European Cooperation in the field of Scientific and Technical Research - COST -

Secretariat

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MEMORANDUM OF UNDERSTANDING

Subject : Memorandum of Understanding for the implementation of a European Concerted Research Action designated as COST Action TU0903: Methods and tools for supporting the use, calibration and validation of traffic simulation models

Delegations will find attached the Memorandum of Understanding for COST Action TU0903 as approved by the COST Committee of Senior Officials (CSO) at its 174th meeting on 26-27 May 2009.

MEMORANDUM OF UNDERSTANDING

For the implementation of a European Concerted Research Action designated as

COST Action TU0903

METHODS AND TOOLS FOR SUPPORTING THE USE, CALIBRATION AND VALIDATION OF TRAFFIC SIMULATION MODELS

The Parties to this Memorandum of Understanding, declaring their common intention to participate in the concerted Action referred to above and described in the technical Annex to the Memorandum, have reached the following understanding:

1. The Action will be carried out in accordance with the provisions of document COST 270/07 "Rules and Procedures for Implementing COST Actions", or in any new document amending or replacing it, the contents of which the Parties are fully aware of.

2. The main objective of the Action is to develop, implement and promote the use of methods and procedures for supporting the use of traffic simulation models, especially on the topics of model calibration and validation.

3. The economic dimension of the activities carried out under the Action has been estimated, on the basis of information available during the planning of the Action, at EUR 56 million in 2009 prices.

4. The Memorandum of Understanding will take effect on being accepted by at least five Parties.

5. The Memorandum of Understanding will remain in force for a period of 4 years, calculated from the date of the first meeting of the Management Committee, unless the duration of the Action is modified according to the provisions of Chapter V of the document referred to in Point 1 above.

A. ABSTRACT AND KEYWORDS

To date, the bulk of resources and effort in the field of traffic simulation have focused on "model development", leading to many simulation models being available on the market. These models are extensively used in applications that have great potential impact on the safety, capacity and environmental efficiency of the road system. However the fidelity of results and conclusions drawn from a simulation study, as well as the range of possible applications the tools can reliably be used for, are questionable: the same simulation study carried out by different people, even when using the same tool, is likely to give different results. Thus, the trustworthiness of the results almost entirely depends on the ability of the model users and on their intuition. Moreover, the increasing complexity of models makes appropriate and correct use a difficult task even for experts, requiring very specific calibration and validation methodologies. For these reasons the main objective of this Action is to develop, implement and promote methodologies and procedures to support the use of traffic simulations, especially on the topics of calibration and validation. To this aim the sharing and exchanging of available traffic datasets will also be a key task of the Action.

Keywords: Traffic simulation models, model reliability, model calibration and validation, traffic measures estimation, O-D flows estimation

B. BACKGROUND

B.1 General background

A rapidly expanding range of traffic and transportation applications call for accurate dynamic modelling of traffic flow due to their potential impact on community and environmental decision making. These range, for example, from the assessment and planning of road infrastructures to evaluation of advanced traffic management and information systems (e.g. dynamic hard-shoulder running), and to testing technologies and systems that aim to increase safety, capacity and environmental efficiency of vehicles and roads (e.g. Cooperative Systems or CVHS, Intelligent Speed Adaptation or ISA). The complexity and scale of these problems dictate that traffic simulation models, rather than analytic methods, are increasingly being used for these purposes.

Many such traffic simulation models are currently available on the market and extensively used both in professional practice and in R&D. However the fidelity of results and conclusions drawn from a simulation study, as well as the range of possible applications the tools can reliably be used for, are questionable: the same simulation study carried out by different people, even when using the same tool, is likely to give (sometime very) different results. Thus, the trustworthiness of the results almost completely depends on the ability of the model users and on their intuition. Moreover, the increasing complexity of these models, which is required to address ever more complex applications, make their correct use a difficult task even for experts. One of the most important steps to be taken in research in this field therefore, is to develop methods and procedures to help users apply available traffic simulation models correctly, effectively and repeatably.

Motivations and solutions to this problem can be found in the nature of traffic models themselves and in the way they are applied, following an approach which is half-way between deductive and inductive,

"whereby one first develops (via physical reasoning and/or adequate idealisations and/or physical analogies) a basic mathematical modelling structure and then one fits this specific structure (its parameters) to real data" (Papageorgiou, 1998).

The latter phase, generally referred to as model calibration and validation, is therefore a necessity in order to adequately represent the real world and to be able to provide reliable estimations and predictions. Unfortunately, calibration and validation against suitable observed data are far from common practice in the field of traffic simulation. There are so far no standardised methods, nor even a common or widespread understanding of these issues, as most effort and resources have been focused only on model (and software) development.

While researchers have recently started working on these topics within national programs, these are on the whole fragmented, based on different data sets, and motivated by different applications. The problem is further complicated by geographic and cultural differences in attitudes towards driving, road design and traffic regulations among different countries, resulting in considerable differences in driving behaviour and traffic operations that further compound the variations that must be accounted for. Research purely at a national level cannot therefore comprehensively tackle this problem and a fundamental initiative is needed for exchange of ideas, data and research results at a European level.

It is worth noting that a crucial requirement for the success of this research is the availability of real-world traffic data, and to this end this COST Action will facilitate the sharing and the exchanging of existing traffic data. In particular, vehicle trajectory data, which are very difficult and costly to obtain, that have been collected in previous or ongoing national research projects will be promoted and shared. Contextual availability of a number of datasets differing in accuracy, temporal and spatial extension, traffic conditions, type of road, etc., will be fundamental for obtaining a thorough insight into model behaviour and allowing subsequent calibration and validation.

B.2 Current state of knowledge

A clear indication on the state of the practice of traffic analysis tools is given by results of the survey carried out by the National Cooperative Highway Research Program "Guidance for the Use of Alternative Traffic Analysis Tools in Highway Capacity Analyses" (NCHRP 3-85), administered by the USA Transportation Research Board (2007) and aimed at defining how traffic simulation should be included in the 2010 update of the Highway Capacity Manual. Only 30% of the analysts interviewed stated that they perform model calibration/validation using site specific data collection studies, while about 60% did not make use of any traffic data when applying these tools.

These results are surprising only at a first glance, as they actually originate from the lack of a common understanding of the problem, of established methods, as well as of appropriate tools in commercial software. At the moment in fact a number of basic questions still remains unanswered: for example, how can different type of measurements - trajectories, point measurements, etc. - and performance measures - speeds, headways, counts, etc. -be most effectively used for model estimation, calibration or validation? What is the effect of data errors on calibration? How, where and when do traffic data have to be gathered, that is, how do traffic phases affect calibration results and, therefore, the ability of calibrated models to provide reliable estimations and predictions?

Recent awareness of the lack of reliability of traffic models on the one hand, and opportunities to collect innovative traffic data - allowed by the recent development of digital technology - on the other, has refocused attention on traffic modelling. Therefore national research projects in Europe have recently started focusing on the analysis of purely highway models basing on innovative traffic data, in particular, individual trajectories of vehicles. Gathering such data has been a major concern of this research and methods have been developed to collect and estimate trajectories by means of video cameras from helicopters, of vehicles instrumented with radars, scanning Lidar sensors or kinematic differential GPS or, recently, even by means of closely spaced loop detectors.

These projects on purely highway models include:

- The Dutch research program "Tracing Congestion Dynamics with Innovative Traffic Data to a Better Theory", sponsored by the Dutch Foundation of Scientific Research MaGW-NOW;
- The Italian Research Program of Relevant National Interest "Traffic Flow Micro-Simulation for the Analysis of Exhaust Emissions" supported by the Ministry of Education, University and Research and by the University of Napoli "Federico II";
- The Israeli research program "Issues in the Calibration of Traffic Simulation Models" supported by the Israeli Science Foundation, Technion - Israel Institute of Technology;
- The Swedish SIMLAB project, funded by the Swedish National Road Administration (Vägverket) and Center for Traffic Simulation Research (CTR) at Royal Institute of Technology (KTH);
- The UK research programs supported by the Engineering and Physical Sciences Research Council, under grant numbers GR/K77624 and 77037 and GR/M94410 and by the University of Southampton, and Lucas-TRW.

Calibration of models had a crucial role in these projects and yet it was not the focus of research and no concentrated efforts were really devoted to drawing general methodologies for addressing such an issue. Therefore, despite a number of significant results and the collection of precious datasets, these projects did not really contribute to attaining a common understanding of the problem.

Also regarding practical (and methodological) issues in the common application of traffic simulation models on networks, research has been very fragmented. Concerning model calibration, for example, "there has been a wave of valuable research work, but there have been no attempts to identify general calibration principles based on their collective experience", (Hollander and Liu, 2008). With reference to the availability and the sharing of standard traffic data for the common practice, it is worth mentioning instead the International Traffic Database (ITDb) project, promoted by European and Japanese researchers (2007), with data from point detectors gathered all around the world being made available via one single on-line platform.

From the EU perspective, coordination of such topics is long overdue and no projects have been directly devoted to both the theoretical background and the practical issues in the application of traffic simulation models. Moreover there has not been a concentrated effort specifically committed to traffic modelling since the conclusion of the very successful SMARTEST project in 1999. However even SMARTEST was aimed at developing the core capabilities of traffic simulation models and did not address issues of the proper use of the models, or their calibration and validation. The lack of effort to address the use of traffic simulation contrasts with its growing use in research projects. Within the EU FPs, traffic simulation has been utilized for evaluating various policies and technologies in a large number of projects, such as PROSPER, WATCH-OVER, CityMobil, eIMPACT, COM2REACT, COOPERS, as well as MEROPE, SESTANTE and MATAARI, three recent projects of INTERREG IIIB MEDOCC EU.

In contrast to the EU situation, concentrated efforts are taking place in the USA, where two ongoing federal programs sponsored by the Federal Highway Administration are worth mentioning:

- The Traffic Analysis Toolbox - aimed at providing guidance, recommendations and examples on the selection and the use of traffic analysis tools. See in particular the "Guidelines for Applying Traffic Micro-simulation Software", that are a first significant step into the field, even if inevitably not yet mature given the weakness of current knowledge in topics like model calibration.
- The Next-Generation Simulation (NGSIM) - aimed at facilitating the further development of traffic simulation models by commercial entities. It focuses on two aspects: the theoretical development of new behavioural models and of collection of detailed trajectory datasets for the estimation of the model parameters and for their validation. At the moment, the vehicle trajectory datasets gathered constitute the most comprehensive source available of such data and the only one freely accessible on the internet. Yet very recent studies have shown significant errors in the datasets and pointed out the limitations of current methodologies applied for their estimation.

It should be clear therefore that substantial steps towards improved trustworthiness of traffic simulation tools and their better use are achievable only by coordinating research efforts.

As illustrated above, most research on these topics relies on traffic data - both advanced, like vehicle trajectories, and ‘standard' such as point detector data. For this reason coordinating the efforts will also mean promoting the exchange of data from national projects and the performing of comparative investigations on common datasets. Setting up the same calibration and validation methodology using datasets differing in accuracy, temporal and spatial extension, traffic conditions, type of road, etc. will indeed provide invaluable insights into the issues of calibration and validation as well as in assembling datasets to support these activities. This approach is necessary in order to succeed in research in this field and it also represents the most important innovation of this Action. Therefore coordination of efforts is the necessary catalyst for this research and COST the best framework to achieve it.

Moreover, given the current state of the art, the experience matured by researchers and the availability of existing traffic datasets, this is an ideal time to start promoting the coordination of research efforts in the field.

B.3 Reasons for the Action

The new methodologies and procedures to support the use, calibration and validation of simulation models that will be developed within this Action, in the short/medium term, will influence and stimulate research and the use of traffic simulation as well as the commercial software market.

However, the greatest benefits are expected in the medium/long term from the professional and R&D applications that involve driver and/or traffic modelling. They will indeed profit from the enhancement of model reliability and from the dissemination of the culture of quantitative validation of simulation tools.

For example, major impacts would be expected on road safety, where the design and evaluation of new technologies, e.g. eSafety technologies, strongly call for the use of reliable driver and traffic simulation and also in the evaluation of sustainable transport strategies, where simulation is currently playing a relevant role in evaluating policies that promote intermodal changes of Green Traffic Management strategies aimed at reducing emissions impact.

More trustworthy evaluations of design alternatives in planning of road infrastructures, or in operating traffic management and information provision systems, will considerably improve technical, environmental and economical efficiency of interventions, also enhancing transparency in all the processes involving public spending.

B.4 Complementarity with other research programmes

Due to its transversal character, research results from this Action will be useful and will add value, i.e. will be more than complementary, to:

- the COST Action TU0702, "Real-Time Monitoring, Surveillance and Control of Road Networks under Adverse Weather Conditions";

- NEARCTIS, "A Network of Excellence for Advanced road cooperative Traffic management in the Information Society";
- and generally to all the projects involving traffic simulation to be funded within FP7 e.g. within the challenges "ICT for mobility, environmental sustainability and energy" or "Traffic and information management".

C. OBJECTIVES AND BENEFITS

C.1 Main/primary objectives

The main objective of the Action is to develop, implement and promote the use of methods and procedures for supporting the use of traffic simulation models, especially regarding model calibration and validation, to ensure their proper use and the validity of the results and the decision made on them.

C.2 Secondary objectives

Secondary objectives are developed within the four themes listed below.

1. State of the art of traffic simulation practice and research

- To perform a survey regarding the use in the common practice of traffic simulation tools, especially covering issues of model calibration and validation against actual traffic data.
- To review data collection techniques and estimation methodologies for innovative traffic data, e.g. vehicle trajectory data;
- To review data reduction techniques for standard, i.e. commonly available traffic data e.g. point detector data;
- To review literature on estimation, calibration and validation of traffic flow models and corresponding methodologies including reference to the problem of estimating and refining travel demand matrices using traffic data.

2. *Highway modelling*

- To share and exchange already available datasets of advanced traffic data - especially vehicle trajectory datasets;
- To define features and minimal requirements of accuracy of vehicle trajectory data for use in design process and/or estimation of traffic flow models;
- To develop and implement filtering/estimation techniques for vehicle trajectory data, according to the stated requirements;
- To develop a general methodology for drawing inference about the impact of parameters on model outputs. The methodology will consider effects on different outputs/measurements, e.g. individual trajectories as well as counts at detectors;
- To understand the variability of parameters from traffic data due to road type, traffic conditions, weather conditions for the most widely used traffic flow models;
- To give a comprehensive statement of the problems of traffic model estimation and validation, also addressing the issues of parsimony, over-fitting and transferability;
- To develop and implement methodologies, suitable for deterministic as well as stochastic models, for estimating traffic model parameters from vehicle trajectory data and standard data;
- To verify the effects on model estimation of measurement errors in traffic data;
- To define methodologies for validation of purely highway models.

3. *Network modelling*

- To share and exchange already available datasets of standard traffic data also promoting the International Traffic Database (ITDb);
- To define features and minimal requirements of accuracy of standard traffic data for use in calibration and validation of traffic flow models in network applications;
- To develop and implement data reduction techniques for standard traffic data according to the stated requirements;
- To get a better understanding of the impacts of randomness on traffic simulation;
- To give a comprehensive statement of the problems of traffic flow model calibration and validation on network, also addressing the problem of refining travel demand matrices and route choices;

- To develop methodology to set up a calibration process on networks; the calibration methodology will also address the issue of variability of parameters over the network with road type, traffic conditions, and weather conditions. Besides it will address the problem of refining travel demand matrices and route choices;
- To verify the effects on model calibration of measurement errors in traffic data;
- To define methodologies for validation of network traffic models.

4. Synthesis, dissemination and training

- To draw general principles and unified conclusions at highway and network level; the whole methodological framework of traffic model estimation, calibration and validation will be covered.
- To prepare common guidelines for setting up simulation studies; the guidelines will encompass methodological and practical aspects from the choice of the most appropriate traffic tool for the specific application to that of the traffic data, to the setting up and the execution of the calibration and validation processes, to the quantitative comparisons of traffic scenarios and design alternatives;
- To define future needs for data gathering and processing;
- To define future needs for model and software development;
- To provide training for end users in setting up simulation studies; to this aim one open workshop, and one training school for early stage-researchers and practitioners will be organized.

C.3 How will the objectives be achieved?

To achieve the objectives, the Action will rely on the exchange of ideas and directions for the development of methods and procedures for calibration and validation of traffic simulation models and on sharing and using of already available empirical and experimental traffic datasets. The use of common datasets is fundamental to carry out all the objectives and will be the key point of the Action.

As regards vehicle trajectories, data gathered by means of vehicles instrumented with radars, scanning Lidar sensors, kinematic differential GPS, and by means of video cameras from helicopters will be used. Moreover time series of vehicle counts, speeds and occupancies at detectors as well as point to point travel times and data from mobile devices gathered all across Europe will be shared for the research.

C.4 Benefits of the Action

This Action will contribute to disseminating best practice on the quantitative validation of traffic simulation tools and the development of innovative methodologies and procedures for supporting their application.

Significant benefits are then expected in all the areas where traffic simulation is applied, such as traffic management, traffic information, road safety technology design, planning of road infrastructures, environmental evaluations, etc.

Major medium/long term benefits are therefore expected in terms of:

- Improved road safety
- Improved environmental efficiency
- Better use of road capacity and associated COST efficiency
- Improved transparency in transport decision making

This Action will also promote the networking of research teams and the exchange of data, ideas and research results. This is particularly relevant in the field of traffic and transportation where, despite similar problems, great cultural differences among exist.

C.5 Target groups/end users

- Transportation authorities
- Transportation consultancies
- Developers of commercial and academic traffic simulation models
- ITS operators
- Road safety technologies developers
- Universities and research institutes

D. SCIENTIFIC PROGRAMME

D.1 Scientific focus

Research will focus on the two modelling levels:

- a Highway level
- a Network level

In the first case, the focus will be on driver/traffic modelling on highways. In this case, simulations describe the evolution of traffic over time on a highway by reproducing traffic behaviour as the result of driver interactions with the environment. Analysis essentially involves traffic flow modelling (macro, meso, micro or nano) and the use of detailed vehicle trajectory data.

In the second case, simulation mainly aims at describing the evolution over time of traffic on a network. Analysis involves Origin/Destination (O/D) travel demand modelling, as well as route choice and traffic flow modelling (macro, meso, micro or hybrid) and will mainly deal with the use of aggregate empirical data (e.g. speeds, counts and occupancies at point sensors).

At the two levels, the basic traffic models are the same, but not generally the approaches adopted for calibration and validation. This is mainly due to the different scale of application, the different type of traffic measurements available and the additional dynamics to be modelled at a network level. Therefore two distinct research areas and corresponding Working Groups (WGs) will be considered. In all, the Action will consist of four research areas and related WGs:

1. Updated review of traffic simulation practice and research;
2. Highway modelling;
3. Network modelling;
4. Synthesis, dissemination and training.

As some problems and methodological aspects are shared by the two modelling research areas, close coordination will be needed, along with the organization of a number of joint WG meetings.

Details on the four areas and specific tasks are provided below.

1. *Updated review of traffic simulation practice and research*

- Task 1.1. Survey of the usage of traffic simulation tools.

A survey regarding the use of traffic simulation tools, especially covering issues of model calibration and validation against actual traffic data will be performed. Different user categories will be interviewed, mainly relying on the broad internet discussion groups formed by traffic simulation software users.

- Task 1.2. Review of traffic data collection and estimation techniques.

A comprehensive review of data collection techniques and estimation methodologies for innovative traffic data, e.g. vehicle trajectory data, will be carried out. Data reduction and data fusion techniques for standard traffic data - i.e. commonly available data like point detector data - will also be reviewed;

- Task 1.3. Review of methodologies for traffic model estimation, calibration and validation.

Literature on estimation, calibration and validation of traffic flow models and corresponding methodologies, including reference to the problem of estimating and refining travel demand matrices using traffic data, will be thoroughly reviewed. Bibliographical research will also embrace other disciplines where problems of model estimation, calibration and validation are tackled.

2. *Highway modelling*

Highway models are the building blocks of whatever traffic simulation tool and the pillars of traffic flow theory. Recently available trajectory data are crucial in developing and evaluating these models. Further, the calibration and validation they allow are not only necessary for their correct use in simulating real systems but can give a much deeper insight into real system behaviour than the mere analysis of observed measurements. However, as mentioned before, both available datasets and methodologies for their estimation and for

model calibration and validation are at a preliminary stage of development. Comparative work on different existing datasets is the cornerstone for research in this field and a major tool of this area of the Action. Therefore this area will accomplish the following tasks:

- Task 2.1. Exchanging and sharing advanced traffic datasets.

The Action will promote the exchange and sharing of existing advanced traffic data gathered in Europe. These not only comprise vehicle trajectories but, for instance, even individual travel times between gateways or aerial densities. Individual trajectories gathered by means of driving simulators could also be included. Common datasets will be compared and used together with the already freely available trajectory data from the US NGSIM program. This will mean assembling a non-trivial sample of driving behaviours and styles, types of road, traffic conditions and measurement accuracies.

The first steps will be to make a census of existing datasets and draw the legal basis for their exchange.

- Task 2.2. Defining contents, quality and estimation techniques for advanced traffic datasets.

Data accuracy, their temporal and spatial extension, the coverage of traffic conditions, all have great impact on calibration results and the very possibility of calibrating models. However, few efforts have been devoted to shedding light on these issues, perhaps due to the underestimation of the bias in results that can arise when using inappropriate or not properly estimated data. In this task, contents, quality and estimation techniques for advanced traffic data will therefore be investigated and defined, using the common datasets assembled in task 2.1 and the calibration methodologies built up in task 2.4. Research steps will also include:

i estimating the noise and bias in the datasets e.g. by means of spectral analysis and statistical inference;

ii) calibrating several models on different datasets;

iii) comparing and crossing over calibration results of each model/dataset;

iv) repeating experiments with laboratory data with known error distributions;

v) testing different estimation techniques.

- Task 2.3. Understanding the role and impact of parameters on model outputs

One of the main problems in the practice of traffic simulation is to understand parameter impact on model outputs. It could sound strange, but the behaviour of many traffic models over a wide range of conditions remains unclear. Due to scarceness of empirical data, most modellers concentrate efforts on analysing mathematical properties of models rather than performances against actual traffic data. For almost all the microscopic models, for example, the variance of the outputs explained by each parameter is not quantitatively known, e.g. how much a specific parameter influences road capacity. This lack of knowledge dramatically affects the practice of traffic simulation. If the really sensitive parameters of models were known, practitioners could concentrate on adjusting only these parameters, massively increasing the accuracy of results whilst decreasing the wasting of time.

Moreover, there is a lack of general and systematic methodologies to draw inferences about the impact of parameters on model outputs.

To this aim, different statistical techniques for testing sensitivity of models respect to parameters e.g. Analysis of Variance, will be used. The study will rely on different outputs/measurements, e.g. individual trajectories as well as counts at detectors.

Variability of parameters from traffic data due to road type, traffic conditions, and weather conditions for the most widely used traffic flow models will be also investigated. This will provide invaluable information in setting up the estimation problem (task 2.4).

All the results drawn within this task will also serve as input for the calibration of network models (task 3.3).

- Task 2.4. Developing techniques for highway model estimation and validation.

The problem of model estimation - i.e. of estimating "appropriate" values for model parameters - will be thoroughly investigated. Results from other disciplines such as optimisation theory or learning theory will be exploited. In particular research will focus on the issue of (quantitatively) addressing the trade-off between model complexity and accuracy, also known as parsimony. Other major subjects will be the over-fitting of models and transferability of models/parameters - very significant for application of traffic modelling.

The study will start providing an unequivocal statement of the different types of parameters and their role, such as parameters whose distribution can be directly measured in the real world or parameters that need to be calibrated.

After carrying out some preliminary experiments on different available datasets, a common statement of the model estimation problem will be discussed. Preliminary experiments will apply and compare existing techniques for model estimation, suitable for deterministic as well as stochastic models. Comparisons will also focus on the differences between techniques using trajectory data and point detector data.

In-depth investigations will follow, and both those based on trajectory data and on standard data will address still unresolved methodological issues like:

i) the proper interval for the aggregation of measurements - only for standard data,
ii) the proper traffic measurement locations - for standard data - and the appropriate time-space coverage - for trajectory data,
iii) the proper traffic conditions for gathering data,
iv) the proper measure of performance,
v) the proper goodness of fit function,
vi) the proper solution algorithm.

For these purposes, methodology laid down in task 2.3 for the sensitivity analysis of models will also be applied. Moreover, a key methodology of this phase of research will be that of executing experiments with laboratory data. These experiments eliminate the uncertainty of empirical data and focus on modelling issues. In fact, unlike model estimations performed on actual measurements of the system, in the case of estimation on laboratory data, "true" values of parameters are known and a comparison can be performed with the presumably sub-optimal values provided by the specific estimation technique applied.

Validation of highway models and, consequently, of the techniques applied for their estimation will constitute the last subtask. Parsimony, over-fitting and transferability of models/parameters will be investigated in this phase of research. Once more, research will start with a comparison of available techniques and the common statement of the problem. Subsequent studies will concentrate on the comparison and cross-validation of models estimated on the different datasets available.

3. Network modelling

Framework and tasks of research in this area will closely resemble those of area 2 on highway models and will therefore be presented below, avoiding repetitions. The same models will be examined at a different scale, but significant differences are introduced by the modelling on network. Major differences are due to:

- the variability of behaviours within the network;
- the modelling of route choice;
- the modelling of OD travel demand;
- the day to day variability of traffic conditions on the network.

- Task 3.1. Exchanging and sharing standard traffic datasets.

Already available datasets of standard traffic data will be shared and exchanged. This task will be accomplished also by promoting the use among participants of the International Traffic Database (ITDb), an ongoing international project devoted to harmonizing and sharing traffic data gathered for different purposes.

- Task 3.2. Defining contents, quality and data reduction techniques for standard traffic datasets.

Missing data, data accuracy and day to day variability are major issues among those covered by research in this task. All of these greatly influence results of model calibration and yet they are not properly addressed in the current literature. As regards day to day variability, for example, previous calibration studies have focused on minimizing the difference between simulated and observed data on a "typical" day. While criteria for choosing the typical day are not well established as the effect on calibration of the choice has not been thoroughly investigated, choosing only one day does definitely not allow a realistic distribution of all possible traffic conditions on the network to be captured, and alternative approaches proposed so far are still at an early stage.

The issue of the fusion of data from multiple sources will also be investigated.
Objectives of this task will be therefore:

- to define features and minimal requirements of accuracy of standard traffic data for use in calibration and validation of traffic flow models in network applications;
- to develop and implement data reduction and data fusion techniques for standard traffic data according to the stated requirements.

As in the case of highway models, issues about data will be closely related to the calibration techniques applied. Therefore topics of this task will be investigated together with those in task 3.3.

- Task 3.3. Developing techniques for network model calibration, validation and O/D matrix refining.

The modelling framework of traffic on a network is generally made up by three components:

i) travel demand, usually in the form of (time varying) Origin Destination (OD) matrices (usually an input to models), *ii*) route choice models and *iii*) flow propagation models, basically highway models and node models (i.e. intersections, roundabouts, motorway merging etc.).

To calibrate the different components separately, detailed and uncorrelated data on each dynamics would be required. Unfortunately direct observation of travel demand and route choices is very rare (e.g. on motorway networks, or in small scale applications using Automatic Number Plate Recognition) and usually only aggregate measurements at point detectors are available, like counts or speeds. As these traffic measurements are the result of the combined effect of the above dynamics, it seems natural to use these measurements to calibrate at the same time all the models, including OD matrices. However, in this case, one runs the risk of compensating errors of supply models with the OD adjustments and vice versa, obtaining calibrated models and adjusted demand matrices not really representative of the actual system.

Computational complexity of the problem must also be considered as it becomes exponential when stating the problem as a black-box optimisation - that is necessary dealing with simulation models rather than analytical.

To deal with this complex problem recent innovative approaches will be discussed and analyzed, also inviting outside experts to the first workshop planned within the Action (see also section E1).

Works in this task will therefore aim:

- to give a comprehensive statement of the problem of traffic flow model calibration on the network, also addressing the problem of refining travel demand matrices and route choices;
- to develop methodology to set up a calibration process on the network; the calibration methodology will also address the issue of parameter variability over the network with road type, traffic conditions and weather conditions.

Given the scale of the problem, particular attention will be devoted to choosing the sub-set of sensitive parameters to which to limit the calibration, also applying the methodologies outlined in task 2.3 for the sensitivity analysis of models.

As in the case of highway models validation will be the last subtask of the topic. Parsimony, over-fitting and transferability of models/parameters will be the main subjects of research also in the network case. As validating a (calibrated) model implicitly means validating also the procedure adopted for its calibration, the validation study will proceed parallel to that on calibration.

4. Synthesis, dissemination and training

- Task 4.1. Harmonizing approaches and outputs

Methodological steps of traffic model estimation, calibration and validation, whilst discussed and developed at highway and network level in other areas, will be reassessed and reviewed in this area in a more general perspective.

Consistency and integration of procedures and methodologies drawn at the two different levels will be verified. The objective of research in this task will be therefore not merely to coordinate research of other areas (a task belonging to the Management Committee) but to clarify, from a higher perspective, meanings and differences of approaches at different levels and their proper fields of application.

To this aim a composite experiment with laboratory data will also be designed and carried out. Furthermore, as methodologies become available e.g. for model validation, it will be pointed out how outputs of the different traffic simulation software could be harmonized in order to allow the straight application of developed methodologies by means of widely used analysis tools like Matlab.

Activities in this task will be preparatory to drawing research conclusions within a common conceptual framework and defining guidelines and best practice. A major outcome of this research phase will be, of course, the definition of future needs for research in the field, especially regarding the issue of data gathering and processing and that of model and software development.

- Task 4.2. Guidelines and best practice for model calibration and validation

Preparation of guidelines and best practice for setting up traffic simulation studies will be a major task of this Action. The guidelines will point at practitioners and will encompass methodological and practical aspects from the choice of the most appropriate traffic tool for the specific application to that of the traffic data, to the setting up and the execution of the calibration and validation processes, to the quantitative comparisons of traffic scenarios and design alternatives.

- Task 4.3. Training end users to the correct use of traffic simulation tools.

One training school for early stage-researchers and practitioners will take place at the end of the research program. It will train people to correctly and effectively apply traffic simulation models by means of the methodologies and procedures developed within the Action also relying on the prepared guidelines. The trainees will cope with setting up and executing a traffic simulation study in a practical application.

D.2 Scientific work plan - methods and means

The Action consists of four Working Groups corresponding to the areas detailed in section D.1. Given the interconnection of themes within and between WGs strong coordination will be sought, also through joint meetings. The following matrix details interactions between tasks within a WG and between tasks belonging to different WGs. In the last case it is also indicated if at least one joint meeting (JM) of the WGs is planned.

Legend:
I= row i is Input for column j
IO = row i is Input and Output for column j (ij=ji)
JM = Joint Meeting of the WGs to which tasks i and j belong to (ij=ji). For example it is advisable that WG2 - when dealing with task 2.4 - has a Joint Meeting with WG3 as task 2.4 is interconnected with task 3.3.

		WG 1.1	WG 1.2	WG 1.3	WG 2.1	WG 2.2	WG 2.3	WG 2.4	WG 3.1	WG 3.2	WG 3.3	WG 4.1	WG 4.2	WG 4.3
State of the art	WG1.1	-					I	I		I	I			
	WG1.2		-		I	I			I	I			I	I
	WG1.3			-			I	I			I	I	I	I
Highway modelling	WG2.1				-	I	I	I						
	WG2.2					-	IO	IO				JM	I	I
	WG2.3					IO	-	IO			JM	JM	I	I
	WG2.4					IO	IO	-			JM	JM	I	I
Network modelling	WG3.1								-	I	I			
	WG3.2									-	IO	JM	I	I
	WG3.3						JM	JM		IO	-	JM	I	I
Synthesis and Dissemin.	WG4.1					JM	JM	JM		JM	JM	-	I	I
	WG4.2												-	I
	WG4.3													-

E. ORGANISATION

E.1 Coordination and organisation

According to the "Rules and Procedures for implementing COST Actions" the Management Committee (MC) will consist of up to 2 representatives from each participating COST country, and will include early-stage researchers.

Four Working Groups (WGs) will be formed, each with a Leader and a Co-Leader appointed by the MC among its members.

Chair, Vice-Chair and the eight Leader and Co-Leader of the four WGs will constitute a Core Group inside the MC, with steering functions. In particular, the Core Group will advise the MC on choosing the research topics and the direction of works, on drawing up detailed plans and arrangements for the distribution of tasks and on defining methods for the different phases of execution of the Action. It will be in charge of coordinating the contributions from the WGs.

To make the management structure work efficiently it is planned that meetings will be held twice a year (except the first year) and will observe the following schedule. They will last for two and a half days and will consist of a one-day plenary meeting, a half-day WG meeting, a half-day Core Group meeting and a half-day MC meeting. On the second day different WGs could have joint meetings focusing on specific tasks as suggested by the interaction matrix presented in Section D2. WGs may have additional meetings when deemed necessary by the Management Committee. The above schedule will be flexible according to the needs and the status of the Action but the participation of all the WGs at the meetings and the grouping of WG and MC meetings will be major concerns.

A dedicated workshop is planned on the theme of the combined calibration of traffic flow models and time varying OD matrices. Outside experts will be invited to give advice and enlarge the application basis of the Action.

Coordination of research will be mainly achieved with a bottom-up approach by sharing and exchanging experimental data already gathered in previous or ongoing national research programs. Both advanced and standard traffic data will be shared (see tasks 2.1 and 3.1 in Section D1) and will form the common basis for research. For this reason,

(1) the consolidation of the traffic databases in the dedicated website will be the first milestone of the Action (Year 1-2). Other major milestones will be (see also table 2):
(2) Establishment of traffic data requirements (Year 3);
(3) Establishment of estimation, calibration and validation methodologies (Year 3-4);
(4) Guidelines and best practice for model calibration and validation (Year 4).

Two open workshops will take place at milestones 2 and 4. In the first workshop experts will be invited to enlarge the application basis of the Action and give specific advice on themes like the combined calibration of traffic flow models and time varying OD matrices. The second workshop will instead be organized to disseminate the results of the Action to specific end users and to a wider audience. Two books collecting works presented at the workshops will be published in international book series, in order to reach an even wider audience and to expose the results of the Action to international review.

A common research team will be created within WG4 to design and implement the experiment with laboratory data mentioned in Section D1. The implemented scenario will represent a common test-bed for the methodologies laid down during the Action and an effective tool for even more promoting the coordination of research efforts.

WG4 will also be in charge of harmonizing results and drawing conclusions of research in order to prepare the guidelines and the recommendations for the practice of model calibration and validation. These guidelines will be one of the main outputs of the Action.

A member of WG4 will be appointed as Short-Term Scientific Mission (STSM) Manager. STSMs will be used as much as possible for the early-stage researchers involved in the Action. Their scope and scale are flexible and will be managed adaptively as the Action progresses.

The work will heavily rely on electronic networking also by means of a dedicated web site. The MC will promote the use of video conferences and web instant messaging among the members of WGs. A discussion forum on the dedicated web site will be set up for timely and efficient exchange of ideas. The website will host a space with access restricted to the members for exchanging traffic datasets and documents and a public space for dissemination of results and publication of all the documents e.g. the minutes of the MC meetings and the calendar of planned events. The Action web pages will be updated regularly (typically every month) by the Action webmaster.

In the final year of the Action, a training school for early stage-researchers and practitioners will be organized to teach the correct and effective use of traffic simulation models. The training school will take place within the European Network for Training, Education and Outreach in the field of ITS (ITS-EduNet).

E.2 Working Groups

Four Working groups (WG) are planned for this Action. Each WG includes a Leader and a Co-Leader, as well as all the participants of the Action who have shown clear interest and motivation to contribute with a defined expertise to the Working Group activities. All Working Groups will meet together during the two annual meetings. Joint meetings of WGs will be held according to the interaction matrix of Section D2.

E.3 Liaison and interaction with other research programmes

To avoid overlapping of activities and research, working liaisons will be set up with the Network of Excellence for Advanced Road Cooperative Traffic Management in the Information Society (NEARCTIS) and the COST Action TU0702, Real-Time Monitoring, Surveillance and Control of Road Networks under Adverse Weather Conditions, also organizing, whenever possible, joint seminars.

Contact it is already established with the Calibration, Verification and Validation (CVV) Task Group, part of the Simulation Sub-Committee of the Transportation Research Board of the National Academies in the USA and with the Next Generation Simulation (NGSIM) Program. Some participants to the Action are also members of both the CVV task group and the NGSIM program. Interaction will be achieved also by means of dedicated meetings at the Annual Meetings of the Transportation Research Board.

Liaison will be also established with the International Traffic Database (ITDb) project also by promoting the use among participants of the platform implemented for sharing standard traffic data.

E.4 Gender balance and involvement of early-stage researchers

This COST Action will respect an appropriate gender balance in all its activities and the Management Committee will place this as a standard item on all its MC agendas. The Action will also be committed to considerably involve early-stage researchers. This item will also be placed as a standard item on all MC agendas.

STSM will be activated as much as possible for the early-stage researchers involved in the Action.

The training school will be devoted to early stage-researchers and practitioners with a particular concern to the gender balance.

F. TIMETABLE

For this COST Action a total duration of 4 years is scheduled.

		Year 1				Year 2					Year 3					Year 4					
State of the art	WG1.1	o	o	o		M						M				M				M	
	WG1.2	o	o	o	o	M						M				M				M	
	WG1.3	o	o	o	o	M						M				M				M	
Highway modelling	WG2.1	o	o	o	o	M						M				M				M	
	WG2.2				o	M	o	o	o	o	o	M				M				M	
	WG2.3				o	M	o	o	o	o	o	M	o	o	o	M				M	
	WG2.4				o	M	o	o	o	o	o	M	o	o	o	M				M	
Network modelling	WG3.1	o	o	o	o	M						M				M				M	
	WG3.2				o	M	o	o	o	o	o	M				M				M	
	WG3.3				o	M	o	o	o	o	o	M	o	o	o	M				M	
Synthesis Dissemin.	WG4.1					M			o	o	o	M	o	o	o	M	o	o		M	
	WG4.2					M						M	o	o	o	M	o	o	o	M	
	WG4.3					M						M				M		o	o	M	o

Table. Timetable of tasks and milestones (M = Milestones)

G. ECONOMIC DIMENSION

The following COST countries have actively participated in the preparation of the Action or otherwise indicated their interest: AT, FI, FR, DE, GR, IL, IT, NL, PL, PT, ES, SE, CH, UK. On the basis of national estimates, the economic dimension of the activities to be carried out under the Action has been estimated at 56 Million € for the total duration of the Action. This estimate is valid under the assumption that all the countries mentioned above but no other countries will participate in the Action. Any departure from this will change the total cost accordingly.

H. DISSEMINATION PLAN

H.1 Who?

Potential audiences will be targeted at a National level to guarantee a more incisive dissemination of results and knowledge. Among the target audiences will be:

1. European level policy makers;
2. National Government, Regional and Local Transportation Authorities;
3. Road Operators;
4. Transportation Consultancies;
5. Road Safety Technologies Industry;
6. Traffic Simulation Software Industry;
7. Universities and Research Institutes;
8. Other Research Networks and Frameworks.

H.2 What?

The following dissemination methods will be adopted to publicize and disseminate results, documents and general information of the COST Action:

- Internet:

  A dedicated Internet Web site will be set up:
  - to share and exchange traffic datasets and documents (restricted access) .
  - to disseminate results and documents e.g. the Guidelines on model calibration and validation or case study, interim and final reports (public);
  - to post general information on events like workshops or the Training School schedule and program (public).

  A Discussion Forum for different categories of target audiences will be organized;
  Video conferences and web instant messaging will be promoted among participants of WGs to facilitate communication and coordination of work.

- Specialised press: national and international conference and workshop proceedings, articles in peer-reviewed scientific and technical journals, non-technical publications, two books on international peer-reviewed book series.

- Events: a number of events will be organized falling into the following broad categories:
  - Two targeted workshops during the Action;+
  - Joint meetings with other research networks and frameworks;
  - Special sessions at international conferences, including those attended by transportation practitioners (e.g. European Transportation Conference, Transportation Research Board Annual Meeting);
  - Workshops at individual nation-level, inviting the relevant researchers, practitioners and national government, regional and local transportation agency members.

- Training School. A training school for early stage-researchers and practitioners will be organized at the end of the Action.

- Guidelines and best practice manual, reports. Guidelines and recommendations will be drawn to assist end-users in setting up simulation studies and to ensure the proper use of simulation tools and the validity of the results and the decision made on them.

H.3 How?

The Action will target each audience adopting the most appropriate dissemination methods according to the following table.

Potential Audience	**Dissemination Methods**
European level policy makers	Guidelines, Case Study and Final Reports, Workshops and Conferences
National Government, Regional and Local Transportation Authorities; Road Operators	National Workshops, General Information on the Website, Guidelines, Case study and Final Reports, Training School
Transportation Consultancies;	National Workshops, Conferences, Case Study and Final Reports, Guidelines, Training School, Internet Discussion Forum
Road Safety Technologies Industry; Traffic Simulation Software Industry	Articles in Peer-Reviewed Scientific and Technical Journals, Guidelines, Workshops and Conferences
Universities and Research Institutes; Other Research Networks and Frameworks	Articles in Peer-Reviewed Scientific and Technical Journals, Guidelines, Case Study and Final Reports, Workshops and Conferences, Training School, Internet Discussion Forum

In order to ensure effective dissemination:

- Specific tasks have been assigned to the WG4, like the drawing-up of the guidelines and the organization of the training school.
- The Core Group will regularly review the plan of dissemination according to results of its evaluation.
- Guidelines for model calibration and validation will be publicly available on the website and publicized on relevant transportation web sites.
- The training school for early stage-researchers and practitioners will take place within the European Network for Training, Education and Outreach in the field of ITS (ITS-EduNet)
- Tight liaison with non-European research frameworks - like the Calibration, Verification and Validation (CVV) task Group as part of the Simulation Sub-Committee of the Transportation Research Board (USA) and the FHWA NGSIM program - will be carried out also with joint meetings and workshops at international conferences, thus exporting the findings of the Action outside Europe.