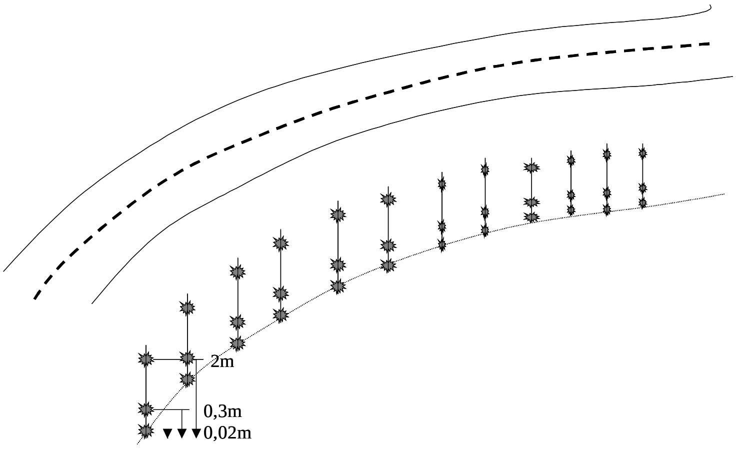

Figure 3: Representation of a motorway by groups of point sources

The source description is defined and detailed in Work Package 1. The source (i.e. the vehicle combined with the road or rail) is described as a group of point sources, each sub-source with its own position (height above infrastructure), its own spectral density of the sound power and its own directivity (figure 3). The source groups are assumed to be incoherent. The sound power levels depend on the operating conditions of the source. Obvious parameters are speed and number of vehicles per unit of time, but many other parameters may be considered as well (that is if the input data is available; if not, default values are to be used for these parameters).

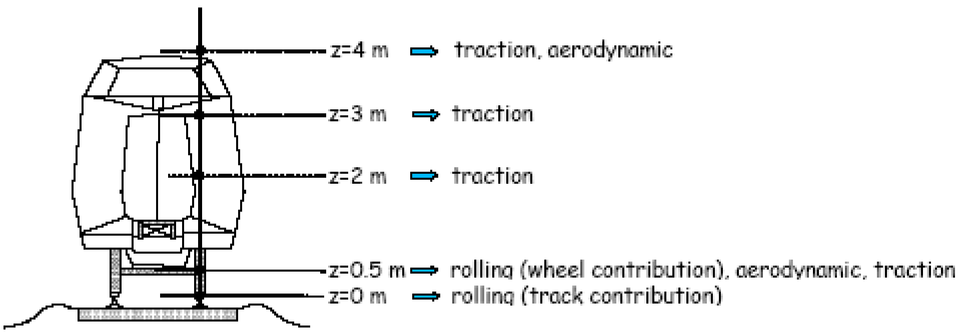

Figure 4: Location of sub-sources within one source.

The location of the sub-sources is chosen such that – as much as possible – a single point source represents a single noise generating mechanism. In some cases different sub-sources are combined within one source location (see figure 4).
For road vehicles, the lower point source clearly represents the tyre road noise and the upper one represents power train and exhaust noise. The scientific basis is not completely maintained, as tyre road noise is considered to be the combined effect of air pumping and mechanical roughness excitation, but as long as a reliable relation between noise output and operational parameters such as speed, tyre type, road surface type can be established, it was considered acceptable to combine the different generating phenomena into one source. The location of the sources in terms of vertical

and lateral direction was chosen such that it is as close as possible to the “real” location of the noise source relative to the road or railway longitudinal axis.

The work carried out in Work Package 1 concentrated on assessing the influence of the different parameters on the sound power radiated by the source. This influence forms the basis for a categorisation structure of vehicles and road and rail surfaces. For some parameters, the dependency relations could be derived from existing state of the art prediction methods. In other cases, tests were carried out either in full scale or in simulation models to clarify the appropriate dependencies. As a result of these experiments, some parameters could be deleted as they were found to be irrelevant.

4. Project results and achievements

4.1 Scientific/technological quality and innovation

4.1.1 Road sources

The source model for road vehicles is a great step forward compared to current prediction models. The most important new features are the separation of rolling noise and propulsion noise and the specification of source heights and directivity.
5 different vehicle categories have been defined, each represented by 2 point sources at different heights, each point source having its own directivity characteristics. These data refer to a reference condition defined by a constant speed, a specified road surface and a specified temperature. For conditions different from the reference conditions, corrections are given for temperature, road surface, acceleration/deceleration, road surface wetness and winter tyres.
[lit: see deliverables table (paragraph 5.1): D7, D8 and D9]

4.1.2 Rail sources

For rail noise, three main noise sources are distinguished: traction noise, rolling noise and aerodynamic noise, which have been distributed over 5 source heights. This means that some source heights combine two or three noise generating mechanisms.

The source model for rolling noise has been innovated structurally by the separation of the excitation mechanism (roughness) and the system response. The more physical description of the excitation mechanisms, based on the separate characterisation of the wheel and track roughness, and system response greatly improves the predictive power of the model. First because it facilitates an accurate description of the roughness, and the changes of roughness in time (e.g. maintenance) and place. Second, by separating the system response in a vehicle part and a track part, the noise generated by any vehicle on any track can be calculated without having to measure each possible combination.

Another important result is a database format, which couples the rail and vehicle parameters to the traction, rolling and aerodynamic noise levels. Even though the model may be complex at some points, the application of this model in noise mapping software is straightforward and is comparable with existing models.
[lit: see deliverables table (paragraph 5.1): D10, D11 and D12 and D13]

4.1.3 Reference model

The Parabolic Equation (PE) method forms the basis of the Reference model. In many cases the PE method will be coupled to a straight ray model or to the Boundary Element Method. A description of sound propagation through a turbulent or layered atmosphere has led to short-term noise levels for 25 meteorological classes. These short-term levels are combined with meteorological statistics to calculate long-term average noise levels.
[lit: see deliverables table (paragraph 5.1): D14, D15 and D16]

4.1.4 Engineering method

The engineering method is a flexible calculation method in such a way that is can be used both for detailed computations in case of noise assessment and for noise mapping.
The method calculates the short-term sound pressure level a at certain receiver position for different meteorological data. This means wind speed, wind direction temperature gradient and absolute temperature and humidity. This short-term sound pressure level per receiver position is calculated by incoherent summation over a number of point-to-point contributions and is weighted with the occurrence of each meteorological situation. Together with the day, evening en night period this gives the L_{den}.

Point-to point calculation is possible by segmentation of the source line. The viewing angle for each source segment is relatively small and the Fresnel zones approach guarantees that the possible errors are very small and acceptable.

Contributions from ground reflections and other diffracting obstacles like barriers are determined by the use of Fresnel zones around the reflection points between source and receiver. The method of Fresnel zones has been adopted from the Nord 2000 method and has been extended to reflecting obstacles. The size of the zone depends on the wavelength of the sound. The model includes multiple screening by using the most efficient edges of each screen.
[lit: see deliverables table (paragraph 5.1): D17 and D18]

4.1.5 Data Collection

The data for road traffic are in the form of half hour equivalent noise levels, where the presumption was that the weather conditions would be fairly stable within one meteorological class for each half hour. For railway train pass by measurements have been collected using the corresponding average half hour weather conditions.
The field experiments do not allow assessment of a true L_{den}, as the field test did not last long enough to be representative for a full year. But the half hour results have been analyzed in terms of applicable meteorological class and then integrated into an equivalent noise level for the duration of the field test.

4.1.6 Validation

Measurement data from road and rail traffic have been collected at an extensive measurement campaign at selected locations in Europe to demonstrate the validity of the reference model. Not only acoustic data are measured, but also meteorological quantities and the ground impedances. The meteorological quantities and the ground impedance are used as input in the sound propagation calculations with the Reference model. The sound levels measured at the microphone position closest to the source are used to assess the sound power level of the source.
The Reference model has been compared to measured sound levels for receiver distances up to 1200m. These comparisons have been performed for short-term sound levels, and for Lden and Lnight determined over the entire measurement campaign.
The validation of the Reference model included 9 measurement campaigns at 6 locations with a large variety of propagation and terrain conditions. The validation of the

Engineering model comprised 5 measurement campaigns at 3 locations with flat terrain conditions.
From the comparisons with the measured results it appeared that the agreement between the Reference model results and the measurements ranges from fairly good in hilly terrain with the road on a viaduct up to excellent in flat terrain. This conclusion encompasses road traffic noise, railway noise and point sources (loudspeaker).

The comparisons between the Engineering model results and the measurements showed excellent agreement for road traffic noise over flat terrain, but the agreement was less convincing for railway noise over flat terrain. Hilly terrain conditions and point sources were not included in the Engineering model validation.
[lit: see deliverables table (paragraph 5.1): D21]

4.1.7 Detail versus default

The very detailed approach has notably affected the opinion of end users with respect to the project; it was often expressed as a criticism that the methods developed in Harmonoise were far too complex and detailed to be practicable. It is therefore important to stress that the level of accuracy of the calculation depends on the user. It was felt that it should be made clear to the end user, what the level of inaccuracy is that is necessarily introduced by using „average“ or default values.

<u>*Example*</u>
if a user of the method is capable of collecting very detailed data of the vehicle flow over the day and over the vehicle categories, and possibly over the different lanes of the highroad, then the prediction can be very accurate, but at the cost of significant effort in collecting the data. If the user is not willing to collect that information, then he will have to accept a lower level of accuracy of the method.

The advantage of the Harmonoise methods compared to other existing methods is the fact that this choice is now made clear and left to the end-user.

4.1.8 Dissemination

The success of the Harmonoise method depends on the acceptance of the method among the end-users. To achieve good acceptance, actions have been performed like conferences, workshops, active communication with the WG-AEN, an active project web site and newsletters to the end-users. The acceptance is measured by questionnaires to the end-users.

A list of 400 e-mail addresses of end-users has been composed, can be divided into three main groups:

- Members of the Working Group on the Assessment of Environmental Noise (WG AEN
- Civil servants in the environmental ministries of the EU Member States
- Other future users like consultants, specialists, scientists, developers of software and civil servants in local governments.

4.2 Community added value and contributions to EU policies.

At least 25% of the EU population suffers from a reduced quality of life due to noise induced annoyance. The annual damage in the EU due to environmental noise is estimated to an amount between 13 and 38 billion Euro. In 1999 the Council recognized noise as one of the most urgent areas for action in the integration of Environment in the Transport Policy.
The harmonised methods for the assessment of environmental noise represent a major element in the future legislative system, where activities such as noise mapping, noise zoning and the design and evaluation of noise reduction plans will be carried out by noise consultants, road, railway and airport authorities, local authorities and governmental organisations in all member states.

4.2.1 European dimension of the problem

At the start of the project, each Member State was free to use their own noise prediction method. These national calculation schemes, if available at all, differ much with respect to reliability and accuracy. All available methods were considered inappropriate by WG3 of the EC noise steering group to serve as European standard. By delivering harmonised accurate and reliable methods, the Harmonoise project directly addresses the need expressed by the WG3 group and the Environmental Noise Directive.

4.2.2 Contribution to policy design or implementation

The Environmental Noise Directive requires the situation of environmental noise of many European citizens be assessed. Mapping of agglomerations of substantial size will be carried out by the member states. The first part of the mapping activities will be done using actual or interim methods. For the later part of the mapping activities, the use of the harmonised methods will be compulsory.

4.3 Contribution to Community social objectives

4.3.1 Improving the quality of life in the Community

The harmonised methods, when applied in all member states, will provide the European Citizen with the possibility to be informed about his present and future noise exposure, expressed in terms of the new harmonised indicators L_{den} and L_{night}. Thanks to these harmonised indicators it will be possible to attribute the total noise exposure to the contributions of different source types, such as road traffic, rail traffic, aircraft and industries. The citizen will be able to compare noise levels due to different sources (road, railway, industry, aircraft,…) and to compare his situation with that of other citizens all throughout Europe. And finally he will be able to judge the efficiency of the noise abatement plans that his local authority has set up for him. With this information he will be better equipped to work on his local authorities and defend his own interests.

4.3.2 Provision of incentives for creating jobs in the Community

Apart from the work directly related to implementation of the harmonised methods into software, the mapping activities and the presentation services for noise maps, the following incentives for employment are foreseen:

- consultancy services related to above activities

- work related to noise abatement (development and construction of measures)
- work related to noise prevention (research and development of components for silent future traffic)
- work related to traffic flow management

4.3.3 Supporting sustainable development

Once the environmental noise exposure has been assessed and presented to the citizens, it is obvious that action plans will be developed to control, or more likely to reduce the impact.

4.4 Economic development and S&T prospects

As for each of the results identified more than one partner is involved, it is likely that some partners with complementary expertise will keep on co-operating after the project during commercial exploitation. Also, as expertise is not equally spread between partners from different Member States, co-operation can be expected between partners that work in the same field but in remote countries.

4.5 Relations and synergies with other relevant projects

4.5.1 Imagine

http://www.imagine-project.org/
In the Imagine project, started December 2003, the Harmonoise methods will be extended to application in the field of aircraft and industrial noise. Also, in Imagine, the implementation of the Harmonoise methods is taken forward, particularly with respect to the collection of input source data. Guidelines for GIS formats and for the application of measurement methods as an add-on to computational methods will be elaborated. As an important step for action planning in urban environments, the link with traffic flow and demand models will be established. Details of these different scopes are treated in other presentations in this same conference.
The Imagine project is partly funded by the European Commission, DG Research, under the 6th Framework Program (CT-2003-503549).
Common partners in both projects are many: AEAT, ARPAT, Autostrade, CSTB, DEBAKOM, DGMR, JRC, Kilde, M+P, SP, TNO, TRL.

4.5.2 SILVIA

http://www.trl.co.uk/silvia
Sustainable Road Surfaces for Traffic Noise Control is a Fifth Framework Project with the objective to provide decision makers with a tool allowing them to rationally plan traffic noise control measures, including low noise road surfaces.
A classification procedure is described to classify road surfaces in terms of tyre noise or noise reduction. Durability and sustainability of roads is tested and converted into monetary terms. Tyre design in combination with pavement, traffic management, driving conditions and other topics are studied.

Both Harmonoise and SILVIA improve the insight in effectiveness of noise reduction measures. The Harmonoise method facilitates to calculate the noise impact of the solutions. In SILVIA the durability of low-noise solutions is investigated and the solutions are compared to new construction and maintenance techniques. Thus focussing on the cost-effectiveness. Common partners in both projects are M+P and TRL, LCPC, VTI and TUG.

4.5.3 Rotranomo

http://www.rotranomo.com/

The Project ROTRANOMO elaborates a tool to calculate road related noise emissions in order to meet future standards of the EU Noise Directive "Assessment and Management of Environmental Noise" (Background). In two steps - first for big then medium-sized agglomerations - the noise exposure in urban areas will be regulated by demanding noise maps and action plans.

The Project approach has foreseen that a European Cities Advisory Group accompanies the Project in order to satisfy users requirements for the simulation tool. Core elements of the simulation tool are

- a detailed traffic flow model
- a detailed vehicle noise model

Rotranomo continues parts of the Harmonoise work by developing software calculation models for traffic flow and vehicle description, based on the more theoretical methods developed in Harmonoise and Imagine. M+P is common partner in both Rotranomo and Harmonoise.

4.5.4 HEAVEN

http://heaven.rec.org

HEAVEN stands for a Healthier Environment through the Abatement of Vehicle Emissions and Noise and is a RTD project of the Information Society Technologies (IST) Programme. This project addressed a common environmental problem: increasing traffic levels in large urban areas. HEAVEN's main goal was to strengthen urban environment and transport management, based on better access to air and noise pollution information.

Both HEAVEN and Harmonoise zoomed in to the environmental 'pollution' by traffic. Objectives of both projects are a better access to information and better base for action plans by the authorities. Exchange of information between Harmonoise and HEAVEN was possible via TRL. TRL was participating in both projects.

4.5.5 STAIRRS

www.stairrs.org

The STAIRRS project forms the basis for the source description of the Harmonoise method. In STAIRRS techniques were developed to separate the contribution of wheel and track to the total noise. By these means it would be possible to attribute separate responsibilities between infrastructure authorities and train operators in the operation of railways, provide assistance to designers of rolling stock and infrastructure and identify, for specific situations, where noise mitigation could most effectively be applied.

In Harmonoise, the techniques developed in STAIRRS have resulted in a source model for rail noise in which wheel and rail roughness and the track contribution have been described separately. For the road source model the separate contributions from

the tyres and the road surface have been studied, which has resulted in a separation of rolling noise and propulsion noise.
TNO, AEAT and SNCF were participating in both STAIRRS and Harmonoise, thus guaranteeing good agreement of the Harmonoise method with the STAIRRS principles.

4.6 Standardisation and maintenance

The main objective of the Harmonoise Project is to produce similar noise maps over all Europe. Different types of noise sources can be compared because the propagation model has been harmonised, and results from different Member States can be compared mutually.

All kinds of different end users will apply the methods in the near future. Their experiences may invoke the need to adjust the methods. It is recommended to install a working group for the maintenance of the source models, the source segmentation, propagation planes, the point-to-point model, the meteorological module. Errors and bugs can be corrected, revisions of the methods will need to be reported.
It is highly recommended that no part of the engineering method remains a "black-box". It is essential that every part of the engineering method can be checked by using the original formulas and algorithms, as depicted in deliverable D18.

For implementation and therefore *official publication* of the Harmonoise methods as noise computation methods for the European Union, three possible paths can be followed:

1. The Harmonoise methods can be described in a revised Annex II of the END.
2. Reference to the Harmonoise methods, available at a supported website, can be made in a revised Annex II of the END.
3. The Harmonoise methods can be proposed for CEN standardisation. Annex II should then only refer to these standard(s).

In the light of the fact that implementation is required directly after the first round of noise mapping, paths 1 and 2 are probably more easy to achieve for the short term. Nevertheless, CEN standardisation is recommended for the long term. A standard is preferred from the view point that the methods need maintenance and revision by the scientific and technical communities.

It is recommended that, apart from main project Deliverables, also the main underlying technical reports and core point-to-point model are made available.
The Harmonoise consortium has published most of these reports as well as the point-to-point model (dll-file + manual for software developers) on the Harmonoise website. After termination of the website, the CIRCA website of the EC may be an appropriate site for these reports.

5. Deliverables and other outputs

5.1 Table of deliverables

No.	Deliverable title	planned	reference* and title	Status	date
1	Project Presentation	T0+3	Harmonoise leaflet	Final	March 2002
2	Dissemination and use plan	T0+6	HAR70PM-020523-AEA03, Dissemination and use plan	Accepted at First Review	12 August 2002
3	Technology Implementation Plan	T0+36	HAR50PM-041104-AEA10	Final	21 December 2004
4	Final Report	T0+38	HAR7TR-030729-AEAT04	Draft	24 February 2005
5	Annual Report 1	T0+12	HAR70PM-020730-AEA10, First Annual progress report	Accepted at First Review	30 July 2002
6	Annual Report 2	T0+24	HAR70PM-030808-AEA10, Second Annual progress report	Final	November 2003
7	State of the art on road source description	T0+6	HAR11TR-020614-SP05 Source modelling of road vehicles	Accepted at First Review	2 August 2002
8	Categorisation of road vehicles, tyres and road surfaces	T0+12	HAR11TR-030108-VTI04 Vehicle Categories for Description of Noise Sources	Accepted at First Review	24 August 2003
9	Comprehensive method for road source description	T0+36	HAR11TR-041212-SP10 Source modelling of road vehicles	Final	12 December 2004
10	State of the art on rail bound sources	T0+6	HAR12TR-020118-SNCF10, Rail sources – state of the art	Final	5 August 2002
11	Categorisation of vehicles and track	T0+18	HAR12TR-021107-SNCF10, Categorisation of vehicles and tracks: overview and draft proposal	Final	4 April 2003
12	Definition of track influence, Part 1	T0+24	HAR12TR-020813-AEA10, Definition of track influence: Roughness in rolling noise	Accepted at Second Review	17 July 2003
	Definition of track influence, Part 2		HAR12TR-030403-AEA11 Definition of track influence: Track composition and rolling noise		23 July 2003
	Definition of track influence, Part 3		HAR12TR-030625-AEA11 Definition of other sources and influence of source measures	FInal	29 January 2004
13	Comprehensive model for rail bound source description, Part 1	T0+30	HAR12TR-040112-SNCF10 Railway source model and user manual of the database	Final	23 August 2004
	Comprehensive model for rail bound source description, Part 2		HAR12TR-031203-AEA12, Practical data collection for the Harmonoise source model: measurement guidelines and analysis	Final	21 June 2004
14	Choice of basic reference model	T0+12	HAR24TR-021018-TNO10, Choice of basic sound propagation models	Accepted at Second Review	12 December 2002
15	1st implementation of basic reference model	T0+24	This is rather a milestone than a deliverable	Agreed that mile-stone is reached	Second annual review
16	Validated reference model	T0+36	HAR29TR-041118-TNO10	Final	22 December 2004
17	Integrated model available	T0+24	HAR32TR-030715-DGMR10, Engineering method for road traffic and railway noise	Final	25 February 2004
18	Integrated model validated	T0+32	HAR32TR-040922-DGMR20	Final	20 January 2005
19	Database of available data	T0+6	Letter DeBAKOM to the Commission	Accepted at Second Review	4 November 2002
20	Measurement results available	T0+27	Database VI	Final	Approved by EC 3 June 2004
21	Validation of integrated model	T0+36	HAR28TR-041109-TNO20	Final	24 February 2005
22	Project web site	T0+6	www.harmonoise.org	Continuously updated	2002 - 2005
23	Seminar	T0+12	Euronoise 2003 Naples		May 2003

5.2 Description of major project deliverables

No.	Deliverable title	Description
1	project presentation	Folder of the Harmonoise Project including a description of the partners and links to the web-site and the IST. Project objectives, key issues and expected achievements are described. The folder has been distributed at conferences, workshops and congresses.
2	dissemination and use plan	Describes ways to disseminate the Harmonoise results to the future users by open conferences, seminars and workshops organised by the consortium, publications and the web-site. The use and market of the main deliverables are described.
3	technology implementation plan	A Framework for the further development, dissemination and use of the results of the Harmonoise Project.
4	final report	An overview of the Project objectives, approach, main results and deliverables as well as the management aspects and further use and exploitation.
5	annual report 1	Overview of Year 1 of the project, including the objectives and progress per work package, contract arrangements and issues like meetings and dissemination.
6	annual report 2	Overview of Year 2 of the project, including the objectives and progress per work package, contract arrangements and issues like meetings and dissemination.
7	state of the art report on road source description (WP 1.1)	State of the art of actual road source methods in Europe and the United States. Concluding with a proposal for the Harmonoise road source model.
8	categorisation of road vehicles, tyres and road surfaces (WP 1.1)	Proposal for vehicle categorisation in Harmonoise including main- and sub-categories. The choice for many categories depends on the balance between the desires for high accuracy and practical use.
9	comprehensive methods for road source description (WP 1.1)	Description of the road source model.
10	state of the art report on railbound sources (WP 1.2)	State of the art of actual rail source methods for rolling noise, aerodynamic noise and traction noise. in Europe and the United States. Concluding with a proposal for the Harmonoise rail source model.
11	categorisation of vehicles and track (WP 1.2)	Overview of the different categorisations that already exist in calculation schemes and those which have been provided by the STAIRRS project. The report summary is a starting point for a categorisation proposal that will be further detailed in the database structure and conclusions on sources knowledge by WP1.2.
12	definition of track influence (WP 1.2)	Part 1: This report deals with the present day knowledge of roughness in relation to noise and a proposal for practical implementation in the Harmonoise model. Part 2: Track categories are defined on the basis of TWINS modeling. Part 3: Definition of other sources, like bridges and rail joints. Implementation of source measures.
13	comprehensive model for railbound source description (WP 1.2)	Railway source model and user manual for the rail sources database.
14	Choice of basic Reference model (WP 2)	An overview of the state of the art in propagation modelling and a description of the Benchmark tests. Selection of the basic sound propagation models for the reference model.
15	1st implementation of basic Reference model (WP 2)	Description of the basic reference model, choices and approach.
16	validated Reference model (WP 2)	Description of the reference model, finalised after the validation.
17	integrated model available (WP 3)	Description of the engineering model, choices and approach. Source segmentation, propagation, reflection, meteorological situations and field of application.
18	integrated model validated (WP 3)	Description of the complete engineering model, finalised after the validation and fine tuning.
19	database of available data (WP 4)	Letter of WP4 to the Commission about the database and available data.
20	measurement results available (WP 4)	Large database with measurement results and site descriptions.
21	validation of integrated model (WP2-3-4)	Description of the validation process and comparison of results of measurements. reference model and engineering model.
22	project web site (WP 5)	www.harmonoise.org
23	seminar (WP 5)	A Harmonoise Seminar at Naples, May 2003, about the Project results and the EU mapping purposes.

5.3 Table of technical reports

ref	Project doc reference	Title	date	Deliverable
[1]	*HAR1MO-020220-SP01*	*The directivity of the sound power from a moving source*		
[2]	*HAR11MO-020201-SP01*	*Measuring height; available Nordic data; Data format for reporting measurements*		
[3]	*HAR11TR-020131-TRL01*	*Review of methods for measuring height and power of sub-sources*	*31 Jan 02*	
[4]	*HAR11TR-020226-TUG01*	*Tyre/road measuring methods*		
[5]	*HAR11-TR020228-TRL01*	*Test Methods for power train noise*	*28 Feb 02*	
[6]	HAR11-TR020301SP07	Test method for the whole vehicle		D8
[7]	*HAR11-MO020410-TNO01*	*Test method for the whole vehicle*		
[8]	*HAR11TR-020513-MP01*	*Source description formulae*		
[9]	HAR11TR-020614-SP02	Source modelling of road vehicles	2 August 2002	D7
[10]	HAR11TR-020701-TUG02	Localisation of tyre/road noise source and relation between sound pressure and sound power measurements	27 Nov 02	
[11]	HAR11TR-020614-SP09v8	Source modelling of road vehicles	draft December 2004	D9
[12]	*HAR11TR-020901-TUG02*	*Influence of road surface wetness on tyre/road noise, part 1*	*4 Nov 02*	
[13]	HAR11TR-021030-TUG02	Influence of road surface wetness on tyre/road noise, part 2	6 Dec 02	
[14]	*HAR11TR-021214-TUG01*	*Modified formulas describing noise sources*	*14 Dec 2002*	
[15]	HAR11TR-030108-VTI04	Vehicle categories for Description of noise sources	14 Jul 03	
[16]	*HAR11TR-030116-VTI04*	*Road Surface categorization and Correction in Harmonoise – basic considerations*	*21 July 2003*	
[17]	HAR11TR-0212231-TRL04	Comparison of methods for measuring power train noise		
[18]	HAR11TR-030516-VTI05	Road surface categorisation		
[19]	HAR11TR-030116-MP02	Background data for source description		
[20]	HAR11TR-031110-TUG01	Tyre/road noise on paving stones		
[21]	HAR11TR-030829-TUG01	Slip influence on tyre/road noise (3 reports)		
[22]	*HAR12MO-020220-SP02*	*Test method for a whole train*		
[23]	*HAR12MO-020220-SP03*	*Additional state of the art information about source models*		
[24]	*HAR12MO-020220-SP04*	*Diesel locomotive noise – an example of source localization*		
[25]	*HAR12MO-020621-TNO01*	*Global overall model for vehicle and traffic noise emission (draft)*		
[26]	HAR12TR-020118-SNCF10	Rail sources - State of the art	Final	D10
[27]	*HAR12TR-020807-DB01*	*Vehicle Description, MAT2S simulations*	*8 Jul 02*	
[28]	HAR12TR-021107-SNCF10	Categorisation of vehicles and track: overview and draft proposal	21 Mar 03 Final	D11
[29]	HAR12TR-020813-AEA10	Definition of Track influence: roughness in rolling noise	17 July 2003	D12, part 1
[30]	HAR12TR-030403-AEA11	Definition of Track Influence: Track composition and rolling noise,	23 July 2003	D12, part 2
[31]	HAR12TR-030625-AEA10	Definition of other sources and influence of source measures	29 January 2004	D12, part 3
[32]	*HAR12TR-030401-AEA01*	*Source model for rail bound sources: a comprehensive model for rolling noise*	*1 January 2003*	
[33]	HAR12TR-020905-SP01	To determine the horizontal directivity of a train pass-by	5 September 2002	
[34]	HAR12TR-021206-SNCF10	Definition of a simple model of sources for the TGV-R		CO
[35]	HAR12TR-030619-SP01	The modelling of source heights for railway rolling noise		CO
[36]	HAR12TR-030618-SNCF10	Assessment of the effects of source position in the presence of barriers		CO

[37]	HAR12TR-031031-SP10	Directivity of railway noise sources		CO
[38]	HAR12TR-020910-SP10	Measurement directivity on test rig		CO
[39]	HAR12TR-030530-SP01	Railway traction noise, the state of the art		
[40]	HAR12TR-030731-SNCF01	Examples of traction noise data		
[41]	HAR12TR-03071-TNO10	Modelling of railway traction noise for input to rail traffic noise model		CO
[42]	HAR12TR-030828-SNCF10	Aerodynamic noise		CO
[43]	HAR12TR-031201-KILDE10	Guidelines for using the results of rail vehicle pass-by measurements as source data in Harmonoise		CO
[44]	HAR12MM-041401-AEA01	A practical method to calculate the sound power of the vehicle and the track using Leq of pass-by measurements		
[45]	HAR12TR-040112-SNCF10	Railway source model and user manual of the database		D13, part1
[46]	HAR12TR-031203-AEA11	Practical data collection for the Harmonoise source model, measurement guidelines and analysis		D13, part 2
[47]	*HAR02MO-020104-TNO01*	*Set up of the Reference model*		
[48]	*HAR02TR-020121-CSTB02*	*NMPB-96 Road traffic noise, new French method for outdoor sound propagation, complete document*		
[49]	*HAR21MO-020214-TNO01*	*Specification of the source description by WP1, suitable as input for the reference propagation model of WP2*		
[50]	*HAR21MO-020116-TNO01*	*Calculation of traffic noise levels*		
[51]	*HAR21TR-011122-TNO01*	*Definition of the physical problem*		
[52]	*HAR21TR-020204-TNO01*	*Calculation of traffic noise levels*		
[53]	*HAR21TR-020204-TNO02*	*Traffic noise levels near the driving line*		
[54]	HAR22TR-020220-TNO11	State of the art of modelling	Final	
[55]	*HAR22TR-020711-TNO01*	*Non-physical behaviour Delaney and Bazley model*		
[56]	HAR23TR-020222-TNO01	Benchmark calculations and modeling approximations		PU
[57]	HAR24TR-021018-TNO10	Choice of basic sound propagation models	12 December 2002	D14
[58]	*HAR25MO-020723-DLR01*	*On a meteorological classification for long term noise calculations*		
[59]	HAR25TR-021104-TNO10	Modeling solutions and algorithms	9 December 2004	PU
[60]	*HAR25TR-030311-CSTB01*	*3D effect of some barrier tops*	*11 March 2003*	
[61]	*HAR25TR-030313-CSTB01*	*Methodology for the integration of 3D barrier top*	*13 March 2003*	
[62]	*HAR25TR-030317-CSTB01*	*Reflections with a complementary Kirchhoff approximation*	*17 March 2003*	
[63]	*HAR25TR-030314-SP01*	*Impedance*	*14 March 2003*	
[64]	*HAR25TR-030318-CSTB01*	*Coupling of models (BEM-GFPE)*	*18 March 2003*	
[65]	*HAR26MO-030708-TNO01*	*Test cases for calculation of Lden*	*8 July 2003*	
[66]	HAR26TR-031113-TNO02	Computation scheme of the Reference model		PU
[67]	HAR26TR-031113-TNO10	Test calculations of day-evening-night levels	14 December 2004	PU
[68]	HAR29TR-041118-TNO10	Description of Reference model	22 December 2004	D16
[69]	HAR28TR-041109-TNO10	Validation of the Harmonoise models	22 December 2004	D21
[70]	HAR20MO-041206-TNO01	Treatment of urban situations in the Harmonoise Reference Model	6 December 04	
[71]	*HAR3MO-020129-SP01*	*Integration of point sources*		
[72]	*HAR3MO-020301-SP01*	*Handling ground altitude variations*		
[73]	*HAR31TR-020725-CSTB01*	*Methodology for the calculation of the occurrences of meteorological conditions unfavorable, homogeneous and favorable to sound propagation outdoors*	*25 July 2002*	
[74]	*HAR31TR-020731-SP01*	*Propagation paths, point source integration, impedances and source heights*	*31 July 2002*	

[75]	*HAR30TR-021220-SNCF01*	*Description of source model railway traffic*	*DRAFT*	
[76]	*HAR30TR-030113-DGMR01*	*The engineering model, definitions*	*13 January 2003*	
[77]	*HAR31TR-030129-DGMR*	*Propagation paths and reflections*	*29 January 2003*	
[78]	*HAR31TR-030416-CSTB01*	*A simple approximate method for the calculation of diffraction by a straight barrier*	*22 April 2003*	
[79]	HAR32TR-030715-DGMR06	Engineering method for road traffic and rail traffic	*DRAFT*	D 17
[80]	HAR34TR-040730-DGMR10	Harmonoise WP3 statistics and accuracy	*29 October 2004*	PU
[81]	*HAR04MM-011120-dBA01*	*Definition of the task*		
[82]	*HAR04TR-020110-dBA01*	*Technical Report on Database for data collected by WP4; Documentation of the Database*	*10 Jan 2002*	
[83]	*HAR40MO-011220-SNCF1*	*site selection and type of measurements to be performed in the WP4*	*20 Dec 2001*	
[84]	*HAR40MO-020328-TNO01*	*Remarks with respect to the structure of the database*	*28 March 2002*	
[85]	HAR40MR-030121-dBA01	Measurement report; Road noise in Ladenburg and Uttrichshausen, Rail noise in Twistringen	6 March 2003	PU
[86]	HAR40PR-030205-LCPC10	Progress report no. 1 covering experiments on the La Crau site, 18-24 October 2002	Final, 5 February 2003	PU
[87]	HAR42TR-011105-DLR01	Summary of boundary layer meteorology and atmospheric meso-scale effects relevant to sound propagation outdoors	5 Nov 2001	
[88]	HAR04MO-030127-dBA02	Description of database; version 1		PU
[89]	HAR04MO-030708-dBA01	Description of database; version 2		PU
[90]	HAR40TR-040401-ARPAT10	Measurement report		PU
[91]	HAR40TR-040927-ARPAT10	Changes to the measurements database		
[92]	HAR40PR-030205-LCPC10	Progress report n°1. Technical report from 2 experimental campaigns at La Crau (F) including protocol, procedure, photos, etc.		
[93]	HAR40PR-040112-LCPC10	Progress report no. 2. Technical report from 1 experimental campaign at Vada (I)	12 January 2004	PU
[94]	HAR40PR-040131-LCPC10	Progress report no. 3. Technical report from 2 experimental campaigns at St Berthevin (F)		
[95]	HAR40PR-040930-LCPC10	LCPC Final report: technical report from 5 experimental campaigns at La Crau (F), Vada (I) and St Berthevin (F)		
[96]		Letter to European Commission on comments Annual Review no. 1: comments to the database and available data	4 November 2002	Approved by EC
[97]	HAR60TR-030813-AEA01	Evaluation report WP 6	15 August 2003	
[98]	HAR60TR-040820- AEA01	Second Evaluation report, Project acceptance among the end-users	20 August 2004	
[99]	Project web site	www.harmonoise.org		D22
[100]	Project presentation	Harmonoise project leaflet	Final	D1
[101]	HAR70QL-011221-AEA02	Quality Procedure (4 parts)	Final	
[102]	HAR70PM-020730-AEA10	First Annual Progress Report	30 July 2002	D5
[103]	HAR70PM-030808-AEA10	Second Annual Progress Report	November 2003	D6
[104]	HAR70PM-020523-AEA03	Dissemination and Use Plan	12 August 2002	D2
[105]	HAR50PM-030610-AEA03	Technology Implementation Plan, Preliminary version at mid-term	Final	
[106]	HAR50PM-041104-AEA10	Technology Implementation Plan, Final version before final term	Final	D3
[107]	HAR70MO-030429-AEA10	Links between work packages	29 April 2003	
[108]	HAR70TR-030709-AEA02	Position Paper	1 August 2003	
[109]	HAR70PM-020731-AEA01	Concise Activity Report Year 1	August 2002	
[110]	HAR70PM-030810-AEA01	Concise Activity Report Year 2	August 2003	
[111]	HAR70TR-030729-AEAT02	Final Report	Draft, December 2004	D4

5.4 Workshops, congresses and conferences

Date	*Type and Title/Scope*	*Number of persons attended + other information*
August, 2001, The Hague	Internoise 2001 conference	Paper presented by AEA
7&8 November, 2001	National congress on noise and vibration, Rotterdam	Paper presented by AEA
	IST workshop, Brussels	Participated by AEA
7 December 2001	Heaven workshop, Paris	Participated by AEA
7 July 2002	Schall 03 meeting, München	Participated by AEA
September 2002	Forum Akustikum in Sevilla (E)	Participated by DGMR
August 2002	Internoise 2002 in Detroit (USA)	
November 2002	NAG-conference (NL)	Presentations by TNO, AEA, DGMR, DLR
September 2002	LRSP in Grenoble (F)	Presentation given by TNO on WP2
18-20 March 2003	DAGA in Aachen (D),	Special session on Harmonoise (9 presentations), 100 attendees
24 March 2003	IST Concertation meeting, Brussels	
19-21 May 2003,	Euronoise, Naples,	Special Harmonoise session, 10 presentations, appr. 60 attendees
29-30 October 2003	ARPA Piemonte Symposium, Torino	Presentation on Harmonoise
12-13 November 2003	National Congress on noise and vibration, Nieuwegein, the Netherlands	Presentation on engineering methods Harmonoise
24 November 2003	WG-AEN	Presentation of the Engineering Method
4-9 April 2004	International Congress on Acoustics, Kyoto, Japan	Presentation on Harmonoise
22-25 Aug 2004	Internoise 2004, Prague	Special Session on Harmonoise
21-22 October 2004	Harmonoise Final Conference, Rhodes	Presentations of all WPs in the context of the END, workshop on noise mapping and action planning.
18 – 20 January 2005	4ièmes Assises Nationales de la Qualité de l'Environnement Sonore", Avignon	18/1/2005: Workshop on Harmonoise and the implementation of the END, organised by CSTB/SNCF/LCPC.

6. Project management and co-ordination aspects

6.1 Performance of the consortium and individual partners

Consortium Agreement and protection of knowledge

A consortium agreement has been drafted at the start of the project, during the phase of contract negotiations. This Agreement was based on the standard provided by the Commission. A table with foreground and background knowledge was to be assembled from contributions of all partners. Due to lack of interest of partners, the consortium failed to complete the table.
In the final year, on 20 July 2004, another attempt by email was made to conclude an agreement based only on IPR matters (as the main part of the agreement is only of interest during the course of the project). Less than 50% of the partners expressed interest, and the attempt was cancelled.
The generally feeling is that partners were not to concerned about legal matters, but were fully engaged with the scientific contents of the project. Also, realising that Harmonoise provides methods for *public* use, the reports and data delivered were generally considered to be publishable.

Full Consortium and Steering Committee meetings

month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Full Consor-tium																																				
Steering committee																																				
WP meetings				A	D		H	O	C		T	O		B	E		D	E	C	I	D	E	D		B	Y		W	P	L						

The Full Consortium meetings have been organised on a 12 months basis.
The Steering Committee meetings were organized 6 months after every Full Consortium meeting, to review the overall progress of the project, will survey possible problems and decide on ways to encounter these. The Steering Committee was mainly responsible for the relation between work packages, both in content and timescale.

Quality Assurance

A Quality Assurance Manual has been agreed upon by all the participants and has been made available to all participants. It describes relevant procedures in the project and provides relevant documents. The QA Manual also provides standards for digital files, versions of software to be used, file naming, archiving, etc. The Quality Assurance Manual was attached to the Consortium Agreement in order to achieve general agreement with the procedures from all partners.

Project Management

For the purpose of project management special software has been used (MS-project) which enabled to monitor progress, cost development, planning, milestones etc. Special progress reporting sheets have been distributed and collected from the partners to feed the software.

6.2 Possible problems encountered and solved

Contract amendments

Five contract amendments appeared necessary during the course of the project. Amendment 1, 2 and 4 were mainly related to changes of legal names of partners and transfers of budget between different categories. The Technical Annex did not change with these amendments. Amendment 3 was a contract prolongation (6 months), see section below.

The fifth amendment, agreed close to the end of the contract, was a "soft" amendment which concentrated on corrections in the Technical Annex. The main changes were in the Table of Deliverables (correct titles and confidentiality level), and the Annex A with legal names of partners.

Communication and document flow

A Harmonoise website, installed in an early stage of the project (WP5), plays an important role in reporting and communication. It has two parts: one part with limited access (participants only) presents information on the progress, on coming events (meeting dates), minutes of meeting, technical reports, a reference list, etc. and contains the text of the consortium agreement and the QA-manual, including forms to be downloaded and used by the participants. Another part is open to any visitor and provides information about the project, its objectives, the participants and the work programme.

Contract Prolongation

At the beginning of Year 3 of the project, it appeared inevitable to request for a contract prolongation. A delay of several months was expected due to late delivery of the WP1.2 railway source model (input to WP3), the WP4 database with field measurements (input to validation process), and problems in development of the test software (WP3). At the Steering Committee of February 2004 (all WP-leaders), it was agreed to request for 3 months delay. After consultation of the Project Officer, who declared that at maximum 6 months delay would be possible, the maximum prolongation was concluded to avoid another amendment if 3 months would appeared not enough. This was not directly communicated with the partners in order to keep the pressure high.

The extra time has been used for a proper validation of the Reference and Engineering models. During this extra time, many partners had to allocate extra resources because budgets limits were reached soon. Thanks to large efforts of all partners involved the project could be eventually be finalised after 42 months.

7. Outlook

7.1 Implementation and exploitation of results

The results of the Harmonoise project will be exploited by the partners in various ways. The following five results have been defined in the Technological Implementation Plan:

1. Acoustic source modelling of road vehicles
    - Initial database with source parameters
    - Measurement procedures
2. Acoustic source modelling of railway vehicles
    - Database structure
    - Measurement procedures
3. Reference computation model
    - Several advanced computation algorithms
    - LDEN computation scheme (recipe + flow-chart)
4. Engineering computation model
    - Description of engineering model (algorithms, D18, free)
    - P2P model + test data (free)
    - Testing software to evaluate performance of Engineering method (restricted consortium)
5. Database of field measurement data
    - Database with field data from 15 situations (site and season)

The main future activities of the partners, in relation to the experience and knowledge gained in the project, are:

- Noise mapping (producing noise maps for the first round, anticipating on the Harmonoise approach)
- Consultancy (for government and other bodies responsible for implementation and execution of the END)
- Training and education (e.g. for offices that carry out noise mapping)
- Research (e.g. for further development of the methods, and also for future noise mitigation policies resulting from the END)
- Software development (of the Harmonoise source analysis methods and Engineering model)

While Harmonoise developed the methods, the IMAGINE project (FP6, DG Research) will provide guidelines, examples and default values that are necessary for practical implementation and application of the Harmonoise methods in the Member States. This project is therefore considered as a successor of the Harmonoise project.

7.2 Evaluation

The value of Harmonoise for the project partners is perhaps proved best by the fact that 13 out of 19 original Harmonoise partners participate now in IMAGINE. An evaluation per partner is given below.

CSTB
CSTB has been carrying out research in traffic noise prediction since a long time. CSTB was also a major actor in writing down the French NMPB methods.
Comparing, sharing and combining our experience with partners having participated in similar actions in other countries was the major challenge for us in the HARMONOISE project, and, I really think, it worked out as expected: through hard discussions, fine argumentation, search for deeper insight and - most of all - a constant will to cooperate, this project resulted in a new milestone being added to the scientific progress in the domain of noise prediction and - hopefully - reduction.

KILDE
Our motivation for joining Harmonoise was that KILDE Akustikk AS shall continue to serve private and public customers by combining knowledge of state-of-the-art acoustics with practical problem solving. KILDE is a SME specializing in acoustics and noise control. The firm employs 10 experienced professionals, providing consulting services as well as running technical courses, developing practical tools for noise planning and -reduction, and creating planning guidelines and handbooks. With our practical/theoretical background, we have in Harmonoise tried to focus on making the calculation and measuring procedures as simple as possible without loosing too much accuracy.
Harmonoise has provided a good environment for development of new ideas and methods. In afterthought, the balance between the weighty theoretical aspects and the more lightly covered practical aspects could have been better. However, this was closely related to background of the participants.
Our overall assessment after 3 years is clearly positive
- we have learnt a lot and are updated in our main fields, and it seems that our (relatively small) contribution may have been useful to other partners
- we have established valuable contacts for future co-operation
- we are equipped to provide Norwegian authorities with information about Harmonoise results and future EC practices, and to develop new national noise reduction and planning tools.

TRL
TRL expected to be able to develop parts of the Harmonoise model and use the model once the project had been completed.

This has been mainly realised. We have contributed to many aspects of the Harmonoise model and are generally pleased with the overall result. We are able to use the point to point propagation program without restriction and have access to the source model. The full Harmonoise model is offered as a "demo" version without all the functionality. We would of course have preferred to have the complete model freely available to Harmonoise partners but we are aware of the extra costs incurred in producing this product that were not covered by the EC.

VTI
VTI took part in HARMONOISE in order to provide its competence and experience on the noise sources of road traffic; especially that of the tyre/road interaction. We hoped that our contribution could aid in making HARMONOISE a good procedure useful for us and others in the future and also make sure that the procedure takes into account special conditions that may occur in the Nordic countries. At hindsight, we believe that we were able to give an input at large in line with the plans, and that HARMONOISE has become the foremost traffic noise model, thanks to the work of all partners. Our work, which included several experimental activities, in combination with the work of other partners,

have given us new knowledge and experience which will be useful in the future. Finally; it has also been exciting to work together with so many competent colleagues in this project.

DB

The requirements in our acoustic group have changed. At the phase of the proposal the acoustic group was divided in one part working for noise emission and a group working on noise immission.

- the emission group decided to work on HARMONOISE
- the immission group decided to watch what was going on in HARMONOISE.

The immision group is working on a new Schall 03 which will be finished this year. The Schall 03 will be the valid German "Directive for the calculation of noise immission of the railway" for the future. How long it will be valid one does not know - the impact of HARMONOISE one does not know. It is not important that something new has to come - it is only important to react in the right manner if something new would come.

What is important for us to know is the influence of HARMONOISE on
- noise mapping
- noise action plans
- a new directive which will replace the Schall 03
- new methods which have to be used for the description of noise sources

SP

We joined the project for two main reasons: One was that we need big projects to finance our research and taking part in European projects normally makes it easier to acquire national research funding. The other reason was that Harmonoise was a kind of follow-up of Nord 2000 and we wanted to be able to influence Harmonoise in such a way that the great efforts spent on Nord 2000 were not in vain. We also have the ambition to remain in the frontline of research concerning prediction methods for environmental noise.

As far as we see it the result has fulfilled our expectations. Thanks to Harmonoise we received several additional national project funds and Harmonoise also led to Imagine, which is leading to similar results. Swedish national funding has already tripled our EU money in Imagine. Professionally we have benefited by increasing our competence considerably, particularly in acoustic source modelling of trains and road vehicles.

TNO

Original expectations: In a densely populated country like the Netherlands noise abatement problems often require a more sophisticated approach in propagation modelling than can be offered by most of the engineering modelling tools. Usually it was the task of TNO to develop methods for this demand, which provided TNO with a rather unique position in the market for noise propagation computations. Based on this consideration TNO decided to participate in Harmonoise and to concentrate on the development of the Reference Model. The expectation was that investing research budgets in this development would result in a future more European based position as a centre of expertise for non-routine noise propagation questions from road authorities, railway companies and governmental institutions.

Evaluation of achievements: The development of a new Reference Model for noise propagation has succeeded. TNO indeed has proven that it is capable of leading a European development in the field where it was already active on a national scale. Also

TNO has demonstrated its position among a small number of institutes in Europe that can handle the sophisticated models intended for in-depth study of noise propagation problems for traffic noise. It is too early to assess the marketing effects of this development and the influence it may have on the volume of commercial activities in this field.

DELTA
DELTA's participation in Harmonoise has increased our expert know-how and reinforced our position as a leading organisation in the field of outdoor sound propagation. During the project period we have been able to improve DELTA's calculation tools, including our environmental noise prediction software exSOUND2000 offered to customers on a commercial basis.

SNCF
SNCF expected to achieve a railway source model to be implemented in the propagation calculations, which fulfils accuracy requirements while satisfying practicability for a future use. This objective was largely reached but calculations of railway cases with the engineering model have not been completely assessed and need further validations.

ARPAT
ARPAT, which has among its core activities the problem of environmental noise, was particularly interested in this project and its importance in application of the EU Directive. Because our national normative poses great attention to measuring pollutants rather that predicting them, it was of main importance that a candidate prediction model, would take care of experimental validation. This was mainly achieved with the HARMONOISE project, leading to a valuable improved prediction model. Our main concern refer the lack of a deeper investigation in urban or complex situation.

DLR
DLR has expected from Harmonoise a intense European cooperation and scientific/technical interchange in the development and application of advanced outdoor sound propagation models (reference) models and a database for validation. These expectations were fully fulfilled in Work Packages WP2 and WP4. Moreover, we expect to benefit from Harmonoise results and cooperations in the approved follow-up project ALPNAP (Noise and air pollution along major Alpine transit routes) which will be funded within the EU Interreg IIIB Alpine Space programme.

AEAT
AEAT had expectations related to project management and to its railway noise expertise. As project coordinator, our company played a central role in communication not only to the EC and the partners, but also to other stakeholders active in the field of traffic noise. Our expectation was that this would promote our name and would lead to further business development in noise consultancy. This expectation has largely come true.
As one of the main partners in WP1.2 on railway noise sources, we expected to further develop our expertise in railway noise modelling and to become one of the leading specialists in Europe in this field. The spin-off of our work in WP1.2 appeared to be a bit disappointing on the national level, but very promising on the international level. Furthermore, we strengthened our relationships with the various project partners hopefully providing a firm basis for further cooperation in other European projects.

8. Conclusions

At the Final Review of the Harmonoise project, 12 January 2005, the Harmonoise Project Steering Committee have presented their final conclusions regarding the Harmonoise methods. The conclusions describe the success of the methods concerning usability, flexibility and publicity.

The Harmonoise methods are pre-eminently suitable for harmonisation of noise calculation in Europe because

- separation between emission and propagation allows flexibility
- source models are adaptable to local conditions
- propagation incorporates arbitrary meteorological conditions
- different ground conditions can be taken into account
- complex geometries can be handled
- large scale validations were carried out
- dissemination has made the models well-known
- the methods are usable at different fields of application
- the methods sustain the implementation of relevant EU noise directives.