COOP-CT-2004-512862

WEATHER

Wind Early Alarm System for Terrestrial Transport Handling Evaluation of Risks

Instrument : CRAFT

WEATHER FINAL ACTIVITY REPORT

DELIVERY D 0.3

Start date of project: October 1st 2004

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Duration: 30 months

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METEODYN

Revision 1

WEATHER ACTIVITY REPORT

Final Technical report

June 2007

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ILLUSTRATIONS

1 INTRODUCTION

In order to appreciate the research work carried out from October 2004 to March 2007 in the framework of WEATHER program, this final report is a summary of the activities and results. The full description of the important work which has been furnished by all the partners can be found in the 9 appendices to this report, which contain all the technical deliverables of the WEATHER project.

The final objective of the Craft “WEATHER” was to develop an innovative wind alarm system for terrestrial transportation, which will enable risk evaluation. The WEATHER system has to be operational at the end of the project. The product has the special feature of predicting both the wind and the risk for a vehicle, in a particular section of road or track.

This final objective was achieved by dividing the research work in 4 main lines as the following:

- ✓ **Workpackage 1: Wind modelling**

To elaborate spatial-time wind models (including prediction models) in compliance with the needs of wind alarm systems.

- ✓ **Workpackage 2: The aerodynamic coefficients**

To develop robust methods to get cross wind forces on vehicles (wind-tunnel, CFD, field measurements). The criterion of success is given by comparison between the field experiment and the computations or wind tunnel studies. A final data base of aerodynamic coefficients has to be collected and to be associated to type of vehicles. It will be used in the Wind Alarm System

- ✓ **Workpackage 3: Risk evaluation**

To develop innovative methods to assess the risk of wind induced accidents of rail and road vehicles occurring at exposed sites

- ✓ **Workpackage 4: Wind alarm system prototype**

To implement these methods and to assist WEATHER SME in the development of the proposed wind alarm systems for terrestrial transport. The operational character of the prototype developed will be tested in real working conditions.

2 ACTIVITY REPORT

2.1 WORKPACKAGE 1 - WIND MODELLING

To calculate the risk of accident on a particular section of road and track, we must determine accurately the wind along this section. The modelling has to predict the wind in both space and time. Indeed, for one section the wind alarm system measured the wind at a weather station generally at a single point on the site.

The objective of the workpackage 1 is to acquire knowledge in wind modelling both in the spatial and the time dimensions. We need also to know the wind at the different scales: the deterministic mean wind speed and direction over 10 minutes period, and the characteristics of the random part of the wind, i.e. the turbulence, including the possibility to generate realistic turbulent time series of wind.

The wind measurements must give information not only in a particular place but also all along the track or the road section. Moreover, the time-prediction is needed because the wind alarms have to be detected before the vehicles encounter a risky situation.

Another objective of this workpackage is to develop a program to generate spatio-temporal wind series along the section. The simulation takes into account the turbulence properties, and theoretical expressions of wind spectral and cross-spectral density functions. The wind simulated will be applied to the vehicle travelling along the section in the dynamic simulation.

2.1.1 Time-prediction modelling (tasks 1.1 and 1.2)

This work has been divided in two tasks. The task 1.1 consists in acquiring field data base for the time-prediction model calibration. The task 1.2 deals with the development of the time-prediction model to predict wind speed and direction for horizons from 10 minutes to 2 hours in advance. Prospects are also given for forecast at longer terms, between 6 hours and 24 hours.

Data acquisition

This task involves five SMEs: Atmos, EMI, Nubila, Geonica and Campbell Scientific. It started from the very beginning of the project. Meteorological stations have been installed in different locations representative of the different european climates. (semi-oceanic, oceanic, mediterranean, continental or mountain). The stations can be divided into two groups:

- Standard measurements (wind, pressure, temperature)
- Pludix measurements related to precipitations

Data were continuously acquired and stored during one year, every ten minutes.

It was also foreseen that Atmos would acquire surface state series data (wetness, ice, …) with its new CIR system. Unfortunately, difficulties in the development of the system have not permitted to get such data in the framework of the WEATHER program.

Table 1 gives the list of the stations for standard measurements.

Site name	Responsible	Geographical Coordinates	Altitude (m)	Climate
Blou (France)	ATMOS	47°23’ N 0°02’ W	40	Plain semi-oceanic
Tours (France)	EMI	47°27’ N 0°40’ W	98	Plain semi-oceanic
Mte Cimone (Italy)	NUBILA	44°11’N 10°42’E	2165	mountain
Argenta Saiarino (Italy)	NUBILA	Longitude: 11.813783° Latitude : 44.624273 °	8	Plain mediterranean
Tierga (Spain)	GEONICA	41°36’ 28” N 1° 35’ 49” W	759	continental
Almeria (Spain)	GEONICA	36°50’ N 2°26’ W	15	sea-side mediterranean
Shepshed (UK)	CAMPBELL Sc.	52°46’ 52 N 1°17’ 05 W	64	Plain oceanic

Table 1 Measurement sites - Standard measurements

Some administrative delays to obtain permissions were observed at the very beginning of project. Nevertheless, continuous time series of wind (speed and direction), pressure and air temperature have been collected for a least a year in all the sites.

Nubila installed 6 sites in Italy with the PLUDIX sensor:

- National research council (CNR) – Bologna research area
- National research council (CNR) – S. Pietro Capofiume Experimental Field
- Mazzorbetto (VE) – Venice Lagoon
- Surigheddu (SS)
- Licata (AG)
- Rotondella (MT)

These 6 sites have supplied data in order:

- To characterize the precipitation events through some microphysical parameters
- To establish relationship between the different types of precipitation and the World Meteorological Organization codes.
- To identify parameters to calculate the risk of aquaplaning (paragraph 2.3.2)
- To test the new PLUDIX version (paragraph 2.4.1)

Time-prediction modelling

It was scheduled to develop two prediction models:

- One model for wind speed and direction
- One model for road surface state

Due to the lack of data concerning road surface date, we focused on developing the prediction model for wind speed and direction. It seems that the road surface state can be characterized thanks to the soil surface temperature from an ARMA model. But some data are needed to understand the interaction between the road surface state, the soil temperature and solar fluxes.

Concerning the wind prediction, a first approach, using neural networks method, was tested. Nevertheless, it appears to give a little gain in comparison with a persistence model and it was difficult to integrate in the wind alarm system. So, Meteodyn elaborated a time-prediction model for wind based on a multivariable algorithm. The model is defined with measured barometric pressure and 10-minutes mean speed and direction. The wind is projected onto two axles: west-east and south-north corresponding respectively to the two components u and v. The convention of signs is given in Figure 1.

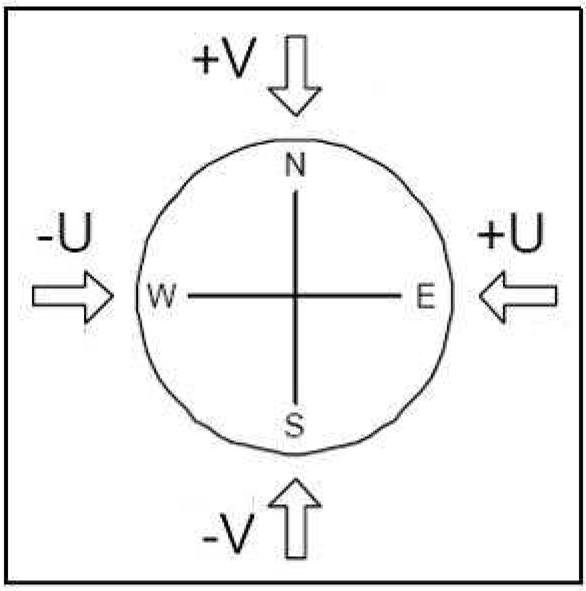


Figure 1 Convention for u and v

The result is an regressive model that can be expressed as:

$$u_{t+H} = a_1 u_{t-20} + a_2 u_{t-10} + a_3 u_t + a_4 (P_t - P_{t-30}) + a_5$$
$$v_{t+H} = b_1 v_{t-20} + b_2 v_{t-10} + b_3 v_t + b_4 (P_t - P_{t-30}) + b_5$$

where

u_t and v_t are the two mean wind components on 10 minutes at the instant t

P_t is the measured pressure at time t

H is the time-horizon of the prediction

a_1, a_2, a_3, a_4, a_5, b_1, b_2, b_3, b_4, b_5 are constant to be defined by calibration

This model has been implemented in the prototype of wind alarm system. A stage of validation has been carried out from wind data of the stations in France, Italy, Spain and England. At present a small, but real, gain in comparison with results coming from a persistence model has been observed. However it has been shown that too few data are yet available to correctly calibrate and validate a model. Then measurements are continuing after the end of the project?

New developments have been launched during the WEATHER program for wind forecast at longer tem (6 hours to 24 hours) which corresponds to a demand by road, motorway or bridge managers. At these terms, it is necessary to adopt physical methods by running meso-scale meteorological models. This aspect is developed in the Appendice 1.

2.1.2 Spatial modelling

During the last years, Meteodyn has developed a wind computation code, named “Meteodyn_NS” which computes wind characteristics by solving Navier-Stokes equations, with an automatic and fast procedure.

A first objective of the task was to improve the software in order to get accurate modelling of the turbulence characteristics. The second objective was to improve our knowledge about the effects of specific perturbations such as embankment, a bridge deck, a bridge pylon. These perturbations have an impact on the wind flow and consequently on wind forces applied on the vehicles.

Implementation of a new turbulence model in Meteodyn NS (Task 1.3)

This task has been achieved as expected in September 2005. The new model has been implemented in Meteodyn NS.

The turbulence was characterized on a specific site and the prediction of large-scale features (10 min mean values) was improved. It was achieved following three stages:

- A state of the art of existing models, including the choice of the most suitable one for the present application.
- Implementation in Meteodyn NS
- Validations

Meteodyn NS was developed by Meteodyn to model wind flow over complex terrain. It solves the Reynolds-Averaged Navier-Stokes (RANS) equations, with boundary conditions and properties based on well-known models of the atmospheric boundary layer. Its main particularity is to be fully automatic, as well as for boundary conditions implantations, convergence parameters, grid generation.

The task has consisted in the introduction of a new model of turbulence with the transport equation of the turbulent kinetic energy

The general form of RANS momentum equations is given by:

$$U_j \frac{\partial U_i}{\partial x_j} = \frac{\partial}{\partial x_j}\left[\nu_t \frac{\partial U_i}{\partial x_j}\right] - \frac{1}{\rho}\frac{\partial P}{\partial x_i}$$

The question of the turbulence modelling consists in evaluating the turbulent viscosity ν_T as a function of the properties of the flow turbulence. This turbulent viscosity can be considered as the product of a wind speed scale and a length scale, these scales being characteristic of the turbulence.

In the previous version of Meteodyn NS, the evaluation of the turbulence viscosity was based on the Monin-Obukhov theory and the mixing length theory, and corrected for expected orography effects with empirical relationships. This method can lead to errors inside wakes behind hills.

From the state-of-the-art study, it was decided to introduce a one-equation model, based on the one proposed by Arritt (1987) and validated for atmospheric flows by Hurley [28] for estimating the turbulent kinetic energy by a transport equation:

$$U_j \frac{\partial k}{\partial x_j} = P_k - \varepsilon + \frac{\partial}{\partial x_j}\left[\left(\frac{\nu_T}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right]$$

with :

$$\begin{cases} \varepsilon = C_\mu k^{3/2} / L_T \\ P_k = \nu_T \left(\dfrac{\partial u_i}{\partial x_j} + \dfrac{\partial u_j}{\partial x_i}\right)\dfrac{\partial U_j}{\partial x_j} \\ \nu_T = k^{1/2} L_T \end{cases}$$

At the lower boundary, a source term is added for taking into account the friction forces.

We consider here only the case of strong winds (neutral stratification).

Then we get from Arritt:

$C_\mu = 0.0474$ and $L_T = 0.556l$ with $\frac{1}{l} = \left(\frac{1}{l_0} + \frac{1}{\kappa z}\right); l_0 = 100\,m; \kappa = 0.41$

Several validations test were carried out. A classical one consists in the Askervein hill test case.

The results from the simulation were compared to extensive fields measurements performed in a hill in a mountainous terrain in the Outer Hebrides of Scotland. (cf Taylor and Teunissen, 1983 [30]). Figure 2 shows the location of the measurements in the terrain.

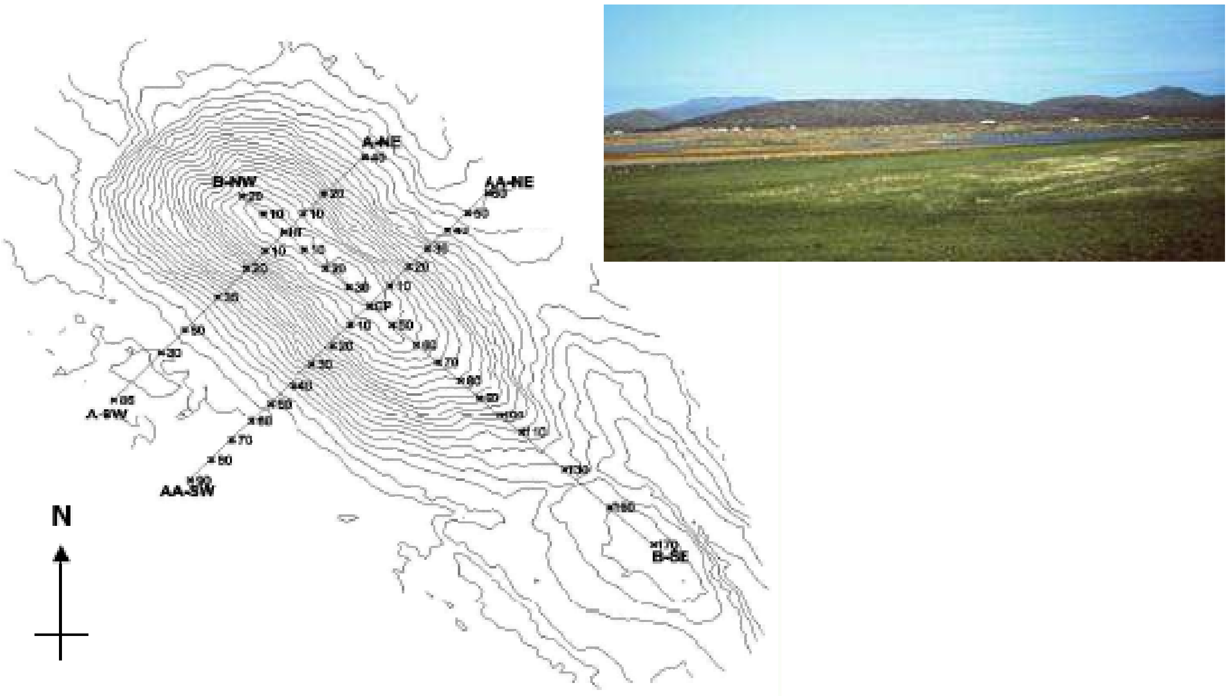


Figure 2 Askervein site and measurement points

Comparisons with measurements at 10 m height have been made for a wind direction of 210 degrees. The mean wind speed profiles along the different lines are well reproduced by the models, whatever the tested turbulence models (Figure 3). The difficulty is to reproduce the recirculation and the turbulence field in the lee-side of the hill. The improvement due to the use of the one-equation model is well demonstrated in Figure 4 and Figure 5.

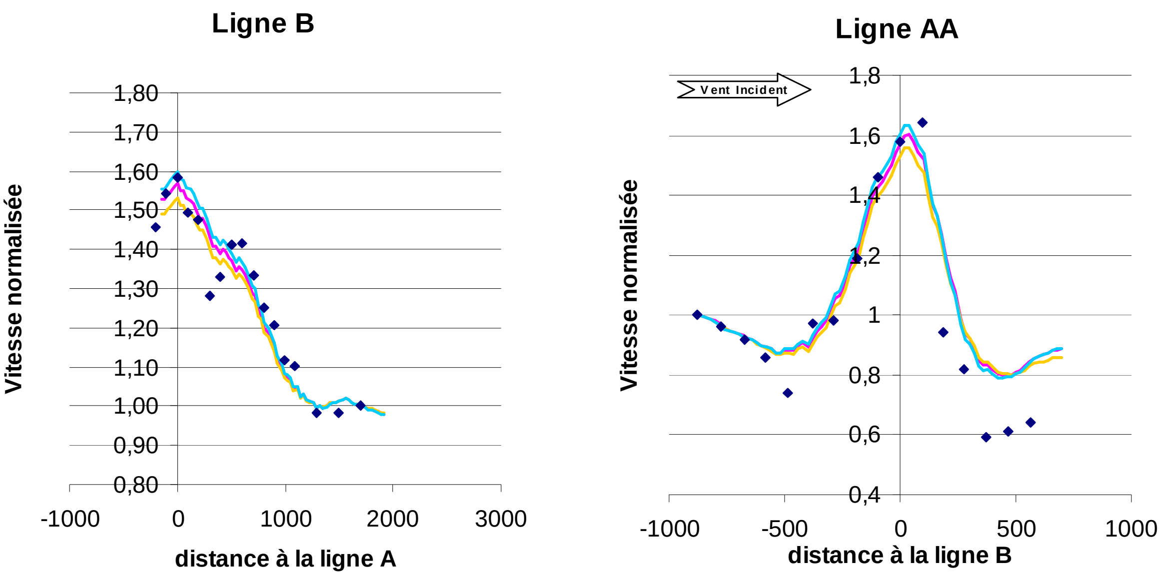
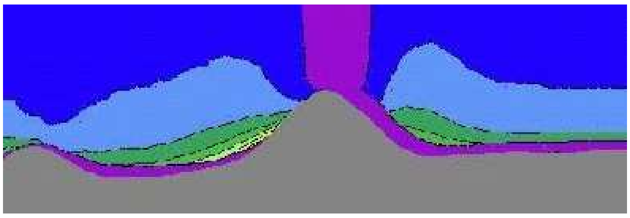
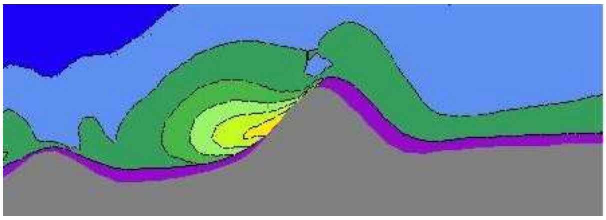


Figure 3 Mean wind speeds predicted by the zero-equation model and one-equation models



(a) zero-equation model



(b) one-equation model

Figure 4 Simulated turbulent kinetic energy on Askervein hill for the zero-equation and one-equation models (wind coming from the right)

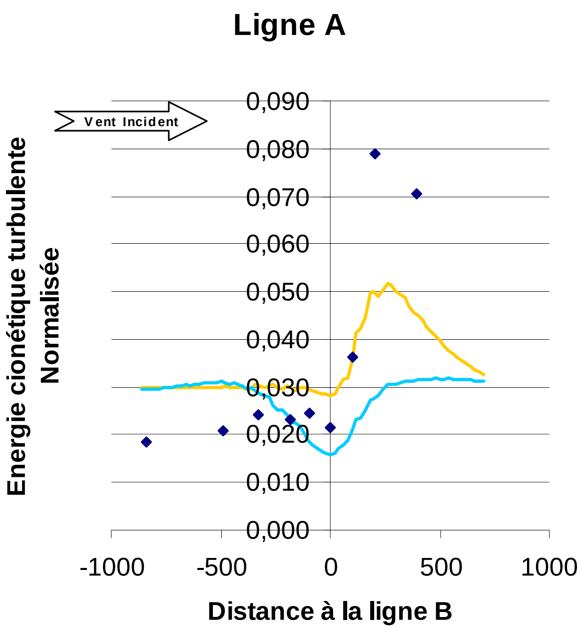


Figure 5 Comparison of measured (points) and computed turbulent intensity in the wake of the hill (blue line: zero-equation - yellow line: one-equation)

Evaluation of the obstacles effects (task 1.4)

The evaluation of embankment effects is a matter of utmost importance for railway applications.

As far as a 2D assumption can be put forward, bibliographical references have been selected to estimate a speed-up coefficient that traduces the ratio of the wind speed above the embankment to the wind speed far downstream. The hypothesis supported by C.J. Baker is proposed to estimate this speed-up coefficient for every wind direction.

For deck and pylon perturbations (mainly road applications), a 3D CFD computation code is being developed for automatic and fast assessment of these perturbations. Cases of typical shape of bridge have been simulated with this code. The calculation allows to determine the characteristics of wind speed and direction at the level of the two-way traffic.

Such a numerical tool can be proposed to deal with any 3D perturbation, including embankment. This tool will be used by the wind alert system in complement of Meteodyn NS for estimating deck briddge effects on measurements, as well as pylon or embankment effects.

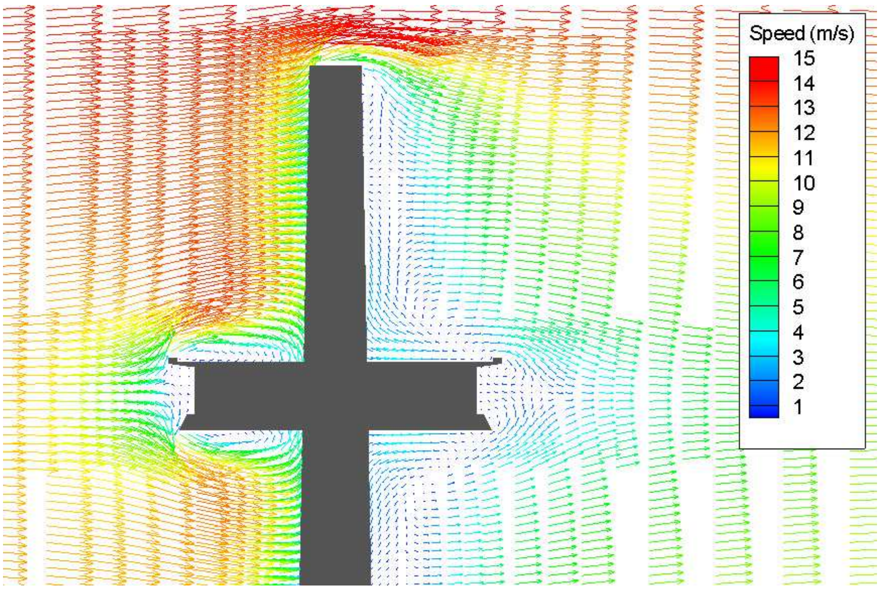


Figure 6 Speed vectors (cross-section through a pier)

2.1.3 Generation of wind series (task 1.5)

The stochastic simulation and the risk evaluation need the simulation of wind time series along the road or the track section. Thanks to the spatial wind modelling, the statistical characteristics of the wind can be known along the section with accuracy to within 50 m. The objective of the task was to elaborate an algorithm allowing generating spatio-temporal wind series representative of the turbulent fluctuations.

Meteodyn has implemented the algorithm of Jin, Lutes and Sarkani (1997 [29]). This algorithm allows generating wind series that respects theoretical spectral and cross-spectral density functions. It simulates wind speed components (u,v,w) for any incidence. So it can be used for any curvature of the road. Validations have been performed. Figure 7 shows a case of validation with a spatial discretization in 51 points. The wind incidence is fixed to 30°. The model generates a signal for the 3 components u, v, w in each point. Wind series are simulated in 100 samples of 1024 points with a lag of 1s. A comparison between Von Karman theoretical spectrum and spectral densities simulated in points 25 and 51 is given in figure 8 for U longitudinal component.

The figure 9 represents the cross-spectral densities S_{uu}, S_{vv}, S_{ww} for the 2 extreme points 1 and 51. We can see that those signals respect the spatio-temporal properties of the turbulence.

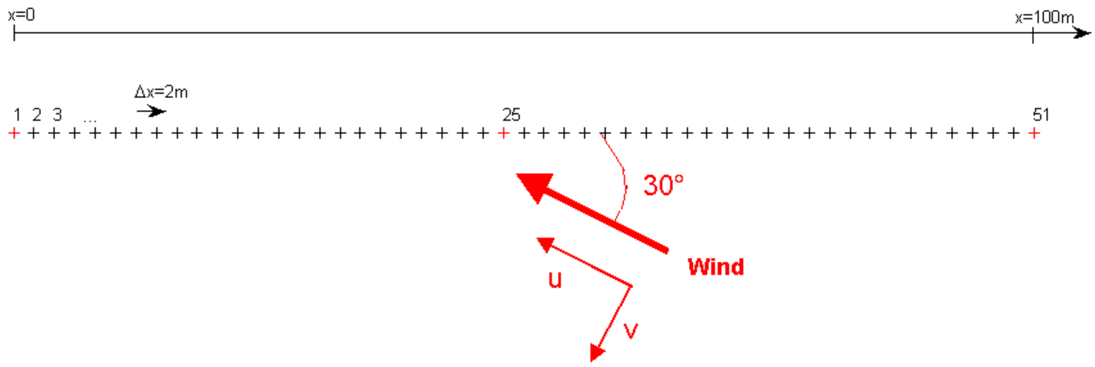


Figure 7 Exemple of simulation (51 points , dt=1s, samples of 1024 points)

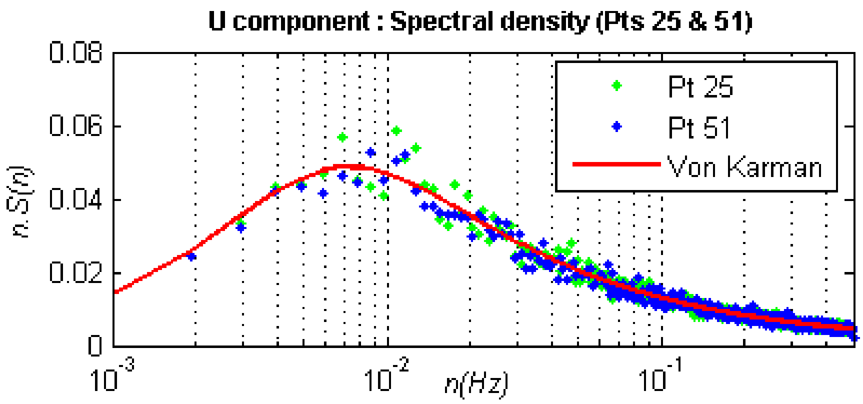


Figure 8 Spectral densities: comparison between theory and simulation

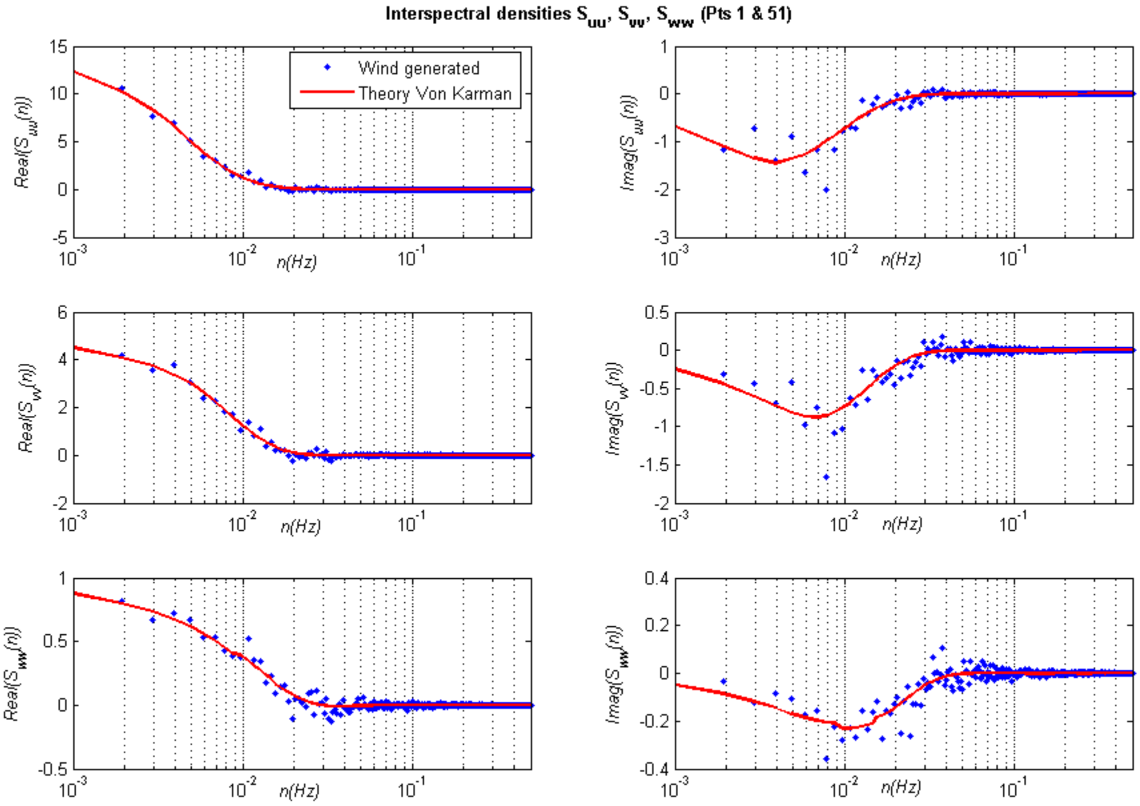


Figure 9 Cross-spectral densities: comparison between theory and simulation (on the left column the real part, on the right column the imaginary part)

During the second year of the project, Alstom has worked on a different algorithm to generate spatio-temporal series in a moving frame. Such a method of generation is a good idea as far as the vehicle speed is high: the space dimension of the wind speed will be prohibitive in a system frame linked to the ground. However, this method makes a stationary or homogeneity assumption and can only be applied for a constant vehicle speed.

Two methods were tested to describe the atmospheric turbulence and the statistical evolution of both components of wind (u, v) in a horizontal plane. The first one is a time-space model based on Cooper research work [26]. The second one is a frequency-space model proposed by Delaunay: coherence functions are fitted with experimental results. Both models derive from Von Karman model [33].

The mean difference between these two models lies in Taylor hypothesis: Cooper model uses a strong formulation of Taylor hypothesis, whereas Delaunay uses a weak formulation. The latter allows the turbulence correlation to decrease along its moving axes.

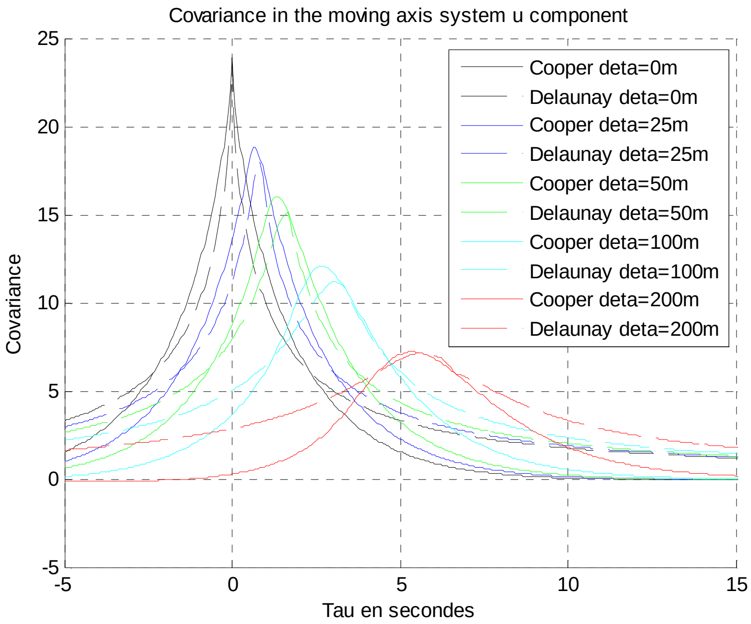


Figure 10 Correlation function seen by the vehicle of a function of space lag $\delta\eta$ (deta), u component

A fast method for generating those fields has been developed. Since the covariance function is known, and since a regular grid is used for wind discretization in both time and vehicle dimension, Chan and Wood [25] or Dietrich and Newsam [27] method was used.

2.1.4 Conclusion / deliverables

Concerning this workpackage, we can consider that the following objectives have been fulfilled:

- A data base of measurements has been collected in different European stations. The data base is needed to define the time model prediction of wind and to quantify the error due to temporal prediction. This error is an input of the risk simulation.

- A time-prediction model for mean wind speed and direction has been proposed and validated on a particular site. This algorithm has been implemented in the data logger of a wind alarm system.

- A turbulence model based on the model of Arritt (1987) and the validations for atmospheric flows by Hurley [28] have been implemented in the solveur METEODYN_NS. The improvement of this method has been proved by a validation stage thanks to the Askervein test case. This model is needed to estimate statistical characteristics of wind along a road section or a track.

- Specific perturbations of the wind flow caused by embankment, deck or pylon were estimated. The CFD software URBAWIND can be used in the future to establish other 3D perturbations.

- The algorithm of Jin, Lutes and Sarkani (1997 [3]) has been implemented and validated in order to generate wind series in a fixed frame. This work has been extended to the case of a moving frame. The wind series are used in the dynamic simulation. They allow computing the wind forces applied on the vehicle along a crossing.

The following table gives the list of the reports (deliverables) relative to the workpackage 1. They can be found in the appendices 1 and 2 of this report.

Task	Author	Title	Deliverables	Appendix
1.1	Meteodyn	Data base for time-prediction model	D.1.1.1	1
1.1	Nubila	Data acquisition for time-prediction model	D.1.1.3	1
1.2	Meteodyn	Elaboration and calibration of the time-prediction model – Wind prediction algorithms to be implemented in the wind alarm program	D.1.2.1	1
1.2	Meteodyn	Elaboration and calibration of the time-prediction model – Methods and Validations	D.1.2.2	1
1.3	Meteodyn	Implementation of a one-equation turbulence model in Meteodyn NS	D 1.3.2	2
1.4	Meteodyn	Bridge and embankment perturbation	D.1.4	2
1.5	Meteodyn	Simulation algorithm to implement in the stochastic simulation program	D.1.5	2

Table 2 WP1 : Wind modelling - Deliverables

2.2 WORKPACKAGE 2 – THE AERODYNAMIC COEFFICIENTS

The assessment of aerodynamic forces is the major problematic for the risk evaluation. The aerodynamic forces are link to the incident wind speed via the aerodynamic coefficients.

The knowledge of both the incident wind and these coefficients allows calculating the wind forces and moments applied on the vehicle. These efforts determine the dynamic behaviour of the vehicle and the risk of accident. The aerodynamic coefficients depend on the vehicle shape and the direction of the incident wind on the vehicle.

The objective of this WorkPackage is both to define a generic data set of aerodynamic coefficients intended to be used in the risk simulation, in order to get a data base for the wind alarm system, and also to validate and assess different methods of obtaining such coefficients in order that the data base could be extended in the future.

A first state of the art was performed. It shows that the aerodynamic characteristics of train are well known by manufacturers and railway manager. So, it was no use trying to progress towards a better knowledge of train aerodynamics.

Contrary to the railway vehicles, the study of aerodynamics road vehicles, regarding crosswind effects is not frequent. During the last two decades, C. Baker and his co-workers have been performing wind tunnel tests to characterize road vehicles. We chose to continue this way.

The aerodynamic coefficients of a van and a trailer have been determined using three methods: wind-tunnel measurements, computational fluid dynamics and full-scale tests. It is the first time that the three methods are assessed together, using exactly the same vehicles.

The objectives of this workpackage were:

- To establish a complete data set of aerodynamic coefficients for the van and the trailer by means of three methods: wind tunnel tests, CFD computations and field tests
- To validate wind-tunnel measurements and computational fluid dynamics according to the field tests in order to be able to extend the data base in the future.
- To establish a complete data set of aerodynamic coefficients for road vehicles

2.2.1 Wind tunnel tests

Politecnico di Milano performed the wind tunnels tests in the very large wind tunnel of Bovisa campus. The van and the trailer are designed at a 1:10 reduced scale. The wind tunnels tests were performed considering two vehicles: a van and an articulated lorry (van + trailer) in 3 different road configurations: flat ground, viaduct, embankment.

Two wind simulations with two types of turbulence were defined:

- Silsoe turbulence : The wind simulation is representative of the full-scale test
- Low turbulence : This is the classical wind simulation used to determine aerodynamic coefficients

Finally, 13 configurations were defined in accordance with the different partners (Table 3)

VAN	Flat ground (Silsoe Turbulence) Viaduct (Low turbulence) 1-way Viaduct (Low turbulence) 2-way - upwind Viaduct (Low turbulence) 2-way - downwind Embankment (Low turbulence) - upwind Embankment (Low turbulence) - downwind Flat ground (Low turbulence)
ARTICULATED LORRY (van + trailer)	Flat ground (Silsoe Turbulence) Viaduct (Low turbulence) 1-way Viaduct (Low turbulence) 2-way - upwind Viaduct (Low turbulence) 2-way - downwind Embankment (Low turbulence) - upwind Flat ground (Low turbulence)

Table 3 Wind tunnel test configurations

The configuration on flat ground with Silsoe turbulence (Figure 14 to Figure 16), have been compared to CFD computations and full-scale tests.

The tests were divided in two campaigns of measurements:

- First campaign: from 18th to 22nd of July and from 19th to the 23rd of September.
- Second campaign : from 18^{h} to 21th of December 2006
-

Figure 11 The "articulated lorry" model

Figure 12 1:10 scale embankment model

Figure 13 1:10 scale viaduct model

The measurements are carried out with a 6-components dynamometric balance located under the vehicle. It gives 3 forces and 3 moments coefficients as a function of the wind incidence.

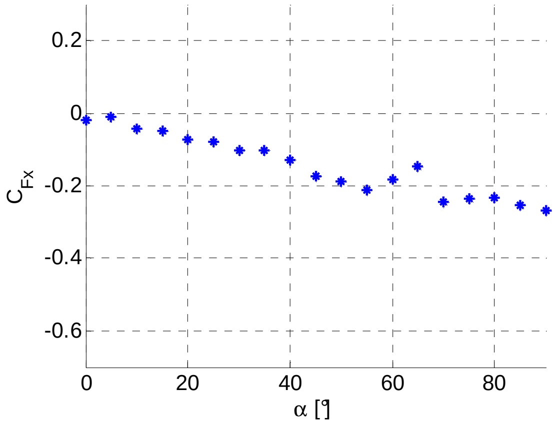


Figure 14 VAN model, flat ground, Silsoe turbulence conditions, hpitot=0.3 m in correspondence of the vehicle position (without vehicle): vertical force coefficient CFx.

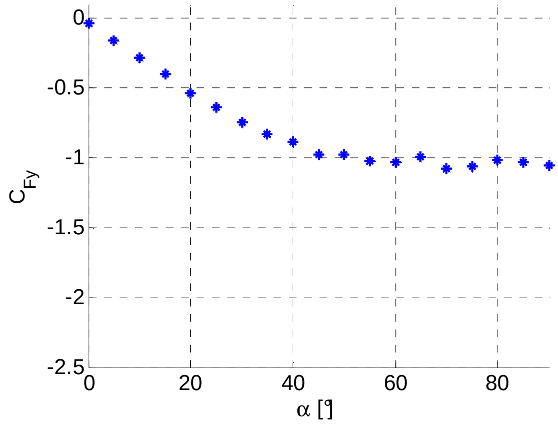


Figure 15 VAN model, flat ground, Silsoe turbulence conditions, hpitot=0.3 m in correspondence of the vehicle position (without vehicle): lateral force coefficient CFy.

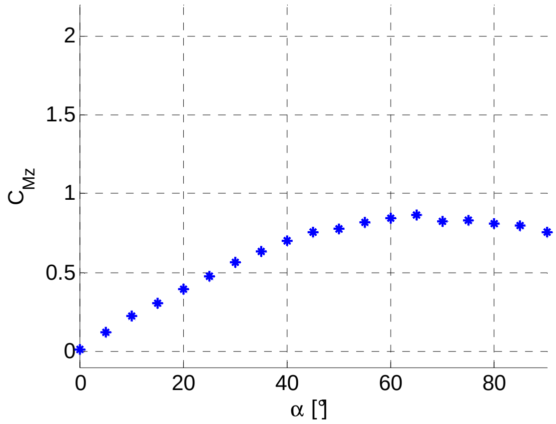


Figure 16 VAN model, flat ground, Silsoe turbulence conditions, hpitot=0.3 m in correspondence of the vehicle position (without vehicle): rolling moment coefficient CMz.

To complete this information, pressure measurements were performed. Pressure taps are split along the vehicles surface and give the pressure distribution. This distribution was compared with field tests and CFD computations. Table 4 sums up the configurations where the pressure measurements have been performed.

VAN	Flat ground (Silsoe Turbulence) Viaduct (Low turbulence) 1-way Flat ground (Low turbulence)
ARTICULATED LORRY	Flat ground (Silsoe Turbulence) Viaduct (Low turbulence) 1-way Flat ground (Low turbulence)

Table 4 Wind tunnel test configurations for pressure measurements.

Figure 17 and Figure 18 give a representation of the pressure distribution around sections of the tractor and of the trailer. The mean pressure coefficients are assumed positive when the arrows are directed from outside to inside the vehicle. For the VAN tractor, an uniform distribution can be seen on the leeward surface. On the windward surface, pressure is negative till the yaw angle is lower than 20°, then becomes positive. In correspondence of the top corner, a negative pressure peak can be observed for yaw angles higher than 60°. Similar considerations can be made for the pressure distribution around the front and the rear sections of the VAN trailer.

A large number of configurations (13 instead of the 8 planned) were tested in wind tunnel. It gives us a wealth of information at our disposal for the risk simulation.

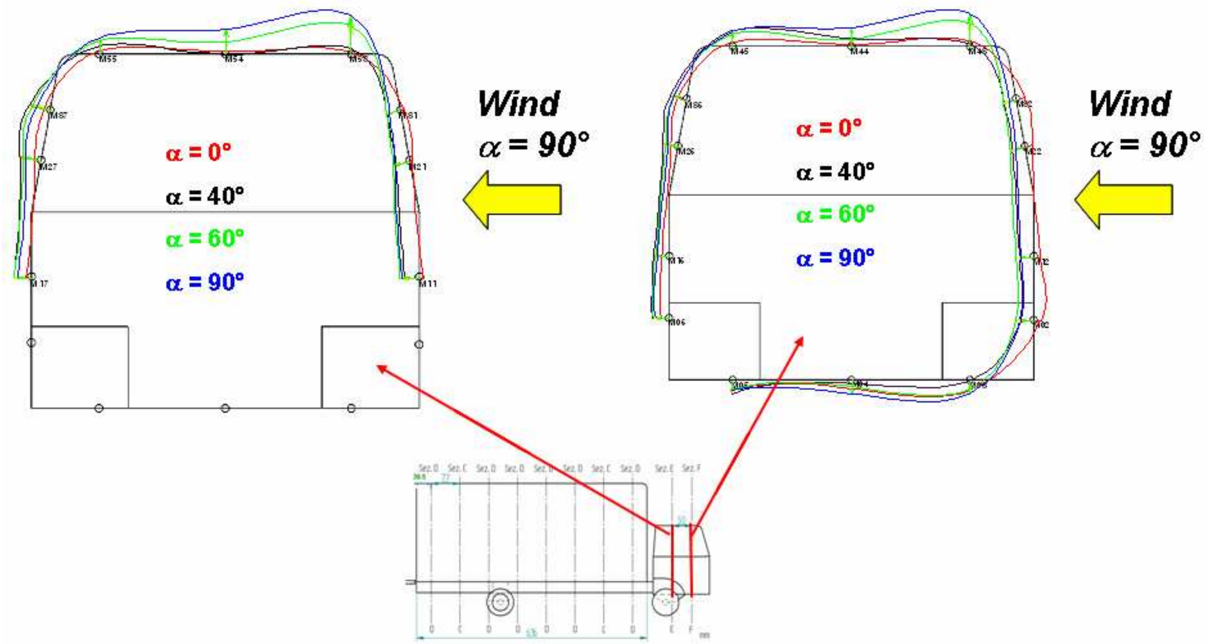


Figure 17 Pressure distributions on the VAN tractor as a function of the yaw angle: front section.

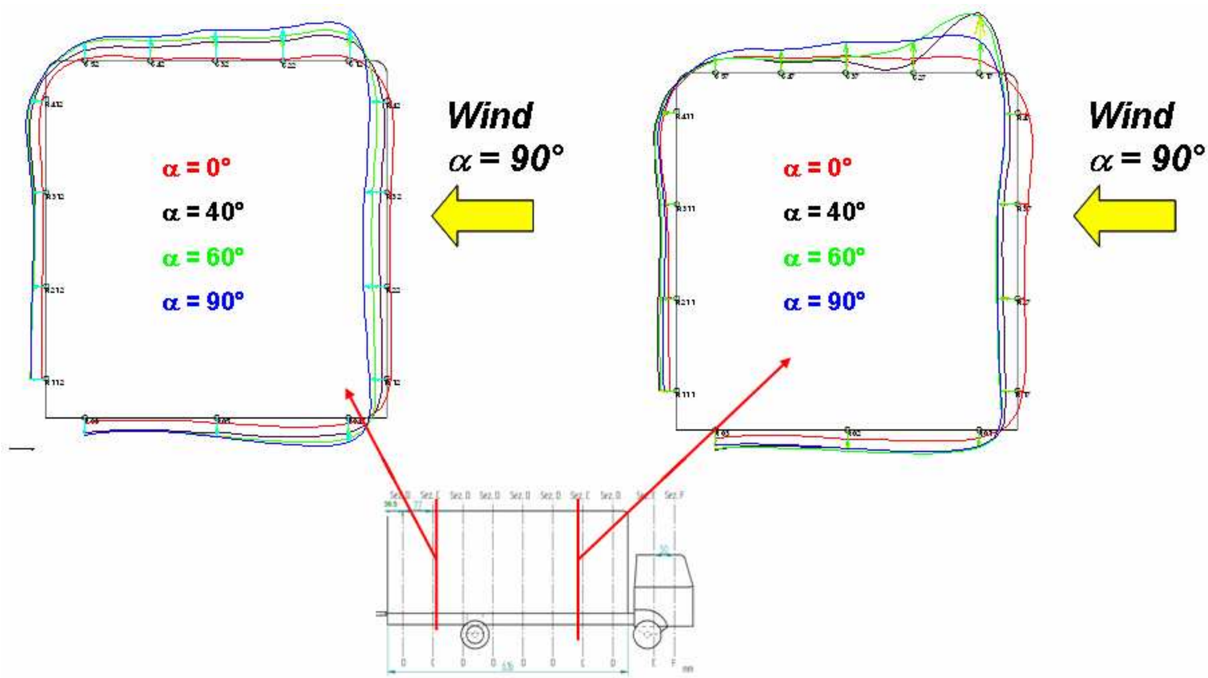


Figure 18 Pressure distributions on the VAN trailer as a function of the yaw angle: front section

2.2.2 CFD calculations

For the computations performed by the University of Nottingham, it was initially planned to consider two generic models for a generic lorry shape and a generic train coach shape on embankment and viaduct at full and wind tunnel scales. This plan has been modified. It was decided to concentrate ours efforts on comparing the results obtained in this project by field tests and wind tunnel tests.

So, the research program has been reduced to the following configurations:

VAN	Flat ground – static vehicle Flat ground – moving vehicle Viaduct 1-way – static vehicle Embankment – static vehicle

Table 5 CFD configurations

The complete set of data available in each approach was a great opportunity to compare the accuracy of the prediction of aerodynamic coefficients by CFD simulations. So the objectives are now to validate CFD as a tool with the potential to be used to compute the aerodynamic coefficients of vehicles under cross-wind conditions.

The meshing of the Silsoe van has been completed: It takes the major part of this first year of research. It reproduces accurately the real lorry. Only the fuel tank has been removed for questions of symmetry.

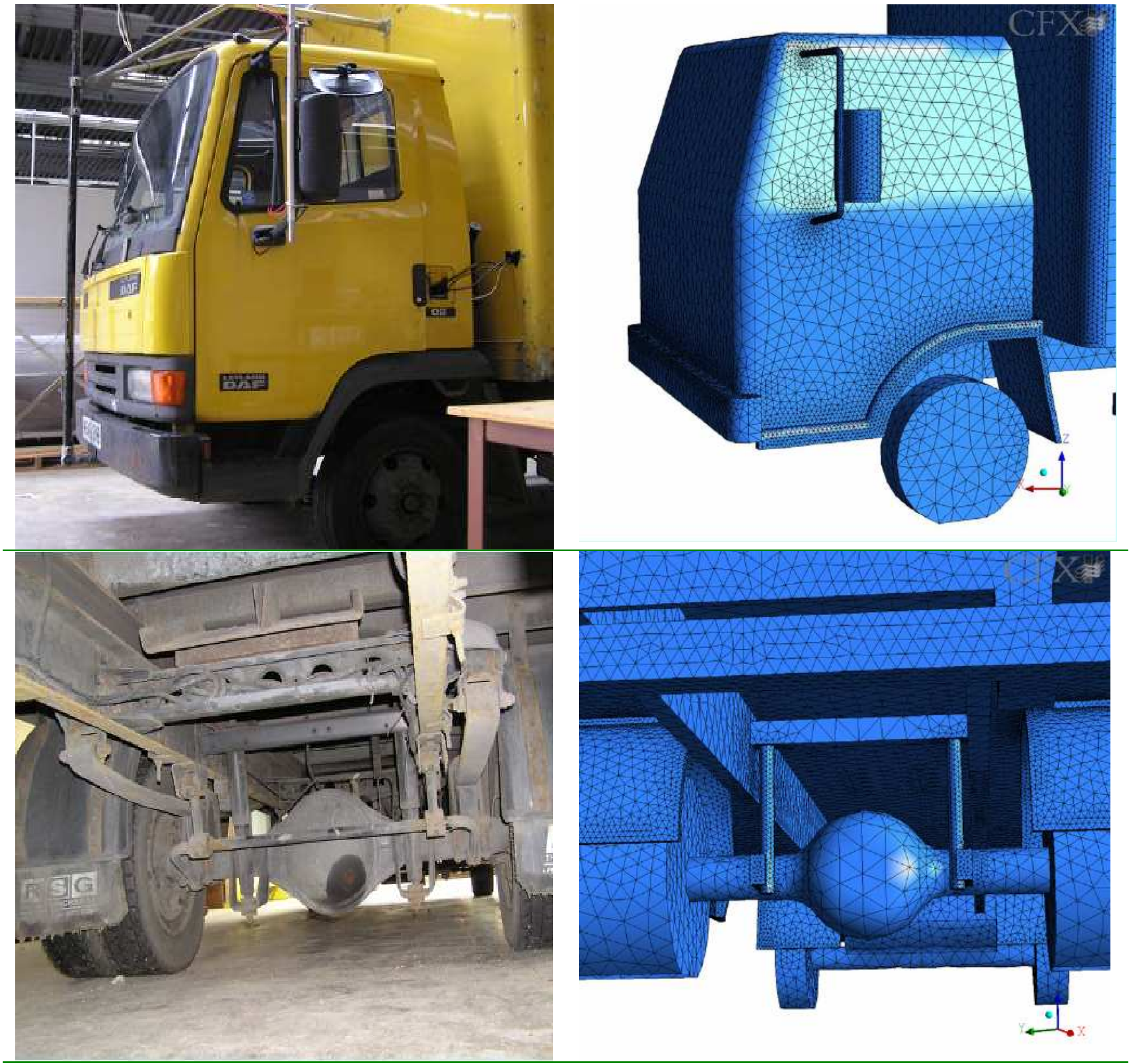


Figure 19 Meshed details

The meshed domain is composed of two parts: a cylinder domain which contains the van and can rotate in the fixed environment. This constitutes a virtual wind tunnel, with the added bonus that the bottom wall can also be set in motion to represent the motion of the road relative to the truck. The motion of the bottom is simulated by means of a helical flow profile inside the domain.

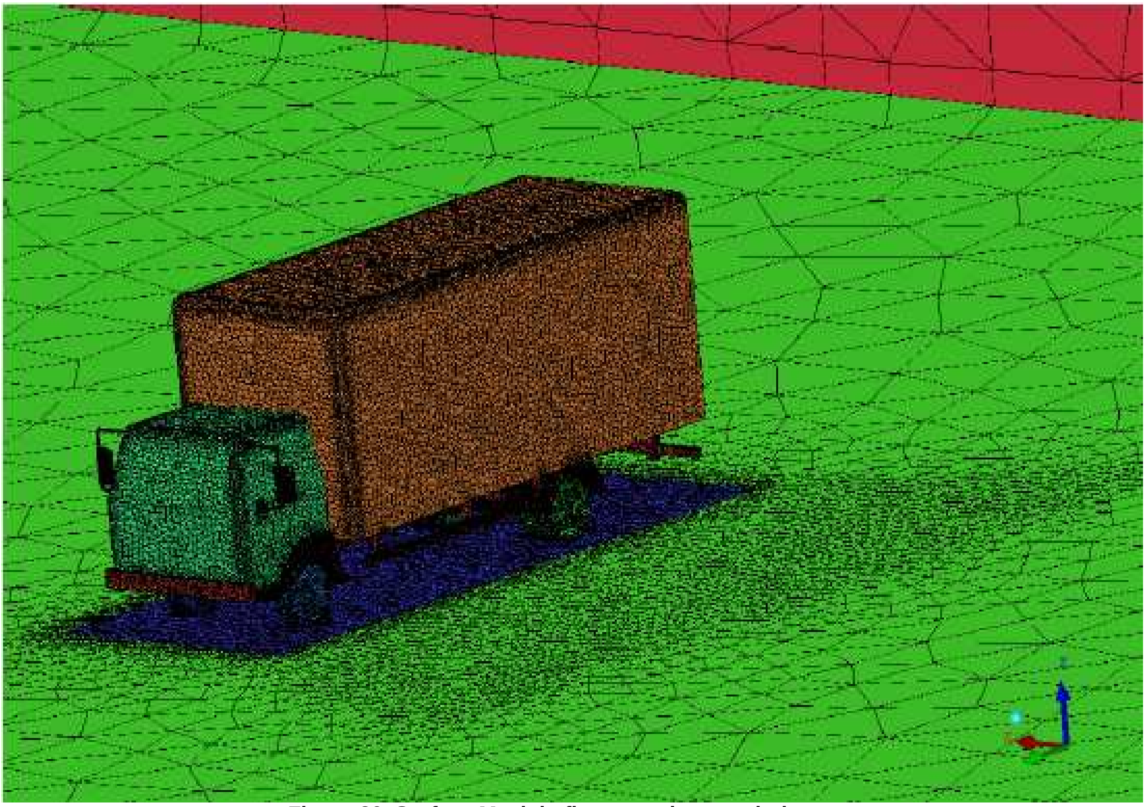


Figure 20 Surface Mesh in flat ground crosswind case

The comparison between static and moving ground computations shows that the effect of simulating relative ground motion is minimal on the side and drag force coefficients but reduces the lift forces substantially.

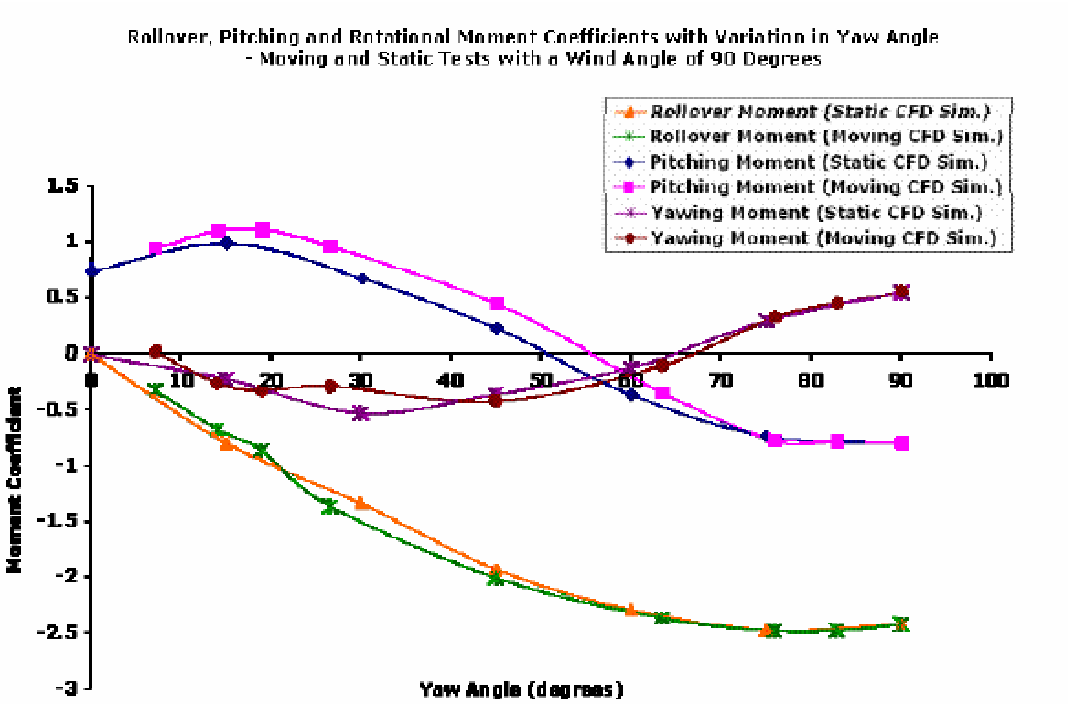


Figure 21 Comparison between static and moving CFD simulations

For the embankment configuration, significant effects associated with the truck location and yaw angle have been observed from numerical simulations. For example, as far as the side force and the rolling moment are concerned, the upwind location on an embankment and angles of yaw smaller than 90 degree can induce more severe wind loads than the downwind location and the 90° angle of yaw do.

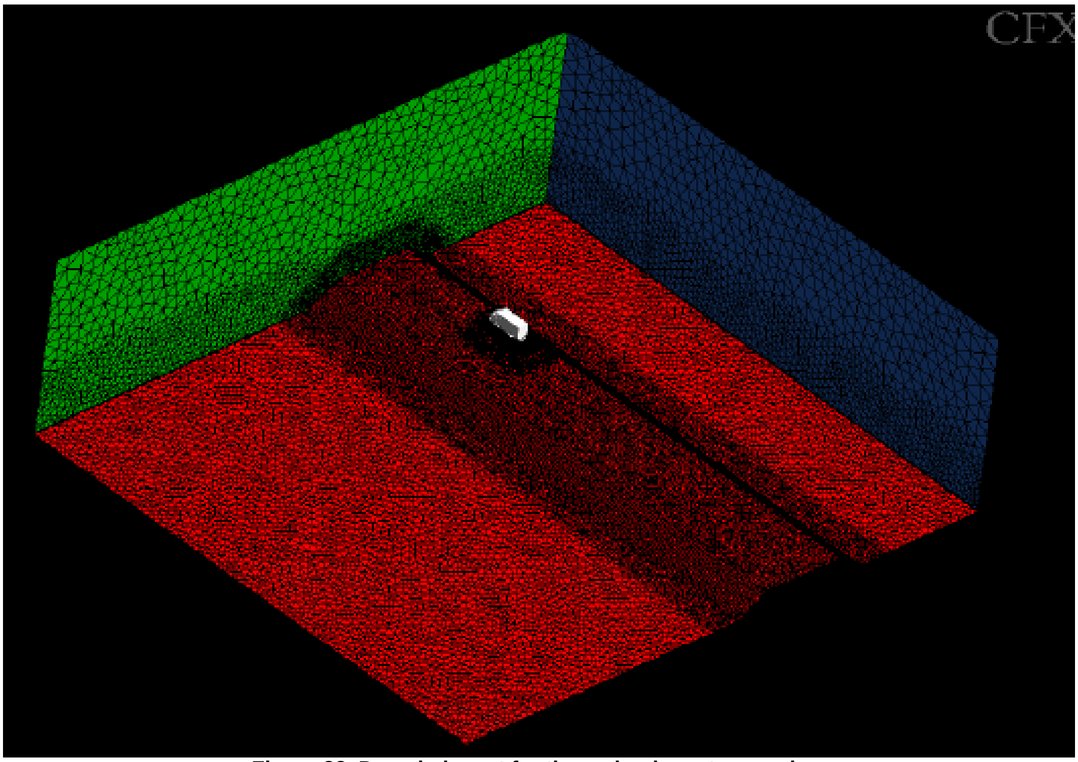


Figure 22 Domain layout for the embankment scenario

Yaw angle (.DEG) / Location on embankment	90	34
Upwind	0.915	0.972
Downwind	0.701	0.739

Figure 23 Side force coefficients for the embankment scenario

For the configuration on viaduct, the results for the upwind case have been found to have higher force coefficients than the downwind cases, except for the lift force coefficient.

2.2.3 Field tests

The field tests had a double objective:

- To supply the data base of aerodynamic coefficients for the risk simulation
- To validate the CFD computations and the wind tunnel tests.

Two types of tests was planned and have been performed: static and dynamic (moving vehicle) tests.

The initial schedule has been completed by a spectral analysis of the static tests. It supplies aerodynamic admittance functions for the rolling moment, for the VAN.

Static tests

The static tests have evaluated the lift force and the rolling moment coefficient of the VAN and the trailer in the atmospheric boundary layer. The measurements were carried out on a rural test site in Silsoe, where similar tests on buildings and other structures have already been performed. Consequently, the properties of the wind in the site are well-known. The main series of measurements were conducted during August 2005 – April 2006 for the van and January 2007 to March 2007 for the trailer.

The vehicle is mounted on 4 load cell. Aerodynamic forces are measured also with pressure tapping points on the sides and roof of the vehicle. (Figure 24 to Figure 26)

Figure 24 Static tests

Figure 25 Load cells and steel support posts on the rear of the vehicle

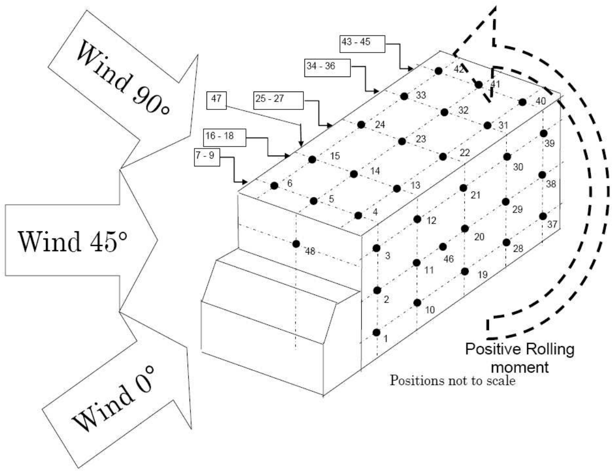


Figure 26 Location of pressure taps

The large degree of scatter in the data highlights the difficulties and the complexity of such full-scale tests. (Figure 27 and Figure 28) Both sets of measurements have been shown to be consistent with each other. However, the static results have to be validated by the moving tests.

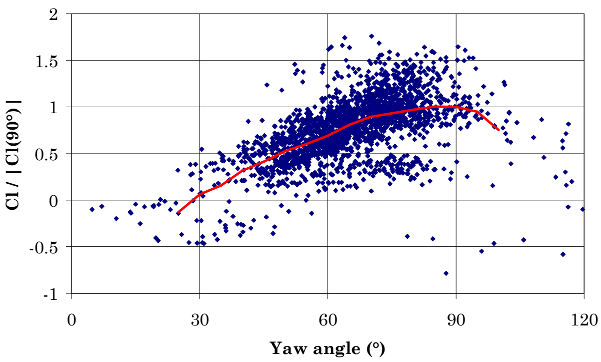


Figure 27 VAN - Lift force coefficient obtained with load cells measurements

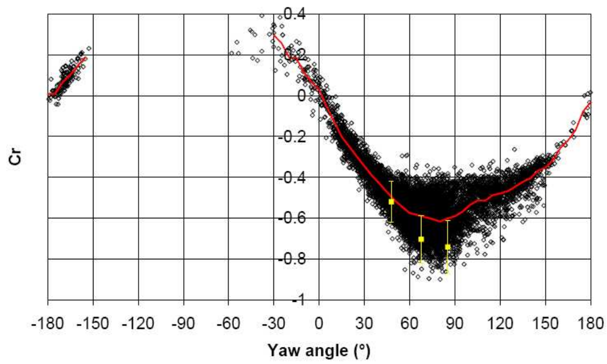


Figure 28 VAN - Rolling moment coefficient obtained with load cells measurements

Dynamic tests

The aim of these tests was to investigate if the stationary measurements agreed with the moving experiments. It is not unreasonable to expect different flow patterns and sizes of separation zones to occur between stationary and moving vehicles.

The moving experiments were undertaken with the van on a short section of the A6 road outside Barton-le-Clay, Bedfordshire in the UK not far from the field site used for the stationary measurements. Complete set tests for a vehicle speed of 90 km/h, have been collected. The van was equipped with 48 taps on the roof and the sides of box.

Figure 29 Instrumented moving van

Figure 30 Front view. Front taps, anemometer

Figure 31 Side tap

The presence of symmetrical tapping points allowed the estimation of the rolling moment due to the crosswind force by forming the difference in pressure coefficient from symmetrical tapping points and integrating these values at each yaw angle value. This analysis was restricted to the yaw range (0°, ±30°) due to the lack of accuracy ou tside this range.

The comparison of this rolling moment with that obtained in the static measurements is given in Figure 32. This comparison shows that the two types of measurement give good agreement for the range of yaw angles available and it's reasonable to neglect the effect of vehicle motion.

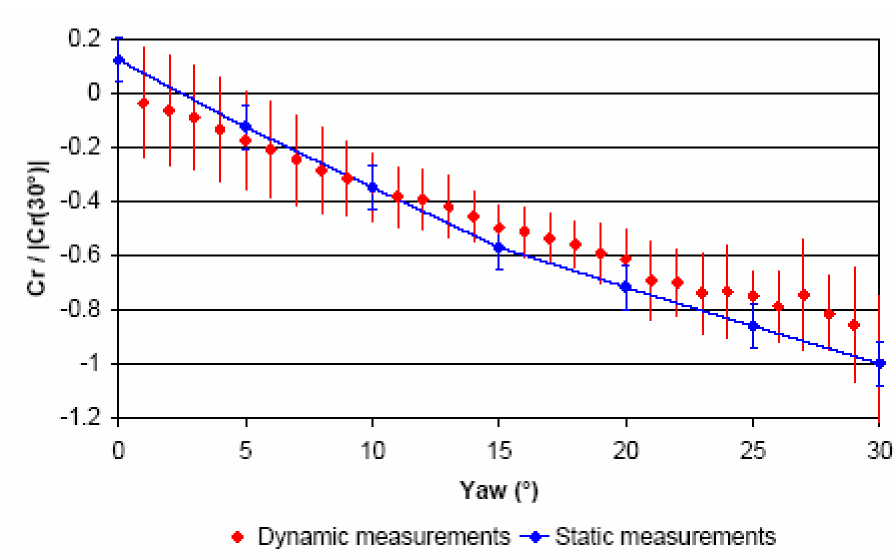
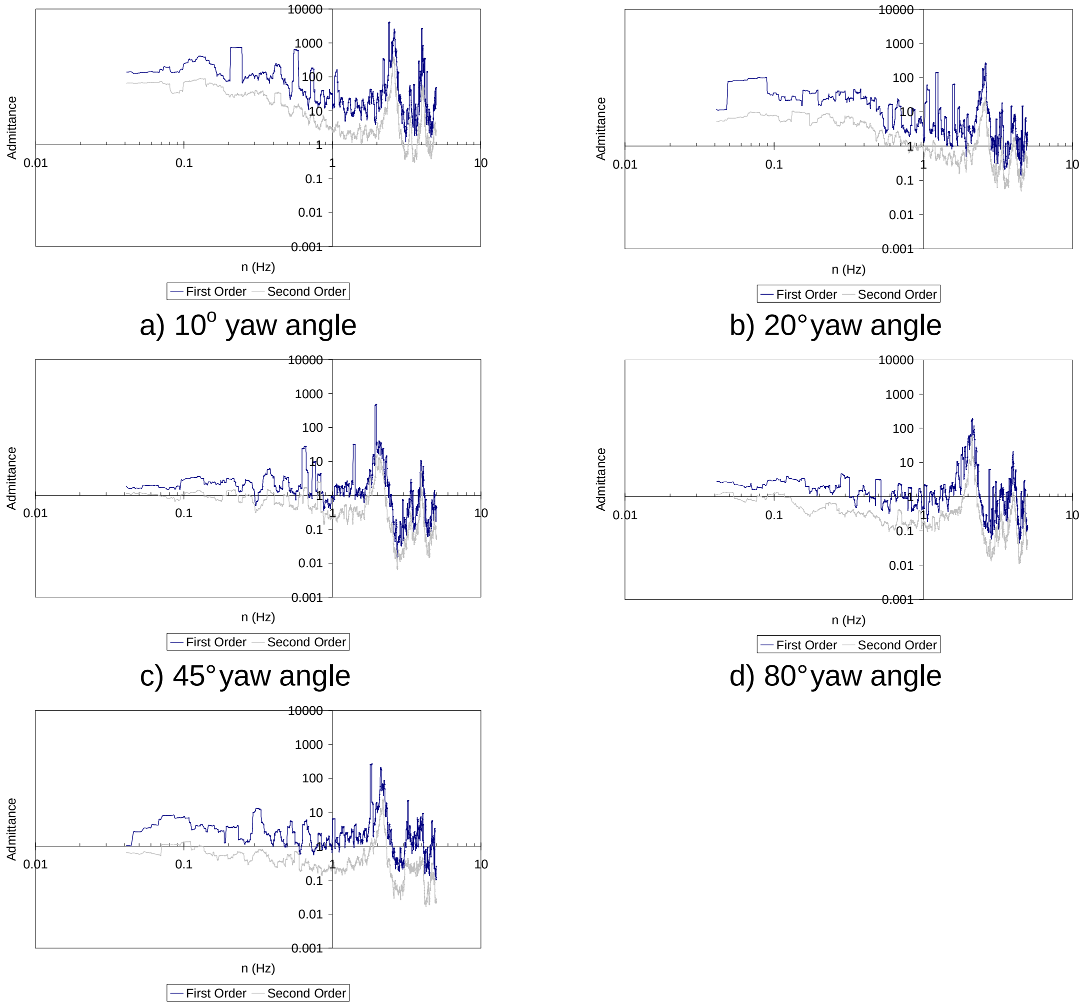


Figure 32 Comparison of the normalised rolling moment coefficients from the static and dynamic vehicle measurements.

Frequency domain analysis

A spectral analysis has been carried on the basis of the static results. A first analysis consists in the estimation of the admittance function for the rolling moment for different yaw angle form 10° to 90°. The admittance has been evaluated assuming two different hypothesises: a quasi steady approximation of the first order (only component u of wind) and of the second order (u and v components of wind).

For all yaw angles, the second order expansion has the effect of reducing the admittance function across the entire frequency range. At yaw angles equal to and greater than 45° the second order expansion tends towards unity at low values of frequency, thus, highlighting the important contribution of the fluctuations of lateral velocity. A local peak at around 2Hz can be observed for all yaw angles. This local peak represents the natural frequency of the mechanism used to connect the load cells to the vehicle chassis.



a) 10° yaw angle

b) 20° yaw angle

c) 45° yaw angle

d) 80° yaw angle

e) 90° yaw angle

Figure 33 Aerodynamic admittances for rolling moment coefficient obtained from the load cells.

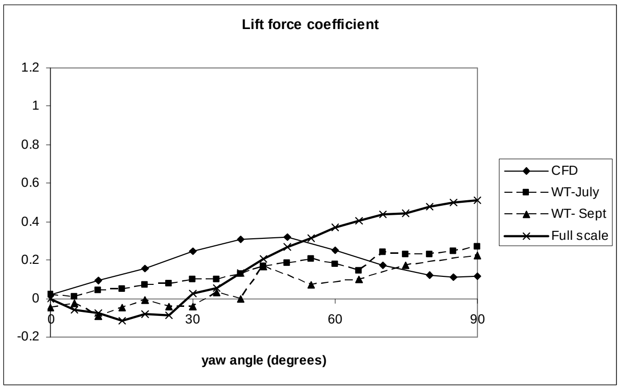
A second analysis estimates the peak factor that is related the maximum value of the rolling moment to its mean value and its standard deviation for different yaw angle. A spectral integration method is used to calculate the peak factor and is compared the directly obtained experimental one. The spectral integration method yields values close to the classical value of 3.0 assumed by Davenport but also underestimates the actual gust factor by an average of almost 20%.

2.2.4 Comparison between wind tunnel tests, CFD computations and field tests

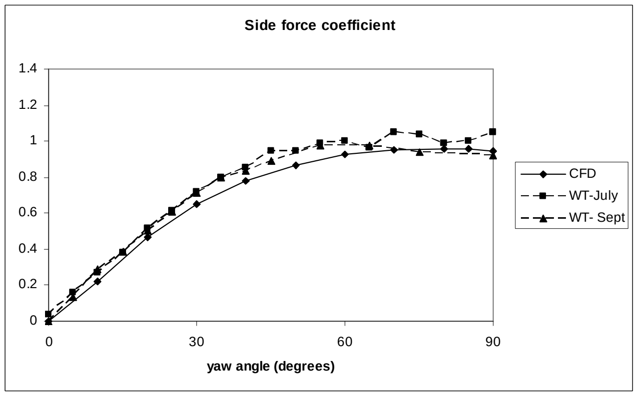
The workpackage supplied results of aerodynamic coefficients for a static van on flat ground by 3 methods: wind tunnel tests, CFD calculations and full-scale tests. The pressure distribution, forces and moments coefficients were determined by each partner and could be compared. The full-scale static experiment was the reference situation to reproduce.

The Figure 34 compares the side force, lift force and rolling moment coefficients obtained. The full scale tests were not able to measure the side force: the comparison concerns the wind tunnel and the CFD results. Also two sets of wind tunnel results marked as “July” and “September” referred to two sets of measurements. They illustrate the level of repeatability of the wind tunnel tests. It can be seen that all the sets of side force coefficient are in reasonably good agreement. The various sets of experiments all predict lift force coefficients of the same magnitude, although with a variety of different trends. For the rolling moment coefficient the CFD results are much closer to the full scale results that the wind tunnel values.

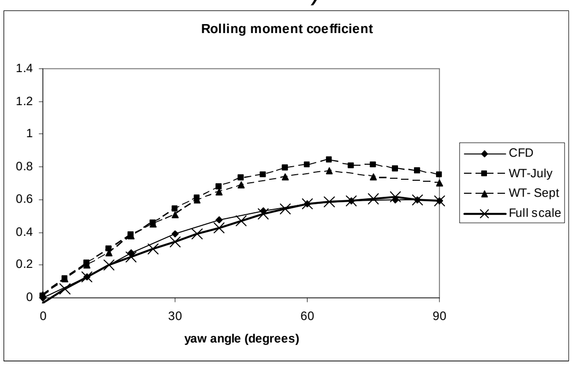
The comparison of pressure coefficients shows that there is reasonable agreement between the various sets of results on the windward face, with the full scale pressure coefficients being in general somewhat below the wind tunnel and CFD coefficients. However, the differences are stark on the roof, and the CFD calculations are unable to match the variation in the pressure coefficients across the roof measured at full scale and in the wind tunnel. A similar comment can be express on the leeside face. It must thus be concluded that the good agreement of the CFD results for rolling moment coefficient with the full scale results must be fortuitous.



a)



b)



c)

Figure 34 Comparison of force and moment coefficients from the full scale measurements, wind tunnel tests and CFD calculations

2.2.5 Data base for the wind alarm system

Road vehicles

The CFD computations, field tests and above all wind tunnel tests supplied a complete data set for the van vehicle and the trailer. Meteodyn has completed this data set by a state of the art. Relevant publications and results have been selected to be used in the dynamic computation of road vehicles. As a final result of this bibliographical work, a reference data set of aerodynamic coefficients was established for three types of vehicles: cars, van and lorries.

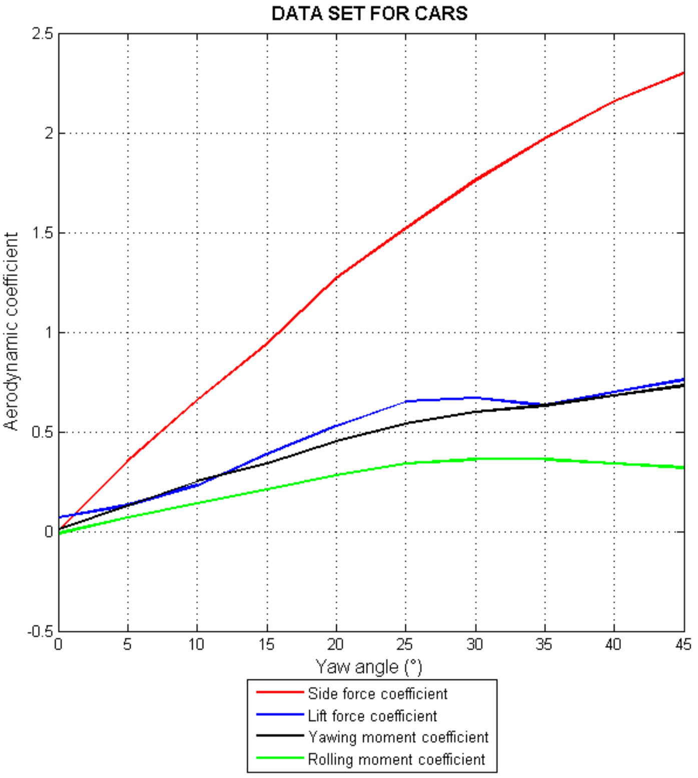


Figure 35 Generic aerodynamic coefficients for cars on flat ground

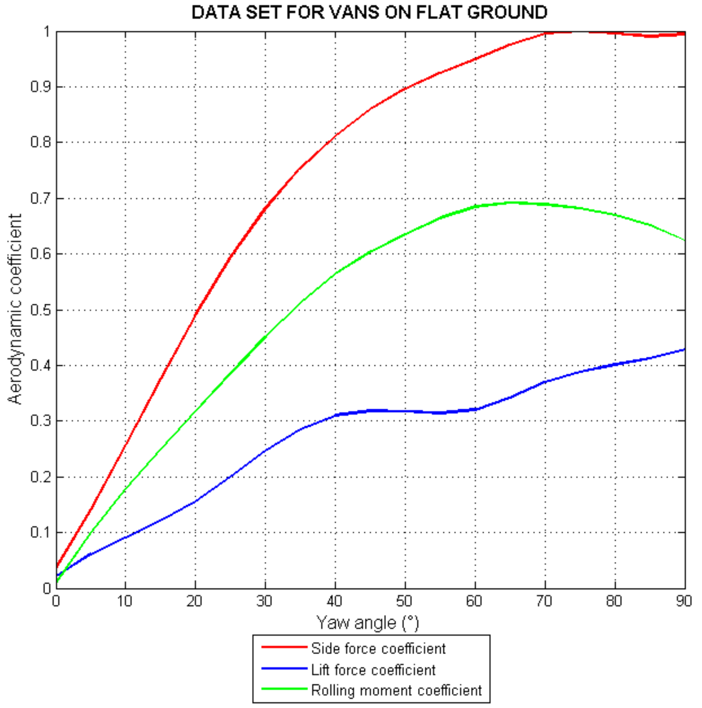


Figure 36 Generic aerodynamic coefficients for vans on flat ground

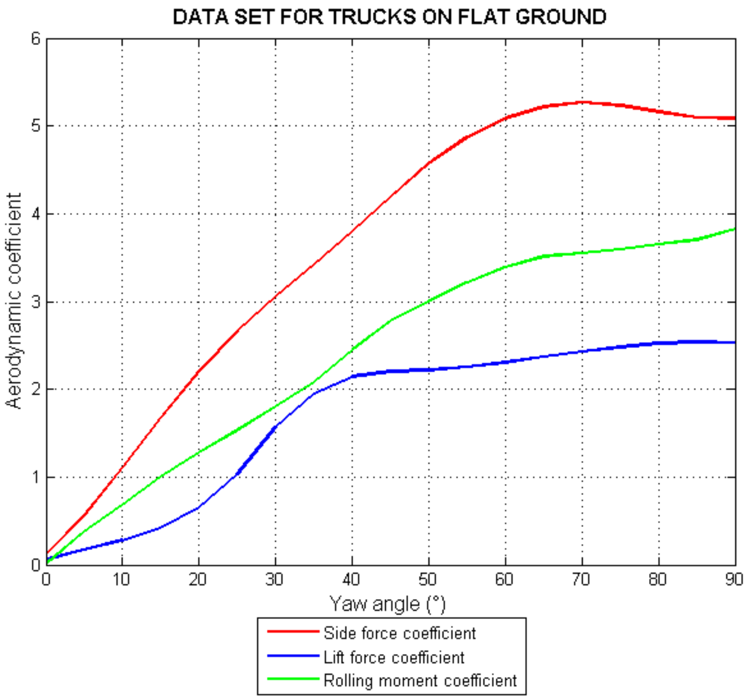


Figure 37 Generic aerodynamic coefficients for lorries on flat ground

Trains

It was initially planned to collect also a data base of aerodynamic coefficients for trains. However, this work was not completely achieved. Alstom has carried out a state of the art of the experimental and numerical studies but all the data are not public. As regards the public data, we can consider the results from TRANSAERO European project and from the extensive cross-wind studies performed in UK.

For the railway actors, investigations on the sensitivity of trains in crosswinds conditions are now mandatory. A TSI group (Technical Specifications for Interoperability) was constituted to harmonize methods / rules / systems on the High-speed European network. It makes a synthesis of many recent results obtained by the European industry. (DB, Ferrovie dello Stato (Trenitalia & RFI), SNCF, AEAT Rail (for RSSB), Bombardier, Siemens, Alstom, etc...) 3 reference High-speed trains were chosen:

- ICE 3
- TGV Duplex
- More recently : ETR 500
-

So, as regards the Wind-tunnel specifications, Aerodynamic coefficients or Vehicle geometry files, documents are intended to be public.

Moreover, aerodynamic coefficients from Deufrako European research project and from measurements carried out in the wind tunnel of POLIMI are in discussion to be published always in the framework of the TSI group.

So for railway vehicles, we can hope to access to a relevant data base of cross-wind results in the future.

2.2.6 Conclusion / deliverables

Concerning this workpackage, we can draw the following conclusions:

- The research work has been limited to road vehicles. Indeed, the partners have best improved the scientific knowledge on road vehicles. The TSI norms and future public documents will give information for trains that could be used in the risk computation.

- 13 configurations were tested in wind tunnel and supplied a large date set of aerodynamic coefficients for the van and the trailer

- According to the CFD computations, a new method has been performed to simulate the ground motion.

- The CFD and the field tests showed a good agreement between static and dynamic results.

- The CFD computations showed significant effects associated with the truck location and yaw angle for the embankment configuration.

- Field tests supplied a set of validation cases for CFD and wind tunnel tests and aerodynamic admittance functions for the rolling moment coefficient.

- The results obtained by the three methods have been compared. For side force coefficients, the wind tunnel and the CFD results are in good agreement. The various sets of experiments all predict lift force coefficients of the same magnitude, although with a variety of different trends and it's difficult to see if one is better than the others. For the rolling moment coefficient the CFD results are much closer to the full scale results that the wind tunnel values but the pressure distribution proved it must be fortuitous.

- Finally, a generic data set of aerodynamic coefficients has been established for road vehicles. This data set will be used for the risk evaluation.

The technical reports describing the works performed in this workpackage are given in the appendices 3 and 4 of this report. They contain the deliverables of this workpackage (see Table 6)

Task	Author	Title	Deliverables	Appendix
2.1	Meteodyn	Collecting of aerodynamic coefficients	D.2.1.1	3
2.1	Meteodyn	Collecting of aerodynamic coefficients – Data base as a function of vehicle classes	D.2.1.2	3
2.2	PoliMi	Report describing the experimental set-up and the wind-tunnel tests methodology	D.2.2.1_m	4
2.2	PoliMi	Complete data collection of the wind tunnel tests in electronic format	D.2.2.2_m	4
2.2	PoliMi	Report resuming the most significant results of the wind tunnel tests	D.2.2.3_m	4
2.2	PoliMi	Aerodynamic coefficient curves for different types of models	D.2.2.4_m	4
2.3	U. of Nott.	Final reports toward WP2	D.2.3.1 and D.2.3.2	5
2.4	U. of Bham	Full scale measurements of wind induced forces and pressures on a lorry and a trailer	D.2.4.2 and D.2.4.3	6

Table 6 WP2 : The aerodynamic coefficients - Reports

2.3 WORKPACKAGE 3 – RISK EVALUATION

This workpackage deals with the definition of an innovative method for calculation of accident risk in cross-wind condition. The objectives can de described as the following:

- To evaluate the possibility to integrate a road condition calculation function in the risk simulation
- To study the interaction between high wind and supercooled droplets and the possibility to detect a potential icing environment
- To define a vehicle dynamic system modelling suitable for the risk simulation as regards the computation time.
- To develop a stochastic simulation method to compute wind induced accident risk.

2.3.1 The surface state conditions

Figure 38 CIR sensor

Atmos has developed the CIR instrument. The system retrieved information about the cloud cover and the soil temperature by means of IR sensors watching upward and downward.

The soil temperature has been characterized with a mono-dimensional model such as :

$$\boxed{a\frac{\partial^2 T}{\partial x^2} + f = \frac{\partial T}{\partial t}} \qquad \text{with } a = \frac{\lambda}{\rho C_p} \text{ and } f = \frac{\dot{q}}{\rho C_p}$$

where T is the soil temperature
λ the thermal conductivity
ρ the density
C_p the specific heat
$\dot{q}$ the internal source for solar irradiance and convection

The model has to calibrate for rain events. Such events are difficult to model with the adequate accuracy. So, an experimental analysis was carried out comparing synoptic observations and CIR data.

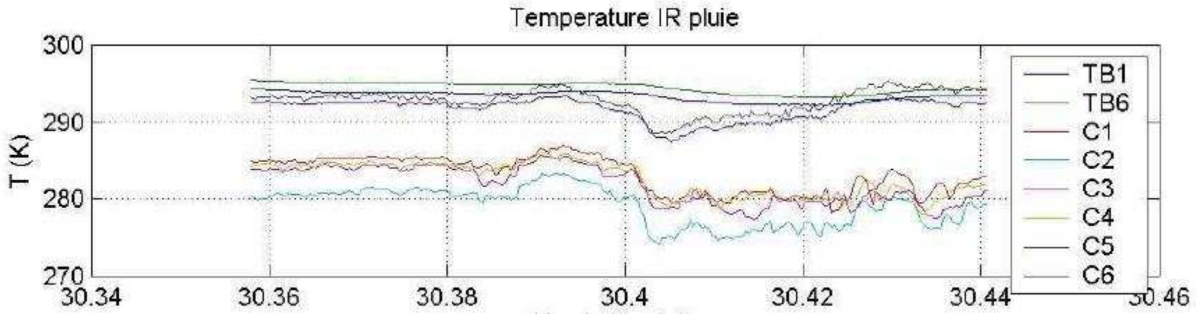


Figure 39 Recording of IR temperature during a rain event

As regard the data collection, an hypothesis was put forward: the temperature of the droplets creates a cooling effect of the soil brightness and the IR temperature decreases. This hypothesis still needs validation data sets on more significant period. Moreover, the interaction of the cloud cover and downward irradiance has to be modelled and quantify with accuracy.
So, for the moment, the study performed did not provide results allowing implementation of an industrial algorithm in the CIR 4 system for determination of the surface state.

2.3.2 Other wind-related risks

Figure 40 Pludix sensor

Nubila has worked on the development of the PLUDIX sensor. Models were developed to detect different types of precipitations (snow, hail, rain…). These models establish the relation between the precipitations and the road safety. This research was based on two main axles:

- The definition of an algorithm to calculate the risk of aquaplaning.
- The improvement of the ability of the PLUDIX to detect any kind of precipitation.

Risk of aquaplaning

The PLUDIX outputs are used to determinate the water volume fallen over the road. The ability of the road to drain water is characterized with a parameter given by the road builder. So, a risk criterion qualifying the aquaplaning was defined by calculating the water volume actually present on the road. 6 different states can be distinguished:

1. No water is cumulating. The road may be dry. It is not raining.
2. No water is cumulating. The road may be dry. It is raining (it starts to rain).
3. No water is cumulating. The road is wet.
4. Limit condition
5. Water is cumulating. Shallow standing water. Aquaplaning
6. Water is cumulating. Deep standing water.

Improvement of the PLUDIX capacities

A complete analysis has been carried out to compare datasets of contemporary records of PLUDIX data and World Meteorological Organization codes given by human observer.
This analysis allowed to improve the efficiency of PLUDIX sensor and its sensitivity to detect all kind of precipitations. The method of detection is based on spectrum analysis.

The newly developed functions are useful for punctual early and dynamical warning of dangerous conditions for surface transports and can be, in this way, fully integrated in the Early Warning System developed under WEATHER project.

2.3.3 Vehicle dynamics modelling

The objective consists in modelling the vehicle dynamic system that will be introduced in the stochastic simulation.

Road vehicles

During the first year, Meteodyn worked on the development of a Simulink/Matlab medium complexity model in order to characterize the dynamic response of a road vehicle to an unsteady wind input. This model is not too complex because the numbers of parameters to identify must be as low as possible. However it must be realistic and will integrate the most relevant elements of vehicle dynamic. Such a model was adopted by LIVIC/INRETS unity research to the development of driver longitudinal and lateral assistance [31], [32]. The diagram (Figure 41) shows the model the simulink model.

This work continued during the second period but two elements lacked to get an operational tool:

- No validation tests were performed to compare the system to a MBS model
- Too many parameters were unknown. It was difficult to define reference vehicles with a complete set of dynamic parameters: We lacked public characteristics.

During the second period, we orientated this task in order to be able to test the stochastic simulation of risk. Meteodyn works on the design of road security systems within the framework of the French research program IRCAD. Then, in contact with road managers and French specialists of road transportation, we learnt that static criteria are used to define the limiting speeds of the vehicle on a particular section of road. So, we decided to work with a simplified model and static criteria. Two criteria were associated to two types of accidents: the road exit and the overturning. For the road exit, the road condition (wet or dry) interacts in the static criteria.

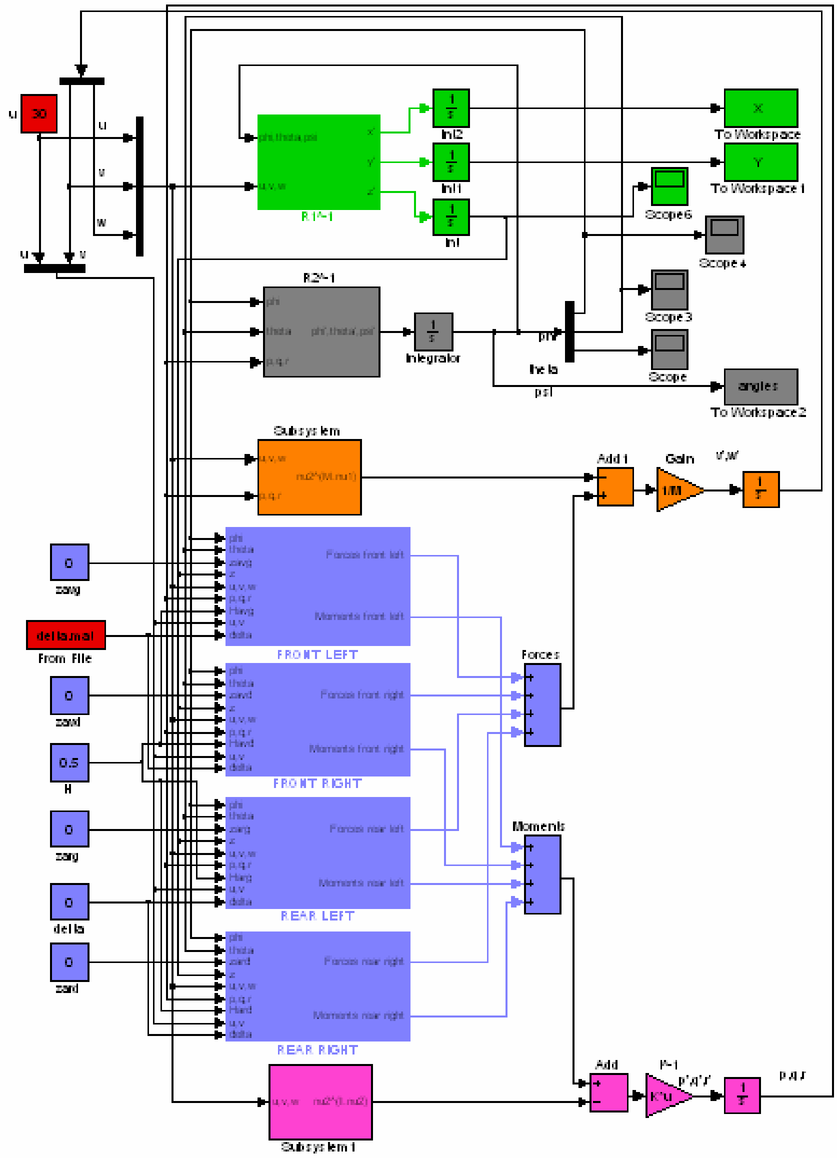


Figure 41 Road vehicle model in development

Trains

The TSI provides a method to guarantee the safety of the vehicle and infrastructure against strong crosswinds and to compute Critical Wind Curves (CWC). This method is based on computing vehicle response to a given gust. The shape and characteristics of that gust were chosen to be representative of the natural wind. Nowadays, this wind modelling seems to be very restrictive in comparison with the natural wind especially for long non deformable vehicles like Alstom's AGV train. During this second year, Alstom has defined a method to obtain Stochastic CWC. A Monte Carlo simulation method is applied with the following steps:

- First some wind fields are generated in a moving frame (paragraph 2.1.3)
- Then the dynamical behaviour of the train in those wind fields is computed with a MSB model. To compute aerodynamical forces, the layer by layer aerodynamical coefficients are used. Those coefficients are computed using CFD code and fitted to trials global coefficient. Indeed, along a vehicle, the correlation of turbulence seen by the vehicle (200m train set) can loss 30% so a single point by vehicle can't carry all the information of the turbulence. Moreover it allows to distinguish the contribution of the different parts of a vehicle on aerodynamic torque.
- Finally the unloading probability law is build. We can deduce the CWC associated to a given rejection rate. The rejection rate has been chosen in agreement with TSI method that is to say, with the gust coefficient chosen.

Comparisons have been made between the Stochastic (SCWC), the Deterministic (DCWC) and the TSI (RCWC) Characteristics Wind Curves for Alstom TGV2N engine car. Those curves are quite different at high speed, and low incidence angle.

The method seems to enhance system security and is well adapted to risk calculation and to train set CWC computation since it doesn't make the gust assumption (which can't be valid for a 200 m vehicle). The TGV2N engine car results show the importance of v component and of the dynamics due to those components by the use of Slice-by Slice coefficients. (the v component is not taken in account in TSI recommendations)

2.3.4 The stochastic simulation

Meteodyn has developed the stochastic simulation method to compute wind induced accident risk. This method allows determining limiting wind curves at the wind alarm station. A limiting wind curve is associated to a vehicle, a type of accident, a vehicle speed and a given level of risk. If the local wind exceeds the limiting wind, a wind alarm is detected. The risk evaluation is based on the simulation of complete time series of wind, rather than a simple consideration of extreme values as it has been the case in the past.

A modular software has been developed by Meteodyn in order to compute the limiting wind curves. The method is based on a Monte-Carlo procedure. For a given mean wind (speed and direction) at the monitoring station a great number (N) of crossing are simulated. For each crossing, signals of wind are generated and applied on the vehicle (workpackages 1 and 2).

The dynamic response of the vehicle is characterized either by a complete dynamic simulation of the vehicle behaviour or by comparing the instantaneous wind to local limiting wind curves. So, for each crossing, it's detected if the vehicle is in a risky situation. Finally, we obtain the conditional probability to be in a risky situation. We said conditional because this probability is associated to given mean wind speed and mean wind direction at the station. The integration on all the acceptable winds gives the risk to have an accident. So it enables to determine a limiting wind curve associated to a given risk of accident.

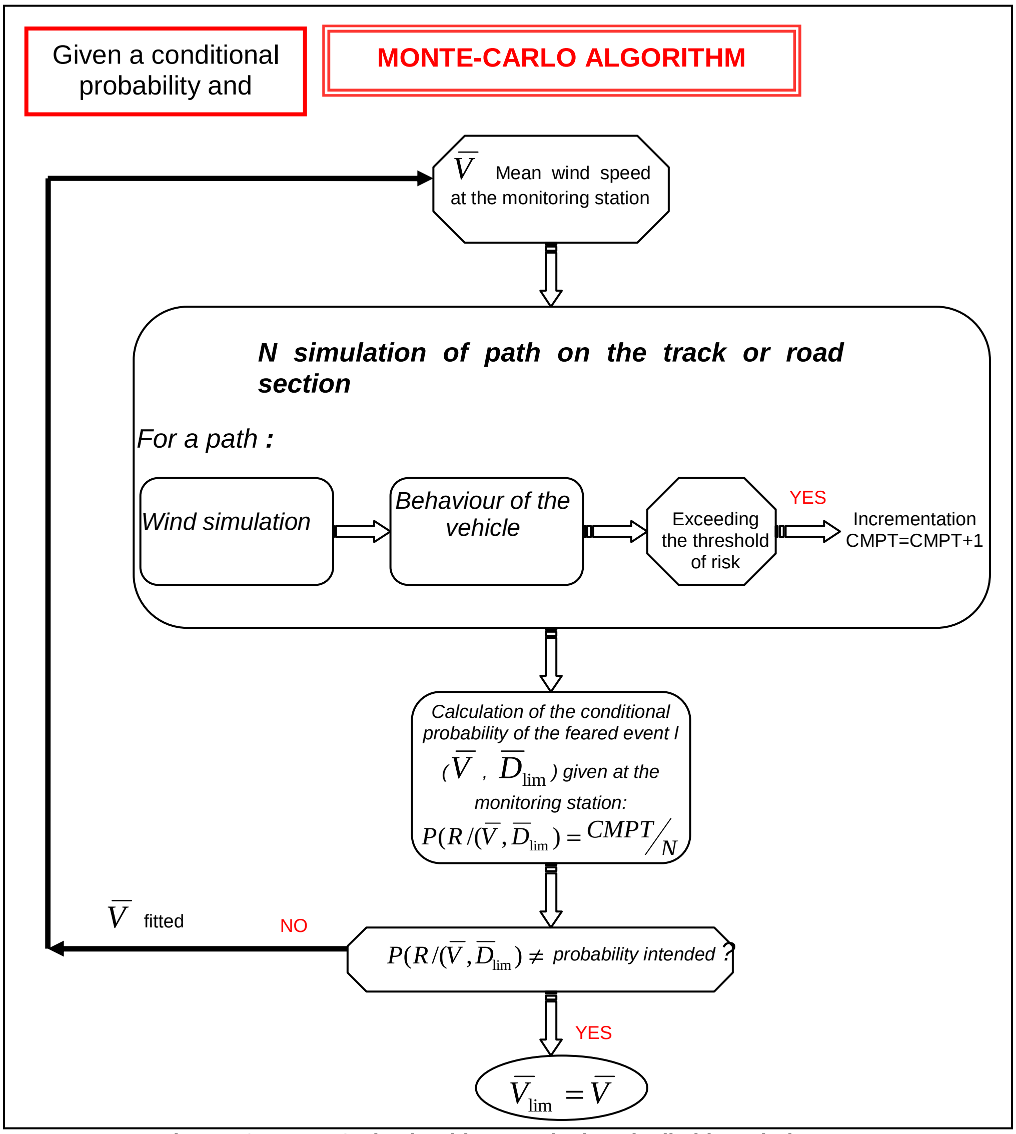


Figure 42 Monte-Carlo algorithm to calculate the limiting wind curve

The robustness of the algorithm has been tested on the site of Maremola, a road viaduct in Italy. Three classes of road vehicles were distinguished: passenger car, van and truck as regards the data set of aerodynamic coefficients obtained with workpackage 2. The dynamic modelling of vehicles has been simplified and two static criteria were used for road exit accident and overturning accident.

The Monte-Carlo protocol was used. For given wind speed and wind direction at the monitoring station, 5000 draws simulate 5000 crossings of the viaduct. For a crossing, wind signals are simulated along the viaduct in every point, every 50m (workpackage 1). The wind seen by the vehicle at each point is compared to the local critical wind curve obtained according to the static criteria of accident. It gives us the conditional probability to overpass at least a local critical wind curve.

For this case, we have not calculated a global risk of accident because we have no idea what the road manager would adopt. Therefore, a conditional probability of 0.1% was fixed. It seems that this condition gives us critical wind speed not too far from the existing alert system

2.3.5 Conclusion / deliverables

As a final result, the risk simulation was applied on the critical place in the viaduct of Maremola. The simulation integrates the research work carried out in workpackages 1 and 2 and validates our methodology. Static criteria were used instead of a complete dynamic modelling of the vehicle. This choice is in accordance with common practice for road manager. However, this part could be improved in the future.

For railway vehicles, a stochastic method to determine CWC has been put in place and the results for TGV2N engine car were compared to the deterministic method recommended by the TSI group.

The description of works that have been developed in this WorkPackage are given in Appendices 7 and 8 of this report. They constitute the deliverables of this WorkPackage.

Task	Author	Title	Deliverables	Appendix
3.1	Atmos	Determination of road surface condition in the scope of the WEATHER project	D.3.1	7
3.2	Nubila	Other environmental impacts	D.3.2	7
3.3	Meteodyn	Vehicle dynamic system modelling.	D 3.3.1	8
3.4	Meteodyn	The stochastic simulation - Example of application in Maremola	D.3.4	8

Table 7 WP3: Risk evaluation - Reports and deliverables

2.4 WORKPACKAGE 4 – WIND ALARM SYSTEM PROTOTYPE

The experimental results and the technical method developed in workpackages 1 to 3 forms a robust input to the technology of the wind alarm system. The workpackage 4 is dedicated to the design of the wind alarm system. Four main objectives have to be accomplished:

- The integration of the sensors: The wind alarm system must be able to integrate standard meteorological sensors (wind, pressure, temperature, humidity...) as well as innovative sensors for the evaluation of road surface condition (PLUDIX and CIR)

- The development of the datalogger: The product must perform the acquisition of the measurements, the prediction of the wind, the detection of wind alarms by comparing the predicted wind to limiting wind curves, the storage of the data

- The development of the transmission systems for the alarm and for the measured data

- The validation of a prototype in real conditions

2.4.1 Sensors integration

Geonica has developed a wind alarm system that offers a great flexibility as regard the integration of sensors. The system meets requirements about the power supply of sensors and the calibration of the sensor's response. Therefore standard meteorological sensors as well PLUDIX or CIR sensors can be integrated. The surface state sensors will be proposed as optional in the final product.

Pludix system

From the beginning of year 2006, NUBILA has performed some works for improving PLUDIX HW/SW technology. In particular, there has been a change of the electronical components of the embedded computer in order both to reduce the signal/noise ratio of the instrument and for having new available signal outputs.

Two different communication network are available. The communication mode chosen will depend on the PLUDIX placement (near or far the host PC) and the transmission channel available. Two data exchange protocols can be distinguished:

- ✓ a proprietary protocol on the RS232 serial channel
- ✓ a TCP/IP protocol (based on the Berkeley BSD 4.3 stack)

Both protocols are offering the same access features to PLUDIX, i.e.: both allow to control and monitor the PLUDIX and to download collected data.

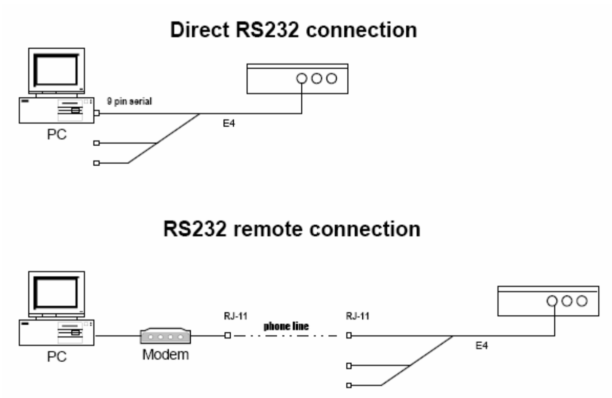


Figure 43 RS232 protocol

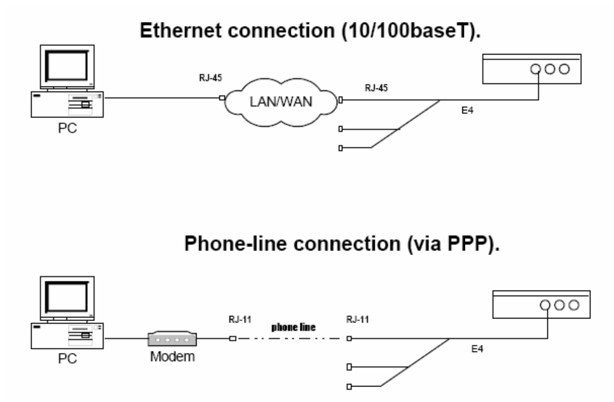


Figure 44 TCP/IP protocol

Surface-state sensor (CIR)

The CIR is still in development and not operational right now for a marketing product.

2.4.2 Data logger development

Geonica has developed a data logger prototype, which can satisfy the needs of the wind alarm system. The prototype proposed by Geonica meets the requirements in terms of:

- Functionalities needed for the hardware and the firmware
- Flexibility for the integration of sensors
- Integration of the time-prediction model
- Flexibility for the integration of the wind alarm program
- Capacity of data storage
- Compatibility of transmission processes with road monitoring systems

EMI has developed an interface (Windmet) which is being used for its own prototype

Nubila has developed data loggers in connection with PLUDIX measurements.

2.4.3 Transmission and information management

The prototype of Geonica allows a great compatibility with road monitoring systems. The mode of communication is flexible enough to be adapted to any system. The transmission and information management for the prototype of Geonica are summarized in the figure below.

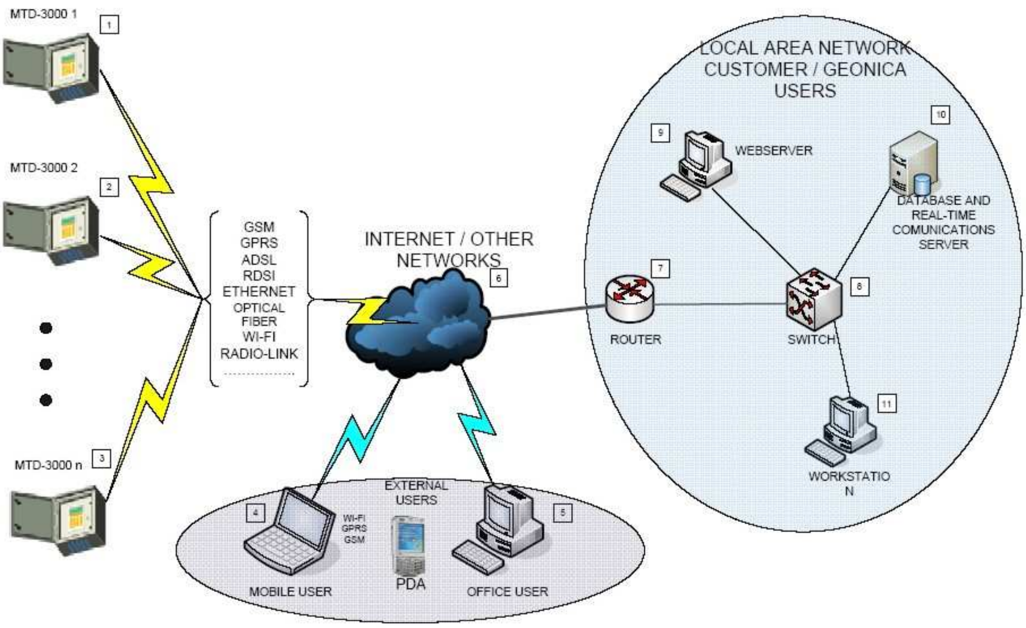


Figure 45 Transmission and information management

The specifications for transmission are:

Communication Ports	4 serial ports total: • COM 1: RS232 (Front Panel and terminal strip) • COM 2: RS232 (Development) • COM 3: RS232/422/485 (terminal strip) • COM 4: TTL (GSM/GPRS/PSNT)
Telemetry/communications	CABLE • RS232/422/485 serial CMOS GSM/PSTN TCP/IP Networking • GPRS • Fiber optical • Ethernet Wi-Fi, etc… OPTICAL FIBER • Point to point (multimode, monomode) BLUTOOTH RADIO LINK SATELLITE
Data transfer Rate	1.200 to 115.200 bps
Alarms Transmission	Programmable with optional transmission of SMS messages (Other messages optional)
Imagery	Alows the connection of one or more WEBCAMS for still images, capture and transmission.

Table 8 Geonica prototype - Specifications for transmission

The prototype of Geonica is operational and meets the requirements of end-users. The data can be received in near-real time via Internet in a specific web site. The end-users can be informed of detected alarms by SMS.

2.4.4 Prototype installation and maintenance

Geonica has installed a prototype on the Maremola viaduct in January 2007 (see figures 46, 47, 47a). Pludix and CIR are not included in the prototype system. So, only the analysis of wind data has been made by Meteodyn.

The system is composed of standard meteorological sensors. The time-prediction model consists in a persistence model as far as the calibration of the model needs a few months of measurements.

A risk simulation has supplied the prototype with limiting wind curves (paragraph 2.3.4). So, the system is operational. Geonica has developed an instantaneous transmission network between the station and their WEB site. So with a login and a password, anyone can access in real-time to the measurements, plot them and export them. The system records the effective wind alarms and can advise by mobile phone.

Figure 46 WindAlert prototype on the viaduct of Maremola

Figure 47 Aerian view – Viaduct of Maremola

Figure 47a: Location of the WindAlert system and the ADF station on the Maremola viaductAerian view

Meteodyn has analysed the first month of wind measurements. A discrepancy between the wind measurements at the two stations, the previous one of ADF and the WindAlert station have been observed (figures 48 and 49)and the wind calculation in relation with the direction has been detected. The Meteodyn NS computations give directions in the range of the difference between the two measurement systems.

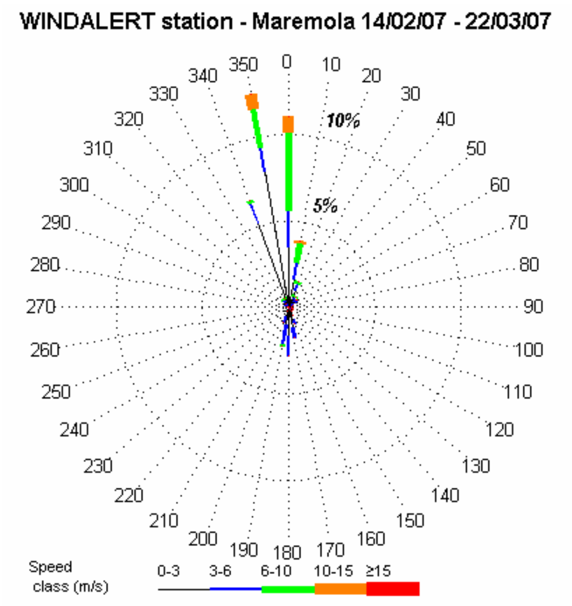


Figure 48 WINDALERT prototype : Compass rose – Frequencies for various wind speed classes

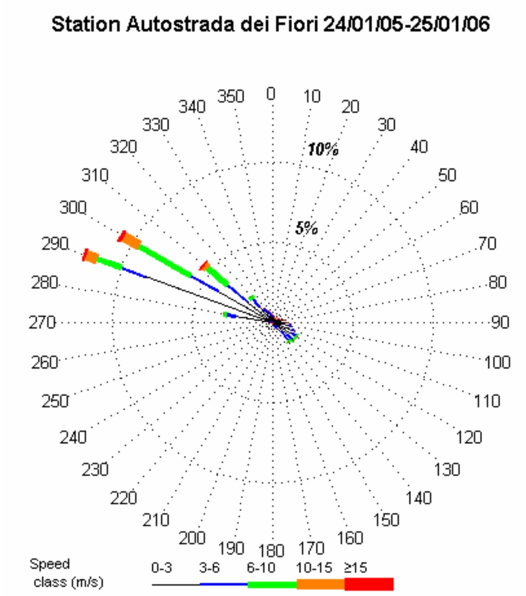


Figure 49 ADF station : Compass rose – Frequencies for various wind speed classes

The Figure 48 and the Figure 49 give the compass roses corresponding to the two stations on the Maremola viaduct. (WINDALERT prototype and Autostrada dei Fiori station). We see there's a discrepancy in the main direction of wind. It must come from a default in the installation of the sensors.

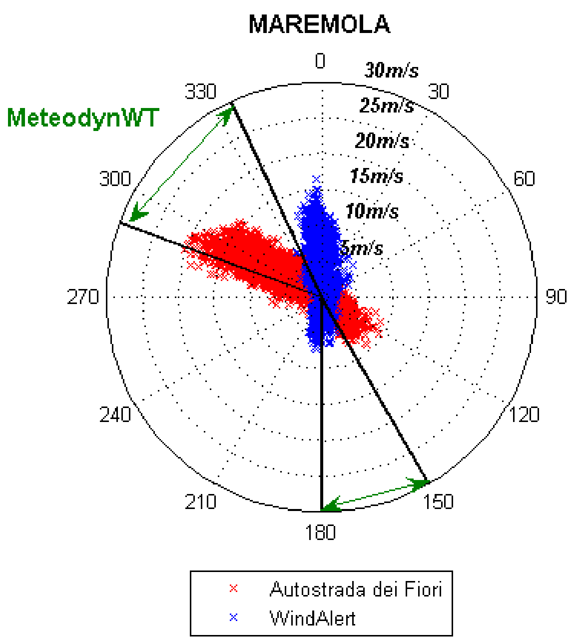


Figure 50 Compass rose : Comparison between measurements from ADF and the WINDALERT prototype and MeteodynWT computations

As an input of the computation of the CWCs, the wind characteristics are computed with the software Meteodyn NS. It gives the relationship between the mean wind (speed and direction) measured at the WINDALERT stations and the mean wind along the viaduct. In this case, the

wind is channelled between the mountains and there is an unique possible axle of direction at the WINDALERT station. From the Meteodyn NS computation, the main direction of wind is [330°, 150°]. Now if we compare (Figure 50) the mea surements in the two stations and the main wind directions computed with Meteodyn WT, we obtain a discrepancy in the wind direction.
It can come from:

- ✓ A problem in the orientation of the sensor
- ✓ A lack of precision in the computation Meteodyn WT. Indeed, the computation was carried out with topographic files with a precision of 90m. For this particular topography, it's perhaps not accurate enough and leads to a smoothed relief.

2.4.5 Conclusion / deliverables

The final product has been validated in real conditions. The wind alarm system is operational in relation to the different points highlighted in workpackage 4:

- ✓ The interconnection between the sensors and the data logger
- ✓ The integration of the algorithms for time-prediction model
- ✓ The integration of the limiting wind curves and the procedure to detect alarms
- ✓ The development of an operational data logger (acquisition, data storage, power supply, prediction algorithm and limiting wind curves)

All these technological aspects appear to be controlled.

The development of PLUDIX and CIR sensors will continue and they can be proposed as optional for the end-users.

The details of works, as well as the deliverables of this WorkPackage can be found in the Appendix 9 of this report.

3 CONCLUSION

When regarding the sum of work which has been carried out inside the WEATHER program, it is satisfactory to note that new technologies and methods have been obtained in all the very different domains concerned by a wind alarm system: wind modelling (in space, time, and turbulence simulation), assessment of methods for aerodynamic forces evaluation, dynamical modelling, stochastic methods for risk assessment, and finally an operational wind alert system, currently in place at the Maremola viaduct.

The sum of these advances makes the WEATHER wind alert system a really innovative product, which should satisfy the requirements of road and rail managers.

The WEATHER partners have collaborated in a very fruitful way and have been able to share their complementary know-how and knowledge. All the modifications of the planned schedule have been justified as regards the final objective to design an attractive operational wind alarm system.

The main results of the WEATHER program concern:

- ✓ The elaboration of spatial-time model in compliance with the needs of wind alarm systems (Workpackage 1). The time-prediction model can be improved in the future, perhaps with the integration of a meso-scale meteorological model.
- ✓ The development of robust methods to get cross wind forces on a van and a trailer (wind-tunnel, CFD, field measurements). A comparison between these three methods has been perfomed (Workpackage 2). Comparisons with other research results could be carried out in the future
- ✓ The definition of a complete data base of aerodynamic coefficients to use in the Wind Alarm System (Workpackage 2). This data base could be supplied with new results in the future.
- ✓ The development of innovative sensors for surface state conditions and other environmental condition (CIR, PLUDIX). They can be proposed as optional in the wind alarm product.
- ✓ The development of innovative methods to assess the risk of wind induced accidents of rail and road vehicles occurring at exposed sites (Workpackage 3).
- ✓ The designing of a Wind alarm prototype validated in real condition in the viaduct of Maremola

The operational feature of the prototype developed has been tested in real working conditions. The SMEs now have a product at their disposal. They have now to continue their collaboration in order to keep their advance and to market the product.

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