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TRANSPORT & MOBILITY LEUVEN

Transport & Mobility Leuven NV
Vital Decosterstraat 67A bus 0001
3000 Leuven
Belgium
Telephone: +32 16 31 77 32
telefax: + 32 16 31 77 39
email: steven.logghe@tmleuven.be

IMAGINE
Improved Methods for the Assessment of the Generic Impact of Noise in the Environment

Review of the suitability of traffic models for noise modelling

WP2: Demand and traffic flow modelling

WP-leader: TNO

Project Co-ordinator: AEA TECHNOLOGY RAIL BV

Partners:	AEAT NL	BUTE	EURO-CONTROL	MBBM	UGent
	AEAT UK	CSTB	JRC	SP	ULeeds
	Anotec	DeBAKOM	Kilde	TML	Volvo
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EXECUTIVE SUMMARY

The development of noise maps requires the extraction of relevant traffic information from traffic models. The intrinsic properties of traffic models and the current and future practice in traffic modelling are reviewed in this report.

A classification is made of existing traffic models along with an overview of the kind of output they can deliver. Furthermore, the required input for the different model types is discussed. The discussion of the linkage of traffic models with noise source models is based on the experience within the consortium.
A preliminary assessment of the Strengths, Weaknesses, Opportunities and Threats was made for the suitability of the different types of traffic models to deliver input for noise models. The interactive workshop with traffic model developers resulted in the refinement of these SWOT-analyses.

It can be concluded that current traffic models, in their various forms, can be used to produce the data needed for noise modelling, but the link between traffic models and noise models is not unambiguous. There are several weak points in traffic models that need attention:

- the consequences of intrinsic model characteristics (with regard to the input data used, the modelling technique and the output produced);
- problems associated with the use of traffic models in practice;
- problems associated with interfacing between traffic and noise models;
- the quality of data for the traffic demand and assignment models, and how this relates to accuracy;
- the effort involved in building, calibrating and maintaining the model;
- the modelling of possible noise reducing measures;
- additional indicators for the assessment of quiet areas and night-time noise.

These caveats arise, because traffic models were originally developed to evaluate transportation policies. It is (also) possible to use traffic models for environmental policies, but usually this requires modifications both to the models and their input.

Improving current traffic models to fulfil the input needs of noise models will require some effort. The formulated recommendations focus on the directions for the development of pragmatic guidelines for the link between traffic and noise within Work package 2 of IMAGINE.

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1 Introduction

1.1 Background

For the production of strategic noise maps as required under the EU Directive 2002/49/EC, improved assessment methods for environmental noise will be required. Noise from any major noise source, be it major roads, railways, airports or industrial activities in agglomerations, needs to be included in the noise mapping. For road and rail, improved methods have been developed in the 5th framework HARMONOISE project (see www.harmonoise.org). These methods will be adapted for aircraft and industrial noise in the IMAGINE project. Noise source databases which are being developed in IMAGINE for road and rail sources will allow a quick and easy implementation of the methods in all member states. The IMAGINE project develops guidelines for noise mapping that will make it easy and straightforward to assess the efficiency of noise action plans.
IMAGINE will provide the link between HARMONOISE and the practical process of producing noise maps and action plans.

The objective of WP2 of the IMAGINE-project, is to provide guidelines and examples for an efficient link between traffic modelling (including the modelling of traffic demand and traffic management measures) on the one hand and noise mapping and action planning on the other. To this end, the partners in this work package study the incorporation of road traffic flow modelling in noise emission modelling, and develop practical solutions for the combination of the two disciplines, including recommendations for additional data collection.

The conclusions from task 2.1 are used as input for task 2.2. In task 2.1, the noise emission models proposed in HARMONOISE and results from WP5 of IMAGINE are reviewed with respect to data needs. The accuracy that the proposed emission models can reach with different qualities of traffic input was evaluated. Recommendations as to what output data traffic flow models should be able to produce were made.

1.2 Purpose of task 2.2 and this report

In task 2.2, existing traffic and transport models are reviewed and their suitability for providing data for noise emission models is assessed. Current practice and research developments (e.g. the HEAVEN project) in the field are evaluated. Attention is paid to problems associated with the need for day/evening/night volumes, detailed speed and acceleration data, fleet composition and the possibilities for modelling changes in demand, mode choice and route choice due to noise action planning measures.

In this report, the discussion of traffic models is limited to traffic assignment models. This means that the demand data is considered to be input for each traffic model discussed. However, because accurate demand data is very important, some general aspects of demand models are also discussed in this report.

1.3 Research methodology

First, an overview was made of existing traffic and transport models. A classification of the different transport models was made and an overview was produced of the kind of output they can deliver. On the other hand, an overview was produced of noise models, and the input they require from traffic models (taken from the task 2.1 report).

After this preliminary inventory, an overview was created of the experience within the consortium with traffic models and linking them with noise models (see ANNEX A). On the basis of this experience overview, a first draft of the report was created, including a SWOT-analysis for each of the types of transport models with regards to their use for noise modelling.

This first draft was discussed with a number of traffic model developers in an interactive workshop (see ANNEX B). The experts were also asked to give their view on market evolutions and to point out possible problems in linking noise source models with traffic models.

As a result of the interaction with these experts, a final version of the report was produced.

1.4 Outline of this report

Figure 1 gives an overview of the different chapters in this report.

In Chapter 2, some background information is given on noise models, as an introduction for non-noise specialists. An indication is given of the kind of input that is expected by noise models from the traffic models. Furthermore an overview is given of the requirements for the input with regard to accuracy, as determined in task 2.1.

In Chapter 3, traffic models and their characteristics are discussed. A classification is presented, and for each type of model a SWOT analysis is given with regard to their use for noise modelling. In this report, traffic models are considered to be merely traffic assignment models. This means that the demand data is considered to be input for traffic models. Traffic demand modelling (to produce the input for traffic models) is discussed separately in Chapter 4.

The combination of noise models and traffic models, is discussed in Chapter 5. Figure 1 shows how the work in each chapter is related to the work in other chapters.

Finally, an overview of the main conclusions is given in Chapter 6.

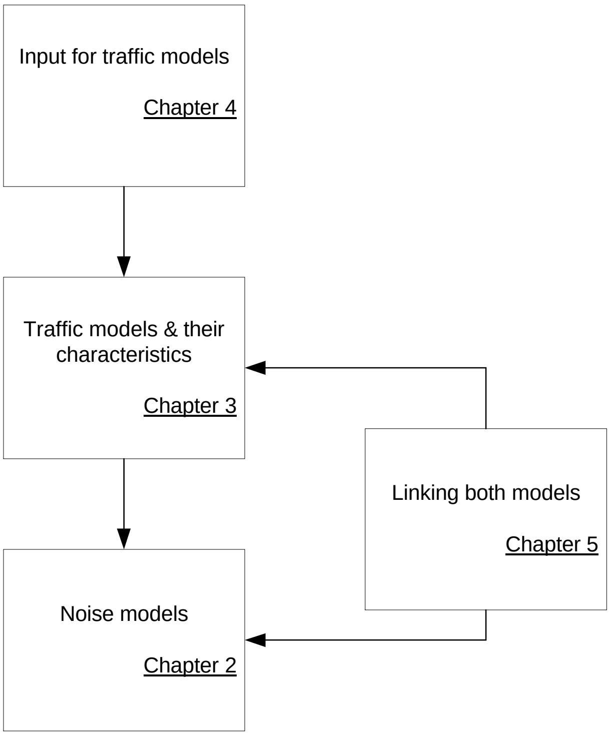


Figure 1 Outline of this report

2 Noise

2.1 Basics

2.1.1 dB scale

Sound levels are expressed on a logarithmic scale in decibels (dB). The sound pressure level L_p is an indication of the strength of an acoustic pressure wave and calculated as

$$L_p = 10 \cdot \log_{10}\left(\frac{p^2}{p_{ref}^2}\right), \quad (1)$$

where p is the amplitude of the pressure wave and p_{ref} is usually equal to $2{\cdot}10^{-5}$ Pa. The acoustic energy of a sound wave is proportional to p^2. Such a logarithmic scale is chosen since it lies close to the human perception of the amplitude of acoustic waves.
Some rules of thumb concerning the perception of differences in L_p are as follows. A difference of 1 dB is hardly perceived by the human ear, while a difference in 3 dB, equal to a doubling of the acoustic energy, is observed as a small increase. A difference of 10 dB is perceived as a doubling of the loudness.

2.1.2 A-weigthing

The human ear does not have the same sensitivity for all frequencies in a sound. Sounds with frequency of a few thousand Hertz are perceived louder than low frequency and very high frequency sounds. To take this difference in sensitivity into account, the sound registered by a microphone is filtered using an A-weighting filter. The resulting sound pressure level is expressed in dB(A).

2.1.3 Equivalent sound levels

Traffic noise levels usually vary quickly over time. The *equivalent* sound level, L_{eq}, is defined as

$$L_{eq} = 10 \cdot \log_{10}\left(\frac{1}{T}\int_{t_1}^{t_2} \frac{p_{rms}^2(t)}{p_{ref}^2}\,dt\right). \quad (2)$$

This L_{eq} is defined as the sound level of a constant sound which carries the same acoustic energy as in the time-varying signal over the time period $T = t_2 - t_1$. The exact value of L_{eq} depends on the length of the time period T. Within the field of traffic noise calculations, another quantity commonly used is the 'sound exposure level', or *SEL*, which is the total intensity (pressure squared) integrated over time. For a vehicle passing by, SEL is equal to L_{eq}+10log(T).

2.1.4 L_{DEN}

The concept of the equivalent sound pressure level is of particular importance since it forms the base of the noise indicator L_{den} proposed by the EU noise directive. L_{den} is defined as:

$$L_{den} = 10 \cdot \log_{10}\left[\frac{12}{24}10^{\frac{L_{day}}{10}} + \frac{4}{24}10^{\frac{L_{evening}+5}{10}} + \frac{8}{24}10^{\frac{L_{night}+10}{10}}\right],$$

where L_{day}, $L_{evening}$ and L_{night} are the A-weighted long-term average sound levels as defined in ISO 1996-2: 1987, determined over respectively the day periods (12 hours, usually from 07:00 till 19:00), evening periods (4 hours, usually from 19:00 till 23.00) and night periods (8 hours, usually from 23:00 till 7:00). Member states may shorten the evening period with one or two hours and lengthen day/night accordingly. As seen from the formula above, the sound pressure level during the evening period is increased ('punished') with 5 dB, and the level at night with 10 dB. In this way, the increase of the impact of noise during the night and the evening (‘rest’-period) is accounted for to a certain degree.

The choice of L_{den} as a common indicator has some important consequences for what is expected from traffic flow models generating the basic data. Traffic data is needed for a 24-hour period (thus also during the night). Since there is some freedom in the choice of evening and night periods, traffic flow models should accommodate this, for instance by generating hourly traffic data.

2.2 Single vehicle source model

The road noise source model developed in the HARMONOISE project describes the noise production (sound power level) of a European Road Vehicle by a set of mathematical equations representing the three main noise sources:

- rolling noise due to the tyre/road interaction,
- propulsion noise caused by the noise production of the driveline of the vehicle,
- aero-dynamical noise due to the turbulent flow along the car body.

The total noise production is the energetic sum of these three contributions $L_{W0}=\lg(10^{LWR/10}+10^{LWP/10}+10^{LWA/10})$. Because rolling noise and aero-dynamic noise behave similarly, the aero-dynamical noise source is incorporated in the rolling noise component in the HARMONOISE model.

The model calculates the **instantaneous sound power level** for a **single vehicle** at 2 source points, to be located at well-defined heights above the road surface (depending on the vehicle type), and this for each type of noise source. At least 3 vehicle categories should be used: passenger cars (light heavy, category 1), medium heavy (category 2) and heavy vehicles (category 3). A correction for the number of axles is suggested. Other categories are less conventional heavy vehicles like tractors, tanks (category 4) etc. and two-wheelers (category 5). Further sub-categorization is possible. The default sound power level refers to a constant speed, an ambient temperature of 20 degrees Celsius and the reference road surface, which is an average of DAC 0/11 and SMA 0/11.

The sound level of the rolling noise L_{WR} is calculated by following regression relation:

$$L_{WR} = a_R(f) + b_R(f) \cdot \lg\left[\frac{v}{v_{ref}}\right];\ v_{ref} = 70\ \text{km/h},$$

where v is the vehicle driving speed, and the coefficients a_R and b_R are given for each 1/3-octave band frequency f from 25 to 10000 Hz, for vehicles of category 1 and 2. The values for category 3 heavy vehicles can be found by adding $10 \cdot \log(\#\,axles/2)$, where ‘# *axles*’ is the number of axles on the vehicle. Accurate data for categories 4 and 5 are not yet available. The rolling noise is assumed to be distributed over two point sources, where 80% of the sound power is radiated by a point source at 0,01 above the road surface and the remaining 20% is radiated by a second point source which is assumed to be located at 0,3 m height for category 1 vehicles, and at 0,75 m for category 2 and 3 vehicles.

For propulsion noise, the sound power level L_{WP} is given by

$$L_{WP} = a_P(f) + b_P(f) \cdot \left[\frac{v - v_{ref}}{v_{ref}}\right];\ v_{ref} = 70\ \text{km/h}, \quad (3)$$

where the coefficients a_P and b_P are also given per 1/3-octave frequency band. For propulsion noise, 20% of the sound power is appointed to a point source at 0,01 m height, and 80% is appointed to the second noise source at 0,3 m or 0,75 m for light and heavy vehicles, respectively.

There are a number of corrections for conditions that deviate from the reference condition. These are corrections for directivity of the noise source, temperature, tyre-type (i.e. correction for studded winter tyre, formula of type : $\Delta L = a(f) + b(f) \cdot \lg(v)$), road surface (formula of type : $\Delta L = a(f) + b(f) \cdot \lg(v/v_{ref})$), acceleration/deceleration (only for propulsion noise, formula of type: $\Delta L = C \cdot a$, with a in the range from -2 to +2 m/s^2).

Further corrections can be introduced to account for regional differences e.g. average vehicle weight, composition of engine types, average vehicle age and state of maintenance, typical tyre composition and average composition of each vehicle class.

2.3 Aggregation to traffic flow

For aggregation to traffic flow over a line segment, at least the traffic intensity Q and average speed v for each vehicle category is needed. Accuracy can be improved if the distribution (in time) of vehicle speed per category is available. For urban driving conditions, a more detailed noise calculation requires also the distribution (in time) of acceleration/deceleration per vehicle category. Maximum detail is achieved when not only the distributions are available but also all information (namely vehicle type, speed, and acceleration/deceleration) for each vehicle separately.

In the context of the implementation of the END, one is mainly interested in the equivalent sound pressure level, keeping in mind the common noise indicator L_{den}. The equivalent line-source power level per unit length for a road segment under study $L_{W,line,eq}$ is calculated as follows:

$$L_{W,line,eq} = L_{W,0} + 10 \cdot \lg\left(\frac{Q}{v}\right)$$

where $L_{W,0}$ is the sound power level obtained from the single vehicle noise model averaged over the time the vehicle is in the segment of the road considered. Depending on the available information, the contributions from either groups of vehicles with certain properties (Q > 1), or the contributions from each single vehicle (Q=1) are to be summed energetically.

Depending on the type of traffic situation, more or less detail is necessary. For a motorway, characterized by high vehicle speed and little acceleration/deceleration, a minimum data set is usually sufficient. On the other side, modelling a road intersection needs acceleration/deceleration data and at best individual vehicle data.

A sensitivity analysis revealed that information of traffic composition (% heavy motor vehicles) and the distribution of speed and acceleration/deceleration data are important for accurate calculation. The resolution of these distributions seemed to be a minor importance. Vehicle intensity is less important, since a doubling of Q only results in an increase of 3 dB. For further details we refer to the internal report of task 2.1 [21].

2.4 Requirements for traffic model

For achieving the goals put forward in the definition of the harmonised European models, the tolerance on the calculated noise emission of the traffic stream is limited to 1 dB. To achieve these goals, the required accuracy on the traffic characteristics has been derived in task 2.1 (see [21]). The table shown below summarizes these requirements

Table 1 Accuracy requirements

25% for vehicle intensity
5% in share of heavy motor vehicles
10km/h in average vehicle speed
0.3m/s^2 in acceleration for accelerating, 0.8m/s^2 for decelerating

It should be kept in mind, however, that the 1 dB accuracy target is for all models together (source model, traffic model, propagation model), so traffic models should preferably deliver more accurate results than presented in Table 1.

Task 2.1 also came to some conclusions regarding the required traffic data for calculating noise maps and drawing action plans in different situations. Table 2 summarises this.

Table 2 Required input in different traffic situations

highway	intensity & average speed
urban traffic	distribution of acceleration
intersections, traffic flow management	acceleration, individual vehicle data

3 Traffic models & their characteristics

In this chapter an overview is given of different kinds of traffic models and their characteristics. The term ‘traffic model’ refers to a model that describes road traffic in a network given the travel pattern. Within the context of a general transport model, we limit this discussion to ‘road supply models’. Transport demand, the number of trips that are made between zones in the study area, is assumed to be given. The modelling of demand is considered as an input for traffic models and is discussed in chapter 4. How the output of each type of model can be used as input for vehicle source noise models is treated in chapter 5.

The proposed classification is based on the way the different models deal with time and space. Four categories are distinguished in this report:

- Static assignment models
- Dynamic assignment models
- Continuum models
- Microsimulation models

This classification can also be seen as a clustering of historical paths in traffic model development. The classification will be consequently used within this report and further IMAGINE reports on road traffic noise.

This chapter contains a detailed description of each type of traffic model. The discussion also comprises a SWOT analysis of each model. We conclude with an overview of the properties of the four models, the current and expected future use of them in practice and the accuracy of the modelling technique.

3.1 Static assignment

Background

Static assignment is the classic approach in traffic modelling: the first transport models developed were of this type. In the sixties, when computers appeared on the scene, it became possible to calculate flows on networks. The rather simple modelling technique and limited data needs made static modelling the logical first step.

Modelling technique

Static traffic assignment [19] is the process of allocating trips in one or more trip matrices (*origin-destination matrices or OD-matrices*) to their routes (paths) in the network, resulting in flows on links (see Figure 2). The assignment process is typically used to produce a number of indicators, not just flows. The main objectives of traffic assignment are (see [3], [16])

- to obtain good aggregate network measures (e.g. total motorway flows)
- to estimate zone-to-zone travel costs (time)
- to obtain reasonable link flows and to identify heavily congested links
- to estimate the routes used between each origin-destination pair
- to analyse which origin-destination pairs use a particular link or route

Static assignment methods are generally hour based: the origin-destination matrix contains for instance the trips of a peak hour. The capacities of the road network are expressed as number of vehicles per hour. As a result, the flows the assignment estimates are average flows per hour.

With a static assignment, it is therefore not possible to get an insight on the development of a peak period. Consequently, these types of assignment are usually applied in long term policy studies.

The basic assumption in assignment is that travellers choose the routes that offer the lowest perceived individual costs. This cost can be divided in travel time and monetary travel costs. Generally speaking, there are three types of static assignment, all using this assumption:

1. *All-or-nothing assignment (AON)*: the simplest route choice and assignment method. This assumes that there are no congestion effects, and that all drivers consider the same attributes for route choice. They weigh and perceive them in the same way. The absence of congestion means that the link costs are fixed per link, and therefore all the drivers from A to B choose the same route. This route will always be the route with the lowest travel costs from A to B.
2. *User equilibrium assignment (UE)*: when the calculated traffic flow on a link will approximate or exceed the link capacity, the realised speeds on the link will decrease. The result is a larger travel time on this link: this effect is called *capacity restraint*. Due to the increased travel time on (a set of) links on a route, the route has possibly no longer minimal travel costs. Other routes can be more interesting now, unless all drivers change to this route. Capacity restraint can be used as a means for spreading the trips on a network. A user equilibrium can be reached when all traffic has chosen routes, in such a way that no individual trip-maker can reduce his travel costs by switching routes. The equilibrium is known as *Wardrop's first principle*. As a result, all routes used between A and B have equal travel costs, and all routes not used have greater costs. UE-assignment takes congestion effects into account.
3. *Stochastic assignment*: a drawback of user equilibrium is that this method assumes total knowledge and equality of the drivers, while in the real world every driver will make slightly different choices based on slightly different perceptions. With stochastic methods this problem can be solved, although the need of finding second best routes introduces a set of new problems. Another feature of stochastic methods is that the result of the calculation will be different in each run. That means that a large number of runs is needed to have significant results. The popularity of stochastic assignment seems to have decreased over the past years.

A problem in most static model applications is that the modelling of different vehicle classes is handled too simply for noise modelling. For instance, results for trucks and motorcycles (which are important for noise issues) are often not distinguishable. However, the static modelling technique is suitable for different vehicle types, but this generally requires more input data.

Time period systems

There are basically two commonly used time period systems in static modelling: *hour based models* and *24 hour based models*. The choice for one of these systems depends mostly on the traffic and transport data available. To make a good hour based model, considerably detailed data is needed on departure times of travellers in the area. An hour based model tries to represent for instance a specific peak hour. The distribution of traffic over the day has to be known to estimate the traffic demand in such a period. For the 24 hour model on the other hand, only the number of trips made per person in the area is enough to know.

In a 24 hour system, it is not possible to take congestion effects into account. All trips of the day are assigned to the network in one iteration. Only an all-or-nothing-assignment is suitable for this. In the hour based system, it is common to use hour based link capacities, so a user equilibrium assignment can be carried out. In hour based models, two types of hours are typically included: peak hour and off-peak hour (midday). Some models have both morning and evening peak hours modelled. Evening and night periods are usually not modelled. This is not necessarily a problem: it is possible to derive a night model from traffic counts. Alternatively, as long as congestion does not occur at night, a simpler approach could be used: the use of day/night conversion factors to estimate the traffic in the evening and night.

Output of static assignment models

The following output is generated by a static assignment model:

- origin-destination matrix with travel times/distances/costs
- flows on links/routes (see Figure 2)
- speeds on links (although in practice, static models are very rarely calibrated on speeds, which means that the predicted speeds may not be reliable enough to be used)
- chosen routes per o/d-pair
- o/d pair's use of a link
- aggregate results, such as:
    - total number of kilometres travelled on the network
    - total time travelled on the network
    - both indicators can be divided by link type

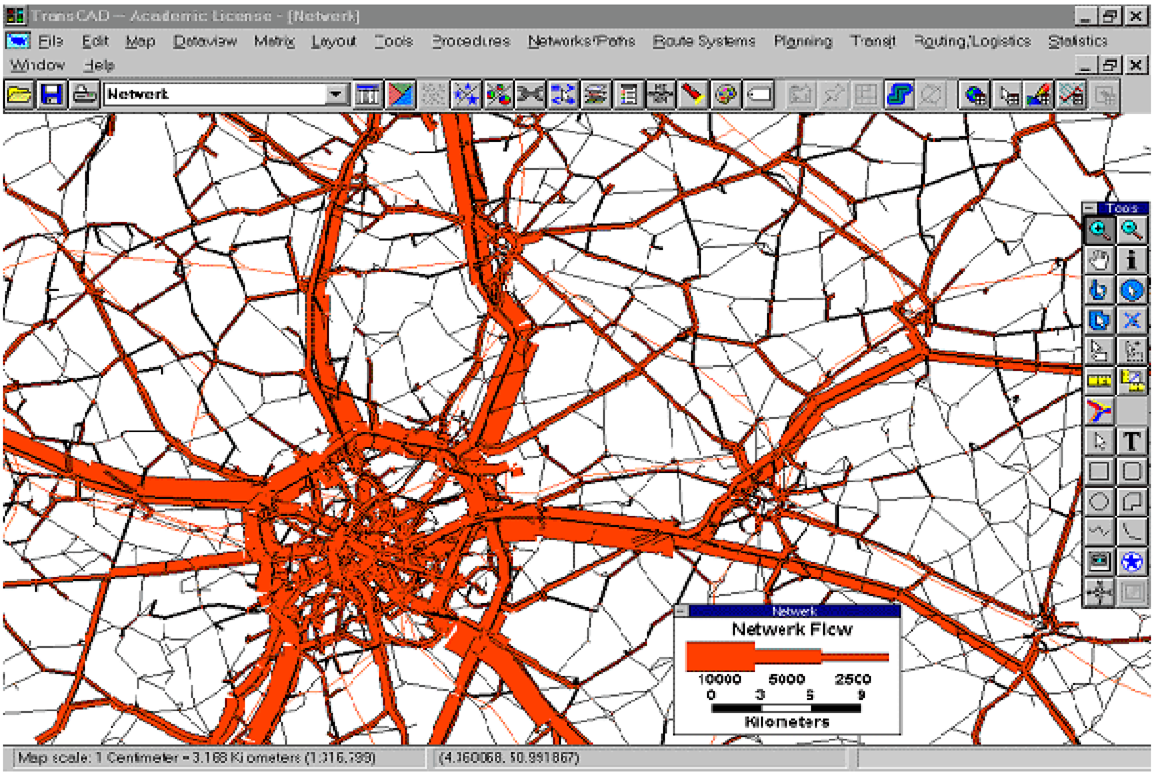


Figure 2 A typical result of a static assignment process

All vehicles on a link are assumed to have generally the same speed, so a speed distribution cannot be derived. Accelerations of vehicles are not modelled either.

Modelling of measures

Network measures, such as a change in capacity or speed of a road, or a new road are easy to bring into the static assignment model. More dynamic measures, like dynamic traffic management or variable message signs are not easily included. For pricing measures, assignments with different user classes are available.

Measures that influence the transport demand, like measures stimulating public transport or spatial planning measures, have to be input in a transport demand model, which generates an origin-destination matrix. This matrix is then input for the assignment.

The relatively simple nature of static assignment modelling, introduces at the same time a possible pitfall. Due to the aggregation level of results and the averaging of indicators, careful attention must be paid to the interpretation of the results and the limitations of static models and the way they are calibrated. Otherwise, erroneous conclusions and a false sense of accuracy are the result.

Expected developments

Unlike in the past, static assignment will not automatically be the first model type where new developments are tested and implemented. Static and dynamic models are expected to grow towards each other.

Table 3 Suitability of static assignment models - SWOT

Strengths • Relative ease of data collection • Fast • Data collection relatively easy • Results easy to understand (Easy-to-understand indicators: average flows and speeds) • 'Concise' results (not too much data) • Results easy to use in GIS environment	**Weaknesses** • All results are (hour-based) averages, fluctuations and peaks cannot be distinguished • Inaccuracy of results (flows[1] and especially speeds per link), due to: o use of relatively large zones and connectors from zones to network o use of general speed-flow diagrams (volumes can exceed capacity) o modelling techniques do not accurately model driver behaviour • Usually night periods are not or inaccurately modelled • Few dynamic management measures can be modelled • Network data (links and co-ordinates) are not always accurate
Opportunities • Model is very common in local, regional & national authorities • More digitised or automatically generated data will become available • Relative simplicity of models ensures that new developments will usually be tried out in static models first – model type will continue to be relevant to model developers	**Threats** • Improvement of model and input to produce better output for noise calculations requires a large effort (data collection) and is no priority for traffic & transport departments • Model results can cause a false sense of accuracy: results seem detailed, but not all indicators are significant

[1]: As static models are usually calibrated on traffic flows, flows resulting from models are generally adequately accurate. Calibrating with flows and speeds is much more difficult, this is not common practice. Therefore speeds from static models are likely to be less accurate

3.2 Dynamic Assignment

Background

Dynamic traffic assignment (DTA) models were and are developed as an improvement of the ‘traditional’ static assignment. DTA models can be used to generate forecasts of traffic that illustrate how traffic flows and congestion levels vary over time. Such models can therefore better represent actual traffic flows and can evaluate in more detail policy options aimed at a more efficient use of the current road network [1][2]. DTA models can also be used for prediction and control purposes (e.g. by traffic operators) and for on-line control. In combination with demand and time-of-day models, DTA models are an alternative for static assignment models in the future. At this moment, DTA models are not very common for practical applications, but they are receiving more and more interest. In general, DTA models use time periods of a couple of hours, mostly including one peak period. But simulations of 24-hour periods are also possible (although this will result in long run times). DTA models focus on the performance over time of the network under study.

Modelling technique

Resembling static traffic assignment, dynamic traffic assignment is the process of allocating *over time* trips in one or more trip matrices to their routes (paths) in the network, resulting in *time-varying* flows on links. The trip matrices are normally defined in trips per hour or trips per quarter of an hour. For each hour (or quarter) of the total time period a different trip matrix is fed into the DTA model to model a time-varying demand, see Figure 3. DTA in general can produce the same figures as the static assignment does, but with DTA more insight is gained into the dynamics of these figures. In general, DTA models can be divided into two separate sub-models: a dynamic network loading model and a route choice model.

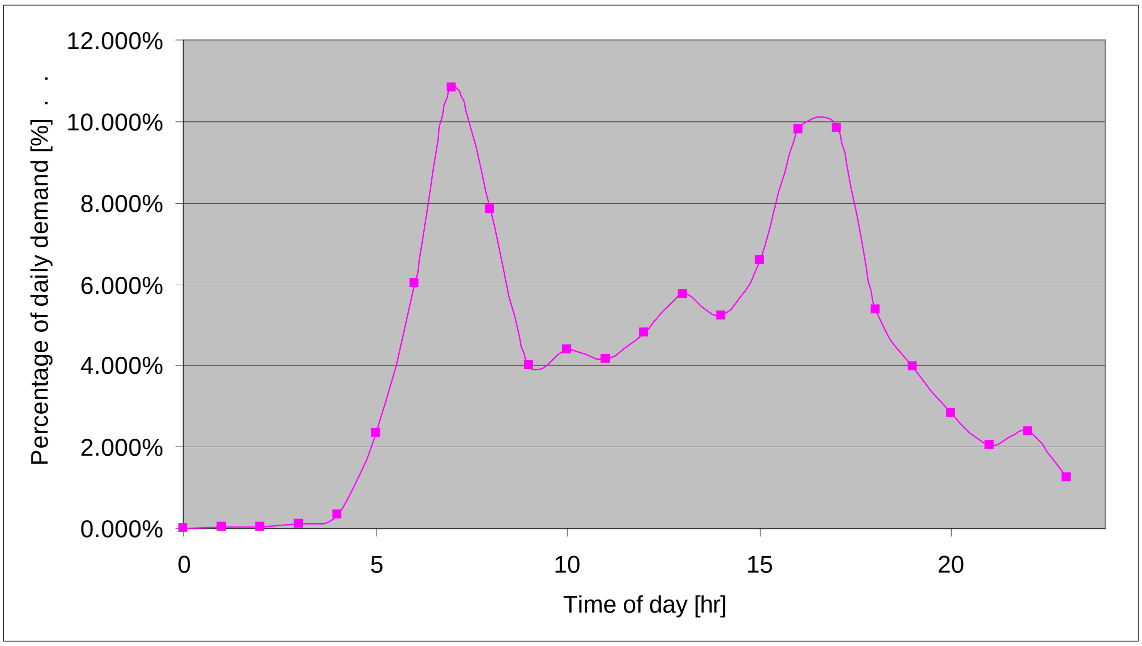


Figure 3 Typical time-varying 24 hr demand profile for DTA models

The dynamic network loading (DNL) model defines the way in which traffic moves along links in the network. DTA models can differ in the way in which the traffic is transported over the network, by using different DNL models. These models can, for instance, make use of speed-density functions, define the in- and outflow rates of vehicles on a link using node modelling or make use of 2nd order traffic flow models. The most important issue here – and a major distinction with respect to static traffic assignment models - is that these DNL models take into account not only the current, but also the historical development of the traffic on the link. Another important remark is that many DTA models require that the time step has to be smaller than the shortest free flow travel time over a link in the network. Otherwise, traffic can traverse over the complete link under consideration when this condition does not hold. DTA models can also be distinguished with respect to the way in which the routing of the traffic is modelled. This can be done by using a fixed route set containing all used routes between the different OD pairs. For each route, the flow proportation between an OD pair is defined. A second method uses split fractions at nodes. With the first method, the routes used between any OD-pair can be easily tracked. With the latter method, this is not always possible.

Within the route choice model, the type of assignment that is carried out is defined. Dynamic versions have been developed for the static assignment types all-or-nothing, user-equilibrium or stochastic assignment. Without departure time choice, these assignment types basically do the same as in the static case, only now routes are re-assigned on a dynamic basis, e.g. every 15 minutes. For the user-equilibrium and stochastic assignments, multiple iterations are required. During each iteration, all traffic for the complete period under study is assigned. Once all traffic has been assigned, and all vehicles have reached their destinations, the next iteration can start.

In the (near) future, DTA models will include realistic congestion spill-back modelling. This requires an accurate geometric description of nodes to be able to realistically model spill back effects.

DTA models combined with simulation

There are also DTA models that combine an iterative traffic assignment algorithm with a traffic simulation model. It can be expected that both continuum and micro-simulation models will be extended with accurate route choice models. Joining DTA and simulation models will certainly lead to improved traffic flow description.

Output of dynamic assignment models

The following output is generated by a dynamic traffic assignment model:

- travel times or costs per O/D-pair per route;
- time-varying route flow proportions;
- time-varying travel times, flows and speeds on links (see Figure 4).

And aggregate results, such as:

- total number of kilometres travelled on the network;
- total time travelled on the network.

All indicators can be generated for specific user classes.

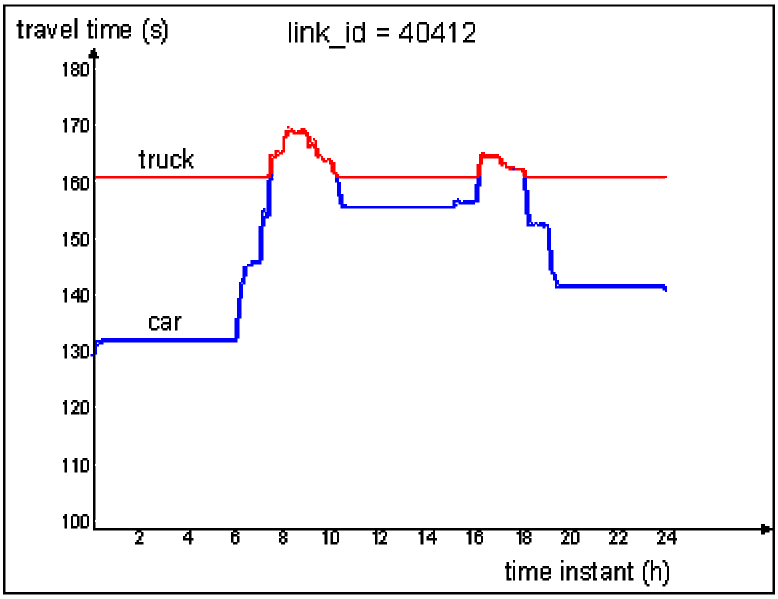


Figure 4 Typically time-varying travel times over a link for two distinct user classes (cars and trucks)

When compared to static models, DTA models give a better representation of the fluctuations in traffic flows and speeds, which improves noise calculations. However, data on acceleration and speed distributions are not generated by DTA models. The models do provide a (time) series of speeds for each link, but these are all average speeds on the complete link (for each time step). Peaks in speed are therefore not modelled.

Modelling of measures

In addition to what can be modelled in static models, DTA models can model dynamic traffic management measures (infrastructure & pricing, spatial planning). Also, it is possible to model the effects of shifts in departure times. Measures influencing traffic flow characteristics cannot be modelled. DTA models can also be used in on-line applications, e.g. for travel time prediction and to support Dynamic Traffic Management.

Table 4 Suitability of dynamic assignment models - SWOT

Strengths	**Weaknesses**

• More accurate and correct modelling of fluctuations in traffic demand than static model
• Possibility to model more accurately and correctly effects like congestion, incl. blocking back than in static model
• DTA models usually include multiple vehicle types
• Dynamic traffic management measures can be modelled
• Results easy to use in GIS environment
• In some DTA models, volumes cannot exceed capacity
	o Dynamic OD-matrix is required[3]
	o Modelling may involve long run times[4]
	o Few OD-matrices for full day available
	o Inaccuracy of results (flows and speeds per link), due to:
	    o use of relatively large zones and connectors from zones to network
	    o modelling errors and bad parameter estimation
	o in some DTA models, volumes can exceed capacity
	o Times step size determines accuracy of results (times steps are generally in the order of 10-20 seconds)[5]
	o Shortest free flow travel time on a link in the network defines maximum time step[6]

Opportunities	**Threats**
o More digitised or automatically generated data will become available[1] o Dynamic models are expected to become (much) faster in the near future[2] o DTA models offer possibilities that are expected to be in high demand in impact assessment studies (e.g. for reliability studies) in the near future o Better visualisation tools are becoming available	o Dynamic models need detailed input data o Difficult modelling technique can lead to 'black box' image for model users[7]

Remarks

1 But the challenge will be to ensure the quality and good management of the data.

2 Because of faster algorithms that are being developed, not necessarily because of increasing computational power – in the past this usually led to more features added to the models, not significantly decreased run times.

3 This in itself is not a major problem, but it requires a bit more work than an OD-matrix for a static model. The estimation of accurate OD-matrices (for any type of traffic model) is discussed in chapter 4.

4 Compared to static models.

5 Not applicable in the case of event-based DTA models.

6 Not a major problem.

7 However, strong visualisation possibilities are becoming available which may help users to gain insight into how the model works (e.g. movies showing the building up of queues).

3.3 Continuum models

Background

The efforts of physicists in describing road traffic resulted in continuum traffic models. The first attempts in transfer fluidum modelling techniques were done by well-known personalities from physics research [10] [11]. These techniques have been improved further and extensions towards typical road based physics are developed. The evolution in model development has not yet led to numerous commercial software packages. Because of that, there is only a limited use of this type of models in practice. Nevertheless, a lot of traffic research is done within this area and these efforts will certainly lead to renewed attention for this type of models, in theoretical as well as in practical applications.

Modelling technique

Within a continuum model, vehicles are not treated as separate entities. The discrete nature of traffic is idealized to a homogeneous fluidum. Within this continuum approach traffic is described using typical variables from physics: density, intensity (also called the flow or flux) and the average speed. Within the model, vehicles and their drivers are represented by identical fluid particles in a tube.

The basic principle of conservation of mass is translated as conservation of vehicles on a road. Pressure is the driving force for the particles in gasses and fluids. This mechanism is substituted for traffic. Particles in the traffic stream (vehicle – driver entity) have some kind of intelligence. The behaviour of vehicles on a road is usually described in an empirical driving behaviour function. This function is then used instead of the pressure equation to have a consistent model of traffic on a crowded road. The easiest assumption of such an empirical relation that reflects driving behaviour on a road is the 'fundamental diagram of traffic flow'. Figure 5 represents this diagram where the relation between flow and traffic density is given. A low density traffic stream results in zero flow (indeed, no vehicles drive on an empty road) while a very dense traffic stream results in no flow ((when vehicles stand still in a queue). Maximum flow, also called capacity, is reached when traffic has an average density.

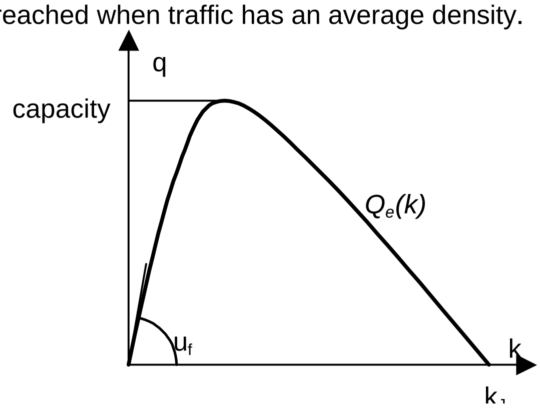


Figure 5 Fundamental diagram of traffic flow on a link. Horizontal axis shows traffic density k, while flow is represented on vertical axis q

The fluidum model is a set of mathematical equations. Sometimes this can be solved analytically, but in practice a numerical scheme is used. This means that a link is divided up in cells with length varying between 10 and 500 meter and that traffic conditions are calculated in time steps of 0.5 to 10 seconds. This results in a detailed description of traffic conditions in a space time lattice. The traffic density, the flow and the average speed are then known along the road at each time step.

Continuum models traditionally focus on long crowded roads. The extension of continuum models to road networks needs the formulation of node rules. Nodes have no physical length and act as flow exchange locations between links. By developing node definitions the model can describe traffic at junctions, off-ramps, on-ramps and traffic lights.

Further extensions focus on typical traffic properties. Traffic is not a real homogeneous medium. Therefore multiclass models are developed where differences in vehicle properties (e.g. long trucks versus small cars) and driving behaviour (e.g. aggressive versus slow acceleration driving behaviour) are developed. Within multilane models, the lanes are modelled as various parallel tubes with exchange possibilities. Other assumptions on empirical traffic behaviour lead to complex higher order models (where traffic pressure is defined) or kinetic models (where overtaking probabilities are calculated).

Output of continuum models

All traffic variables calculated can be listed and aggregated. Also statistics and parameters based on these core variables can be calculated and reported. Based on the detailed flow pattern an average flow on a link during a certain period can be calculated.
Since no commercial packages exist, the use of this type of models is rather limited. Therefore, it is difficult to say something about the ‘standard’ output of continuum modelling packages.

Figure 6 shows the possibilities of calculated traffic data. The evolution of the average speed and the flow on a highway stretch is represented using a colour scheme. This way it becomes possible to show where and how congestion occurs, where speed variations start and how the general traffic operations are influenced over time and space.

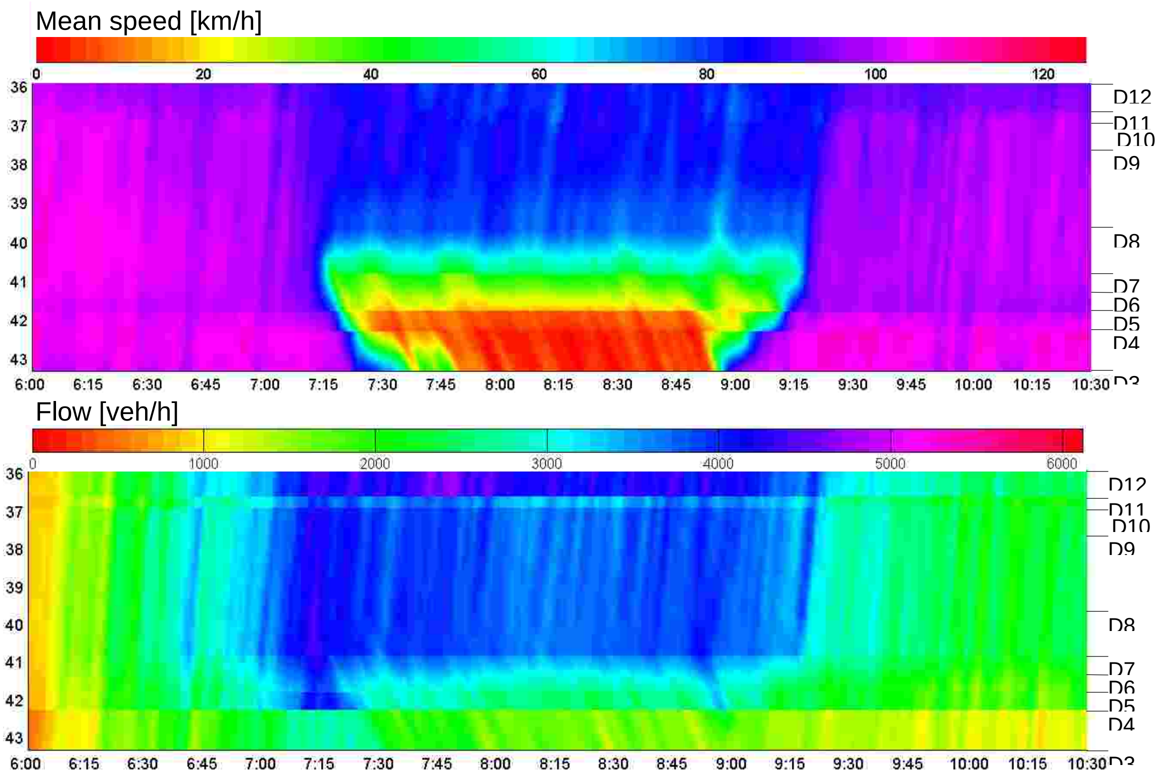


Figure 6 (a) The average speed and (b) the flow in a t-x diagram. Horizontal axis shows time evolution (between 6:00 and 10:30, while vertical axis shows location on a highway (between km 43 to km 36) (see [12])

Modelling measures in continuum models

Continuum models describe traffic operations in detail. Therefore they are specialised in measures that influence traffic flow characteristics. Measures that do not influence traffic demand and route choice are the most likely to be modelled. Therefore continuum models are mostly used for the evaluation of short term measures (e.g. impact of removing incidents, ITS measures,…) or in on-line control systems (predicting travel times, as input in control algorithms of traffic signals).

Continuum models in practice

Until now, this type of models was rarely implemented in practice. Commercial continuum software packages are rare (examples are netcell, metanet,…). We can see growing interest in the development of fast continuum models. In particular, their use as dynamic network loading model in the framework of dynamic assignment models seems near. This will result in more software packages and application within traffic control and traffic operations.

Table 5 Suitability of continuum models - SWOT

Strengths • Very detailed description of traffic operations both varying spatially along road links and temporally. This includes congestion, blocking back, • Analytical model technique resulting in equilibrium without instabilities for certain types of continuum models. • Designed to model dynamic traffic management measures • Volumes can never exceed capacity • Calculation time does not depend on number of vehicles • Input of network data is limited compared to microsimulation	**Weaknesses** • Detailed demand pattern required. Like other models, evening and night periods are usually not the subject of study. • No route choice. This means that also a route tree is demanded as input. • Commercial continuum packages have not a large market share. • Modelling may involve long run times due to small spatial and temporal discretisation.
Opportunities • New commercial software packages will be developed. The link with noise models and GIS systems can be included in this development process. • Possible future link with DTA model will result in combining strengths of both model types. • The development of semi-automatic calibration and validation techniques is possible. • Easy to use in combination with traffic detector data	**Threats** • Possible ‘black box’ image for current practitioners • Still challenges in developing models for priority nodes and urban road networks.

3.4 Micro-simulation

Description

Traffic micro-simulation attempts to model the progression of individual vehicles through a road network during a specified simulation time period. A micro-simulation model breaks the overall simulation period down into a large number of discrete time steps, and within each time step uses a number of individual algorithms to generate decisions for all vehicles within the network area. The decisions made are then used to update vehicle position, speed and acceleration information. The methodology used for the simulation process in micro-models falls into two main categories:

- Models in which the available road space and vehicles are treated as fundamentally separate units, with road space viewed as a continuum, and:
- Cellular Automaton (CA) models, where road space is divided into a number of discrete segments, each approximating a vehicle length, which may be occupied or un-occupied at any given time.

The ability to model individual vehicles gives micro-simulation models a number of advantages over traditional, static models. Micro-simulation is typically used to study the effects of short-term traffic management schemes, signal control policies or public transport priority schemes. With care and careful calibration, such models may be used to accurately assess the effects of heavy traffic levels and urban congestion. Advanced models may be used to study the impacts of incidents (e.g. shockwave propagation after traffic disruption), lane changing or weaving behaviour, Intelligent Transport Systems (ITS), dynamic route guidance systems or in-vehicle systems such as Intelligent Speed Adaptation (ISA).

On a typical office PC, at the time of writing, the scale of micro-simulation models may range from small regions, spanning several junctions, to entire city areas spanning several hundred junctions and several thousand vehicles at any given time. There has also been a number of highly-parallel micro-simulation models developed, capable of modelling entire regions within a country or state on multi-processor systems. In order to reduce running costs, it is a general requirement for the simulation package to run at greater than real-time speeds.

A given micro-simulation package may contain a vast array of sub-modules, depending on the exact application to which the package is applied. However, a number of core components in any micro-simulation model may usually be identified:

- A *network editor*: The network editor provides for the development and maintenance of a representation of the traffic network under consideration. At the most basic level this representation may be little different to the network description of a traditional static-assignment model – it is common practice to use a network representation from a static model as the basis for micro-simulation. On a more complex level, the micro-simulation package may allow features such as junction stopline set-backs, flared approaches, insets and lay-bys, HOV or bus lanes, banned turns etc. to be encoded. Ideally, the editing of a network representation should be carried out using a GUI (Graphical User Interface) to allow visualisation of the network, and to identify and minimise potential errors prior to simulation.

- A *traffic-signals* database: The traffic signals database stores signal timing settings and controlled traffic streams for individual junctions in the network representation. At the simplest level only fixed time signals with no coordination between junctions may be represented. More complex models may allow signals to vary dynamically with time-of-day, or be vehicle actuated. As with network editing, ideally a micro-simulation package should provide a GUI to facilitate the editing and testing of signal timings prior to simulation.

- A *vehicle/driver* database: The vehicle database holds information on vehicle characteristics such as classification, specific physical or mechanical parameters (e.g. vehicle length, maximum speeds maximum/minimum acceleration rates). The driver database holds representations of behavioural parameters (e.g. distributions of reaction times, tolerance or aggression levels, acceptable gaps etc.)

- A *simulation* module: The simulation module is the heart of any traffic micro-simulation model. When running the simulation module iterates through the simulation period using discrete time steps to model the progression of vehicles. The simulation module takes as input the network, traffic-signals and vehicle information, along with additional information on the length of the desired simulation period. Depending on the exact package used, vehicles may be generated using link-based flows, output from an existing static or dynamic assignment model, or the package may possess its own assignment routines. Routes through the network are typically generated as part of the assignment process, though a number of micro-simulation packages allow dynamic route assignment during a simulation run.

  A typical simulation module contains a number of sub-components that may be run within a given time step. These include:
  - The *vehicle generation* algorithm: The vehicle generation algorithm injects individual vehicle units into the network. The exact time of entry to the network is usually controlled by a selected distribution of vehicle headways (e.g. shifted-negative exponential or log-normal distributions). Vehicle units themselves are usually generated as a stochastic process, and represent an amalgam of both physical properties of the vehicle (class, length etc.) and behavioural properties of the driver (e.g. reaction time, aggression).
  - The *car-following* algorithm: Gabard [5] defines a car following model as “a differential difference equation giving the acceleration of a vehicle with respect to the behaviour of the preceding ones”. The general form of a car following model may be given as:
    Response = f (Sensitivity x Stimulus)
    where response is the acceleration or deceleration of a following vehicle and stimulus is a function of the physical distance and velocity difference between the leader and follower. The exact nature of the sensitivity parameter(s) may be highly complex, and significantly abstracted from directly quantifiable vehicle/driver parameters.
  - The *signal-behaviour* algorithm: Some micro-simulation models use specific algorithms that govern how leading and following vehicles interact with traffic signals. This is done to account for such factors as start-up delay following a complete stop, and to better model slow moving traffic.
  - The *gap-acceptance* algorithm: The gap-acceptance algorithm governs how and when vehicles will enter an opposed traffic stream (e.g. behaviour at non-signalised intersections and circulating flows on roundabouts).
  - The *lane-changing* algorithm: The lane changing algorithm governs a vehicles’ desire to move across lanes. This may be triggered by a variety of stimuli, such as a following

vehicle moving due to a slower leading vehicle or moving to the correct lane for a particular turning movement.

- The *vehicle-update* algorithm that applies the results of any decisions to vehicles to update there position. In CA models the update algorithm determines which cells become occupied or unoccupied.

NB: The above list is by no means exhaustive; many models may contain specific features for select application. Certain micro-simulation packages provide hooks or callback functions to trigger third-party applications during the operation of the simulation module.

- An *output or visualisation* module: A typical micro-simulation package provides tools to both visualise and display vehicle movements during simulation (the often impressive “birds-eye” view of traffic) and to collate and output vehicle or network performance parameters. In some instances this may be done in interactive fashion whilst the simulation is running, or forms part of a post-processing operation. Recent advances in computing hardware and the development of graphics APIs (Application Program Interfaces) have meant that 3D visualisations are becoming common.

Screenshots for editing facilities and visualisations from a number of micro-simulation packages are shown in Figure 7:

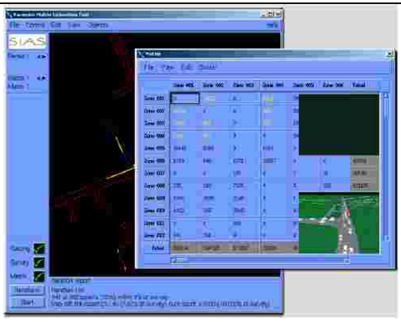
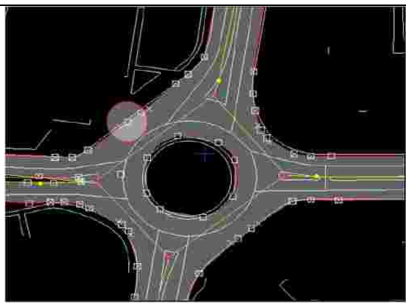
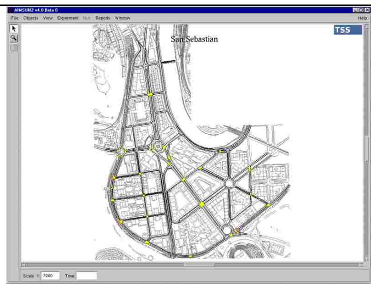
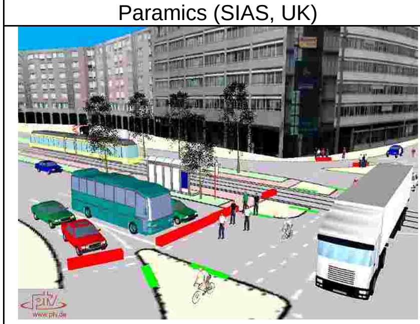
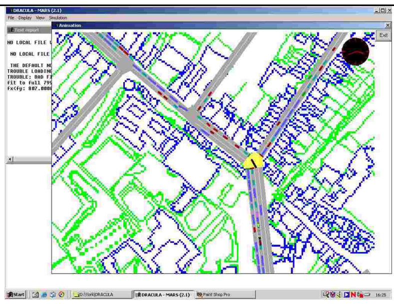
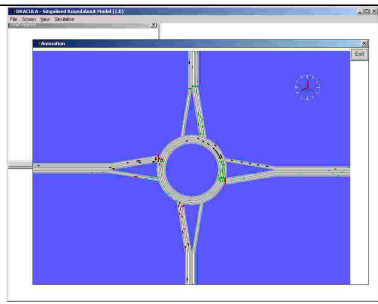
 Matrix estimation and manipulation : Paramics (SIAS, UK)	 Link and node editing : Paramics (SIAS, UK)	 Network editing and modelling : AIMSUN2 (TSS, Spain)
 3D Visualisation : VISSIM (PTV, Germany)	 Junction modelling : DRACULA (ITS Leeds/WS Atkins, UK)	 Roundabout modelling : DRACULA (ITS Leeds/WS Atkins, UK)

Figure 7 Sample micro-simulation models and facilities ([6], [7], [8], [9])

Outputs for traffic micro-simulation:

Micro-simulation models may produce output on a variety of levels. A typical micro-simulation may provide output at the micro-, meso- or macro-scopic level, depending on the amount and scope of data aggregation applied.

Micro-scale outputs:

- Initial vehicle/driver parameters: (e.g. vehicle length, initial speed, initial location, chosen route, driver reaction time etc.) from the vehicle generation algorithm.
- Vehicle trajectories: (i.e. vehicle ID, class, position, speed and acceleration in each time step). Usually models offer the ability to filter the trajectory information by vehicle class and sampling methodology (e.g. trajectories from selected links, or vehicles performing a certain manoeuvre) to limit the size of output. Figure 8 shows a time distance diagram of sample vehicle trajectories generated by micro-simulation along a signal controlled link.

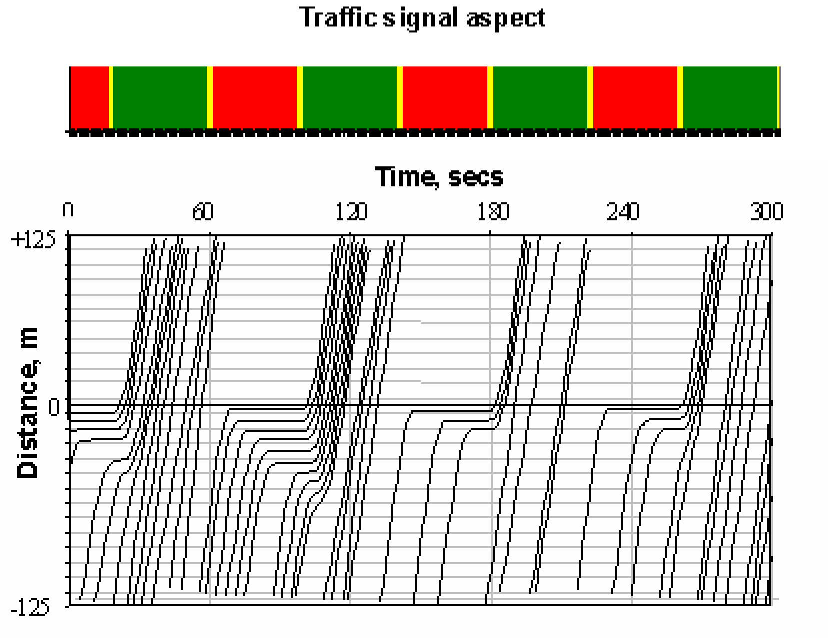


Figure 8 Time-distance diagram from simulated vehicle trajectories

- Traffic signal changes: (e.g. exact time of stage changes, possibly triggered by simulated detector systems).
- Simulated detector output: Many micro-simulation models offer the ability to place simulated detectors within their networks. Modelled detector output may be of a similar nature to vehicle trajectory information (i.e. vehicle ID, class, speed and acceleration at the instant of passing the receiver location). For the sake of simplicity, some models assume a detector has no physical dimension, existing only as a point location. Other models may allow detectors to occupy a finite length of road space, allowing the calculation of occupancy measures, such as those used by traffic signal control systems. Some interpolation/aggregation of instantaneous vehicle parameters is usually necessary to generate detector output (e.g. where detector location falls in-between a vehicles location in two consecutive time steps).
- Application specific outputs (e.g. dwell times at specific bus stops for given public transport vehicles from a micro-simulation of public transport priority measures, or vehicle specific pollutant emissions rates for environmental assessments).

Distributions of parameters (of vehicle speeds and accelerations for example) are usually derived from micro-scale parameters.

Meso-scale outputs:

- Link or route based output, such as mean flow, speed and journey times. Usually such results links may be output either for the entire simulation period, or for smaller time periods within the main period. Figure 9 shows a sample visualisation of mean vehicle speeds on individual links from DRACULA, a UK micro-simulation model.

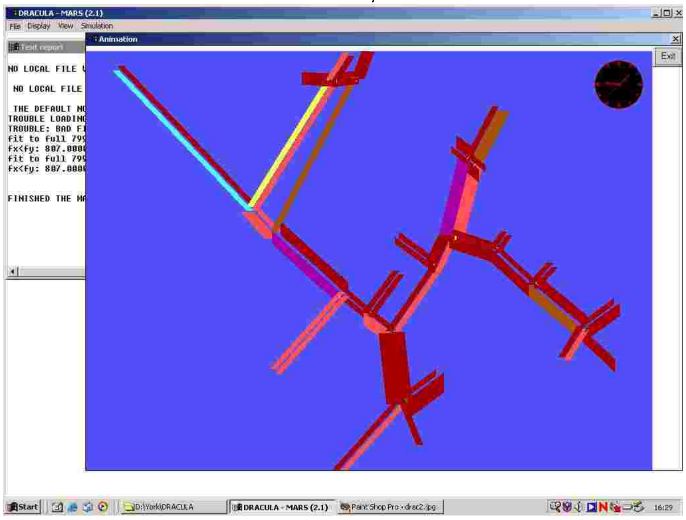


Figure 9 Visualisation of aggregate link based data (mean speed data classified by colour) from a micro-simulation model

- Node or junction based output, such as turning movements undertaken or mean queue lengths on junction arms within a given period.

Generally, most micro-scale parameters may be aggregated to provide summary information in a form comparable to the output found from static or DTA models, with some additional information on variability within the simulation period being available. The exact aggregation methodology used will vary depending on spatial and temporal requirements, and may require substantial interpolation and post-processing.

Macro-scale outputs:

- Aggregate network parameters, such as total number of vehicles simulated within the given period, total kilometres travelled, total network travel time, mean network speed, global network emissions rates etc.

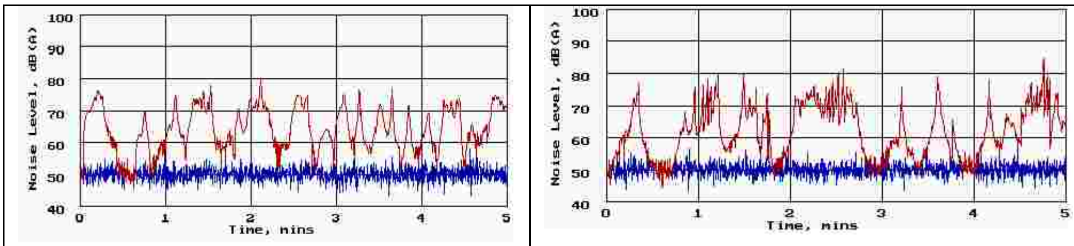
The stochastic nature of micro-simulation models means that it is normal practice to repeat simulation runs, with differing initial seed values. This is done to:

- assess the stability of the model, to ensure there are no break downs in flow due to problems with the car-following algorithm (typically these can occur in a commercial model if unsuitable time step or car-following sensitivity parameters have been selected by the user);
- assess variability in selected parameters between simulation runs.
- test model sensitivity to select parameters.

The exact outputs from a given micro-simulation package are usually tailored to the exact application of the model. Given that the models deal with the road transport network at its most fundamental level almost any output is theoretically possible, provided that all desired features are present and adequately modelled within the selected package. Developers and vendors of micro-simulation packages are usually willing to work directly with clients to ensure the quality of any modelling.

The ability to harness vehicle kinematics information directly is of primary interest to noise modelling, allowing the emission of vehicle sound power levels to be calculated in greater spatial and temporal detail than for other types of traffic model. The variety of traffic schemes that may be modelled by micro-simulation also exceeds that for other model types. However, the broad scope and level of detail of such models means that a variety of approaches may exist for the precise methodology used to aggregate emissions levels and assign them to the road space.

Figure 10 shows examples of sound level history calculated for two receiver locations on a link (one at a junction stopline, one 100m upstream of the stopline) using a micro-simulation model to calculate instantaneous sound power levels for vehicles in each simulation time step, followed by propagation to the receiver location by ray-tracing. Whilst such a level of detail may be inappropriate for large scale noise mapping, the figure acts as an illustration of the potential of micro-simulation modelling.



Noise level adjacent to stopline location

Figure 10 Sound level histories at two receiver points derived from micro-simulation modelling (NB: blue line is normally distributed background level)

Table 6 Suitability of Micro-Simulation Models - SWOT

Strengths	**Weaknesses**

• Traffic parameters vary, both spatially along road links, and temporally.
• Modelling at incredibly detailed levels is possible. It is relatively easy to gain vehicle speed and acceleration information, broken down by user class from a micro-simulation. For noise assessment a variety of aggregation procedures could be undertaken, e.g:
  o Use instantaneous vehicle parameters to calculate emissions, then assign emissions to a section of road.
  o Use aggregate vehicle parameters for a given road section/time period to produce noise emissions.
• Modelling of a wide variety of traffic schemes possible.
• Modelling of short-term transient events (e.g. incidents or in-peak congestion).
• Micro-simulation packages often include very powerful network editing, visualisation and post-processing tools.
• Powerful visualisation tools can help in the calibration and validation process.
	• Model accuracy depends on initial assignment of flows – possibly from an independent model.
	• The stochastic nature of microsimulation necessitates multiple model runs that are potentially time-consuming.
	• Road networks need to be defined with more precision than is typically required and commonly undertaken for other categories of model.
	• Stability of models may depend on selection of a particular value of time step (usually 0.5 – 1 second). This may not be appropriate for noise modelling.
	• Specific algorithms, rules or parameter values used in a given package targeted at one member state may not be transferable to other member states.
	• Micro-level results require aggregation for large-scale and/or GIS use[1].

Opportunities	**Threats**
• The running speed and spatial scope of micro-simulations is improving all the time as computing power increases, and software engineering and data structures become more efficient. • Variety of traffic schemes that may be modelled is increasing – vibrant research area. • Micro-simulation models offer possibly the best method for assessing future ITS and in-vehicle systems. • Micro-simulation models have been directly linked to on-street UTC systems such as SCOOT, SCATS or UTOPIA and on-street detector systems. • Possibility to add further parameters to the model through additional research, (e.g. time-of-day or weather dependent parameters affecting driving characteristics). • Microsimulation will be a growth area in the coming decade as more authorities adopt such models.	• Micro-simulations are data-intensive applications – possibly more so than other categories of model. • Large range of input parameters and potential modelling issues often require expert advice, developer support and reliance on “default values”. • Fully calibrated and validated micro-simulation models may be time intensive to set-up for large areas. • Impressive visualisation of results may lead to overconfidence in unreliable data.

[1] However, the fact that micro-scale results are available is also considered a primary strength.

3.5 Discussion

This discussion section starts with some overview tables of traffic model characteristics. Next, a discussion follows on expected traffic model developments and evolutions within practical traffic model use. This discussion takes into account the input from the interaction with traffic model developers.

3.5.1 Overview traffic model characteristics

The classification and suitability study of traffic models can be summarized in overview tables. Table 7 shows the capability of traffic models to produce the required input for traffic noise source models. For each of the four classes of models an evaluation is made of their suitability to produce reliable traffic volumes, speeds, speed distributions (within an hour over a link, where the speed differences depend on differences in the driver characteristics and on changes in traffic conditions), acceleration and the traffic fleet influence (the influence on traffic flow properties depending on the vehicle composition of the traffic flow). These issues are discussed on link level. Furthermore it is supposed that a reliable description of traffic demand is available as input for these models. The weakness of this last assumption will be discussed extensively in the next chapter.

Table 7 Suitability of traffic models to produce detailed output

	Static	Dynamic	Continuum	Micro-simulation
Traffic volumes	+	++	-	+/-
Speeds	+	+	++	++
Speed distributions	-	+	+	++
Acceleration	-	-	+	++
Traffic fleet influence	+/-	+/-	+/-	+

++ available and reliable

\+ available; possibly not reliable

\- not available

The low score of continuum and micro-simulation models with regard to traffic volumes is due to their lack of accurate route choice models. However, some micro-simulation packages already offer an assignment model.

The different types of traffic models can all estimate the impact of a range of traffic flow measures. Within the design of noise maps, typical traffic flow measures can be proposed. In the Imagine state of the art report [13] these measures are categorized into three main categories. An evaluation for each traffic model type is made for these categories of noise reducing traffic flow measures. It should be noted that many measures heavily influence traffic demand and that therefore their effects should be also assessed with a demand model. Table 8 only gives an indicative overview of the ability of the traffic models to model most of these measures, assuming a good modelling of traffic demand.

Table 8 Capability of traffic models to model traffic flow measures

	Static	Dynamic	Continuum	Micro-simulation
Reducing traffic volumes	+	++	-	+/-
Changing traffic conditions	-	+/-	++	++
Changing traffic composition	+/-	+/-	+/-	+

++ available and reliable

+ available; possibly not reliable

- not available

3.5.2 Expected evolutions of traffic models

Several traffic model experts observe a growing overlap between the different model types. Static assignment is traditionally the last step of the classical four step transport model. Presumable this last step will be extended to a dynamic assignment. Dynamic assignment depends heavily on a dynamic representation of travel times in a network. The modelling of traffic operations to calculate dynamic travel times is done by a dynamic network loading model (DNL). Traffic modelling experts expect a growing fusion between the model types, because both continuum and micro-simulation models can be used as DNL for the dynamic network assignment.

Almost all consulted traffic model experts stress that modelling daily and annual evolutions is not restricted by the traffic models themselves, but by the input for these models (traffic demand). Therefore it can be concluded that the absence of off-peak periods and daily and annual evolutions in current models is caused by current practice, which does not provide traffic demand data for the periods considered. However, the basic data needed to derive demand for the periods needed for noise modelling (day, evening, night) is available.

The experts believe that currently the static traffic model is applied in roughly all major cities and regions. They expect an increasing shift from static to dynamic assignment models in large area applications. This will probably occur simultaneously with the extension of the modelling period from the peak period to a whole day period. However, traffic models of night periods are not expected to be introduced very fast. Furthermore the use of micro-simulations to model small – but increasingly larger – urban and local situations will grow. Complete coverage of a large city or a region with micro-simulation models remains less likely.

4 Traffic model input

In Chapter 2, an introduction to noise models was given, including an overview of the input they require from traffic models. Chapter 3 discussed traffic models themselves, giving an overview of the different types of models and their suitability to produce the output required for noise modelling. Traffic models are considered to be merely traffic assignment models. This means that traffic models themselves require a large amount of input data. As the input data has a major impact on the accuracy of the output, this chapter discusses the kind of input that is required by traffic models, and the accuracy that can be expected.

Traffic demand is by far the most critical input for traffic models. Traffic models (as this report considers them to be merely traffic assignment models) are the supply part of general transport models. The output of the ‘demand model’ is quite critical: on a theoretical level (methodology, accuracy) as well as on a practical level (e.g. time periods considered by the demand model, availability and suitability for different traffic models,…).

Obviously there still is some other input required for traffic models, such as network layout (see also the study of noise and GIS in WP1). Another type of input are traffic control systems (e.g. traffic lights), enabling the simulation of traffic control measures. A last type of input consists of traveller/driver properties and vehicle properties (vehicle stock), which are important when heterogeneous traffic flow (different types of vehicles, different types of driving behaviour) is to be simulated.

Part 4.1 of this chapter discusses the most important input, common to all types of traffic models: demand modelling. In part 4.2 the additional input needs and properties are discussed for each of the different types of traffic models. Part 4.3 ends this chapter with some conclusions.

4.1 Demand modelling

Background

Modelling transport consists of describing the equilibrium between transport supply and demand. The demand part of this process consists of searching for the driving forces that determine whether someone wants to make a trip between a certain origin and a certain destination at a certain point in time. The demand can be described in an origin – destination matrix (OD table), representing the number of people that want to travel during a certain period between the origin and destination zones using a certain mode of transport.

The traditional approach of constructing an OD table comprises the first three steps of the classical four step transport model. The last step consists of the static assignment model as discussed in section 3.1. The three choices at the basis of the trip making decision will be clarified in the next section.

Modelling technique
The classical three demand steps correspond to three choices that every traveller makes :

- Will I make a trip?
- Where will I travel to ?
- What mode will I use?

These choices are simulated for all people in the study area during the study period. Usually a differentiation is made between classes of people. This differentiation can be made on different levels, resulting in a hierarchical classification.
In most cases, the first level of differentiation is made on the basis of travel purpose: are people making trips from home to work, from home to school, for business reasons, for recreational purposes …? Sometimes the classification is further subdivided, for example on the basis of car availability. Other ways of subdividing are possible, for example on the basis of income.

The first choice (*Will I make a trip?*) is modelled in the **'generation'** step. This step results in an overview of the number of starting trips (productions) and arriving trips (attractions) per zone. Productions and attractions are determined on the basis of socio-economic data, travel surveys and activity parameters.

The second **'distribution'** step links the departing travellers to the calculated destinations (*Where will I travel to?*). Linking origins to destinations is modelled on the basis of trip distribution functions, which are observed relations between trip resistance and the number of trips.
Trip resistance is a general quantity taking into account all variables relevant for the distribution process, such as travel distance, travel time, toll costs, … Since a number of these variables (primarily travel times) are dependent on traffic conditions, the distribution process will also be dependent on traffic conditions on the network. Furthermore, the distribution process also depends on the available travel modes. Therefore this second step is mostly combined with the third **'modal split'** step (*What mode will I use?*). In that case separate trip distribution functions are needed for each travel mode.

The result of these three steps is a number of tables containing the number of trips between each zone, one table for each purpose and mode. These OD tables are a static representation of travel demand for the study period.

As mentioned in step 2 (distribution), traffic conditions (in particular travel times) are quite important for the transport demand modelling. Therefore the search for a transport equilibrium needs the iterative run of both demand models as well as traffic models.

Possible improvements
This traditional demand modelling framework seems quite pragmatic but has some drawbacks. For instance modelling the impact of e.g. time-of-day and price measures, will lead to difficulties. Therefore a more complete and coherent framework from general econometric modelling can be used. Using mathematical techniques (e.g. logit models, see [17],[18]) a more disaggregated and stochastic demand model was developed. This framework will possibly be extended based on extensive research in the area of 'activity based modelling' [20]. Trip demand is then expected to be modelled as a derivative of spatial and temporal activity patterns.

At the moment methodologies are developed to model time-of-day choices (e.g. the choice between travelling during peak or off-peak period). Knowledge of the evolution of demand over time becomes increasingly important because dynamic traffic models need this input. The activity based approach seems promising in delivering more supported dynamic OD tables. However, the accuracy of traffic demand will probably remain a difficulty. Calibration of OD patterns needs a large amount of data. Furthermore, (in most cases) an OD table can't be observed, only traffic flows on individual network links.

Other challenges exist for the modelling of freight demand. Freight transport is only a small part of freight logistics. Similar to activity based models, the complete modelling of the logistic processes can result in better OD tables for freight. It should be noted that the lack of data is here even more critical. Obtaining data is very difficult, largely because transport firms are reluctant to disclose their logistic processes.

Output of demand models

The origin – destination tables represent the output of demand models. Figure 11 gives a graphical representation of such a table.

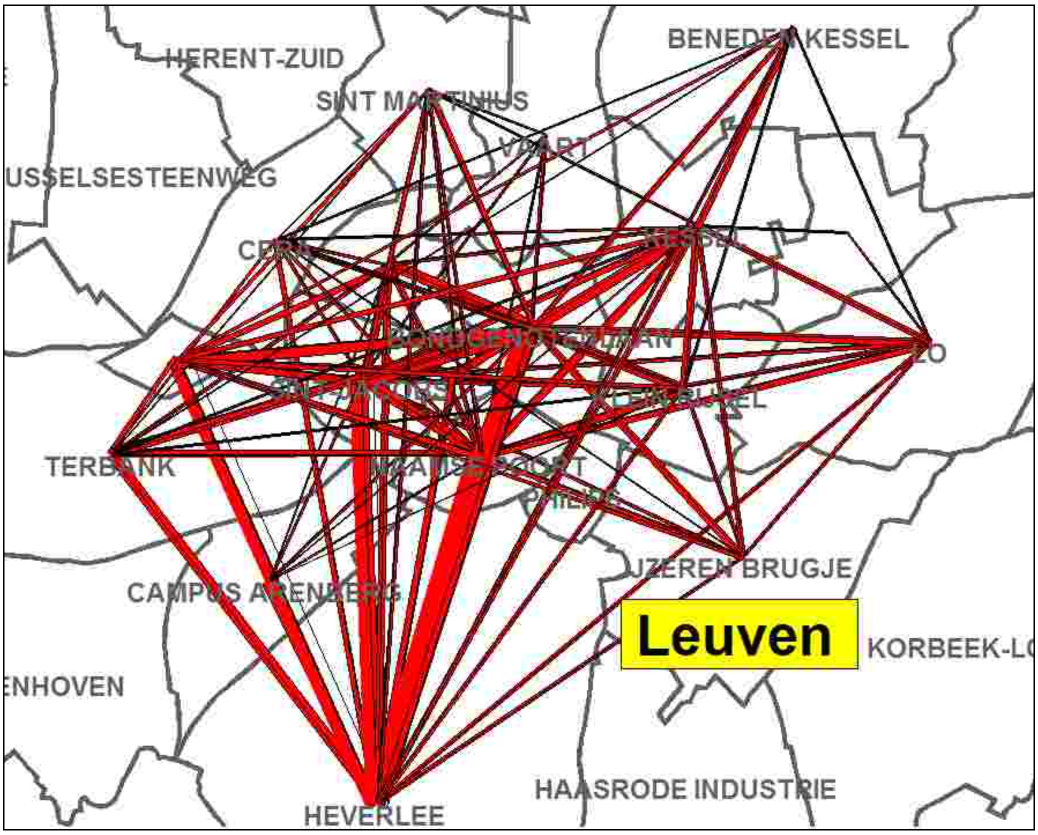


Figure 11 Graphical representation of an OD table

The typical use of demand models results in demand information per zone (areas between the size of 0.5 km² for a model of a town and 1000 km² for a model of Europe) and per time period. The simulated time period is typically 1 hour for a peak model, but dynamic evolutions occur (for example consisting of 5 minute periods).

Modelling of measures

All kind of measures can be modelled. It should be noted that time costs also come into the picture. Traditional measures comprise changes in transport supply (new infrastructure, changes in public transport, …). Interest is growing in the prediction of the impact of pricing measures and changes in the driving forces of transport demand (e.g. changes in the spatial activity system).

Table 9 Suitability of Demand models - SWOT

Strengths	**Weaknesses**
• Large experience resulting in a coherent set of procedures to model demand. • Traditional data sources for modelling transport demand during peak periods suffice for modelling whole day travel patterns (e.g. socio economic data, travel surveys, data from traffic detectors,…)	• Current practice focuses heavily on peak periods • Accuracy and quality of demand model output. This depends on local model building experiences. • Low traffic volumes during off-peak periods cause relatively larger errors in noise models (e.g. : flow x 2 = noise level + 3Db). • Most demand models do not incorporate vehicle or driver related differences. (e.g. type of car, type of driver). • Freight remains a difficult issue within demand models.
Opportunities	**Threats**
• Vehicle fleet modelled for air emissions can be used for noise related vehicle fleet. • Increasing interest in congestion charging measures requires the development of whole day transport models. This means that traffic demand models will be developed for whole day. • Use of on-line traffic control models results in new data availability for calibration of off-line models. • A lot of ongoing research in upgrading demand models to 'activity based transport demand'. • Increasing use of econometric approach to model traffic demand.	• Calibration of demand (origin-destination tables) can hardly be done independently of traffic model. • Bad insight in the real elasticities of traffic demand makes it difficult to model traffic measures correctly.

4.2 Input for the different types of traffic models

4.2.1 Static assignment

To do a static assignment, two types of input data are required: network data and transport demand data.

Network data:
- zones with properties (e.g. parking costs) and coordinates
- nodes with properties (e.g. crossing penalty) and coordinates (coordinates are not needed for calculation, only for illustration of the results and network in a GIS-environment)
- links with properties (length, capacity, free flow speed)

The accuracy of these data does not need to be too high. Too much detail slows down the calculation, and the nature of the assignment process is not too precise. It is fairly common in static assignment networks that the links are straights between junctions, when in reality the represented road could be winding. This can pose a problem in impact assessment studies such as noise maps.

Transport demand data:
- origin – destination matrix with trips for a certain time period

Transport demand data is usually derived from a transport demand model, described in section 4.1. This OD-matrix can consist of multiple user classes (but this is not yet very common). These user classes represent for instance different trip purpose groups or different vehicle types. The behaviour of the different classes in the assignment can differ, due to divergent reactions on travel costs. Modelling with different user classes will improve the noise calculations but it should be noted that in general only a few user classes are distinguished (3-5).

Data for future years should not be a major problem. Changes in the network are usually well known in advance (in infrastructure plans). Changes in demand have to be estimated with a demand model (a standard procedure, static models are often used for prognoses for the future years). Some other parameters (e.g. travel and parking costs) may have to be adapted.

4.2.2 Dynamic Assignment

DTA models require as input both the traffic demand (trip matrices) and supply (the network). For the modelling of Dynamic Traffic Management (DTM) measures additional inputs may be required.

The traffic demand input consists of trip matrices per period (e.g. per hour) and per user class, defining the number of trips between each O/D-pair within that period. Again, the number of user classes is limited. Usually, data is collected for a peak-hour period with a short period before and after it.

The network input consists of:
- zones;
- nodes and coordinates of nodes (only for visualization or GIS purposes);
- links between nodes, with information on e.g. link length, (user class specific) free flow speed, capacity and additional parameters that define e.g. a speed-density relationship for that link;
- connectors, connecting the zones to nodes of the network.

For modelling DTM measures, event lists may be used as input. These event lists define at which moment specific measures are (de)activated. The effects of these measures can be modelled by dynamically changing the capacity and speed of links.

As with static models, data for future years for DTA models should not be a major problem.

4.2.3 Continuum

Continuum models need traffic demand data, data related to the network and information on control and measures.

Traffic demand

Continuum models completely focus on traffic operations on a network. This means that route choice is not part of the model. Traffic demand must be detailed further as time dependent flows on the networks. Traffic demand can therefore be given in two forms :
- Dynamic demand flows at the origins of the network with split fractions at each node. This approach is mainly used when continuum models are linked to data from traffic

detectors. The model can therefore serve as ‘gap filler’ and reproduce detailed traffic operations in a network with insufficient detectors. This form of input is also used for on-line use where traffic is predicted to control traffic or to generate traffic information.

- A complete overview of dynamic OD flows over the different routes.
  This information must come from a detailed demand model and dynamic route choice model. Therefore, output from static or dynamic assignment models is sometimes used as input. The strengths of both the assignment and continuum models become available by this method. Complexity and calculation time forms a weak point in this model combination.

The quality of the input is very important for the results of the model. The first method will traditionally give better results (no multiplication of several model errors), but can not be used to produce long term model estimates or to evaluate measures that affect traffic demand.
More detailed models also need more detailed demand data. The modelling of vehicle classes is only possible when an accurate description of demand is available per vehicle class. When total traffic demand is lower, the relative error will become larger. This results in less reliable input for low volume roads and night periods.

Network data
The road network consists of links and nodes.
Links in a continuum model can be represented by lines. This means that there is a potential link with GIS databases. Since few commercial packages are available, this link is not implemented yet. The properties allocated to the links are related to the empirical relation as represented in Figure 5 in Chapter 3. Mostly this contains some basic parameters of this function : the road capacity, the amount of lanes, the maximum speed, … More detailed models (e.g. multiclass, multilane,…) also need more data.
Node information is also quite basic : priorities, capacities, traffic signals, …

Information on control and measures
The control measures comprise typical road signals and traffic light cycles, ramp metering algorithms, etc. Also lists and details can be inserted, but no general input format seems available.

4.2.4 Micro-simulation

Due to the detail level of micro-simulation models a large number of input parameters are required. These may be broadly broken down across a number of categories: network data, signal data, supply/demand data, vehicle/driver and other, application specific data data:

Network Data:

- Node (junction) locations;
- Link data (topological connection between nodes is the minimum requirement – for GIS and visualisation requirements it is more typical for links to be described as geographically accurate vector chains);
- Lane data within links (number of lanes, width of lanes, special properties (e.g. bus only lanes);
- Allowable turns at nodes for given lanes;
- Desired speed on individual links or lanes (possibly including distribution of desired speeds by vehicle class).

NB: The desired speed is usually the most important parameter in calibrating vehicle behaviour – most car following models allow a vehicle to cruise at its desired speed when not directly interacting with a leading vehicle or traffic signals. In most flow regimes this leads to output speeds reflecting the original desired speed parameter (and any allowed distribution of such). Hence the desired speed should be carefully selected. Use of posted speed limits as the desired speed in micro-simulation models may lead to erroneous results, especially in urban locations.

Signal Data:
Input signal data includes:

- Signal stages and their connections to traffic streams on individual links;
- Signal intergreens;
- Signal offsets for coordination between junctions;
- Any links between signals and detectors for Selected Vehicle Detection (SVD) or Vehicle Actuated (VA) signals.

Supply/Demand Data:
Micro-simulation models may include an assignment package capable of generating flows based on supplied OD matrices, or may be dependent on using flow data assigned through the use of an independent model. Usually vehicle turning proportions at junctions or vehicle routes through the network are also provided to the model. Again, these may come from an inbuilt assignment package, or independent model.

Hence, in the need for such data, micro-simulation models share a weakness with other traffic models in that it is rare for complete OD matrices or assignments to exist throughout an entire day period, and even rarer for such data to be disaggregated by vehicle user class.

Vehicle/Driver Data:
Input vehicle/driver data may include abstract sensitivity parameters for the car following algorithm, as well as more tangible parameters, such as:

- Vehicle classes;
- Vehicle lengths and distribution of lengths;
- Maximum allowable vehicle speeds (mechanical constraints);
- Maximum allowable vehicle accelerations/decelerations (mechanical constraints);
- Typical vehicle acceleration/deceleration rates;
- Driver reaction times;
- Vehicle start-up delay factors;
- Driver “aggression” or “courtesy” factors (influencing acceleration rates and gap-acceptance behaviour at junctions);
- Lane changing and overtaking desirability factors;
- Vehicle class specific emissions factors.

NB: Alteration of many of the above parameters allows calibration and fine tuning of saturation flow rates at junctions).

Other Data:
Other input data may be specific to the application to which the micro-simulation is being used, such as:

- Detector locations and required detector output;
- Public transport routes, schedules and interchange/stop locations;
- Pedestrian or cycling facilities;

- Incident/road-work/obstruction locations and durations;
- Presence of parking (sources/sinks) on- or off-street;
- Presence of tidal flow or flow control measures.

The above list is by no means exhaustive – with individual applications having specific input requirements.

4.3 Discussion

The accuracy of traffic models is determined primarily by the quality of the input. The most critical factor is the output of the transport demand models. The growing fusion between traffic model types will result in a better description of traffic conditions. This will increase the emphasis on demand models as a critical link in the chain of modelling transport even further.

Traffic models are used in practice to study a certain area during a certain period of time. Their use is closely related to the availability of demand models. Therefore an overview table on the use of the different traffic models for different geographical and temporal scales is presented in this chapter (see Table 10).

Table 10 Current practice of traffic models

	Static	Dynamic	Continuum	Micro-simulation
Study area				
Regional/National	++	+	N	N
City	+	++	N	+
Local motorways	N	+	++	+
Local urban	N	0	0	++
Study period				
Peak hour	++	+	+	+
Day	+	++[1]	0	+
Year	0	0	N	N

++ available and reliable

+ available; possibly not reliable

0 (neutral)

N not available / not common practice

1: May involve long run times

Static models are mainly developed for large areas during peak hours. A growing interest in the modelling of off-peak periods can be noticed. This increase in the modelling of the daily evolution is accompanied by the implementation of dynamic assignment models because of the shortcomings of the static assignment in modelling peak spreading.
Continuum models are mostly used in applications on motorways involving congested traffic.
Micro-simulation models are implemented in local traffic situations where the visualisation of traffic operations is important. A growing interest in the development of larger micro-simulation models is expected.
Modelling several typical days can lead to a better assessment of the evolution within a year. Until now, however, few modellers do this. Another issue that needs attention is that currently most models are based on working day data (excluding the weekend).

5 Linking both models

Chapter 2 focused on noise models and how vehicle noise source models are treated in Imagine, including an overview of the input noise models require from traffic models. In chapter 3 traffic models were discussed, giving an overview of the different types of models and their suitability to produce the output required for noise modelling. Chapter 4 studied the influences of the input of traffic models.

This chapter discusses the use of traffic model output as input for noise models. Two types of problems will be discussed:

- Theoretical: difference in detail level between the output of traffic models and the expected input for noise models
- Practical: reported traffic model output does not match required noise model input

The following approach was chosen. First an overview is made of the theoretical data needs on the link level of traffic noise source models. Then the theoretical possibilities of traffic models to deliver this data are discussed. This leads to a discussion of practical problems that can be encountered when using data from traffic models for noise models. Lastly, a s*et up of (dis)aggregation possibilities is given.*

Paragraph 5.1 of this chapter discusses the aggregation of the output of traffic models, as required for the noise models. In the subsequent paragraphs, each type of traffic model is discussed with regard to their use for noise modelling.

5.1 Traffic representation in traffic models

The noise source models for rolling and propulsion noise are developed within Harmonoise and WP 5 of Imagine. These models define the instantaneous noise level. To calculate the L_{DEN} values, the total energy emitted on each location must be calculated. Theoretically, this can be done when the individual paths of all vehicles are known on a certain link over a whole year. The representation of such a vehicle path is called a trajectory. The noise source models therefore need the description of all trajectories on a link while also vehicle class characteristics are known for each individual trajectory. Figure 12 represents a set of trajectories on a link. The vertical axis represents time, while the location x along the link is represented on the vertical axis.

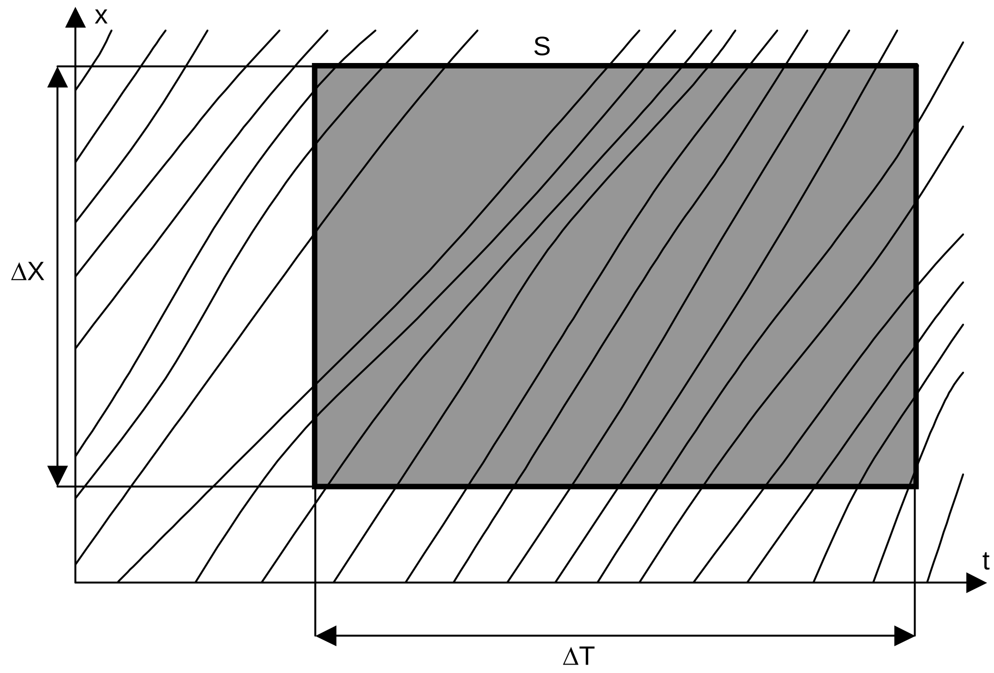


Figure 12 Trajectories in a t-x diagram with trajectories (from technical disaggregation note)

Within the Harmonoise / Imagine framework, the instantaneous sound levels are averaged over time periods. Because L_{Eq} is calculated, this time period ΔT comprises a full year. Furthermore, the propagation model needs point source models. Therefore, the noise emitted over a certain distance ΔX is summed to calculate the equivalent point noise value. The space interval needs to be rather small (ΔX < 50m).
Therefore, we can define the L_{Eq} values to be a representative of a time – space interval.
Supposing the exact position of the trajectories and the vehicle properties are known, the following formula represents the emitted L_{Eq} point source over the $\Delta T - \Delta X$ interval :

Propulsion noise in the interval S :

$$L_{eqm}^{P}(S) = 10 \cdot \log_{10}\left(\frac{1}{\Delta T} \cdot \sum_{i} \int_{t_e}^{t_l} 10^{a_P(f)+b_P(f)\cdot\left[\frac{v-v_{ref}}{v_{ref}}\right]} dt \right)$$

The propulsion noise in the interval *S* can be calculated as the sum over all individual vehicles i. The noise per vehicle corresponds to integration along the trajectory. A vehicle enters this interval at t_e and leaves it at t_l.
Analogously the rolling noise is calculated as:

$$L_{eqm}^{R}(S) = 10 \cdot \log_{10}\left(\frac{1}{\Delta T} \cdot \sum_{i} \int_{t_e}^{t_l} 10^{a_R(f)+b_R(f)\cdot \lg\left[\frac{v}{v_{ref}}\right]} dt \right)$$

It should be clear that perfect knowledge of all trajectories and vehicle properties along all roads over a whole year is not feasible in traffic models (or, for that matter, in measuring campaigns). Because the intervals in traffic models do not correspond to the required noise source model interval, several mismatches are possible. We classify them according to the space and time discretisation.

Regarding spatial intervals:

- The traffic parameters are reported in a ΔX interval that mostly differs from the required spatial resolution of noise models, in the sense that most links in a traffic model network are (much) longer than 50m.

Regarding time intervals:

- The length of the interval ΔT is extracted as the interaction of three separate evolutions :
  - The evolution of traffic within an hour.
    This is strictly related to the intrinsic properties of the traffic model: can it model and report the details of the trajectories or relevant averaged values of it over an hour? This includes the accurate description of speed, speed distribution, acceleration, fleet composition (and the impact of it on speed and acceleration).
  - The evolution within a day.
    This is related to the current and future practice of the considered traffic models: are these models developed to describe variations over a day? Can they describe the evolution of hourly rates?
  - The evolution over the year.
    Basically, it must be known what the evolution over a year is, what typical situation a traffic model represents and how this day is related to other days over a year. This could be achieved by the use of several model runs each representing a typical period.

The averaging of the three temporal evolutions comprises each time a central question: do we average traffic variables or do we average noise variables? Averaging traffic values will result in an average speed, a speed distribution, possibly also an estimation of mean accelerations and a dependency of these values on vehicle composition. The influence of the evolution in traffic variables can not be estimated anymore when noise values are calculated for one period. This can be best understood when considering two vehicles. The averaged noise level of a slow and a fast vehicle does not match the noise level of two vehicles at the average speed of both vehicles.

The averaging effect has an influence on all the kind of evolutions. The impact of speed evolution within an hour can be resolved by defining a speed distribution. Fast vehicles will contribute more than slow vehicles. The speed evolution within a day must be treated analogously. The time period where vehicles drive faster has a larger impact on overall average noise levels. It should be noted that the evolution over the day of the speed distribution also has a large impact. The same argumentation holds for the evolution over the year. This third evolution in time is also influenced by the other variations: hourly speed distributions and daily traffic patterns.

When evolutions and distributions of speed and flow do not exist, the calculation of noise level simplifies to:

$$L_{W,line,eq} = L_{W,0} + 10 \cdot \lg\left(\frac{Q}{v}\right)$$

Because of the occurrence of large evolutions (within a day and over the year) and non homogeneous traffic conditions (speed distribution), this simplified formulation does not hold and a more profound calculation becomes necessary. This incorporates the calculation of noise levels for several typical periods and an averaging of the sound levels over these periods.

The next section will discuss the ability of traffic models to be linked with noise models. The aggregation of vehicle trajectories and the evolution of traffic patterns will be quite an important issue for the different model types.

5.2 Static assignment

5.2.1 Common use of static assignment models

Static models do not work with individual trajectories. The intrinsic representation of traffic is the averaging of the traffic characteristics in a time – space interval. Traffic conditions are averaged along a link, thus ΔX equals the link length (between 100m and 5km). Traffic is also averaged over time (the time period modelled). In most cases this means that ΔT is 1 hour long.

This intrinsic representation of traffic and common practice cause some mismatches between the static traffic model and the noise model. The following problems will generally be encountered when the output of a static assignment model is used as an input for a noise mapping software :

1. Lateral spatial matching: Static assignment is generally used to model traffic flow on a larger geographic scale. In general, the construction of the model involves simplifications of the road network: an approximation of the real road alignment is made and parallel roads are frequently joined. The link is abstracted to a line, not taking into account the physical width of the road. Noise modelling (especially when the number of people exposed has to be determined), requires a geographical detail of about 10m for highways and one meter for urban situations[1].
2. Longitudinal spatial resolution: The links used in static assignment models are often rather long. Parameters, in particular traffic speed, are connected to a link. More realistic modelling of the influence on noise emissions of traffic speeds on roads with several traffic lights, roundabouts, crossings, may require the improvement of traffic speed distributions along a link based on road characteristics.
3. 24h data: The EU common indicator for noise exposure L_{den}, is based on the knowledge of noise sources for a period of 24 hours. The average for each period (day, evening, night) is an energetic average and the sound power of a traffic stream depends linearly on the number of vehicles (if one neglects the influence of traffic intensity on traffic speed for simplicity). So basically the only information that is needed is the average number of vehicles during day, evening, and night. Nevertheless, these data are generally not available from static assignment models. If one takes into account that traffic speed is influenced by intensity (e.g. due to saturation) and/or that propagation conditions change due to meteorological conditions, then hourly or 15 minute data are needed.
4. Yearly average: The common noise indicator represents a yearly averaged value. Again, due to changing propagation conditions, it is required to have at least a few representative situations for each period of the year modelled. Again, it is not common practice to run static assignment models for the acoustically relevant situations (evening and night).

[1] Noise modelling software may include features to prevent roads from actually crossing the observer locations thereby reducing this problem.

5. Extending to lower level roads: In most countries common land use (planned or not) has resulted in most people living close to a small road rather than along a major connecting road. Static assignment models are often used to retrieve traffic on the most important roads only. Traffic on the lower level roads is neglected or treated as access traffic within the zone that is regarded as one node in the traffic demand matrices. In urban areas, the contribution of traffic on lower level roads to the general noise level may be considerable. Therefore it may be necessary to estimate the traffic on these roads (by including more lower level roads or alternatively, based on intrazonal traffic extracted from the model).
6. Traffic composition: To calculate the noise power of individual vehicles of a traffic flow, at least three categories of vehicles should be used. Static assignment models often do not include these different types of vehicles, so other sources may have to be consulted.
7. Traffic speed: In a number of practical applications, the traffic speed obtained from static assignment models was very unrealistic. Based on the characteristics of the road and on the driving speed allowed, at least a cross-check should be performed.

In task 2.3 some default approximations to overcome these problems will be studied.

5.2.2 Fundamental restrictions on applicability

To achieve the goals put forward in the definition of the harmonised European models, the tolerance on the calculated noise emission of the traffic stream is limited to 1 dB. To achieve these goals, the required accuracy on traffic characteristics has been derived in task 2.1 (see [21]). Table 11 shown below indicates which criteria could possibly be met using static assignment traffic models. These judgements concern the possibilities of delivering data for one hour. As we have discussed above, the averaging over day and year is a critical transport demand issue for all traffic models.

Table 11 Indication of the ability of static models to meet accuracy criteria

25% for vehicle intensity	+[1]
5% in share of heavy motor vehicles	-
10km/h in average vehicle speed	-
$0.3 m/s^2$ in acceleration for accelerating, $0.8 m/s^2$ for decelerating	--

++ very well possible, + likely to be achieved, - unlikely to be achieved, -- impossible

[1] provided the traffic demand matrix is known with sufficient detail.

Table 12 below gives for some situations where traffic models could be applied, the requirements (from task 2.1) and the applicability of static traffic assignment models.

Table 12 Indication of ability of static models to provide the input needed in different traffic situations

highway	intensity & average speed	+
urban traffic	distribution of acceleration	-
intersections, traffic flow management	acceleration, individual vehicle data	--

++ definitely applicable, + probably applicable, - probably not applicable, -- impossible

5.2.3 Examples

A static traffic assignment model was used to obtain traffic intensities on highways and major roads in Flanders (Belgium). Noise emission and propagation were calculated in accordance with the Dutch “standard rekenmethode 2”. For the 1996 version, vehicle speed was assumed to be equal to the allowed speed for each road section. In 2001, statistical data on speed distribution as a function of road type and allowed vehicle speed were used as an estimate of real traffic speed distribution. Road surface and noise barriers were taken into account. The exposure of the population was estimated based on land use (dwellings) and population density per statistical sector.

In the chart below, the exposure of the population as calculated using the static traffic assignment is compared to measurements made in front of 250 dwellings that were randomly selected (population based selection). These measurements were corrected for disturbances, time of day, and weather conditions. The important underestimation of exposure to high noise levels that can be observed in the chart is caused by the neglection of traffic on smaller roads.

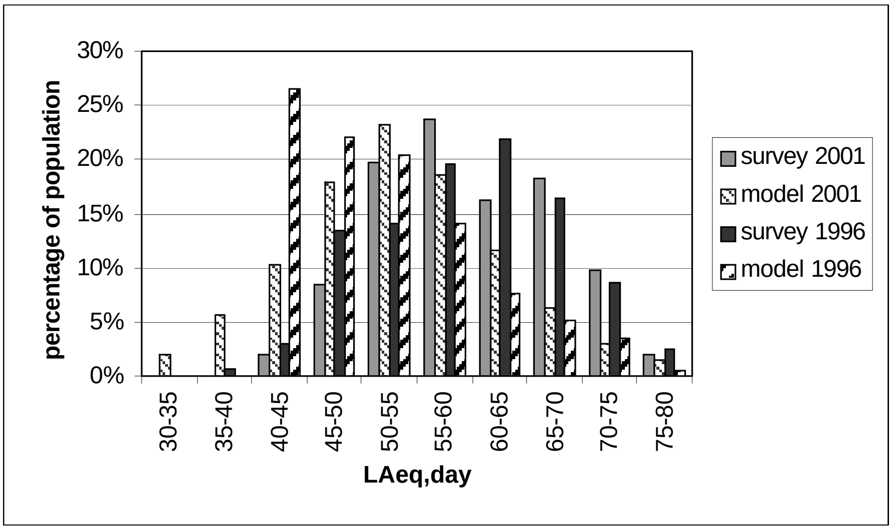


Figure 13 Comparison of noise exposure calculated on the basis of traffic intensities obtained from a static assignment model compared to L_{Aeq} from a measurement survey.

5.3 Dynamic assignment

5.3.1 Common use of dynamic assignment models

Similar to static assignment models, dynamic assignment models also don't work with individual paths of vehicles. Again, the characteristics of the traffic stream are averaged in a time-space interval. The spatial resolution equals the link length as in static models (ΔX between 50m and 5km). The time resolution is finer and typical values of ΔT fall between 10 seconds and 5 minutes.

The intrinsic representation of traffic and common practice cause mismatches. The following problems will generally be encountered when the output of a dynamic assignment model is used as an input for a noise mapping software:

1. Lateral spatial matching
2. Longitudinal spatial resolution
3. 24h data
4. Yearly average

Depending on common practice and the type of model, the following issues are expected to be less problematic in dynamic traffic assignment models (as compared to static models):

5. Extending to lower level roads:
   As we expect the dynamic models to have a more complete and dense network compared to static models, we expect a higher coverage of the busiest road network. Therefore, we expect that the coverage will be sufficient for noise mapping.
6. Traffic composition:
   Dynamic traffic assignment models exist that model different vehicle classes. Nevertheless, the accuracy of traffic model input is quite critical here.
7. Traffic speed:
   Traffic speed is supposed to be much more reliable in dynamic traffic models. However, working with dynamic travel times is not sufficient to model realistic urban traffic operations.

5.3.2 Fundamental restrictions on applicability

As mentioned in 5.2.2, the required accuracy of the traffic characteristics to achieve the tolerance of 1 dB on the calculated noise emission of the traffic stream, has been derived in task 2.1. Table 13 gives an indication of the ability of dynamic assignment models to meet the accuracy criteria.
These judgements concern the possibilities of delivering data for one hour. As discussed in 5.1, the averaging over day and year is a critical transport demand issue for all traffic models.

Table 13 Indication of the ability of dynamic assignment models to meet accuracy criteria

25% for vehicle intensity	+[1]
5% in share of heavy motor vehicles	+[1]
10km/h in average vehicle speed	+
0.3m/s^2 in acceleration for accelerating, 0.8m/s^2 for decelerating	--

++ very well possible, + likely to be achieved, - unlikely to be achieved, -- impossible

[1] **provided the traffic demand matrix is known with sufficient detail.**

The table below gives for some situations where traffic models could be applied, the requirements (from task 2.1) and the applicability of static traffic assignment models.

Table 14 Indication of ability of dynamic assignment models to provide the input needed in different traffic situations

Highway	intensity & average speed	++
urban traffic	distribution of acceleration	-
intersections, traffic flow management	acceleration, individual vehicle data	--

++ definitely applicable, + probably applicable, - probably not applicable, -- impossible

5.4 Continuum models

5.4.1 Common use of continuum models

Continuum models represent traffic in very fine time-space intervals. The time interval ΔT in this interval lies between 1s and 15seconds. Space intervals ΔX are also very short (between 20 and 400 meter). However, this detailed level of information is not sufficient to guarantee a perfect match with noise models. An overview is constructed of potential problems in linking a continuum traffic model with a noise source model.

1. Lateral spatial matching:
   The road network is also represented by nodes and (line) links in a continuum model. When the model is not GIS based, the practical linking to noise mapping software must be resolved.

The lack of accurate demand data will cause similar problems as with the assignment models :

2. 24h data
3. Yearly average

The spatial and time resolution is much finer in continuum models. This will cause less problems with :

4. Longitudinal spatial resolution
5. Traffic speed
6. Traffic composition
   Heterogeneous continuum models explicitly take into account the differences in traffic operations for several vehicle classes. The accuracy of the demand model is quite critical here.

The practical application of continuum models is still in its infancy. Therefore we can not assess what details will be modelled when this type of model is applied in 2010. Probably lower roads will be taken into account to have a fine network description.

5.4.2 Fundamental restrictions on applicability

In task 2.1 the required accuracy of the traffic characteristics was determined, to achieve the tolerance of 1 dB on the calculated noise emission of the traffic stream (see also 5.2.2).
In Table 15 an assessment is made of the ability of continuum models to meet the accuracy criteria.
These judgements concern the possibilities of delivering data for one hour. As discussed in 5.1, the averaging over day and year is a critical transport demand issue for all traffic models.

Table 15 Indication of the ability of continuum models to meet accuracy criteria

25% for vehicle intensity	+[1]
5% in share of heavy motor vehicles	+[1]
10km/h in average vehicle speed	++
$0.3 m/s^2$ in acceleration for accelerating, $0.8 m/s^2$ for decelerating	?[2]

++ very well possible, + likely to be achieved, - unlikely to be achieved, -- impossible

[1] **provided the traffic demand matrix is known with sufficient detail.**

[2] **has to be investigated further, depends strongly on the specific model type.**

The table below gives for some situations where traffic models could be applied, the requirements (from task 2.1) and the applicability of static traffic assignment models.

Table 16 Indication of ability of continuum models to provide the input needed in different traffic situations

highway	intensity & average speed	+
urban traffic	distribution of acceleration	+
intersections, traffic flow management	acceleration, individual vehicle data	+

++ definitely applicable, + probably applicable, - probably not applicable, -- impossible

5.5 Micro-simulation

5.5.1 Common use of micro-simulation models

Micro-simulation models calculate individual trajectories of traffic at time intervals ΔT of typically 0.5 seconds. Therefore this is the most complete traffic description of the discussed traffic models. However, we can still expect some problems in linking these micro-simulation models with noise models.

Exporting data from micro-simulation model for noise mapping

Several options are available for linking micro-simulation model output to the noise emission calculation module:

1. Average data, in particular number of vehicles (of different types), vehicle speed distribution and distribution of accelerations can be calculated for each relevant segment. This data can be exported from the traffic model for future use in noise mapping software. The output generated by micro-simulation models is very similar to the output of continuum models, so we refer to the discussion above.
2. All details about all vehicles in the model (position, speed, acceleration, …) can be exported at each time step and the resulting database can be processed into relevant emission data subsequently. This way of working is rather inefficient due to the huge amount of data that has to be processed.
3. A suitable noise emission module implementing the European harmonised vehicle sound power model can be integrated into the micro-simulation model. This module calculates the (octave band) sound power level for every vehicle in the network. If required (see below), the noise emissions can be summed for a limited number of locations for a predefined time period.

Linking to sound propagation model

Sound pressure levels at the locations of interest can be calculated by either the following two approaches:

1. Use of fixed grid of emission points. Vehicles are mapped to the nearest emission point at each time step. This means that only a single calculation of propagation from the fixed point to the receivers is needed. However, there is a loss of directional information when cars with different direction are mapped to the same emission points, in the case of a fixed grid that is too coarse.
2. Emission points for all vehicles at their exact location at each time-step. Directional information is fully accounted for. The disadvantage is that a new sound propagation calculation is needed at each time-step.

If the sole interest is in obtaining L_{den}, the first approach is clearly the most appropriate one because it limits calculation time. The choice of a suitably fine grid is critical. In urban conditions, where propagation through side streets and alleys could be important, a finer grid of emission point is required.

The second approach is required to accurately predict maximum noise levels and statistical levels (e.g. L10) that may play a role in the definition of additional indicators for the night or for identifying quiet areas. To optimise calculation time, actual instantaneous locations can be used for cars that are close to the receiver while the contribution of cars on segments of the road that are further away from the receiver can be modelled as fixed sources linked to each road segment.

Restrictions of current implementations of micromodels

- At free flow, all vehicles tend to travel at the same speed. This results in noise immission levels that are more constant than what is measured.
- If directivity of the sound emission is taken into account as suggested by the harmonised noise emission model for single vehicles, the instantaneous direction of a vehicle has to be known. Micro-simulation models make this information available but when vehicles change lanes, the angle with respect to the axes of the road is often unrealistic.

5.5.2 Fundamental restrictions on applicability

In task 2.1, the required accuracy of the traffic characteristics to achieve the tolerance of 1 dB on the calculated noise emission of the traffic stream, has been derived (as mentioned in 5.2.2).
Table 17 gives an indication of the ability of dynamic assignment models to meet the accuracy criteria.
These judgements concern the possibilities of delivering data for one hour. As discussed in 5.1, the averaging over day and year is a critical transport demand issue for all traffic models.

Table 17 Indication of the ability of microsimulation models to meet accuracy criteria

25% for vehicle intensity	+[1]
5% in share of heavy motor vehicles	+[1]
10km/h in average vehicle speed	++
0.3m/s² in acceleration for accelerating, 0.8m/s² for decelerating	+[2]

++ very well possible, + likely to be achieved, - unlikely to be achieved, -- impossible

[1] provided the traffic demand matrix is known with sufficient detail

[2] has to be investigated further

The table below gives for some situations where traffic models could be applied, the requirements (from task 2.1) and the applicability of micro-simulation models.

Table 18 Indication of ability of microsimulation models to provide the input needed in different traffic situations

highway	intensity & average speed	+
urban traffic	distribution of acceleration	+
intersections, traffic flow management	acceleration, individual vehicle data	++

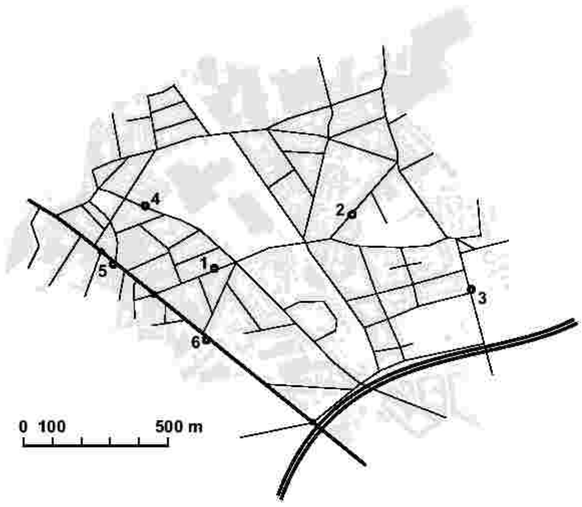
++ definitely applicable, + probably applicable, - probably not applicable, -- impossible

To obtain good correlations with noise measurements, optimising the model on traffic counts is often necessary.

5.5.3 Example

A micro model was constructed for an urban area (part of the city of Gent, Belgium). The model was fine-tuned on the basis of traffic counts at various typical hours. Additional demand was generated inside the area of study to account for local traffic.
Emission values are function of vehicle type (cars, dual-axle heavy vehicles and multi-axle heavy vehicles) and speed. Each vehicle has a single, directional source spectrum.

For vehicles within 150m from the observation point the actual instantaneous location of each individual vehicle is taken into account (approach 2 mentioned above). For vehicles further away, the emission is aggregated in a limited number of fixed sources corresponding to road segments.
The propagation is calculated in accordance with ISO 9613-2 [15]. Diffraction around vertical boundaries is taken from NORD 2000 model since this part of ISO 9613-2 is not accurate enough.
At the locations shown in the map below, 15 minute sound measurements are compared to simulated results. The statistical distribution of sound levels at 6 measurement locations is given in the charts. More information can be found in [14].



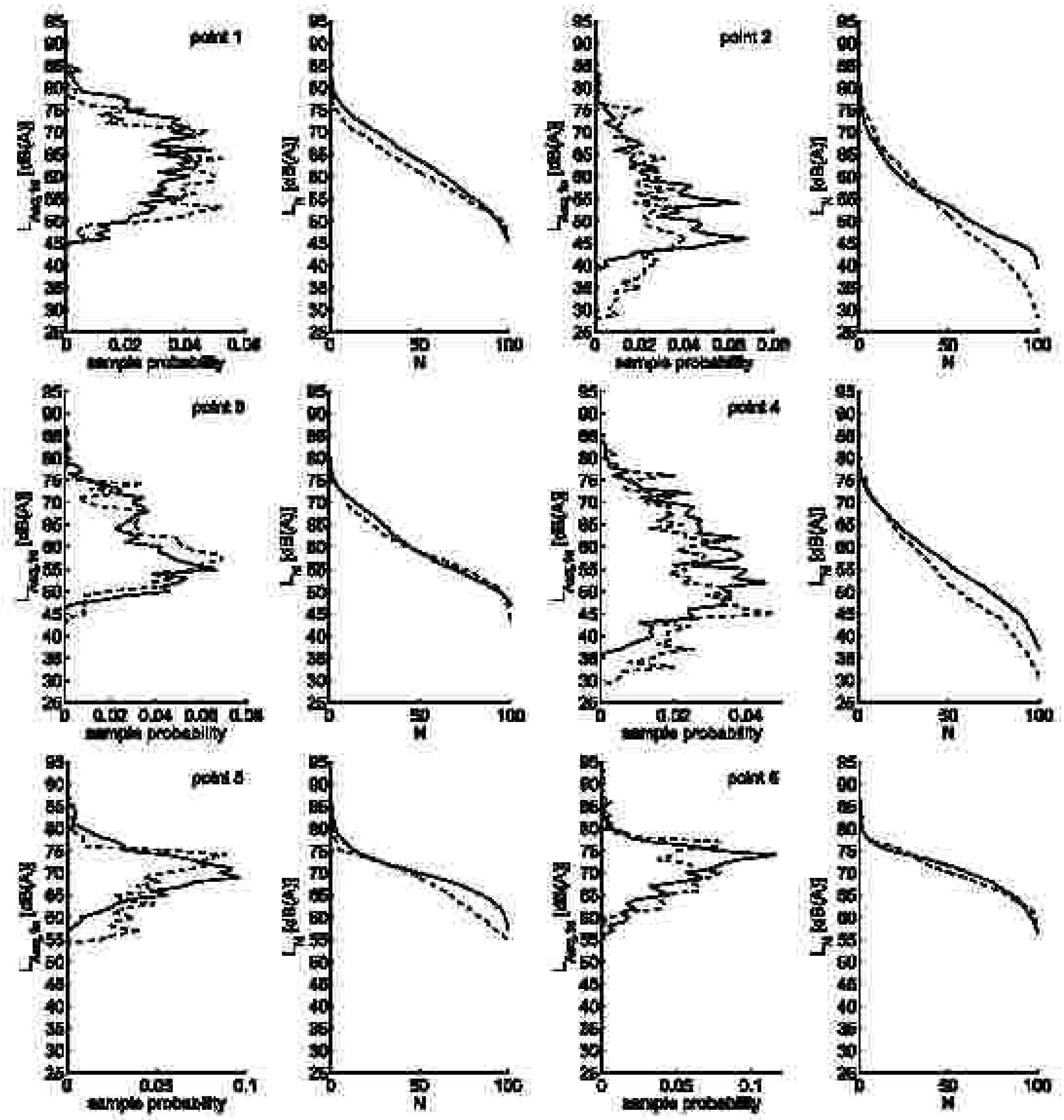


Figure 14 Statistical distribution of 1-second noise levels: measured (full) and simulated (dashed) based on micro-traffic-model

5.6 Discussion

The discussion sections of the previous chapters resulted in an overview of the suitability of traffic models to deliver detailed output (concerning the intrinsic representation of traffic), the possibilities to model measures and the use of models in practice.

The linking of traffic and noise models is related to all these aspects. Additionally, some practical aspects of linking these models will be treated here as well as how close they come to the ideal situation where trajectories are known for all vehicles.

Linking traffic and noise models starts from what functionalities are available in current software packages. A first issue concerns the lateral spatial matching. Noise models use a GIS based representation of roads (see Imagine WP1), while traffic models use their own representation. Static assignment, dynamic assignment and continuum models abstract a road to a line. This representation does not take into account the physical width of the road and the different lanes. However, a transformation to GIS databases seems possible. Micro-simulation models have a much more detailed representation. A transformation to a GIS database is again possible, but seems not straightforward to do.
In practice, traffic models focus on the busiest roads. Lower level roads are abstracted in large scale models. Further investigation into the need for the modelling of more lower level roads (under what kind of traffic conditions does traffic on these roads result in noise levels that are too high?) and the practical consequences of doing so is desirable
Detailed models will produce large amounts of data. In practice, linking traffic and noise models will be hindered by this. Modelling noise sources within the traffic model software could be a solution.

The resolution of the traffic models is also very important. Theoretically, the individual paths of all vehicles along the network over a full year will yield perfect noise model input. However, traffic models have been developed for other reasons than noise mapping and therefore have their own internal representation of traffic. The aggregation over space and time is an intrinsic property of each model. The scale of the resolution is also an indication of the variation in traffic variables that they can handle.
Table 19 gives an overview of practical aspects and the resolution mismatches that can be encountered when linking traffic and noise models.

Table 19 Linking traffic and noise models

	Static	Dynamic	Continuum	Micro-simulation
Practical :				
Lateral spatial matching	+	+	+	+/-
Lower level roads	-	+/-	+	++
Data exchange with noise models	++	++	-	+/-[1]
Traffic model resolution				
Longitudinal spatial resolution	-	+/-	++	++
Time resolution	-	+	++	++

++ definitely feasible
+ probably feasible
- probably not feasible

1 : problem in practice : very large amount of data

6 Conclusions

The development of noise maps requires the extraction of relevant traffic information from traffic models. The intrinsic properties of traffic models and the current and future practice in traffic modelling have been reviewed in this report. It can be concluded that current traffic models, in their various forms, can be used to produce the data needed for noise modelling, but the link between traffic models and noise models is not unambiguous. There are several weak points in traffic models that need attention:

- the consequences of intrinsic model characteristics (with regard to the input data used, the modelling technique and the output produced);
- problems associated with the use of traffic models in practice;
- problems associated with interfacing between traffic and noise models;
- the quality of data for the traffic demand and assignment models, and how this relates to accuracy;
- the effort involved in building, calibrating and maintaining the model;
- the modelling of possible noise reducing measures;
- additional indicators for the assessment of quiet areas and night-time noise.

These weak points can be explained by the fact that until now, traffic models were developed to implement transportation policies. The application of these models for environmental policies is possible but usually requires adaptations to the models and/or their input. An example can illustrate the different scope: traffic models are used to study traffic flows during peak hour on the busiest roads, while noise models need, for instance, accurate speed values over the whole network for the night period. Furthermore, there is no directive that obliges member states to develop and maintain detailed traffic models. So; there is no guarantee that suitable traffic models exist in every region or agglomeration that is obliged to produce a noise map.

Improving current traffic models to fulfil the input needs of noise models will require some effort. This conclusion recapitulates the output that can be produced by traffic models and discusses its accuracy. Subsequently the shortcomings in linking traffic and noise models are discussed. At the end, a set of recommendations for future tasks within Work package 2 of IMAGINE are formulated.

6.1 Suitability of traffic models

Within the framework of IMAGINE Work Package 2, traffic models were categorized into four main types: static assignment, dynamic assignment, continuum and micro-simulation traffic models. These models use the output of demand models. Based on the review of data needs for road noise source modelling within task 2.1 of IMAGINE, we assessed the suitability of the different types of traffic models to deliver reliable output. The main conclusions are discussed below.

6.1.1 Intrinsic traffic model characteristics

Model resolution

The representation of traffic depends on the model type used. Ideally, traffic along a road is described using the paths the individual vehicles drive over time. The best approximation of this representation is achieved by micro-simulation models. Other models use average values of traffic characteristics. The time and space resolution of a model determines its level of detail and also determines which traffic variables are available.

Model variables

Average volume and speed are basic variables in all models. Static and dynamic models are usually calibrated on flows, so the data they produce on flows is generally good. However, the volumes on the network level will not necessarily be accurate in continuum and micro-simulation models. The latter can have a route choice model that leads to network volumes.
Regarding speeds: static models use travel times to quantify the user cost. Speed values are derived from travel times. They are therefore not necessarily accurate.
Acceleration and speed distribution are not always modelled. Dynamic models produce more detailed speed and acceleration values, but again, there is no guarantee of their accuracy.
Vehicle class information (most importantly the share of heavy vehicles) is available in some models. The accuracy of this information depends strongly on the quality of the traffic demand model. Some models can incorporate different traffic behaviour for the various vehicle classes; this is most common in micro-simulation models.

Table 20 summarises the intrinsic properties of the different traffic models.

Table 20 Intrinsic properties of the traffic models

	Static	Dynamic	Continuum	Micro-simulation
Traffic model resolution				
Longitudinal spatial resolution	-	+/-	++	++
Time resolution	-	+	++	++
Traffic model variables				
Traffic volumes	+	++	-	+/-
Speeds	+	+	++	++
Speed distributions	-	+	+	++
Acceleration	-	-	+	++
Traffic composition influence	+/-	+/-	+/-	+

++ available and reliable
+ available; possibly not reliable
- not available

6.1.2 Traffic demand and traffic models in practice

Traffic (demand) models traditionally focus on capacity analysis. Using traffic models in environmental impact analysis can lead to some problems and mismatches. These relate to:

- the area that is the subject of the noise map;
- the time periods that must be assessed for noise maps.

Also, it may be that in some cases, a region or agglomeration may not have any traffic model at all. Recommendations for these cases must also be provided.

Area modelled
The geographical area studied is linked to a specific type of traffic model. Static models are used more for large areas, while micro-simulation models traditionally focus on smaller urban networks.

Time period studied
The different traffic models, and the demand models feeding them, are usually limited to peak hours. A shift towards day models can be expected, especially for models of congested areas (in order to model peak spreading correctly). The expansion of hourly/daily data to yearly values is a general problem for all models.

Combination of time period and area modelled
In practice, the static model is commonly implemented in regional/national peak hour models, while micro-simulation models are used frequently for isolated local studies. We expect a growing market share for dynamic assignment models in the near future.

Table 21 summarises the application of traffic models in current practice.

Table 21 Current practice of traffic models

	Static	Dynamic	Continuum	Micro-simulation
Study area				
Regional/National	++	+	N	N
City	+	++	N	+
Local motorways	N	+	++	+
Local urban	N	0	0	++
Study period				
Peak hour	++	+	+	+
Day	+	++[1]	0	+
Year	0	0	N	N

++ available and reliable

\+ available; possibly not reliable

0 (neutral)

N not available / not common practice

1: May involve long run times

6.1.3 Linking traffic and noise models

Linking traffic and noise models requires an interface between both software tools. This includes the management of large amounts of data. Furthermore, the representation of road networks will differ. Table 22 gives an overview of some practical issues.

Lateral spatial matching
Lateral spatial matching involves the linkage of databases: the network database and the database with spatial information as needed for noise modelling. Static, dynamic and continuum models represent traffic roads as lines. A link of a database of such networks with a GIS database can be established relatively easily. For micro-simulation networks, this can prove to be

more difficult. The representation of micro-simulation networks is more detailed. Even though this is an advantage when looking for the desired level of detail for noise modelling, accuracy is not guaranteed as most networks in micro-simulation models are constructed in a GUI.

Lower level (minor) roads

In current practice, traffic models focus on large roads. Most lower level roads are not represented in the network. Often, the larger roads that are included in the model implicitly incorporate the capacity of parallel minor roads. This has a large influence on the possibility to model detailed quiet areas and local noise disturbance. In current practice, this applies particularly to static models, because they are developed for larger study areas. However, the inclusion of minor roads remains a problem in the other model types as well, unless the study area is very small (neighbourhood level).

Data exchange

Linking traffic and noise models requires the exchange of large amounts of data. The more detailed the traffic model, the larger the amount of data. The amount of data exchanged can be reduced by implementing source noise models within the traffic model software. A real-time calculation of noise levels will result in a smaller amount of data (e.g. just a noise level instead of speed, type of vehicle, acceleration). Recommendations are needed regarding the possible ways of linking common models.

Table 22 Practical issues in linking traffic and noise models

	Static	Dynamic	Continuum	Micro-simulation
Practical :				
Lateral spatial matching	+	+	+	+/-
Lower level roads	-	+/-	+	++
Data exchange with noise models	++	++	+/-[1]	+/-[1]

++ definitely feasible
+ probably feasible
- probably not feasible

1 : problem in practice : very large amount of data. This can be resolved by calculating source noise in the traffic model

6.1.4 Data quality (and accuracy)

One of the major uncertainties that comes up when linking traffic and noise models, is the expected overall accuracy. A clear definition and a methodology of how it can be estimated and measured will be developed in Work package 3 of IMAGINE. This will also lead to the clear formulation of the required accuracy of the input of noise models.

The quality of the input data for the traffic model is very important to ensure that the resulting traffic data is accurate enough for the purpose of noise modelling. This starts with the traffic demand model, which results in the table with the number of trips between all zones in the study area (the origin-destination or OD-matrix). Improvement is needed for the non-peak periods of the day, especially the evening and night period. This is predominantly a question of the effort required to expand the OD-matrix to the periods in question; the basic data is usually available.

Recommendations with regard to information about the fleet composition are also needed, as currently, few models include accurate data on heavy vehicle movements.

6.1.5 Effort involved in building, calibrating and maintaining the model

All traffic models require quite a large effort to be built, calibrated and maintained (so that information about the network and the traffic demand remains up-to-date). Static models require, relatively speaking, the least effort to build, calibrate and maintain. Micro-simulation models generally require more effort, but tools supporting the building and calibration process are improving, which will reduce the effort in the future. Table 23 summarises the efforts for the different traffic model types.

Table 23 Efforts involved in building, calibrating and maintaining the model

	Static	Dynamic	Continuum	Micro-simulation
Building the model	+	0	-	0
Calibrating the model	+	+	+	-
Maintaining the model	+	+	+	0

+ relatively small effort
0 neutral
- relatively large effort

6.1.6 Traffic flow measures

The formulation of noise action plans will require modelling of traffic flow measures. In the state of the art report, three main types of measures are considered. It should be noted that the traffic demand model used again has a large influence on the overall accuracy and the possibilities of the models. Table 24 gives an overview of the capabilities of the different traffic models.

Reducing traffic volumes
Modelling the reduction of traffic volumes needs accurate demand modelling and estimation of route choice effects. Dynamic models are best suited to do this.

Changing traffic conditions
Changing traffic conditions can be done with many different measures. In general, the more detailed the model, the better it will be at modelling the impact of traffic flow measures. Static and dynamic models can model the fewest of these measures (with dynamic models offering more and better possibilities).

Changing traffic composition
Modelling traffic composition strongly depends on the capability of the model to incorporate multiple user classes. In theory, this can be done in all model types, but it is not very common yet, except for micro-simulation models. In addition to that, there is the issue of the impact of traffic composition on speeds. This can, in theory, be incorporated in all but the static models.

Table 24 Capability of traffic models to model traffic flow measures

	Static	Dynamic	Continuum	Micro-simulation
Reducing traffic volumes	+	++	-	+/-
Changing traffic conditions	-	+/-	++	++
Changing traffic composition	+/-	+/-	+/-	+

++ available and reliable

\+ available; possibly not reliable

\- not available

6.1.7 Additional indicators for the assessment of quiet areas and night-time noise

Various working groups are discussing additional indicators, e.g. for night-time noise and for quiet areas. The END mentions these additional issues. However, they have not yet been fully elaborated in the END, which makes it difficult to asses the suitability of traffic models in that regard. For instance, it is as yet unclear whether traffic models must be capable only of evaluating quiet areas, or also of identifying quiet areas. In either case, minor roads are again an important issue.

6.2 Recommendations

The use of output from traffic models as input for traffic source noise models is not unambiguous. Difficulties can be expected on accuracy, the discrepancies in the intrinsic representation of traffic and the different scope of traffic and noise models in common practice. There is no superior type of traffic model to deliver input for traffic noise models. Depending on the study area (e.g. major roads, or agglomerations), several traffic model types are capable to deliver the required output.

As recommendations we can formulate some directions for the development of pragmatic guidelines for the link between the traffic and noise models:

- Formulation of methodologies for the (dis)aggregation of traffic variables to calculate annual noise levels.
- Preparation of a set of default values that can be used when traffic models can not deliver intrinsic information that is relevant for noise models (e.g. no speed distributions in static models). This should also comprise the possibility that no accurate traffic model is available.
- Preparation of a set of default values that can be used when traffic models cannot deliver data due to lack of this information in common practice (e.g. information on night periods).
- Preparation of some accuracy estimations and sensitivity analyses for the different traffic models that can be used, in order to formulate strategies to increase the reliability of the overall noise mapping effort.
- Elaboration of the balance between costs (of traffic model improvements) and benefits (more accuracy). This comprises the computation time, the time and cost to improve existing models (e.g. adding minor roads, estimate night period traffic), the effort to exchange data, etc..
- A discussion on which models could be useful for calculating additional indicators for night-time noise and for quiet areas.

REFERENCES

[1] Malone, K.M., M.C.J. Bliemer, C.H. Menard & H.H. Versteegt (2003), *Testing INDY for use as the Dynamic Traffic Assignment model in the Dutch National Model*, Delft, TNO Inro report 2003-30, June 2003.

[2] Friesz, T.L. & D. Bernstein (2000), *Analytical dynamic traffic assignment models*, in: Handbook of transport modelling, ed. D.A. Hensher & K.J. Button, Oxford, UK, Elsevier Science Ltd, 2000.

[3] Willumsen, Luis G. (2000), in *Handbook of Transport modelling* (Ed. D.A. Hensher & K.J. Button), Elsevier Science, Oxford UK, 2000.

[4] Algers, S., Bernauer, E., Boero, M., Breheret, L., Di Taranto, C., Dougherty M., Fox, K. and Gabard, J-F. (1997). *Review of Micro-Simulation Models.* Deliverable of the SMARTEST Project (Simulation Modelling Applied to Road Transport European Scheme Tests).

[5] Gabard, J-F. (1991). Car-following models. Article in *Concise Encyclopædia of Traffic and Transportation Systems, 1st edition*, edited by Papageorgiou, M. Pergamon Press, Oxford.

[6] *PARAMICS screenshots from the SiAS Paramics Microsimulation 2004 Demonstration Disk, courtesy of Peter Sykes, SiAS Transport Planners.*

[7] *AIMSUN screenshot from http://www.aimsun.com.*

[8] VISSIM screenshot from http://www.ptv.de.

[9] DRACULA screenshots courtesy of Dr. Ronghui Lui, Institute for Transport Studies, University of Leeds.

[10]Lighthill M.J. and Whitham G.B. (1955) *On kinematic waves. II A theory of traffic flow on long crowded roads*. Proc. Roy. Soc., A. 229, 281-345.

[11]Prigogine I. and Herman R. (1971) *Kinetic theory of vehicular traffic*. American Elsevier Publishing Company, New York.

[12]Logghe S. (2003) *Modelling heterogeneous vehicular traffic*. PhD. thesis KULeuven.

[13]IMAGINE – State of the Art, Deliverable 2 of the IMAGINE project, reference file IMA10TR-040423-AEATNL32

[14] Bert De Coensel, Tom De Muer, Isaak Yperman and Dick Botteldooren *The influence of traffic flow dynamics on urban soundscapes*, Applied Acoustics, In Press, Available online 15 September 2004

[15] ISO 9613-2. Acoustics – attenuation of sound during propagation outdoors – part 2: A general method of calculation. Genève, Switzerland; 1996

[16] Ortuzar, J. de D. en Willumsen, L.G. (1995) *Modelling Transport*. Second Edition, Wiley

[17] Ben Akiva, M.E. en Lerman, S.R. (1985) *Discrete Choice Analysis: Theory and Application to Travel Demand.* The MIT Press, Cambridge Mass.

[18] McFadden, D. (1974) *Conditional logit analysis of qualitative choice behavior* in Zarembka, P. (ed.) Frontiers in Econometrics, Academic Press, New York, 105-142.

[19] Sheffi, Y. (1985) *Urban Transportation Networks*. Prentice-Hall, Englewood Cliffs, N.J.

[20] McNally, M. (2000) *The activity-based approach*, in Hensher, D.A .and Button, K.J. (eds) Handbook of Transport Modelling, Elsevier Science Ltd, 53-69.

[21] IMAGINE – Internal Report WP2.1: Review of data needs for road noise source modelling, 15 june 2004, reference file IMA2TR-040615-M+P10

ANNEX A TRAFFIC AND NOISE MODEL EXPERIENCES

Introduction

The relationship between traffic and noise models is investigated in detail within WP2 of Imagine. To have an overview of experiences within the consortium, we asked the consortium members to fill in a document about experiences with linking traffic and noise models in earlier projects. In this annex, the different responses are bundled. This has permitted all partners to exchange ideas and experiences and has helped in the development of this report.

A.1 ULeeds – Platform Grant

Project identity

Platform Grant, funded by the UK – Engineering and Physical Sciences Research Council (EPSRC)
Institute for Transport Studies : University of Leeds

The Platform Grant has as its core objective, 'to carry out fundamental research into individual vehicle traffic characteristics measured simultaneously with the pollutant dispersal and microclimate to gain an increased understanding of the complexities of transport of pollution in the built environment'.

One element of the overall Platform Grant is the development of a combined traffic micro-simulation and roadside noise model, based on development of ITS' DRACULA (Dynamic Route Assignment Combining User Learning and microsimulAtion) model[1] and previous experience with the TUNE (Traffic – Urban Noise Evaluator) model, developed at ITS as part of a Ph.D. student project[2].

Traffic model

Both DRACULA and TUNE are traffic microsimulation models. DRACULA is the more advanced of the two, capable of handling large areas of a city (e.g. the entire York major road network has been modelled) or individual junctions. TUNE is capable of modelling up to 100 links and up to 10 junctions – though, to date, has only been used to model a region spanning three junctions.

Typically either model may be run over a set period (e.g. 1-hour simulation period plus ½ hour warm-up and cool-down periods prior to and after the useful simulation time) or over a longer period (typically less than 1-day duration).

As with any microsimulation model both DRACULA and TUNE require large amounts of input data, including:

- Network parameters: link and lane locations and dimensions, appropriate junction types and road markings/allowed turns, saturation flows, posted speed limits, desired link cruise speeds or free-flow link journey times, gap acceptance parameters, circulation parameters for roundabouts (DRACULA). Dracula also accepts networks in the same format as the SATURN (Simulation and Assignment of Traffic to Urban Road Networks) assignment model.
- Traffic signal parameters: Allowed turns and controlled traffic streams, stage lengths, stage sequences, intergreen period lengths.
- Vehicle parameters: vehicle classes, vehicle lengths by class, allowed speeds by class, desired accelerations and decelerations by class, emergency deceleration values, courtesy factors, used in gap-acceptance (DRACULA) brake reaction times, (TUNE), start up delay times by class (TUNE).
- Flow parameters: O-D matrix for desired period (DRACULA), time-varying actual link flows (TUNE), SCOOT Dynamic Traffic Control System derived link flows (TUNE),

headway model to be used (e,g, uniform, shifted-negative exponential, normal, log-normal, composite headway distributions (TUNE)).

- Public service vehicle parameters: Bus timetables and routes (DRACULA).
- Virtual detector system data (DRACULA).

As with most micro-simulation models, output from either TUNE or DRACULA may range from microscopic (individual vehicle trajectories or generation parameters) to macroscopic (bulk flow, speed, density or queuing parameters over the entire simulation period). As either model is stochastically based, the model should be run a number of times to give a range of output values and highlight any stability issues within the traffic simulations.

Noise model

The original TUNE micro-simulation model includes an integrated Source Noise Emissions Model (SNEM) and a broadband ray-tracing propagation model. The developments to DRACULA currently include only a source noise emissions model.

The SNEM in TUNE/DRACULA use the instantaneous values of speed, acceleration for a given vehicle in a particular time step to calculate the sound pressure level at a reference distance from the vehicle. The various formats of emissions model currently available within TUNE are summarised below (extract from unpublished paper):

1. Relationships between source noise emissions and vehicle speed in the following format:

   $$L_V = k_1 \qquad \text{for } v < v_t \qquad [1]$$

   $$L_V = k_1 + k_2 \log_{10} v \qquad \text{for } v \geq v_t \qquad [2]$$

   where k_1 and k_2 are constants dependant on vehicle classification. Here a vehicle's source noise level is assumed to be constant under a certain threshold speed, v_t. Above this threshold speed, the noise level is assumed to increase as a function of the logarithm of vehicle speed. The validation exercises for TUNE included two variants of this format. The first variant provides values of k_1 and k_2 for a total of five vehicle classifications with threshold speeds also dependant on vehicle classifications, the second provides parameters for two vehicle classifications (light and heavy vehicles).

2. The model presented by Jones and Hothersall in 1980[3], based on regression analysis of 1045 roadside pass-by noise measurements, yielded a source noise relationship in terms of speed and acceleration in the following form:

   $$L_V = k_1 + k_2 \log_{10} v + k_3 a + k_4 a \log_{10} v - k_5 a^2 \qquad [3]$$

   where k_1 to k_5 are constants dependant on vehicle classification (light or heavy vehicles).

3. The relationship presented by Jacobs *et al*. in 1980[4] that uses Equation 2 as a base, but varies the parameters k_1 and k_2 depending on an assumption of gear selection for the vehicle. During acceleration from rest, a vehicle makes four gear changes at set speeds, before its cruise speed is reached. When decelerating the vehicle is assumed to remain in fourth gear until stationary. The maximum noise emitted by a vehicle cruising at 60 km/h is assumed to be 5.5 dB(A) lower than that of the same vehicle accelerating in first gear.

4. The approach presented by Favre in 1979[5], suggested an algorithm for light vehicles of a similar form to Equation 3:

$$L_V = k_1 + k_2 \log_{10} v + k_3 a + k_4 a \log_{10} v \quad [4]$$

However, the approach in 4 differs from that in 2 by allowing k_1 to k_4 to vary based on assumed gear selection.

5. The US Community Noise Model relationships, presented by Wayson and MacDonald in 1995[6] that use separate noise level with speed functions based on vehicle operating mode (cruising and accelerating or decelerating):

$$L_V = 10\log_{10}\left[(0.6124v)^{k1}10^{k2} + 10^{k3}\right] \text{ for cruising and accelerating vehicles [5]}$$

$$L_V = k_1 v + k_2 \text{ for decelerating vehicles} \quad [6]$$

Equation 5 is derived from the FHWA REMEL curves used in the new US standard noise prediction model TNM (Traffic Noise Model). Note that the cruising (and accelerating) model relationship is functionally little different to using a threshold speed and a combination of Equations 1 and 2.

For all emissions algorithms, a floor value may be provided as an absolute minimum value based on vehicle category. Additionally a standard deviation of emissions level may be provided based on the vehicle class.

The propagation model is a simple ray tracer that uses a distance function based on the inverse-square relationship for energy transfer. The ray tracer allows for 1st and 2nd order reflections, diffraction around adjacent objects (both vertical and horizontal propagation paths over or around the object) and propagation over soft ground areas (alpha factor method). Final output is in terms of L_{Aeq}, $L_{N\%}$ and maximum/minimum parameters for either the simulation period or fraction thereof. The propagation model requires extra input in terms of the specific locations of buildings and soft ground areas, as well as their acoustic properties (e.g. coefficient of absorption for buildings, alpha factors for soft-ground areas etc) and background (i.e. non-traffic) noise level (mean background and standard deviation of background level in dB(A)).

Test

No validation work has been done on the DRACULA noise emissions model so far – though extensive work has been done in a number of other projects on the validation of the traffic micro-simulation elements.

The TUNE model has had some limited validation based on either:

- Collection of traffic and noise parameters for freely flowing links (15 observations), using observed traffic parameters (flow, speeds, %HGV) as direct input into the micro-simulation model. Regression analysis of modelled $L_{Aeq,1\text{-}hour}$ levels with observed values gave R^2 values in the range 0.78 – 0.86, with standard errors of the estimate (SEoE) of approx 1.4 dB(A).
- As above, but at sites with traffic signal controls and interrupted flows (44 observations), giving R^2 values in the range 0.17 – 0.67, with SEoE of 0.96 – 2.43 dB(A). Results were variable depending on:
    - o The threshold values at which a vehicle is assumed to be accelerating or decelerating (determining the choice of emissions equation used for source algorithms 4 and 5 above).

  - The threshold values used to determine the selection of gear for the vehicle in source models 3 and 4 – especially important during deceleration and low speed <10 km/h manoeuvres.
  - Categorisation of vehicles used (e.g. inclusion of buses or vans into the light or heavy vehicle categories for those source noise algorithms only supporting two vehicle categories).
  - Assumptions about the background level for those sites heavily influenced by the effects of signals (highly platooned traffic).
- Final validation was carried out by comparing by short term roadside predictions (5 min level) over a two-day period at four roadside locations along a single radial link in Leicester, using data from a cordon of inductive loop detectors in the surrounding area. From analysis of modelled traffic data (flows, speeds and queue lengths) with manual journey time surveys and video data, the use of individual vehicle detector data as direct input to the model was found to significantly improve queue length estimation over simply specifying a desired headway distribution. Generally modelled $L_{Aeq,\ 5\text{-}min}$ levels were only weakly correlated with observed values (R^2 in the range 0.01 – 0.55 depending on source algorithm and measurement location), but standard errors of the estimate still fell within the range 0.56 – 1.50 dB(A).
- A large number of sensitivity tests have been conducted with the TUNE model – with exact results varying depending on the particular emissions algorithm used and the number of model runs used to calculate mean emission values.

Experiences

Combining two computationally intensive processes (micro-simulation and ray-tracing) in a single package at the most fundamental level (individual time-steps) substantially limits the scope of the area (i.e. number of receiver locations) that may be studied in a reasonable time frame. The alternate method of post-processing vehicle trajectories to gain noise emission levels results in the need to process large data files (of the order of 100+ MB for each hour simulated). Neither approach is really practical for large-scale, long-term noise mapping.

Using aggregate data from a micro-simulation model, run a number of times to give estimates of the variance of parameters would be a far better approach for large-scale mapping. However, the exact nature of the aggregation required needs to be clearly specified before running the model (e.g. DRACULA can provide speed values based on temporal aggregation using individual vehicle passing a single detector location (spot speed) or by spatial aggregation using journey times along a number of links (space mean speed) for vehicles within the simulation period.

References

[1] Liu, R. (1994). *DRACULA Microscopic Traffic Simulation*, ITS Working Paper 431, Institute for Transport Studies, The University of Leeds.
[2] Goodman, P.S. (2001). *The Prediction of Road Traffic Noise In Urban Areas.* Ph.D Thesis, Institute for Transport Studies, The University of Leeds.

[3] Jones, R.R.K & Hothersall, D.C. (1980). Effect of operating parameters on noise emission from individual road vehicles. *Applied Acoustics* **13**, pp. 121-136.
[4] Jacobs, L.J.M., Nijs, L & Van Willigenburg, J.J. (1980). A computer model to predict traffic noise in urban situations under free flow and traffic light conditions. *Journal of Sound and Vibration* **72**(4), pp. 523-537.
[5] Favre, B. (1978). Noise at the approach to traffic lights: Result of a simulation programme. *Journal of Sound and Vibration* **58**(4), 563-578.
[6] Wayson, R.L., MacDonald, J.M., Eaglin, R.D & Wendling, B. (1995). Simulation approach to transport noise modelling*. Transportation Research Record* **1601**, pp. 64-70.

A.2 ULeeds - HEAVEN

Project identity

HEAVEN (Healthier Environment through the Abatement of Vehicle Emissions and Noise) (Institute for Transport Studies, University of Leeds; Leicester City Council)

The global aim of the HEAVEN project was to develop and demonstrate concepts or tools that would allow cities to estimate emissions from traffic in near real-time. This would enhance the identification and evaluation of best strategies for transport demand management.

The key objective of HEAVEN was the development of a **D**ecision **S**upport **S**ystem (DSS) that will provide an operator with integrated, near real-time information on both noise and air pollution, as well as a comprehensive overview of the current traffic situation.

ITS' contribution to the HEAVEN project was in the form of the development of a new noise modelling system for Leicester City Council, as part of the council's AIRVIRO air quality management system, supplied by the Swedish Meteorological and Hydrological Institute (SMHI). The new AIRVIRO[1] noise model provides the Leicester HEAVEN DSS with hourly updates on roadside L_{Aeq} levels, based on traffic data from Leicester's SCOOT system.

Traffic model

The HEAVEN project built on existing infrastructure at Leicester City Council Area Traffic Control (LCC ATC). This infrastructure includes:

- Static traffic data (overall flow volume and mean flow speed) for a number of time periods (AM peak hour/PM peak hour/Off peak hour and Annual Average Daily Total (AADT)) derived from the use of the TRIPS (CitiLabs) model across the whole Leicester area.
- Dynamic traffic data collected directly from Leicester's SCOOT (Split, Cycle, Offset Optimisation Technique) system. SCOOT data is available for several hundred links, distributed in regions across the city, usually in congested areas (e.g. the inner ring-road and radials). Dynamic data includes 5-min traffic flow volume and delay – these values are integrated and averaged to give hourly flow volumes and mean speed along given links.
- Within Leicester's AIRVIRO AQMS (Air-Quality Management System) individual links have been classified by ATC operators, with each classification having a set vehicle mix (Petrol Car, Diesel Car, Petrol LGV, Diesel LGV, HGV, Bus, MC) and associated hourly flow profile by day category (weekday, Friday, Saturday, Sunday). The static TRIPS flow data is scaled by the appropriate day, hour and type factors to give an hourly value for a given link and day. The static data is then used as a template and merged with the dynamic SCOOT data where appropriate. The final dynamic pattern of traffic is saved as a specific Emissions DataBase (EDB) within the AIRVIRO system and typically used with dynamic meteorological data to predict and forecast urban air-quality over Leicester and the surrounding area.

Noise model

The HEAVEN project developed two link-based Source Noise Emission Models (SNEM's) directly within the AIRVIRO AQMS, one derived from the UK "Calculation of Road Traffic Noise (CoRTN)[4]" procedure and another derived from the French "la Nouvelle Méthode de Prévision du Bruit (NMPB)[5]" procedure. Both source models were coded in tabular form, to allow processing in the same manner as AIRVIRO's exiting methodology for air-pollutants. Note that the two procedures give differing outputs – the procedure derived from CoRTN produces hourly L_{A10} or L_{Aeq} levels at a given reference distance from the roadside edge (i.e. sound pressure), whilst the NMPB procedure provides source energy (i.e. sound power) values along the length of the link.

Propagation modeling is handled by a separate package, developed at ITS Leeds, AVTUNE SPM (Sound Propagation Model) which takes the hourly output from the SNEM's as input in the form of plain text files. The SPM then uses either an abridged version of the CoRTN propagation procedure, or an inverse-acoustic ray-tracer based on the ISO 9613-2 procedure to calculate hourly levels at an individual receptor point, along a receptor transect or across a grid of receptor points.

Whilst the emissions model was developed to handle the entire Leicester area (approx 17km x 17km) using real-time dynamic data, the use of a ray-tracing model excludes such large areas. Depending on the configuration of rays (length of rays, number of allowed intersections/reflections) areas of approximately to 1km x 1km may be analysed. The two HEAVEN study areas ranged in size from 0.5km x 0.7km to 4km x 0.6km.

Test

Within HEAVEN the noise modelling procedure was subject to both a verification testing phase and a demonstration testing phase.

- The verification phase consisted of a comparison between model predictions using the CoRTN procedure and daytime measurements of $L_{Aeq,\ 1\text{-hour}}$ at 16 façade locations adjacent to the roadside. The HEAVEN validation plan specified that a simple linear regression analysis would be used to determine the accuracy of the model and define "success" in terms of the project's goals. The results of the CoRTN procedure using combined TRIPS[2]/SCOOT[3]/AIRVIRO traffic data showed an R^2 (correlation coeff.) value of 0.85, with 94% of modeled values being within +/- 2dB(A) of the measured values.
- The demonstration phase repeated the analysis of the verification phase in a different area of the city. During the demonstration phase a further 32 $L_{Aeq,\ 30\text{-min}}$ façade measurements were taken and compared to modeled values. The results showed an R^2 value of 0.93, with 87.5% of modeled values being within +/- 2dB(A) of the measured values.
- The demonstration phase also included comparisons between CoRTN modeled data and two twelve-hour measurements in order to assess performance of the procedure in the day, evening and night periods. Generally, at the two sites adjacent to a busy main radial, the procedure over-predicted noise levels during the day and evening by 0.9 – 1.8 dB(A), but under-predicted at night by -1.8 - -2.3 dB(A). Considerable problems were encountered with accuracy of speed data using SCOOT delay over the night period – the effects of the small number of vehicles and assumptions about modelled speed drastically altering overnight L_{Aeq} predictions.

During both the verification and demonstration phases concurrent classified traffic counts were taken alongside the noise measurements – generally the manual counts and SCOOT data correlated very well (R^2 > 0.9). However, these analyses are a comparison between two observation types (observer vs. SCOOT loop detector) – not between modeled traffic data and other observations. No analysis was conducted of observation against the underlying TRIPS static data.

The HEAVEN Demonstration phase also included sensitivity testing based on a number of scenarios. These scenarios included:

- A “do-nothing”, base-case scenario.
- A ban on all HGVs within the study area – modelled both with and without reassignment of traffic.
- A 20% reduction in speeds within the study area – modelled both with and without reassignment of traffic.
- The implementation of a Park-and-Ride scheme within the study area.

The sensitivity analysis showed:

- Night time $L_{Aeq,\ 1\text{-hour}}$ levels were modeled as 10-15 dB(A) below daytime values.
- Removal of HGVs gave the most benefit, reducing daytime roadside $L_{Aeq,\ 1\text{-hour}}$ levels by up 2.7dB(A) and nighttime levels by up to 3.1 dB(A).
- Speed reduction (20%) was less effective, with reductions of the order of 0.4dB(A) during the day on major links. When re-assignment was taken into account, predicted levels increased around some junctions by up to 1.0dB(A) on secondary roads due to increased flows and lowered speeds (CoRTN increases noise emission levels at speeds <20 km/h).
- Introduction of the park and ride scheme did little for noise levels during the day (0.2 dB(A) decrease on average) or at evening/night (04 dB(A) decrease).

For more information on HEAVEN verification and demonstration see:

Verification results:
http://heaven.rec.org/Deliverables/WP7%20Verification/HEAVEN%20-%20D7.1%20-%20ANNEX2%20-%20LEICESTER%20RESULTS.pdf

Demonstration results and sensitivity analysis:
http://heaven.rec.org/Deliverables/WP8%20Demonstration/HEAVEN%20-%20%20D8.11%20-%20Demonstrator%20Leicester.pdf

Experiences

A number of problems arose during the HEAVEN project, most arising from the integration of diverse models and modelling technologies. These included:

- Formatting of input and output from the various models. AIRVIRO uses a number scripts to process input data from SCOOT and TRIPS as plain text input into its own internal format. Further scripts/executables are needed to extract data from AIRVIRO EDBs for input into the SPM.
- AIRVIRO and TRIPS are “strategic” models, whilst SCOOT is a dynamic “tactical” system, therefore the AIRVIRO, TRIPS and SCOOT representations of the Leicester road network differ considerably, requiring the use of “link-equivalency” to provide the mapping between TRIPS and SCOOT link data. Whilst these can be produced quickly, they are time-consuming to check manually and need to be updated regularly.
- There is a discrepancy between the geographic locations of TRIPS/AIRVIRO strategic links and the exact positions of links required for the SPM. This requires further link-equivalencing to ensure that the correct emissions data is transferred to the correct link segment in the propagation module.
- Coverage between TRIPS scoot data and SCOOT dynamic data is largely different. Therefore static trips values coupled with AIRVIRO link information are adopted across the majority of the network. Unfortunately, the current AIRVIRO system only uses a

single speed value for individual links throughout the day and is in the process of being developed to incorporate time-series speed data.

- AIRVIRO's use of tabulated data for emissions calculation leads to a certain loss of resolution in the input of data (e.g. tables have been set up in AIRVIRO for 0%, 1%, 2%, 3% HGVs etc., therefore a value of 1.7% HGVs cannot be entered without revising the input tables).
- Differences between the vehicle classifications in the air-quality model and the noise emissions models lead to the need to convert vehicle categories for input to the emissions models (e.g. petrol-car + diesel car = CAR, petrol LGV + diesel LGV = LGV etc.)
- There may be considerable differences between the assigned vehicle fleet-mix assigned to a link classification in AIRVIRO and the actual fleet mix on-street.
- There may be considerable differences between dynamic SCOOT flows and static TRIPS flows.
- Differences in the output two emissions prediction procedures (CoRTN and NMPB) require separate handling in the propagation model.
- The CoRTN procedure + use of SCOOT data lead to unreliable assessments of noise levels at night, given the SCOOT kernal's assumptions about traffic flows and delay in quiet period and CoRTN's procedure for low-traffic flows. Depending on the assumptions allowed, the final prediction of $L_{Aeq,\ 1\text{-hour}}$ may vary by up to 4.5 dB(A).
- The CoRTN procedure produces L_{A10} predictions, and therefore requires a conversion procedure in order to produce L_{Aeq} values.

References

[1] SMHI. (2002). *Airviro user documentation,* Airviro User's Guide Version 2.40.00. SMHI (Swedish Meteorological and Hydrological Institute), Norrköping, Sweden. See http://airviro.smhi.se.

[2] Citilabs Europe (2001). *TRIPS (TRansport Improvement Planning System).* Citilabs Europe. Wokingham, Surrey, UK. See http://www.citilabs.com.

[3] Hunt, P.B., Robertson, D.I., Bretheron, R.D & Winton, R.I. (1981) *SCOOT – A traffic responsive method of co-ordinating signals*. TRRL Laboratory Report 1014, Transport and Road Research Laboratory, Crowthorne, Berkshire. See http://www.scoot-utc.com.

[4] DoT (Department of Transport) (1988). *Calculation of Road Traffic Noise*. Department of Transport – Welsh Office. HMSO, London, UK.

[5] SETRA (1996) *Nouvelle Méthode de Prevision du Bruit (NMPB)* - Routes-96 (SETRA-CERTU-LCPC-CSTB) The French national computation method

A.3 UGent - Mobilee

Project identity

Imagine partner name:	UGent
Project name and fund:	Mobilee, founded by the Belgian Federal Office for Scientific, Technical and Cultural Affairs (DWTC), under the PODOII program
Partners:	Vito, Flemish Institute for Technological Research Langzaam Verkeer, Centre for Mobility Management Traffic Planning and Highway Engineering group, KULeuven
Date:	2002 - 2005

Description

The Mobilee project aims to develop an instrument for local governments to assess the impact of mobility management strategies on traffic flow quality (accessability, accidents…) and more general on the quality of life and environment (air quality, noise…). An integrated model of different indicators would make it possible to compare different strategies, based on sustainability, and to choose an optimal scenario.

This model was and is tested, validated and demonstrated on a case study; a traffic model of a part of Gentbrugge, Belgium, was constructed. Our research group has the noise part responsibility. This consists of coupling the traffic model data to a noise emission model and a propagation model, to make simulations of some typical traffic environment topologies, and finally to derive engineering rules for the prediction of different traffic noise indicators. The acoustical simulation of parts of the case study area resulted in a joint publication [1].

Traffic model

Quadstone Paramics [2] was used as the traffic model. This commercially available microsimulation model allows users to write plugins, consisting of a dynamic link library (dll, usually programmed in C or C++), which bundles a set of callbacks, each called at defined points in the simulation. This makes it relatively easy to integrate other models into the simulation core.

The study area consisted of a part of Gentbrugge, a suburban area near Ghent in Belgium. The area contains local streets with low and medium amounts of traffic, a district road connecting the city of Ghent with other suburban areas, and a part of the E17 highway highway located on a viaduct. A micromodel of the study area was created, which contained about 180 nodes and 450 links.

Traffic data was gathered in different steps. Simulations with the Macroscopic Traffic Model of the City of Ghent gave a rough image of the origins and destinations of the vehicles on the major roads passing through the network, during the morning and evening rush-hour. For these periods the number of vehicles passing by per hour on the major roads was calculated. Subsequently, on different locations within the study area, traffic counts were done by the Roads and Traffic Administration of the Flemish Community (AWV), using loop detectors. For a period of a couple of weeks, the number of vehicles passing by per hour was counted continuously. During the same period, manual counts were also done at several points. The AWV provided us with reasonable traffic data for the E17 highway; the Flemish transport company De Lijn provided us with the timetables of busses, trams and trolleys.

The 29 different vehicle types used in the simulation were grouped into 4 categories. For each category a dynamic OD matrix was constructed by combination and interpolation of the gathered data. An iterative process was used to match the link flow intensities to traffic counts. This finally made it possible to do a 24h simulation of the full network, with a timestep of 0.5 seconds. For the results in [1], only the evening rush-hour was considered.

Noise model

Source model

A vehicle noise emission plugin was written for Paramics. At each timestep, positional data of each vehicle inside a predefined subarea of the network is gathered, together with among other things vehicle type, speed and travelling direction.

With each vehicle, one or more sources are then associated, each consisting of an ISO octave band spectrum with center frequencies from 63 Hz to 8 kHz. In a first implementation, the Nord 2000 vehicle noise emission database was used [3]. In this calculation scheme, a single directional source spectrum is associated with each vehicle. Emission values are only function of vehicle type and speed (in the form of tables), and only three emission classes are used: cars, dual-axle heavy vehicles and multi-axle heavy vehicles. The vehicle types used for traffic modelling were mapped to these 3 classes.

Subsequently, the sources associated with each vehicle are mapped to a set of emission points. Two main configurations are possible. A first possibility is to place a grid of emission points (Cartesian, along the roads…) on part of the network. During simulation, the vehicle sources are then mapped to the nearest emission point. When the distance between adjacent emission points is large, it is possible that multiple sources are mapped to the same emission point, not necessarily coming from vehicles with the same travelling direction, so directional information cannot be taken into account. A second possibility is to construct emission points on the fly for all vehicles at their exact location. This way directional info can be used. However, the positions of the emission points are changed each simulation timestep, which makes it necessary to do a propagation calculation each timestep. Often a hybrid configuration is used, where exact source locations are used nearby the observers to retain a good spatial resolution, and a grid is used for sources further away to make propagation calculations not too time-consuming.

The final product of this source model is a set of time-changing vehicle noise emissions. More particularly, at each timestep an XML (Extensible Markup Language) file is written, which consists of a list of all emission points and values in the network at that timestep. For larger networks and longer simulation durations, this can result in a large amount of data, but because of the frequent recurrence of the tags, compression tools make this manageable. An XML representation was chosen because of the existence of free, fast and extensible parsers, and the possibility to extend the data format easily with backward compatibility.

Propagation Model

Dynamic noise immission at a set of observers is calculated using a propagation model. This model is implemented as a separate program, written in C++ and Python, which has to be run after the microsimulation is complete, and takes the emission XML files as an input. This model mainly consists of 3 steps: path generation, attenuation calculation and immission calculation. A beam tracing model is used to generate paths between the emission point and the receivers, the technique used is object precise polygonal beam tracing [4]. A beam consists of a group of rays, following about the same path, and bounded by the objects (ground, walls…) in the simulation area. The most important advantages of this method in comparison with conventional ray tracing is that no receivers are missed, and that diffraction can be modelled efficiently.

The model uses a 2.5D representation of the world, which consists of a terrain model with super-positioned blocks representing the buildings. Horizontally, the beam tracing is made in 2 dimensions; multiple reflections and diffractions on boundaries are possible. Next to this, a vertical path is calculated between each source and receiver, possibly over buildings. These buildings are only considered as beams with a certain height, not as real 3D structures, therefore the fractal dimension. Terrain and building data are loaded from standard GIS maps.

The attenuation model used is based on the ISO 9613 model [5], and has been extended with diffraction along vertical boundaries according to the Nord 2000 model [6]. This model allows to take into account geometric divergence, atmospheric attenuation, ground effects and meteo effects (moderate downward refraction according to ISO 9613).

Finally the immission values at the receiver points are calculated by multiplying the emission with the attenuation coefficients. When exact source positions are used as emission points, the whole propagation calculation has to be performed at each timestep. When a fixed grid of emission points is used, the propagation calculation is done only once, and the attenuation between each emission point and receiver pair is stored. This way, it is possible to rapidly compute immissions for a series of timesteps, as noted earlier. Figure 1 gives an overview of the complete dynamic noise model.

Test

Sound measurements were done at 6 observer points in the case study area, during the evening rush-hour. Simultaneously the number of vehicles passing by was counted. Five simulation runs were made using the Paramics network to validate the traffic counts. Overall the difference between different runs was mostly small; the simulated number of vehicles differed by at most about 25% from the actual counts, which is small enough to have no significant effect on equivalent noise levels.

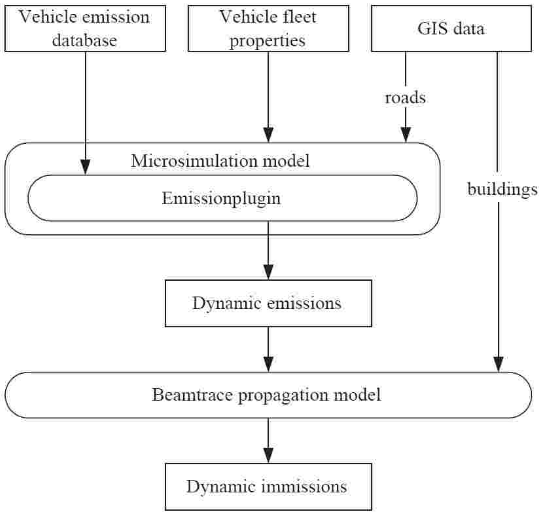


Figure 15. Methodology outline**.**

Traffic simulation, emission calculation and propagation calculation of the coded network at the evening rush hour resulted in a 15 minute time series of $L_{Aeq,1s}$ immission values at each observer point. Because of the probabilistic nature of traffic micromodelling, the simulated and recorded time series were not equal, but about the same dynamic pattern seemed to arise; the duration and magnitude of the acoustical events were also comparable.

A statistical and cumulative level distribution at the 6 observer points was also calculated, both for measurements and simulations. For the $L_{Aeq,15min}$, L_5 and L_{50} values, the deviation between simulation and measurement was on the average within 3 dB(A), the deviation in L_{95} was more striking for some points. This could be explained by the noise coming from other sources than road traffic, such as the wind, birds, pedestrians and cyclists, planes at high altitude, ventilation and cooling systems etc., which causes the level not to drop too low in reality, while it does in the simulation.

Experiences

- Acoustical properties of vehicles and road surfaces, possibly needed by the source model, are not present in the traffic model. These include among others the vehicle age, number of axles, the tyre type, the road surface type, wetness, temperature coefficient and chip size. These additional properties can be added easily through the programmers interface (API), by making use of look-up tables.
- The programmers interface (API) of Paramics is very large and allows to control and extend a large part of the simulation. However, it also contains a lot of obscurities and bugs. Some examples:
    - The function that returns the vehicle acceleration does not work, and although the Quadstone staff is aware of this, it was not solved in any of the latest updates, because it would “negatively affect other parts of the software”. This can however easily be solved by using the speed history.
    - Contrary to what is said in the manual, it is not possible to use OpenGL code in the user plugins on windows platforms, because of the use of Exceed, a unix emulator. This strongly limits the possibility to add additional graphical output.

- The micromodel tends to maximize the vehicle speeds when there are no near predecessors, giving them the maximum allowed speed for the road. When the traffic is in free flow regime, this results in all cars passing by at exact the same speed. All vehicles of the same type have then the same emission value, which can lead to peaks in the statistical immission distribution, which are not seen in reality. This can partly be solved by dividing the vehicle categories into subcategories with slightly different maximum speeds.
- Changing the simulation timestep detail can change the dynamic behaviour of a network, therefore models which have been calibrated at a certain timestep detail, can not be used at other timesteps. For traffic planning purposes, a timestep detail of 0.5 seconds is small enough – the Paramics model is only guaranteed to give realistic traffic behaviour with timesteps not smaller than 0.2 s. For precise acoustical simulations however, this is a rather low limit value. A car travelling at a speed of 90 km/h will move about 5 m each timestep.
- The construction of a road network in Paramics can be time consuming and tedious. Here are some remarks:
    - The network has to be constructed as a whole; making different parts and then adding them together is not (yet) possible in Paramics. This can be a drawback with large networks.
    - For traffic modelling, the position of the roads is most important; for propagation modelling the building positions are most important. These can be part of different GIS databases, and it is possible that roads travel “through buildings”, due to a too large spatial resolution in one of the datasets. In the construction of networks, we therefore use a separate plugin that visualizes the buildings in Paramics, to make sure this is not the case.

References

[1] The influence of traffic flow dynamics on urban soundscapes. B. De Coensel, T. De Muer, I. Yperman and D. Bottedooren. Accepted for publication in Applied Acoustics in july 2004.

[2] http://www.paramics-online.com. Paramics is being developed by Quadstone Ltd.

[3] H. G. Jonasson and S. Storeheier. Nord 2000. New Nordic prediction method for road traffic noise. Technical Report 2001:10, SP Swedish National Testing and Research Institute; 2001. http://www.delta.dk/nord2000.

[4] P. S. Heckbert and P. Hanrahan. Beam tracing polygonal objects. In Proceedings of the 11th international conference on computer graphics and interactive techniques (SIGGRAPH ’84), Minneapolis, USA; 1984.

[5] ISO 9613-2. Acoustics – attenuation of sound during propagation outdoors – part 2: A general method of calculation. Genève, Switzerland; 1996.

[6] B. Plovsing and J. Kragh. Nord 2000. Comprehensive outdoor sound propagation model. Propagation in atmosphere without significant refraction. Technical Report AV 1849/00, Danish Electronics, Light and Acoustics (DELTA); 2000.

A.4UGent - MIRA

Project identity

Imagine partner name:	Ugent
Project name and fund:	MIRA, annual report on the state of the environment, funded by the VMM (Flemish Department for the Environment)
Partners:	
Date:	Annually

Description

The MIRA report summarizes the state of the environment each year. The responsibility of INTEC lies in coordinating the effort by various partners and providing the results concerning road traffic. Selected indicators are computed each year and every five year there is a measuring campaign. Among the computed indicators are the L_{den}, L_{day} and the number of people exposed to level above 65 dB. The region of interest is Flanders covering about 15.000 km^2.

Traffic model

Emission are compute basd on about 40.000 road segments, totaling 18.000 km. Traffic counts are available at around 600 rounds, mainly large roads. The traffic is extrapolated spatially by computing a “normalized traffic pressure” at each measurement. The normalized traffic pressure is defined by the traffic intensity scaled by the mean intensity for the type of road under investigation. These normalized pressures are spatially extrapolated using a grid method. For each segment where the traffic intensity is unknown the reverse operation is carried out.

The real speed distribution is based on nationwide statistics. For each type of road available in the GIS system there is a distribution of speed limits. This distribution is then convoluted with the real speed distribution for each given speed limit.

The amount of heavy traffic is set constant and varies by class of roadtype.

Noise model

Source model

The emission is computed based on the Nord2000 database. For each road an equivalent source level is determined for the regular and heavy traffic based on intensities for each speed provided. The source level for the line source is then redistributed to point sources with a distance of 25m. The ISO standardized octave band spectrum between 63 Hz and 8 kHz is used. Direction of sound is not taken care of.

Propagation Model

The ISO9613 model is used as base for the propagation model. Due to the large area under consideration no real geometry is used. The shielding by built up regions as defined in ISO9613 is however used. The base for this attenuation is the land use map of Flanders. Ground attenuation is used with source and receiver regions set to 0.1 and the middle region to 0.9.

Receivers are positioned based on population densities. 1 million receivers are distributed over Flanders. For each square km the grid resolution is determined. About 200.000 are placed along the major roads to improve the resolution close to roads.

Test

The number of people exposed to levels higher than 65 dB is compared to the data from the measuring compaign. The results is 3% higher than the 30% measured.

Experiences

In mapping areas of the size of Flanders a lot of compromises need to be made. Computational effort and data availability are the two main concerns. For the region of Flanders there is no detailed building layer that covers the whole region. Even then the computational effort would be too large to consider reflections and/or diffractions. The current computation time amounts to about 200 hours at 2 Ghz PC's. Due to the interpolation method of the traffic, the maps of early years get updated, so the amount of computation time for one year is about 60 hours. The software has been parallellized so the effective wall time can be a lot less.

The interpolation of the traffic has been largely automated although there is still room for improvement. Each step left unautomated leaves room for human error which the process is prone to.

An other project in progress

The same noise model is used in a ongoing project to evaluate the environmental impact of the mobility plan of the city of Ghent. The city has 220.000 inhabitants and does not require a noise map and action plan according to the European Noise Directive 2002/49/EC. It is however a very good test case for calculating noise immission in a larger city.
The traffic is available for a larger set of road segments due to a traffic flow model owned by the city. It is used to assess traffic changes due to major mobility changes in the city (prohibiting parking, new roads, change in public transportation and so on). The model is only used to assess the rush hours. The traffic data is spatially more detailed but less detailed in time.
Screening of buildings is taken into account and the distribution of the population is based upon the actual buildings.

References

H. G. Jonasson and S. Storeheier. Nord 2000. New Nordic prediction method for road traffic noise. Technical Report 2001:10, SP Swedish National Testing and Research Institute; 2001. http://www.delta.dk/nord2000.

SO 9613-2. Acoustics – attenuation of sound during propagation outdoors – part 2: A general method of calculation. Genève, Switzerland; 1996.

B. Plovsing and J. Kragh. Nord 2000. Comprehensive outdoor sound propagation model. Propagation in atmosphere without significant refraction. Technical Report AV 1849/00, Danish Electronics, Light and Acoustics (DELTA); 2000.

A.5 TNO - Urbis

Project identity

Imagine partner name:	TNO
Project name and fund:	Urbis
Partners:	-
Date:	1998

Description

The Urbis model was developed by TNO with support from the LIFE-programme. The main reasons for developing the model were the increased responsibilities for local authorities regarding the environment, developments in Europe (environmental directives) and the inadequacy of information on the quality of the environment.
Urbis is a methodology for calculating spatial distributions of air pollution and noise and the associated health risks for (part of) municipalities. The methodology describes the current and possible future states by means of maps and indicators of environmental quality and risks. It also produces overviews of sources and their relative contributions [Miedema, 1999].

Traffic model

Urbis uses traffic data supplied by the local authority. The data is preferably supplied in the form of GIS maps covering all roads in the municipality, usually with a traffic volume higher than 1500 vehicles / 24h.

Noise model

Noise emissions (dB(A)) are calculated on the basis of digital road maps in which traffic volume, speed and road surface type are attributes of road segments. Lines with noise emissions are divided into segments with a maximum length of 10 m. The midpoints of each segments are treated as point sources. Further input for the noise transmission calculations are digital maps of land use from which the surface type is derived, and maps of buildings and other objects (e.g. noise screens). Meteorological, ground, object and screen attenuation, and first order reflections close to the noise source are included in the modelling of noise transmission. Noise immissions are calculated for receptor points at a height of 4 meter on a 25 x 25 meter grid, supplemented with receptors close to the noise sources and receptors at the façades of buildings with direct sight on a noise source. A 3×3 meter noise grid is derived by interpolation from the calculated noise levels at these receptors. The noise levels (L_{Aeq}) are calculated for the day, evening and night, and combined to a map of the *DENL*.

Test

Noise calculations with Urbis are compared with noise measurements and with noise calculations performed with the Netherlands standard calculation method (SRMII). Comparison shows that Urbis calculations are in most cases within 2 dB of the noise measurements and that these differences are of the same magnitude as the differences between SRMII calculations and measurements. In situations with behind noise barriers, where the noise levels are mainly caused by reflections, differences between noise measurements and both calculation methods are larger.

Experiences

In some cases, the traffic model is schematic and not geo-referenced. Using GIS (Arc/Info) the schematic network is geo-referenced by ‘rubber sheeting’ it over the ‘real’ network. Using an module of Urbis, the data (traffic volumes) from the schematic network is transferred to the ‘real’ network.

The traffic volume is in a number of cases not divided into the different vehicle types (light, middle and heavy duty traffic). If possible, the percentage of middle and heavy duty traffic is obtained from prior inventories. If not, the percentage freight traffic is estimated on the basis of road type and traffic volume. The same approach is followed for the estimation of the average day evening and night volumes.

The road surface type is important input for the noise emission calculation. This data is often not linked to the traffic model. Using overlay techniques in GIS, the type of road surface is taken over from other available data sources, e.g. from the municipal department that is responsible for road maintenance. In some cases, the data is provided in the form of an analogue map and is entered using the GUI of Arc/Info.

The speed limit is usually taken as basis for emission calculation. In some cases, the speed limits are provided in the form of an analogue map and are entered using the GUI of Arc/Info.

References

Gerretsen, E., A.R. Eisses, J.B. Fritz, H.C. Borst, “*Urbis: instrument voor Lokale MilieuVerkenningen – rekenmethoden voor geluid*” [in Dutch], TNO report 99.039, Leiden, 1999.

Miedema, H.M.E., K.D. van den Hout, J.B. Fritz & H.C. Borst (1999), *“Urbis: instrument for local environmental surveys – Executive summary”*, Leiden, TNO, October 1999.

Miedema, H.M.E., H.C. Borst, “*Urbis: an Instrument for Local Environmental Surveys*”, Proceedings of the Institute of Acoustics, Volume 23, Part 7, 2001

TNO, http://www.inro.tno.nl/urbis, 2003

A.6 TNO - Overschie

Project identity

Imagine partner name:	TNO
Project name and fund:	Quickscan optimale snelheidslimiet op Nederlandse snelwegen (Quick scan optimal speed limit on Dutch motorways), carried out for the Transport Research Centre of the Department of Transport
Partners:	TNO (WT, Inro, TPD, MEP, TM)
Date:	2004

Description

In 2002, the speed limit on the A13 motorway in Overschie was lowered to 80 km/h to improve the air quality. The new speed limit was strictly enforced using speed cameras reading the license plates (‘trajectcontrole’, meaning that the time vehicles spend on a certain stretch of road is measured and they are fined only when their average speed is above the limit). Solving air quality problems (and possibly noise problems) this way could be a very cost-efficient measure.
However, the choice for 80 km/h was rather arbitrary. The Ministry of Transport commissioned TNO to carry out the project ‘Quick scan optimal speed limit on Dutch motorways’, to investigate the optimal speed (80, 90 or 100 km/h, with or without strict enforcement), assessing not only air quality, but also noise, traffic efficiency, safety and acceptance [Riemersma, 2004].
Very little data was available to evaluate the effects of 80, 90 or 100 km/h with strict enforcement. Therefore, the effects of the measure on traffic flow were evaluated using a microscopic simulation model (MIXIC). The traffic data generated by this model was used for the subsequent analyses of air quality, noise and safety.
Time and budget for this ‘quick scan’ study were limited; this has of course influenced many of the choices for the use of data and models.

Traffic model

The traffic model used was MIXIC, a microscopic simulation model developed for the assessment of the effects of driver assistance systems. MIXIC models individual vehicle movements on a straight stretch of motorway with a variable number of lanes (but no curves or exits). MIXIC contains detailed submodels describing drivers, vehicles, assisting systems and their interfaces. The model has been filled and validated for four driver and four vehicle types (when it was built). The output of MIXIC ranges from the possibility of recording vehicle/driver combinations, to the measurement of aggregated traffic quantities and the occurrence and severity of shockwaves [Arem, 1997].
MIXIC was chosen for the simulations because it is possible to change the speed profile (speed distribution at lower speed limit and strict enforcement, resulting in smaller variance in speeds). Even though MIXIC is not capable of modelling a whole network (not feasible in this quick scan anyway), this model was judged the best for this project because it models the traffic in a very detailed and realistic way; more detailed than microscopic models such as Paramics.
The changes in speed distributions were based on the speed distributions found in Overschie after the introduction of the new speed limit and the strict enforcement. Also, speed data from other roads with and without strict enforcement were used for comparison.

Five scenarios were simulated:
1. 120 km/h without strict enforcement (‘base case for motorways’)
2. 100 km/h without strict enforcement
3. 100 km/h with strict enforcement
4. 90 km/h with strict enforcement
5. 80 km/h with strict enforcement

The runs with these scenarios resulted in the following traffic data:
- maximum flow (in a bottleneck situation)
- average speed and standard deviation
- speed distributions (based on individual vehicle data)
- number of shockwaves
- distribution of traffic over lanes

Noise model

Source model

For each scenario, the noise emissions were calculated using the statutory Dutch noise calculation scheme ‘Reken- en Meetvoorschrift Wegverkeerslawaai 2002’ [VROM, 2002]. The emissions are calculated for three vehicle categories separately and then added up energetically. Correction factors for road surface type were applied. First, emissions based on the MIXIC simulations were calculated. The simulations covered a period of 2 hours and 45 minutes, comparable to a peak period on a busy road (such as the A13 motorway running through Overschie).Then, values for day-evening-night were calculated (based on traffic data measured on the A13 for scenario “80 km/h with strict enforcement”, adapted to take into account the effects of lower speed limits and strict enforcement on the average speed). The following MIXIC output was used for the noise calculations:: average volume and speed, per vehicle category (three categories). The volume and speed were averaged in time over the whole simulation period. The average speeds were weighted by volume.

Propagation Model

For the calculation, the programme ‘Geonoise’, version 4.03, based on the ‘Reken- en Meetvoorschrift Wegverkeerslawaai 2002’ was used. The model takes into account the height of the buildings and noise abatement screens along the road.

According to the ‘Reken- en Meetvoorschrift Wegverkeerslawaai 2002’, the value of L_{etmaal} (a whole day) is defined as the highest value of:
a. de value of the equivalent sound level in the day period;
b. the equivalent sound level in the night, increased with 10 dB(A).

The value for the night is increased with 10 dB(A) because of the higher annoyance in the night period.
Because is L_{etmaal} replaced by L_{den} in July 2004, L_{den} values were also calculated.

To predict awakenings in the night period, Sound Exposure Levels (SEL: defined as the equivalent sound level normalised to 1 second) have been calculated at a number of receptor points. The use of one-minute interval data (individual vehicle data from MIXIC only being available for the ‘peak period’) results in a (unknown) underestimation of the SEL-values.

Test

The vehicle trajectories as produced by MIXIC have been compared to trajectories measured on the A13. In general, they were found to match quite well; the only differences found were in the case where a vehicle has no predecessor. MIXIC then lets the vehicle accelerate to its desired speed and keeps this speed constant, whereas in reality, there is always a small variation in speed. Other comparisons of MIXIC output data and real-world data could not be made.

Experiences

The difficulty in this project was that there is hardly any real-world traffic data on the behaviour of vehicles in the scenarios studied, because (a) the speed limits proposed can only be found on the underlying road network (where traffic behaves very different because of different geometry etc.) or on stretches of motorways with congestion or road contruction works), and (b) the strict enforcement resulted in quite unusual behaviour (drivers tend to stay well under the speed limit). The limited budget and time available meant that we could not add extra functions to MIXIC (like making it possible to model more complicated geometric situations), nor was it possible to extend the simulation period to a whole day. However, the client recognised and accepted the limitations and were satisfied with the result.

With regard to the linking of the traffic and noise model, the following specific problems were encountered:

- MIXIC only produced data for the simulation period of 2:45 hrs. Data for a whole day had to be collected for the L_{etmaal} and L_{den} calculations. Developing ‘injection files’ (used to introduce individual vehicles into the simulation) for a whole day or for new situations requires a large effort.
- The additional traffic data used to predict awakenings in the night period (data measured by induction loops) was less detailed, especially with respect to speed distributions, so peaks in noise levels were (probably) levelled out.
- The database with data on buildings and noisescreens was incompatible with the software used for the calculation of the sound levels at receptor points, which meant extra time and money had to be spent to measure the data on the location instead.
- A model like MIXIC is suited to very specfic questions regarding traffic flow characteristics only. However, it is easier to model some advanced driver assistance systems or ITS measures in MIXIC than in standard microsimulation packages. A combination of MIXIC and network based microsimulation systems can be a solution for studying the effect of some of these measures.

References

Arem, B. van, A.P. de Vos & M.J.W.A. Vanderschuren (1997), *"The microscopic traffic simulation model MIXIC 1.3"*, Delft, TNO Inro, report nr. INRO-VVG 1997-02b.

Riemersma, I.J., N.L.J. Gense, I.R. Wilmink, H.H. Versteegt, J.H. Hegema, A.R.A. van der Horst, F. de Roo, I.M. Noordhoek, S.D. Teeuwisse, Y. de Kluizenaar & W. Passchier (2004), *"Quickscan optimale snelheidslimiet op Nederlandse snelwegen"*, Delft, TNO, 12 mei 2004, TNO-rapport 04.OR.VM.016.1/IJR.

VROM, Ministerie van (2002), *"Reken- en Meetvoorschrift Wegverkeerslawaai"*, Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieu (Dutch Ministry of Housing, Spatial Planning and the Environment), 2002.

A.7 M+P – JARI model

Project identity

M+P has been involved in a joint research program in 2003/2004 with the Japanese Automobile Research Institute (JARI). The JARI has, over the last ten years, developed a traffic model to predict vehicle noise emission levels. Both the noise model and the traffic model are fairly simple, and the amount of information on validation is limited.

Traffic model

The JARI have their own microsimulation model, regarding discrete vehicles of three categories (passenger cars, light and heavy trucks). The model includes a calculation procedure for left/right turn behaviours at intersections, including the average turn duration and vehicle speed. For free-flowing traffic, a car following model by M. Bando et al. [Phys. Review, E58, 5429-5435 (1998)] is adapted, which calculated the acceleration of each vehicle by

$$\ddot{x}(t) = \alpha \left(V_{optimal} + v_{lead} - 2 \cdot v_{follow} \right),$$

where v_{lead} and v_{follow} are the vehicle speeds of the leading and following vehicle, respectively.

The model has been mainly applied to urban traffic, focusing on a single intersection or a single road including one or more intersections. Typical driving behaviour patterns have been developed using in-traffic measurements with three test vehicles (one for each category).

Noise model

The noise model distinguishes between exhaust noise and tyre/road noise:

$$\begin{aligned} L_{We} &= A_0 + A_1 S + A_2 L \\ L_{Wt} &= B_0 + B_1 \log(V) \end{aligned},$$

where V is the vehicle speed, S is the engine speed (in rev/s) and L is the engine load (or torque). A simple model related S and L to the vehicle speed by using tables with transmission ratios for each vehicle category and gear, and assumed gear positions for specific vehicle speed ranges. The noise model also includes horizontal and vertical directivities. Coefficients are based on measurements of one test vehicle per category.

Test

In their paper for Internoise 2003 in Korea, T. Suzuki, et al. [paper nr. N557] present the result of twelve L_{Aeq} measurements at one intersection, where measurements and predictions correspond within 1.5 dB(A).

ANNEX B INTERACTIVE TRAFFIC MODEL DEVELOPER WORKSHOP

Introduction

An interactive workshop with traffic model developers was organized as part of task 2.2 of Imagine. The objective of this information exchange was to have an overview of the view of these traffic model developers on:

- the **S**trengths, **W**eaknesses, **O**pportunities and **T**hreats (SWOT) of the model type under consideration: do they agree with the assessment of the consortium? The SWOT analysis prepared by the consortium for the model type discussed, served as a starting point for the discussion.
- future developments in the model: will they make the models more suitable (or less) or easier (or more difficult) to use?

It should be noted that the model developer could discuss the model type as a whole as well as specifically his own package.
The virtual workshop comprised e-mail discussions and interviews with modelling experts from across Europe. For each expert, 4 points of discussion were prepared:

Part 1: Assessment (SWOT) of model type

- Comments and additional insights regarding the SWOT-analysis (made by the consortium) of the model type considered

Part 2: Traffic model development

- *Theoretical evolutions for the specific model type*: are there any trends and future perspectives that will change the usage of this type of model (for noise mapping and noise action planning)?
    - Accuracy: what developments are expected that can result in more accurate predictions of traffic flows and speeds (& speed distributions)?
    - Ease of use & costs: will it be easier or more difficult, cheaper or more expensive to use the model in the future? Will the model therefore be more commonly used by local/national authorities?
    - Traffic flow measures: which measures can be incorporated into the model - state of practice, future expectations?
- *Model input & output, modelling technique*: questions about specific items from the SWOT (e.g. accuracy of traffic prognoses for the night period)

Part 3: Market forecast and expected future practice

- View on the kind of traffic models that will be in use in 2010
- Expected practice in 2010 within Europe by the target group: local/regional (municipalities/agglomerations) and national authorities – how many will be able to use this type of model?

Part 4: Noise related possibilities

- Experiences (if any) of the expert in linking traffic and noise models
- Filling the gap between traffic and noise models (data exchange) – what are the possibilities of adapting model input and output and modelling technique to make the model more suitable for noise mapping and noise action planning
- Expected developments regarding the availability, accuracy and cost of input data

Interviewees

The virtual workshop comprised e-mail discussions and interviews with modelling experts from across Europe. The following organisations/people were contacted:

Type of model	*Organisation/person*	*Contacted by:*	*Paragraph / page*
Static models	Omnitrans (Netherlands)	TNO Inro	B.1 / p.91
	PTV (Germany)	TNO Inro	B.2 / p.96
	ITS Leeds	ULeeds	B.3 / p.100
DTA models	Delft University of Technology / Michiel Bliemer (Netherlands)	TML	B.4 / p.106
	INRO consultants (Canada) / Michael Mahut	TML	B.5 / p.109
Continuum	Inrets / Ludovic Leclercq	TML	B.6 / p.114
	KU Leuven / Chris Tampère	TML	B.7 / p.117
Micro-simulation	PTV (Germany)	TNO Inro	B.8 / p.120
	SIAS / Peter Sykes	ULeeds	B.9 / p.124
	TSS / Jaime Barceló (AIMSUN)	TNO Inro	B.10 / p.131

B.1OmniTrans (Static Models)

Interview with **Eric Pijnappels and Joost de Bruijn** (Goudappel Coffeng)
This interview was carried out as part of the Interactive traffic model developer workshop.
Date: November 10, 2004
Location: Goudappel Coffeng, Deventer, The Netherlands.

General notes

Goudappel Coffeng is the developer of the transport planning package *Omnitrans*, which consists of several packs with different functionalities (e.g. static and dynamic traffic assignment (DTA), and user specified jobs), from model building to generating reports, including graphical output. Goudappel Coffeng also develops the environmental package *Promil spatial*, which is used in the Netherlands to produce maps of the effects of traffic on the environment ('verkeersmilieukaarten'). This package is designed to work together with Omnitrans and takes the necessary traffic flow data from Omnitrans.

Part 1: Assessment (SWOT) of model type

Strengths

Goudappel Coffeng have no specific comments on the strengths in the original SWOT

Strengths
1. Relative ease of data collection
2. Fast
3. Data collection relatively easy
4. Results easy to understand
5. 'Concise' results (not too much data)
6. Results easy to use in GIS environment
7. Transparent and comprehensible modelling technique

Weaknesses

Goudappel Coffeng have the following remarks on the weaknesses in the original SWOT:

Weaknesses
1. All results are (hour-based) averages, fluctuations and peaks cannot be distinguished
2. Inaccuracy of results (flows and speeds per link), due to:
   - use of relatively large zones and connectors from zones to network
   - use of general speed-flow diagrams (volumes can exceed capacity)
   - modelling techniques do not accurately model driver behaviour
3. Usually night periods are not or inaccurately modelled
4. Few dynamic management measures can be modelled
5. Network data (links and co-ordinates) are not always accurate

Bullet 1: all results are hour-based: this is true but at least fluctuations in route choice per period considered are incorporated. Modellers/authorities can determine the extent to which they incorporate the fluctuations over the day.
Coudappel Coffeng generally use equilibrium assignment models for peak periods because of demand exceeding capacity in those periods. In quieter periods of the day all-or-nothing assignment is sufficient. While this means that speeds are not known, this is not considered a problem by Goudappel Coffeng, as they say that in practice, speeds on links are assumed to be the speed limit on that link, in environmental models (because any other speed, e.g. speeds produced by an equilibrium model or even measurements, will lead to endless discussions in court). (Note: 30 km/h roads, where measured speed distributions often show that speeds more often than not exceed the speed limit, are exempt from noise mapping). Apart from that, models are often used to make prognoses for future situations. This brings with it more uncertainties, meaning that speed becomes an even more debatable factor.

Bullet 2: inaccuracy of results: Goudappel Coffeng recognise that speeds produced by static assignment models are generally inaccurate and should therefore not be used. This really is a weakness of static assignment models. The use of speed limits as links speed therefore seems the best solution. Another argument for using this speed is that traffic networks and the traffic on it are subject to frequent change (new housing and business developments, changes in road geometry, etc.).
Traffic flows, also described as a weakness in the original SWOT, are generally much more accurate. Goudappel Coffeng would not describe this as a weakness. Capacity restraint modelling (equilibrium assignment) and the inclusion of intersection modelling (more and more common) mean that flows can be and are modelled quite realistically. Goudappel Coffeng point out that there is a trend towards the combination of static and dynamic assignment (in which flows can no longer exceed capacity). They are therefore confident that the developments in traffic models can follow the trends in and expectations of environmental models.
Goudappel Coffeng expect that in the (near) future, the distinctions between different types of traffic models will fade and that the main difference will be whether individual vehicles (and driver behaviour) are modelled or not. They expect many existing models will be linked. Static models will probably remain important as they will usually supply the OD-matrix.

Bullet 3: flows in the night period are usually derived from traffic counts and this works fine.

Note: The requirements posed by environmental models have forced traffic departments to improve the networks used in models, in the sense that they have had to make them more detailed and accurate. Traffic departments are generally not very happy about having to spend money on this. This has mainly to do with the fact that traffic and environment are different areas of expertise in most authorities. Extra effort must therefore be put in bringing both parties together and increasing understanding between them.

According to Goudappel Coffeng, the most important weaknesses are:
- speeds (travel times) and how these are incorporated into environmental models
- the more congestion, the more difficult it is to get meaningful results out of static assignment models
- modelling truck traffic! Goudappel Coffeng do not expect much improvement in this area in the near future (next 5 years)

A large amount of the data needed can be measured in some way, but it is a question of how much added value is derived from using more detailed data (there is a point where more detail no longer results in increased accuracy).

Opportunities

Goudappel Coffeng have the following remarks on the opportunities in the original SWOT:

Opportunities
1. Model is very common in local, regional & national authorities 2. More digitised or automatically generated data will become available 3. Relative simplicity of models ensures that new developments will usually be tried out in static models first – model type will continue to be relevant to model developers

Bullet 1: Goudappel Coffeng agree wholeheartedly. In their opinion, a static model is needed as a first step in most traffic modelling exercises (to produce an OD-matrix). There have been many developments over the past years: 6-7 years ago, all-or-nothing assignment was still the norm, then equilibrium assignment became common, and now intersection modelling is included more and more often. They expect that in a few years time, (macroscopic) dynamic assignment will be included. The static model can easily be expanded to include DTA.

Bullet 2: monitoring systems will increasingly provide data that can supplement (but not substitute – noise action plans will generally need to be carried out with the help of a traffic model that 'predicts' the future) data provided by traffic models.

Threats

Threats
1. Improvement of model and input requires a large effort (data collection) and is no priority for traffic & transport departments

Goudappel Coffeng agrees with the one threat listed here. The environmental department wants very detailed traffic data, and the traffic department cannot provide this: providing very precise numbers of vehicles for a future situation would give a false sense of accuracy.

Another threat would be that with more data and more sophisticated models available, it would be tempting to carry out more complex calculations. This would, however, lead to very few people understanding what they are doing, which would lead (again) to a false sense of accuracy.

A final problem is that traffic and environmental models are usually managed by different departments. Each time a noise map has to be made, linking the two models will probably have to be done again, as both models are likely to have evolved independently. This is generally less of a problem with more detailed models (like microscopic models) because most of the data needed will be available at the level that is needed for these models (whereas for macroscopic models adaptation takes more effort, e.g. because the network representation is simplified).

Part 2: Traffic model development

Modelling technique:
Goudappel Coffeng, when doing environmental analyses, take the requirements of the environmental models (or directives) as a starting point: they determine the quality of the data that is needed. When looking at noise models, it is obvious that truck traffic and the night time period are the most important, and it is therefore important to get the data for these aspects right.

Producing good data for a full day is possible; this is no longer done by just extrapolating from the peak periods. To get the modelling of the peak periods right, the other periods of the day must be considered as well. It is however still not customary to model weekdays – usually working days are modelled because of the importance of peak periods (or rather capacity problems) in traffic modelling. So this remains a problem. However, Goudappel sees a trend where OD-matrices are produced for every day of the week.
In the developments mentioned above, developments in traffic have been the incentive (and not the environmental models, although it is to their advantage as well).

The different periods of the day (day, evening, night) as required for noise modelling are not yet included as such in their models. Mostly the two peak periods are modelled and traffic in the other periods of the day are derived 'by hand', e.g. by assigning shares of daily traffic volumes, with the shares of each hour depending on the type of road. Usually, this is based on traffic counts. The reason for this is that from a traffic engineering point of view the peak periods are the most interesting. Traffic models and environmental models each have their own objective and they must be combined in an efficient way.

Truck traffic is modelled separately, more and more often, but not in as much detail as passenger car traffic. Usually, there is no distinction between different periods of the day, and also no distinction between medium and heavy trucks. However, the assignment of routes for truck traffic is already a great improvement. In the past, only traffic counts were used. Today, traffic counts and models are combined (with the model providing prognoses for total truck traffic), and additional calculations are made using relationships between general traffic and spatial characteristics and truck traffic observed in practice. The use of modelling means that the effect of measures and autonomous developments can be assessed.

Goudappel Coffeng would, at this moment, use static assignment models for noise calculations (but static and/or dynamic models for air quality calculations). This is because with the present noise calculation method it would be 'overdone' to use a more sophisticated traffic model. They would use a more sophisticated model only when (new) environmental calculation methods would give cause for this. Obviously, this is also a question of costs and benefits: the authorities they work for will be satisfied with the simplest approach possible. Goudappel Coffeng usually build models for entire cities/regions - quite large networks, which means that costs of data acquisition and processing can become high. Goudappel are therefore always looking for the balance between the level of detail of the models used (traffic & noise model): the more detailed the traffic data, the more you want to know about the position of the road, and the positions of the buildings along the road, etc.. More and more GIS-databases containing such data are becoming available. Goudappel Coffeng think that the Netherlands are ahead in this field.

Goudappel Coffeng would rather focus their efforts on acquiring extra data, e.g. on speed distributions, to use in addition to static assignment models, than build and calibrate 24-hour DTA models, because at this moment DTA models do not really have added value. However (see also the remarks under *Opportunities*), they do expect that by 2010, dynamic assignment will be quite common, as well as intersection modelling. Goudappel Coffeng expect that traffic models will be able to keep up with developments in environmental models (which will become more detailed).

Measures

DTA models will be better capable of including traffic management measures, so if DTA models are combined with static models it will be easier to model measures adequately.

Input

All data used must be checked, as inconsistencies are common; they will often become visible in the calibrating process. Good OD-matrices are the cornerstone of good traffic models; static models will stay important because they provide the OD-matrix.

Accuracy

Goudappel Coffeng's estimate of accuracy of (static) traffic models: on motorways +/- 10%, on other roads +/- 20% (flows).

Part 3: Market forecast and expected future practice

Much about market forecast and expected future practice has already been treated in Parts 1 and 2.
Goudappel Coffeng recommends that the guidelines to be produced by WP2 indicate clearly what traffic variables have a large effect on noise levels, in other words: for which variables it is the most important to get accurate data.

Part 4: Noise related possibilities

No specific remarks – see rest of interview.

B.2 PTV (Static Models)

Interview with **Klaus Nökel and Thomas Benz** (PTV)
This interview was carried out as part of the Interactive traffic model developer workshop.
Date: November 15, 2004
Location: PTV, Karlsruhe, Germany.

General notes

PTV is the developer of the transport planning package *VISUM*, which consists of several packs with different functionalities (e.g. static and dynamic traffic assignment (DTA), and user specified jobs), from model building to generating reports, including graphical output. They also developed *VISSIM* a microscopic traffic simulation model, which can model different user classes, such as cars and trucks as well as public transport, cyclists and pedestrians. VISSIM is equipped with a very powerful and realistic visualisation mode.

Klaus Nökel is head of the Transportation Planning Systems department and mostly involved in macroscopic static models, such as VISUM. Thomas Benz has experience on microsimulation modelling as well as traffic noise modelling.

The experts of Ptv were interviewed about static models as well as microsimulation models. In this chapter, static models are dicussed. The discussion with ptv about microsimulation can be found in B.8 (page 120).

Part 1: Assessment (SWOT) of model type

Strengths

PTV have the following remarks on the strengths in the original SWOT

Strengths
1. Relative ease of data collection
2. Fast
3. Data collection relatively easy
4. Results easy to understand
5. 'Concise' results (not too much data)
6. Results easy to use in GIS environment
7. Transparent and comprehensible modelling technique

Bullet 1: Network data is easy to achieve by using the networks available in navigation systems. A major advantage is that routability and connectivity within these networks are assured. However, this data is actual data and not directly suited for future networks. Network editing remains thus necessary for modelling future scenarios. Furthermore, link capacities and some other attributes cannot be obtained easily in this way. The number of lanes might be available and can also be collected quite easily by field study. Another related advantage is that these

navigation system networks will generally require less post-processing than GIS networks, e.g. to get routing correct.
In their models, PTV distinguish two separate layers: the basic network data layer and a layer with data added later on (such as capacities etc.). As a result, updates of the basic network data can be more easily implemented (no need to add all previously added data again). Companies which do the noise calculation should use the same approach to ensure an easy interface of results. The basic network data layer should ideally be the same for both traffic and noise models.

Bullet 4: OK, the averaging is powerful, but expertise is needed for a correct interpretation of the results. This is illustrated by looking at the accuracy of modelled traffic volumes and travel times. Calibrating both simultaneously is difficult, and for many transportation planning projects this is simply not required, because only one of both is actually used afterwards. So PTV's main caveat is: when noise emissions are computed a posteriori from a supposedly calibrated static model, we cannot assume that both speed and volumes have been calibrated. That is a possible pitfall and the calibration needs to be checked again, before any confidence can be placed on the emission computation.

Bullet 5: PTV think the static modelling is not good enough for noise modelling. The results are too averaged and too aggregate.

Bullet 6: In the PTV models, results for the static assignment can be exported to other models, such as noise models. This makes it easier for both traffic and noise models to make use of the same base data.

Weaknesses

PTV have the following remarks on the weaknesses in the original SWOT:

Weaknesses

1. All results are (hour-based) averages, fluctuations and peaks cannot be distinguished
2. Inaccuracy of results (flows and speeds per link), due to:
   a. use of relatively large zones and connectors from zones to network
   b. use of general speed-flow diagrams (volumes can exceed capacity)
   c. modelling techniques do not accurately model driver behaviour
3. Usually night periods are not or inaccurately modelled
4. Few dynamic management measures can be modelled
5. Network data (links and co-ordinates) are not always accurate

Bullet 2a: Of course, it is possible to use a more detailed zone level, but then the OD matrix estimation becomes more difficult, due to smaller modelling units. This is a trade-off.

Bullet 2b: Nowadays, it is very common to add intersection modelling to static modelling. However, this technique is vulnerable for oversaturation. In the first iteration of a static assignment, all traffic of between one OD pair will use one route, which leads to very high intersection loads. The travel times of other routes using these intersections will increase unrealistically. Eventually, this effect will smooth out, but due to this effect, more iterations are required to reach equilibrium.

In practice, consultants usually use fewer iterations than required to achieve real equilibrium. The problem is that running enough iterations (1000 iterations) is too much for everyday practice. Using too few iterations leads to artefacts in the link based results.
Blocking-back can generally not be modelled using static models in a fully correct way. Blocking-back effects can be estimated using post-processing algorithms which try to estimate queue lengths (travel times), but this will then not influence route choice anymore.

Bullet 5: Not a weakness in the PTV approach (using navigation systems data), see strengths.

Opportunities

PTV have the following remarks on the opportunities in the original SWOT:

Opportunities
1. Model is very common in local, regional & national authorities
2. More digitised or automatically generated data will become available
3. Relative simplicity of models ensures that new developments will usually be tried out in static models first – model type will continue to be relevant to model developers

Bullet 3: This depends heavily on the development which is being tested. Some developments cannot be tested using static models. However, there is still scope for improvement of static models itself: like data collection, convergence of route choice, automated calibration methods, etc. This is true despite the increasing popularity of dynamic and microsimulation models.

Threats

Threats
1. Improvement of model and input requires a large effort (data collection) and is no priority for traffic & transport departments

Threats
Improvement of model and input requires a large effort (data collection) and is no priority for traffic & transport departments

PTV agrees with the one threat listed here, but remark that data collection efforts are applicable to all model types.

PTV state that if noise models are going to be linked to static models primarily, the increasing popularity of dynamic and microsimulation models might be a threat because these will make static models outdated.

<u>Part 2: Traffic model development</u>

Not explicitly discussed, is covered in other parts of the interview

Part 3: Market forecast and expected future practice

Nowadays, some municipalities in Germany have their own traffic models, other use consultancy firms, like PTV. PTV don't expect that to change in near future.

In 2010, dynamic or mesoscopic models will become more popular, depending on scale level. Static models will still be used for sketch level problems and prescreening (selecting promising scenarios using a static model).

Part 4: Noise related possibilities

In Germany there are very strict guidelines on how to perform evaluation studies of socio-economic and environmental effects. New guidelines are expected in 2005. In the current guidelines, evaluations are done using 24h averaged data.

B.3ITS Leeds (Static Models)

Interview with Dr. David Milne (ITS, Leeds)
This interview was carried out as part of the Interactive traffic model developer workshop.
Dates: October 2004 and 7 December 2004
Location: ITS, Leeds University, UK

General notes

The following summary of two interviews undertaken with Dr. David Milne of the Institute for Transport Studies, at the University of Leeds, regarding the SATURN traffic assignment modelling suite.The first interview was undertaken prior to the first draft of this IMAGINE deliverable being available, the second after Dr. Milne had read the first draft. Comments from both interviews have been amalgamated. Dr. Milne himself has worked as a senior assistant engineer with a consultancy, before joining ITS, Leeds and has over 15 years in using the SATURN programme suite. He is a close colleague of Dr. Dirck Van Vliet, the developer of SATURN.

Note that the primary source for the introductory information on the SATURN model below, is the SATURN website: http://www.its.leeds.ac.uk/software/saturn/index.html.

SATURN (**S**imulation and **A**ssignment of **T**raffic to **U**rban **R**oad **N**etworks) is a suite of programs designed for the analysis of road transport networks. It has been under continuous development at the Institute for Transport Studies, University of Leeds for a period of 25 years, and has been marketed worldwide by the UK consultants WS Atkins since 1981.

Currently SATURN is in use with over 300 consultants, research institutes, local, regional and national authorities, in over 30 countries worldwide, on 6 continents. Its primary purpose is in the evaluation of road schemes, but a number of secondary, research-driven applications have been developed, such as the evaluation of road charging or route guidance systems. The SATURN acronym itself is slightly misleading, as the suite is not limited to solely urban traffic, rather SATURN has been applied at everything from a local to a national level.

The original basis for SATURN was as a pure traffic assignment package based on a fixed user-defined trip matrix. The SATURN suite of programs now includes facilities for:

- Modal split and distribution across networks integrated directly into the assignment phase of modelling.
- Multiple levels of detail are available within a single network to enhance computational efficiency.
- Matrix estimation tools based on observed link flow values (Maximum Entropy Matrix Estimation – ME2 Application).
- Inbuilt simulation of junctions, so that the effects of traffic signal changes on vehicle queues may be viewed interactively and output.
- An MS Windows compatible front end to handle module selection and batching of runs (SATWIN application).
- Specific applications for the graphical editing of networks and the display of results in GIS-style formats (P1X application).
- Direct linkage of SATURN with the DRACULA microsimulation model, also produced by ITS Leeds.

Other select features of the SATURN suite include:

- Fully interactive analysis of results, including on-line help files
- Estimates of fuel consumption and (in a highly experimental form) pollutant emissions.
- Traffic signal co-ordination modelled
- Lane structure of intersections and choice of lane modelled
- The growth and decay of queues modelled quasi – dynamically
- Facilities to “skim”, e.g., inter-zonal time matrices
- Bus routes, bus-only roads and bus-only lanes included explicitly
- Both left-hand and right-hand drive accepted
- Selected link analysis
- Multiple User Class Assignment differentiating between, e.g., cars, taxis, HGV’s, etc.
- Full analysis of O-D routes generated by the assignment
- Network and trip matrix cordoning for sub-areas.
- Facilities to both “dump” SATURN data into ascii files for input into, e.g., spreadsheets or other suites of transport programs and equally to re-input data files from these external procedures.

General comments on this deliverable:

Dr. Milne made the general comment that the overall portrayal of static assignment models seemed rather negative, with a perception that perhaps the authors viewed static assignment models as a poor relation to the other model types considered.

With regards to the description provided of static modelling techniques (section 3) the following specific comments were made:

1. Aggregate network performance measures should include the total number of vehicle kilometres travelled in the network.
2. The statement that the main objective of static models to obtain “reasonable” flows sounds somewhat negative – any model should be able to achieve “accurate” flow values depending, of course on the quality of input data.
3. Models like SATURN or CONTRAM are not just assignment models, they also include detailed simulation of junctions – so therefore it is possible to get an idea of junction delays and queues from the same modelling package. Emphasis is shifting towards more integrated solutions.
4. The statement that “…it is therefore not possible to get an insight on the development of a peak period” using static models is not necessarily correct. Models such as SATURN may operate on multiple, linked time periods, with spill back from one period to the next, allowing more dynamic analysis.
5. The statement that “…cost can be divided in travel time and monetary travel costs” doesn’t include the fact that overall distance may be a factor in route choice. Quoting Dr. Milne directly:

> “SATURN uses the concept of “generalised cost”. This cost is made up of a value of time & a value of distance PLUS any extra monetary tolls that might be added on for road pricing etc. The value of distance has been traditionally thought of as vehicle operating cost, so that may be considered a monetary cost. Over time, research has shown that it’s more complex than that. In practice, people’s perception of space will affect what routes they consider using, with a definite bias towards the shorter / more direct ones. So, for example, in a specific EPSRC route choice project, it was attempted to make SATURN routes fit those suggested by number plate matching surveys. At first, any comparison was

relatively poor, until the value of distance was increased well beyond levels that economics would suggest. Then something very close to observed behaviour appeared. This may be more complex than the IMAGINE document intends to go, but it is important to understand that: (1) distance based costs for representing the money cost of travel like fuel & depreciation etc are maybe rather different to direct money charges for using the road network like tolls; and (2) the cost definition required to represent behaviour may not be the same as that normally considered in economics, which may make some aspects of modelling (eg evaluating benefits) rather more awkward than modellers like them to be."

6. "All-or-nothing assignment", whilst mentioned in the deliverable for the sake of completeness, is almost never used in isolation – it is a means to an end, used as only part of other processes.
7. For user equilibrium assignment and Wardrop's first principle, it is more correct to state that "…all routes not used have greater ***or equal*** costs".
8. The statement that "…the popularity of stochastic assignment seems to have decreased over the past years" may not be true, as the technique is advisable for uncongested traffic. Again, quoting Dr. Milne directly:

"I'm not really sure whether or not the use of stochastic assignment in the real world is going up or down. What I do know is that people on the research side of modelling are increasingly keen on it. Also, separately, the advice for SATURN has always been that stochastic approaches are most important in less congested situations, especially when modelling strategic traffic across a region. Basically, the more congested the network, the closer WUE & SUE solutions will tend to be to each other, because of the shape of the cost flow curves. So, if you're focussing on a congested city centre, the results of WUE & SUE should be remarkably similar."

9. The statement that "there are basically two commonly used time periods in static modelling : hour based and 24 hour based", forgets AADT and AAWT modelling that require further analysis and modelling to be of interest at the day period or hourly level.
10. The statement that only all or nothing assignment is suitable for a 24-hour modelling system is not strictly true.
11. Many authorities will also have Saturday/Special Event Day models as well as peak-hour, off-peak hour weekday models.

With regards to Model Input (Section 4) Dr. Milne made the following comments:

1. Inputs should include a definition of the cost-flow relationship(s) used for assignment.
2. The statement the "the accuracy of data need not be too high" is wrong. The old computing adage of "garbage in -> garbage out" always applied. Care must always be taken to ensure that the accuracy of the input data matches the overall purpose for which the modelling is undertaken. The following statement that "too much detail slows down calculation" is not as relevant in the current day and age – regional and national models produce results within acceptable time frames on current computing technology. This comment would be better levelled at microsimulation.
3. The representation of roads as straight links is more of a graphics and visualisation problem, than a hindrance to impact assessment studies.
4. The statement that "transport demand data is usually derived from a transport demand model" is not correct for city sized models. Collection of OD data from direct surveys, though time consuming and infrequently done, is preferred for accurate results. Feeding modelled output from a demand model into the assignment model introduces another set of potential errors – given the assumptions made about demand!
5. Multiple user class OD matrices are not common.

6. The statement that "data for future years should not pose a major problem" is slightly misleading. Whilst such data exists, there will always be concerns over the accuracy of predictions and a wide range of potential outcomes (c.f. low, medium and high growth factors).

Whilst Dr.Milne agreed with the SWOT analysis overall, the comment was again made that it seemed to present a negative picture of static modelling. The following specific points were raised:

Part 1: Assessment (SWOT) of model type

Strengths

1. Relative ease of data collection
2. Fast
3. Data collection relatively easy
4. Results easy to understand
5. 'Concise' results (not too much data)
6. Results easy to use in GIS environment
7. Transparent and comprehensible modelling technique

Strengths:

- Whilst results may be easy to use in a GIS environment, but might not be appropriate for noise modelling without an additional step of linking a network representation to geographically accurate coordinates. Static models tend to use straight links between nodes rather than curving link sections as these are not necessarily required for demand analysis. However, it is possible to use geographically correct data in assignment models as long as care is taken at the input stage.
- Assignment models are the standard way to obtain route choice information for planning and analysis purposes – other modelling types such as microsimulation do not typically produce such data.

Weaknesses

1. All results are (hour-based) averages, fluctuations and peaks cannot be distinguished
2. Inaccuracy of results (flows and speeds per link), due to:
    a. use of relatively large zones and connectors from zones to network
    b. use of general speed-flow diagrams (volumes can exceed capacity)
    c. modelling techniques do not accurately model driver behaviour
3. Usually night periods are not or inaccurately modelled
4. Few dynamic management measures can be modelled
5. Network data (links and co-ordinates) are not always accurate

Weaknesses:

- The statement "use of relatively large zones and connectors" is a subjective view. Whilst a strategic model of a country might, for example, only have 25 zones covering a conurbation, it is perfectly possible for a more detailed network in the same model to have hundreds of zones. The problem is the resolution of the input data and the time requirements to collect such data, rather than a specific weakness in the model type.
- The statement that "usually night periods are not or inaccurately modelled" is again a function of the paucity of the input data – not an inherent weakness in the model type.
- Whilst the strict definition of the modelling methodology for static models would suggest that vehicle speeds cannot be directly obtained, given that SATURN also contains a junction simulation model, Dr Milne was confident that some representation of

accelerations, decelerations, delays and stops can be made. Indeed such representation of primary and secondary stops on a link forms the basis of the current pollutant emissions algorithm in SATURN.

- Network data and coordinates may be accurate if the time is taken to correctly implement the network, possibly using additional mapping data sources.

Opportunities
1. Model is very common in local, regional & national authorities
2. More digitised or automatically generated data will become available
3. Relative simplicity of models ensures that new developments will usually be tried out in static models first – model type will continue to be relevant to model developers

- No specific comments

Threats
1. Improvement of model and input requires a large effort (data collection) and is no priority for traffic & transport departments

No specific comments

Part 2: Traffic model development

Most developments to SATURN specifically have been fuelled either by research projects – to answer specific research questions, or by specific desires of clients who were willing to fund developments.

Developments in network modelling as a whole will continue to push static models towards the use of linked time slices to better model congestion, peak-spreading etc. These will feed into better appraisal of new technologies, road-charging regimes, dynamic management systems etc.

Part 3: Market forecast and expected future policies

Local and national authorities already possess static models, are familiar and competent with their use, and can readily exchange data in the required formats with consultants or sub-contractors; hence such models will remain popular for the foreseeable future. However, the use of microsimulation to model ever expanding areas will grow in popularity.

Part 4: Noise related possibilities

Models such as SATURN are already used as part and parcel of the economic appraisal and transport evaluation process, therefore as additional requirements for noise mapping grow it becomes inevitable that further links between models will be developed. A research project at the University of Leeds has already provided a common interface between SATURN and a program for calculating basic noise levels in accordance with the UK CoRTN standard (the TEMMS model[1]).

At the current time, it is envisaged that the hypothetical method of passing data from SATURN to any noise model would be the exchange of plain text files. If advanced graphical output is required then this would be best handled by specialist applications or packages.

SATURN already supports multiple user classes – depending on the availability of OD matrix data. It is usually more difficult to obtain reliable data for heavy vehicle classes for instance.

References

[1] Namdeo, A., Dixon, R., Mitchell, G., May, A.D., and Kay, D. (1999) *Transport Emissions Modelling and Mapping Suite (TEMMS)*. Paper 99/847. 92nd Annual Meeting and Exhibition of the Air and Waste Management Association (AWMA), St. Louis, MO, USA.

B.4 Michiel Bliemer (DTA)

Interview with **Michiel Bliemer** (Professor at the Delft University of Technology)

This interview was carried out as part of the Interactive traffic model developer workshop.
Date: November 15, 2004
Location: Delft, The Netherlands.

General notes

- Michiel is a developer of the dta package INDY. Indy started as an extension of a model development at MIT and is now further developed by TUDelft, TNO-FEL and TNO Inro. A first version has been released. A second version will include spill back of congestion.
- Michiel proposes another classification of traffic models, because both microsimulation models and continuum models (will) become part of (dynamic) assignment models. In his opinion, there are three main categories of dta models :
    - Equilibrium : The model searches for a deterministic or stochastic user equilibrium : every traveller searches for the shortest route, assuming (perfect or imperfect) knowledge of all traffic circumstances. These models are mostly used for off-line purposes. A further division of this category :
        - Pure analytical models : They calculate both shortest routes as well as traffic conditions on the network in one analytical calculation step. This type of models is limited to small networks and is subject of scientific research, which as of yet, did not result in commercial software packages. The PhD work of Michiel resulted in this kind of model.
        - Simulation based : These types of models work in two steps. In the first step, traffic conditions in a network are calculated. This step is also called dynamic network loading (dnl). Both microsimulation as well as macrosimulation (continuum models) can be used. Indy can be classified as a macrosimulation dta model.
          In the second step, route flows are determined using a route choice model, given the travel times of the simulation model.
    - Non-equilibrium : These models do not necessarily result in the shortest route for every user. They comprise ‘en-route’ route choice (for example a user can change route along his way while experiencing bad traffic conditions) in contrast to ‘pre-trip’ route choice based on actual or instantaneous travel costs. Non-equilibrium models are mostly used for on-line purposes. Models can use split fractions at nodes (for example 50% of approaching traffic turns left), instead of ‘paths’.
    - Heuristic models are fast ‘engineering’ models, which do not guarantee a consistent solution.

Part 1: Suitability of dta models (SWOT)

Michiel adds some additional relevant points into the discussion :

Strengths and opportunities

Michiel basically agrees with these points.

Strengths
1. Better modelling of fluctuations in traffic demand than static model
2. Easier to model effects like congestion, incl. blocking back than in static model
3. Dynamic traffic management measures can be modelled
4. Results easy to use in GIS environment
5. In some DTA models, volumes cannot exceed capacity

Remarks :

- Bullet 1 and 2 : The words 'better' and 'easier' do not reflect the true meaning : DTA models are more accurate and more correct.

Opportunities
1. More digitised or automatically generated data will become available
2. Dynamic models are expected to become (much) faster in the near future
3. DTA models offer possibilities that are expected to be in high demand in impact assessment studies (e.g. for reliability studies) in the near future

Remarks :

- bullet 1 : It is not clear for Michiel what kind of data will become available. Regarding the Netherlands, already a lot of data is available from traffic detectors, surveys,…
- bullet 2 : Indy was already successfully tested using parallel computing techniques. DTA models can therefore become very fast.

Weaknesses

Weaknesses
1. Dynamic OD-matrix is required
2. Modelling may involve long run times
3. Few OD-matrices for full day available (and run time will be very long)
4. Inaccuracy of results (flows and speeds per link), due to:
a. use of relatively large zones and connectors from zones to network
b. modelling errors
5. in some DTA models, volumes can exceed capacity
6. Times step size determines accuracy of results (times steps are generally in the order of 10-20 seconds)
7. Shortest free flow travel time on a link in the network defines maximum time step

Remarks :

- bullet 1 is only relevant when a comparison is made with static models. Traffic demand is always required as input, for all kinds of traffic models. Although a lot of research is being done on traffic demand, he doesn't expect big improvements in the accuracy of demand models.
- bullet 2 : The run time depends on a number of parameters: the number of links, time discretisation and study period. In comparison to microsimulation models, dta models using a macroscopic simulation are becoming quite fast as the run time is more or less independent on the amount of traffic on the network, yielding possibilities for applications on large area networks. It should be noted that memory usage is the most critical factor and not calculation time. In Indy, the number of OD pairs is the critical factor (since they determine memory usage). He mentions that building the model is quite easy and fast in comparison to microsimulation models.
- bullet 4 : there is also an inaccuracy of results due to bad parameter estimation. It should be noted that these points are valid for all types of models.

- bullet 7 : this is valid for all dynamic models and is not a huge problem. Smaller time steps can be used in ‘short link’ networks. For example, using a time step of three seconds results in a minimum length of 100 meter in case of a maximum speed of 120 km/hour.
- Additional remark : It is very easy to add heterogeneous vehicles in microsimulation models, while being more difficult in macrosimulation models. In INDY multiple vehicle types have successfully been included in the dynamic network loading model (i.e. the macrosimulation model).

Threats

Threats
1. Dynamic models need detailed input data
2. Difficult modelling technique can lead to 'black box' image for model users.

Remarks :

- Bullet 2 : There are large visualisation possibilities. Even ‘microsimulation views’ can be produced : showing moving cars based on traffic variables calculated within the dta model. Movies showing the evolution of traffic variables are now also possible. Adding these visualisations gains a better insight into the traffic situation, resulting in a better understanding of the traffic process.

Part 2: Traffic model development

The models become quite fast. Indy works with 30.000 links and 140.000 OD pairs while modelling a whole day with 7.000.000 vehicles using a time step of 10 seconds.

Demand modelling will remain the most difficult area. Incorporating time-of-day models will complicate things a little bit more. In that case, dynamic OD matrices per time slice must be replaced by an OD table and additional ‘arrival times’ or ‘departure times’. Furthermore, additional info on the cost of leaving/coming too late or too early must be searched for.
There is no theoretical reason why traffic models shouldn’t be able to model nightly traffic. Again, it is the demand model that is the critical factor.

Part 3: Market forecast and expected future practice

Michiel sees a growing fusion between packages. Commercial traffic modelling packages will evolve to a combination of a graphical user interface and a data manager, allowing the implementation of different types of models. This means that data collected for other model developments can be completely re-used for new modelling techniques.
Therefore, Michiel foresees the use of DTA models in 2010 for all Dutch regions and cities where static models are used now. However, there is no large market for traffic models. He foresees that each country will use the models developed within that country.

Part 4: Noise related possibilities

Michiel has no experience in and no knowledge of linking dta models to noise models. The predecessor of INDY developed at MIT has already been used to model vehicle emissions.

B.5 Michael Mahut (DTA)

Interview with **Michael Mahut** (Traffic model developer at INRO Consultants, Canada)

This interview was carried out as part of the Interactive traffic model developer workshop.
Date: November 29, 2004

General notes

- Michael developed a prototype DTA model in his PhD thesis (Université de Montréal). The DTA software, now called Dynameq (for *Dynamic Equilibrium*), is being developed and marketed by INRO (which also sells the EMME/2 static planning software). The beta version is going through a 6-month evaluation period where it is being used by 10 organizations, located in Europe, Scandinavia, USA and Canada. The beta version is not available to other organizations. The first general release is planned for January 2005.
- Dynameq combines an iterative traffic assignment algorithm with a traffic simulation model, in order to achieve a dynamic (pre-trip) assignment that approximates the true dynamic user-equilibrium conditions. This means that drivers using the same origin-destination (O-D) pair, that leave the origin at approximately the same time, have approximately the same experienced travel times (in the last iteration of the simulator) to the destination.
- The traffic simulator (network loading model) is based on a simplified car-following model. The model is solved using a very efficient event-based algorithm, which runs 50 to 100 times faster (computationally) than conventional (time-step) simulation models. Multiple vehicle classes can be distinguished and detailed node interactions are modelled.

Part 1: Suitability of dta models (SWOT)

Strengths

Strengths
1. Better modelling of fluctuations in traffic demand than static model
2. Easier to model effects like congestion, incl. blocking back than in static model
3. Dynamic traffic management measures can be modelled
4. Results easy to use in GIS environment
5. In some DTA models, volumes cannot exceed capacity

Remarks :

- Concerning the representation of temporal traffic phenomena, Dynameq is hardly comparable with a static model. It is in fact derived from micro-simulation approaches, and it generally provides very comparable results to other traffic simulators (when variables such as path choice are controlled for). To reply to the points individually:
  (1) I strongly agree. Dynameq explicitly models the movement of individual vehicles and other events, such as signal timing. Time is continuous in an event-based simulation.
  (2) I strongly agree. Dynameq explicitly models the traffic phenomena that cause congestion: traffic signals, conflicting movements at intersections, and lane-changing (weaving effects). Queue (congestion) density implicitly reflects prevailing flow rates (as with any car-following model), resulting in realistic blocking back effects.
  (3) Agree.
  (4) Results from Dynameq can be easily exported and used with GIS software, if desired.
  (5) In Dynameq, volumes do not exceed capacity, which is necessary for modelling queueing appropriately.

Opportunities

Opportunities
1. More digitised or automatically generated data will become available
2. Dynamic models are expected to become (much) faster in the near future
3. DTA models offer possibilities that are expected to be in high demand in impact assessment studies (e.g. for reliability studies) in the near future

Remarks :

- (1) I agree that there is great potential for much more data, which can be easily obtained, with today's technology. The real challenges are (a) how to ensure the quality of that data, and in general how to manage it, and (b) to develop new models in the case of new types of data that we've never had before. For example, with mobile phone tracking and GPS, it may be possible to actually get information about the paths that drivers choose. This is immensely richer information than just knowing the origins and destinations of trips. I am not aware of any commercial traffic modelling software packages that could directly (i.e. automatically) make use of such data.
  (2) Models could become faster because (a) new models are developed that are less computationally demanding, or (b) because computers are getting faster. I will address each of these points separately:
  (a) Dynameq is in fact such a model, as it is based on a new type of traffic simulation model, which is solved with a very efficient (i.e. not computationally demanding) event-based algorithm.
  (b) Whether it is increased computing power or increased memory size, all developers tend to see increases in computer capacity as an opportunity to add in more features and more detailed modelling that they could not permit themselves before. Consider how much faster computers are today compared with 10 years ago, when traffic simulators first started being used. Are they that much faster today? Not nearly to the same degree, but the models are much more powerful than before.
  (3) Yes, absolutely. See my comments below on applications of DTA models (in Parts 2 and 3).

Weaknesses

Weaknesses
1. Dynamic OD-matrix is required
2. Modelling may involve long run times
3. Few OD-matrices for full day available (and run time will be very long)
4. Inaccuracy of results (flows and speeds per link), due to:
a. Use of relatively large zones and connectors from zones to network
b. modelling errors
5. in some DTA models, volumes can exceed capacity
6. Times step size determines accuracy of results (times steps are generally in the order of 10-20 seconds)
7. Shortest free flow travel time on a link in the network defines maximum time step

Remarks :

I don't agree that all of these points should be thought of as "weaknesses". I would call the first 4 points "challenges" instead. Points 1, 3 and 4 are what I would call "modelling challenges", as they really pertain to the preparation of input data. The second point is clearly a "developer challenge", as it is strictly a property of the model and its implementation by the software developer. Points 5, 6 and 7 could legitimately be called "weaknesses", when they actually apply (are true) for a specific model.

- (1) Dynamic OD data is a significant new challenge related to dynamic models. However, I believe that the results are more sensitive to the quality of the model than they are to the accuracy of the demand dynamics. I would have more confidence using a relatively static (e.g. 1 hour) matrix with a good DTA model, that incorporates a realistic representation of traffic dynamics, than using a more detailed demand matrix with a less realistic model. Are one-hour matrices that hard to get?
  (2) This statement depends on many things: (a) the model (software) being used, (b) the available hardware, (c) the size of the network, and (d) how quickly you need the software to give you some answers. Although Dynameq does not yet do en-route modeling for real-time applications, the computational speed of the simulator would allow networks of considerable size (e.g., with a demand of 100,000 vehicles per hour) to be modelled fast enough for real-time applications (e.g. running 100 times faster than real-time) on a regular PC.
  (3) As I suggest above, any statements about run times depend on the context of the analysis. Real-time analysis does not require modelling the full day, while off-line analysis could.
  (4a) Dynamic modelling is always more detailed than static modelling, and may often require a higher number of smaller zones. Matrix estimation is an important (mathematical) tool for this that is still not fully mature in the context of dynamic models.
  (4b) There are many possible sources of error in the models commonly used, and there does not appear to be much agreement, or really that much understanding, of which sources of error are the most significant. Dynameq is built on two basic ideas:
  - Only an iterative assignment algorithm, based on a well-defined property such as user-equilibrium, can provide you with results that can be compared in a meaningful way across different scenarios.
  – For results to be sufficiently accurate and reliable, the model must be based on a fairly realistic representation of traffic phenomena and congestion (i.e., you need the kind of fidelity you find only in simulation models: car following, lane changing, gap acceptance, etc…).
  In general, I think that many people who use simulation models grossly underestimate the importance of getting the right assignment (path choices).
  (5) This point appeared earlier in the questionnaire. This is an example of the insufficient realism of the traffic modelling in some DTA packages. Dynameq does not have this problem.
  (6) The simulation model in Dynameq is completely event-based. Since time is continuous in such a model, there is no time step involved. This is an advantage over conventional micro-simulation as well, where results are also affected by the size of the time step.
  (7) Dynameq has no such constraint.

Threats

Threats
1. Dynamic models need detailed input data
2. Difficult modelling technique can lead to 'black box' image for model users.

Remarks :
It is not clear to me why these points are labelled as “threats”. I will simply comment on the points as I see them:

- (1) I agree with this, of course. Quite simply, detailed analyses require detailed data: but in the end, it depends on what kind of analysis you need to do. Sometimes, the users of traffic modelling software spend too much time collecting detailed data that has no real impact on the results, and don’t spend enough time focusing on the inputs that are critical. Dynameq has been designed to allow the modeller to focus on the most critical parts of the network. For example, traffic signal data is not required for every intersection that has traffic lights; the model will take care of these intersections (usually on the periphery of the network) using default logic.
  (2) I also agree very much with this statement, which is why Dynameq is a simplified model. It is critical for the analyst to understand in advance, as much as possible, what the effect of changing a parameter will be on the outputs. At the very least, it must be understandable in retrospect.
  General comment:
  There are also concerns about the speed of deployment of DTA. Large data requirements

and difficult calibration can make deployment costly and time consuming. Dynameq addresses these concerns through the two points discussed above (i.e., minimal data requirements and simplified models).

Part 2: Traffic model development

I was asked whether DTA models will replace the traditional 4-step planning process. My reply can be summarized as follows:

Since DTA models generally do assignment only, the current state of the art puts them in a position to complement static models for the assignment step. Gradually, more tools are being developed for dynamic models, such as dynamic O-D estimation and O-D adjustment, which are enlarging the domain of dynamic models. It is only a matter of time before multi-modal dynamic-equilibrium assignment tools become available. As these methods based on dynamic models become more widely used, accepted and refined, they may begin to be used in place of static models for certain applications. However, very large networks that are currently handled with static models are still well outside the practical scope of dynamic models.

Not only will DTA models improve traffic description, they will also increase the level of detail which is possible when reporting traffic characteristics. Dynameq can report point information at the exit position of a link (e.g. exiting movements), link (even lane) based information (e.g. queue length and detector-type data) and class based information (e.g. travel times). Detailed information is also available at the nodes.

My general opinion is that the primary domain of application for DTA today is not long-term planning or forecasting. Dynamic models, simulation models, and DTA have evolved out of a need to have more accurate models that would be appropriate for things that static models are not designed for, and are not appropriate for.

Part 3: Market forecast and expected future practice

The first commercial release of Dynameq, expected in January 2005, will handle pre-trip assignment only, and will be suitable for off-line operational planning studies.

Dynameq is intended for short-term (“operational”) planning studies. These studies include evaluations of:

- Impact of permanent changes to the network topology: adding or removing links or lanes from the network.
- Traffic management policies, including lane-based policies, such as reserved lanes for buses, taxis, or HOV (high occupancy vehicles).
- Alternative traffic signal control policies: the equilibrium DTA predicts how drivers will change their routes over time in response to the traffic signal plan.
- Effects of temporary network modifications, e.g. the impacts of work zones. Again, the DTA model predicts how drivers will, or should, modify their routes if the work zone impacts their travel times.
- Impacts of special demand scenarios, i.e. special events.

Part 4: Noise related possibilities

I have no experience in linking DTA models to noise models. I expect no problems in linking both model types. The central question is data availability: What are the additional data needs of noise models and what accuracy do they require of traffic models?
Modelling night periods is basically no problem from a traffic model developer view, because this only depends on (demand) data. If accurate OD tables are available, the details of multi-class DTA models can improve the potential link with noise models.

The question of noise modelling, as with other environmental impact modelling, depends on whether the inputs to the environmental model can be provided with sufficient accuracy by the traffic model being used. Noise modelling does not receive much attention in North America (at least not to my knowledge), but we are planning to implement models of vehicle emissions and fuel consumption, for which we believe that Dynameq can provide sufficiently accurate inputs. Based on this, I would expect that Dynameq also has sufficient detail to support the implementation of a noise model.

B.6 Ludovic Leclercq (Continuum Models)

Interview with **Ludovic Leclercq** (Researcher at ENTPE – Ecole Nationale des Travaux Publics de l'Etat – Lyon France)

This interview was carried out as part of the Interactive traffic model developer workshop.
Date: November 18, 2004

General notes

- Ludovic develops continuum traffic models (based on LWR models) and links them to detailed noise models.
- This research hasn't yet resulted in commercial software packages.

Part 1: Assessment (SWOT) of model type

Ludovic basically agrees with the SWOT except for some items in the weaknesses and threats.

Strengths

Ludovic agrees with all the strengths given below. He furthermore adds a *strength*

Strengths
1. Very detailed description of traffic operations both varying spatially along road links and temporally. This includes congestion, blocking back,
2. Analytical model technique resulting in equilibrium without instabilities
3. Designed to model dynamic traffic management measures
4. Volumes can never exceed capacity
5. Calculation time does not depend on number of vehicles
6. Input of network data is limited compared to microsimulation
7. Continuum models make it possible to estimate dynamic mean noise level

Remarks :

- On bullet 6: he definitely agrees with this bullet and mentions that this greatly facilitates the calibration and the validation of such models.
- On the added bullet 7: Continuum models make it possible to estimate dynamic mean noise level. This concept is quite hard to explain but crucial. For example, when a micro traffic model is used to estimate noise, it produces each time step (typically half a second) the noise level associated to a particular representation of the traffic behavior. This corresponds to what can be directly measured in the neighborhood of a road. A continuum model represents mean traffic behaviour depending on traffic demand, road configuration and the effect of traffic management systems. So the associated description of noise corresponds to a virtual traffic situation corresponding to the mean of all the situations that can occur within the present constraints. Thus the dynamics of the noise level are not associated to vehicles but to the vehicle flow. (For example, a continuum model can not reproduce the increased noise levels when a vehicle is located perpendicularly to a receiver, but it can model the effects of flow variations).

Opportunities

Opportunities
1. New commercial software packages will be developed. The link with noise models and GIS systems can be included in this development process.
2. Possible future link with DTA model will result in combining strengths of both model types.
3. Analytical formulation enables development of semi-automatic calibration and validation techniques.
4. Easy to use in combination with traffic detector data

Remarks :
- Bullet 4: Ludovic agrees with this as far as traffic measurements are accurate enough!

Weaknesses

There are some weaknesses that Ludovic disagrees with.

Weaknesses
1. Detailed demand pattern required. Like other models, evening and night periods are usually not the subject of study.
2. No route choice. This means that also a route tree is demanded as input.
3. Few commercial packages available.
4. Few field proven experiences
5. Modelling may involve long run times due to small spatial and temporal discretisation.

Remarks:
- Bullet 1 : A continuum model can easily study different time periods (like day and night) if the traffic demand is known for each period.
- Bullet 2 : Correct at the moment, but research is being done on this point. Hopefully, in 5 years time some models will have been proposed.
- Bullet 4 : Not completely accurate. Experiments have been performed to validate such models, especially in the USA. Some studies have also been carried out in Europe. For example, the model (Symubruit which is typically a continuum model linked with a noise emission model), Ludovic develops with one of his colleagues (Joël Lelong, INRETS France) has been validated for a starting platoon at a traffic signal. Furthermore they plan to realize a major experiment in 2005.
- Bullet 5 : Incorrect for the traffic simulation. Accurate for the noise calculations if they are made by octave.

Threats

There are also some threats that Ludovic disagrees with.

Threats
1. ‘Black box’ image for current practitioners
2. Bad visualisation possibilities makes it difficult for policy makers
3. Still challenges in developing models for priority nodes and urban road networks.

Remarks :
- Bullet 1 : Ludovic disagrees with this point. Continuum models (and especially the simplest of them like the LWR one) are based on waves. This concept can be quite easily understood by practitioners.
- Bullet 2 : Not completely true. It is correct that a continuum representation of flow density is harder to understand than a microscopic representation of vehicles. However, such models

make it possible to easily produce dynamic noise maps which can be understood by policy makers.

- Bullet 3 : This is the major research theme of Ludovic.

Part 2: Traffic model development

Several research teams work on continuum models all over the world. Ludovic believes that continuum models will become more and more accurate in representing major traffic behaviour. Furthermore, some research is being done on the use of such models in an urban environment (like Ludovic does), by including public transport and other things which are specific to such an environment. There is still some research to be done to improve the modelling of intersections and of merging and diverging zones, but he thinks that in 2010 these problems will be solved. He also thinks that dynamic route choice modelling can be more easily integrated in such models than in microscopic ones.

Part 3: Market forecast and expected future practice

At the moment, continuum models are mainly used to predict travel times or to estimate the evolution of traffic jams on freeways. Ludovic thinks that in the future, continuum models will be used for a more wide range of applications, including urban ones.

Part 4: Noise related possibilities

For annual averaged noise values and even for day/night values, there is no need to use continuum models. In fact, Ludovic thinks that continuum models can help to better estimate the noise in situations where traffic is very fluctuating, as is the case in urban areas. Continuum models may help to calculate more accurate indicators than the aggregated L_{eq} (like L_{eq} during day or night for example). For example, continuum models make it possible to calculate statistical indicators like L_{10} and to qualify noise emergence.

B.7 Chris Tampère (Continuum Models)

This interview was carried out as part of the Interactive traffic model developer workshop.
Date: September 1, 2004
Location : Leuven, Belgium

General notes

- Chris develops continuum traffic models (gas kinetic) and focuses on the details of driving behaviour.
- This PhD research hasn't yet resulted in commercial software packages.

Part 1: Assessment (SWOT) of model type

Strengths

Strengths
1. Very detailed description of traffic operations both varying spatially along road links and temporally. This includes congestion, blocking back, …
2. Analytical model technique resulting in equilibrium without instabilities
3. Designed to model dynamic traffic management measures, (theoretically) investigate traffic flow dynamics, …
4. Volumes can never exceed capacity
5. Calculation time does not depend on number of vehicles
6. Input of network data is limited compared to micro-simulation

Remarks :
- Bullet 2 : I This does only hold for 1st order models, so not for kinetic models, neither for continuum models in general.

Opportunities

Opportunities
1. New commercial software packages will be developed. The link with noise models and GIS systems can be included in this development process.
2. Possible future link with DTA model will result in combining strengths of both model types.
3. Analytical formulation enables development of semi-automatic calibration and validation techniques.
4. Easy to use in combination with traffic detector data

Remarks :
- Bullet 3: This is not only valid for analytical formulation, also numerical methods exist, see for instance Ngoduy et al.

Weaknesses

Weaknesses
1. Detailed demand pattern required. Like other models, evening and night periods are usually not the subject of study.
2. No route choice. This means that also a route tree is demanded as input.
3. Few commercial packages available.
4. Few field proven experiences
5. Modelling may involve long run times due to small spatial and temporal discretisation.

Remarks:

- Bullet 3 : Few commercial packages? Metanet, Madam, but also many others like Saturn, Visum etcetera. Also those based on particle discretisation of actually continuum models, like Integration, Dynasmart etc.
- Bullet 4 : Few field proven experiences: many of these continuum models have been validated against data! This is their main reason of existence: their direct comparison to real life data.

Threats

There are also some threats that Chris disagrees with.

Threats
1. 'Black box' image for current practitioners
2. Bad visualisation possibilities makes it difficult for policy makers
3. Still challenges in developing models for priority nodes and urban road networks.

Remarks :

o Bad visualization possibilities: I do not agree. Continuum models as such can be visualized rather easily. Moreover, with particle discretisation techniques individual vehicles can also be visualized easily (build trajectories based on speed vector field).

Part 2: Traffic model development

Chris sees a lot of future research in continuum models and applications on small locations for testing of advanced measures. Premature software tools will become available for continuum models in the next decade, but not yet in practice. This is only true for the gas-kinetic modelling, not for continuum models in general (see earlier remark).

Part 3: Market forecast and expected future practice

Chris does not see a commercial use of kinetic models in large area models. So, the use of them to model noise is rather limited.

He only sees static models to be used over whole Europe by 2010 and does not believe that other model types (DTA, continuum, micro-simulation) will cover all the large cities and regions where noise maps becomes necessary.

He expects an evolution to more micro-simulation models, in stead of continuum models in practice. A combination of activity based modelling with micro-simulation models can lead to complete 'discrete choice' models in both the modelling of transport demand and traffic supply. Available calculation power will enforce this, but calibration and validation stays rather difficult (complex, lot of detailed data needs). There is surely a trend to ‘process modelling’. However this detailed models will not cover the whole area where noise maps must be developed.

Part 4: Noise related possibilities

Chris doesn’t have experience in noise models. Modelling night periods is no issue in traffic model development. This is mostly a ‘demand model’ problem.

B.8 PTV (Microsimulation)

This interview was carried out as part of the Interactive traffic model developer workshop.
Date: November 15, 2004
Location: PTV, Karlsruhe, Germany.

General notes

PTV is the developer of the transport planning package *VISUM*, which consists of several packs with different functionalities (e.g. static and dynamic traffic assignment (DTA), and user specified jobs), from model building to generating reports, including graphical output. They also developed *VISSIM* a microscopic traffic simulation model, which can model different user classes, such as cars and trucks as well as public transport, cyclists and pedestrians. VISSIM is equipped with a very powerful and realistic visualisation mode.

Klaus Nökel is head of the Transportation Planning Systems department and mostly involved in macroscopic static models, such as VISUM. Thomas Benz has experience on microsimulation modelling as well as traffic noise modelling.

The experts of Ptv were interviewed about static models as well as microsimulation models. In this chapter, microsimulation models are dicussed. The discussion with ptv about static models can be found in B.2 (page 96).

Part 1: Assessment (SWOT) of model type

Strengths

PTV have the following remarks on the strengths in the original SWOT

Strengths

1. Traffic parameters vary, both spatially along road links, and temporally.
2. Modelling at incredibly detailed levels is possible. It is relatively easy to gain vehicle speed and acceleration information, broken down by user class from a micro-simulation. For noise assessment a variety of aggregation procedures could be undertaken, e.g:
    a. Use instantaneous vehicle parameters to calculate emissions, then assign emissions to a section of road.
    b. Use aggregate vehicle parameters for a given road section/time period to produce noise emissions.
3. Modelling of a wide variety of traffic schemes possible.
4. Modelling of short-term transient events (e.g. incidents or in-peak congestion).
5. Micro-simulation packages often include very powerful network editing, visualisation and post-processing tools.

Bullet 1: This can also be considered a weakness, especially for noise calculation (it may require too detailed computations).

Bullet 2/2a/2b: PTV agree, they use the instantaneous data for noise modelling themselves.

Bullet 3: PTV state that this is the major strength of microsimulation models.

Bullet 4: This is a strength of microsimulation models, albeit that incident modelling is difficult due to unknown route choice effects. In real life, car drivers adapt their routes not before they encounter or are informed about the incident.

Bullet 5: This is not a specific strength for microsimulation models according to PTV. This depends primarily on the modelling package used.

Weaknesses

PTV have the following remarks on the weaknesses in the original SWOT:

Weaknesses

1. Model accuracy depends on initial assignment of flows – possibly from an independent model.
2. Modelling may take a long time and will involve multiple simulation runs.
3. For accurate geographic mapping and modelling links need to be defined with more precision than is typical in static or DTA models.
4. Stability of models may depend on selection of a particular value of time step (usually 0.5 – 1 second). This may not be appropriate for noise modelling.
5. Selection of different time steps may alter results (e.g. fine time steps of under <0.25 seconds may not significantly alter aggregate parameters, but could the affect the distribution of accelerations produced).
6. Output speeds from micro-simulations often depend on the “desired speeds” set for individual links (tendency for non-following vehicles to remain at the desired speed).
7. Boundary conditions and/or selection of network cordoning affects modelling.
8. Specific algorithms, rules or parameter values used in a given package targeted at one member state may not be transferable to other member states.
9. Micro-level results require aggregation for large-scale and/or GIS use.

Bullet 1: PTV state that this is not a weakness specifically for microsimulation models, it is a typical “garbage in = garbage out” remark. This also holds for other model types.

Bullet 3: Microsimulation models need the same amount, or even less data than other model types. Furthermore, data for microsimulation networks might be easier to obtain, because they are understandable to the human eye, like number of lanes. While, for instance, the road capacity in vehicles per hour required by static models is far more difficult to gather.

Bullet 4: PTV do not understand this weakness. It does certainly not apply to VISSIM.

Bullet 5: According to PTV this does not hold for time steps, but is more applicable to the use of random seeds. This might be primarily a problem in congested areas. Enough different seeds should therefore be used, to allow statistically sound conclusions.

Bullet 6: PTV do not want to see this as a weakness, but just as an essential part of microsimulation modelling. The tendency to remain at desired speeds has been tackled in VISSIM, so this weakness does not hold for all models.

Bullet 7: Results can be distorted at boundaries (especially platooning and blocking-back at intersections), boundaries should be chosen to be far enough from study area.

Bullet 8: True, e.g. in southern European countries two-wheelers are causing the larger part of the noise problem. This could also be considered a strength, because microsimulation models (at least VISSIM) are able to model it, instead of some other model types.

Bullet 9: PTV consider this very true, but not very relevant for noise modelling with microsimulation traffic models.

Opportunities

PTV have the following remarks on the opportunities in the original SWOT:

Opportunities
1. The running speed and spatial scope of micro-simulations is improving all the time as computing power increases. 2. Variety of traffic schemes that may be modelled is increasing – vibrant research area. 3. Micro-simulation models offer possibly the best method for assessing future ITS and in-vehicle systems. 4. Micro-simulation models have been directly linked to on-street UTC systems such as SCOOT, SCATS or UTOPIA and on-street detector systems. 5. Possibility to add further parameters to the model through additional research, (e.g. time-of-day or weather dependent parameters affecting driving characteristics).

Bullet 1: According to PTV, there exists a trade off between running speeds and accuracy (larger areas to prevent boundary effects take more run time). So the availability of faster computer systems has lead to larger study areas. The calculation times stayed on the same level.

Bullet 4: This is considered true, but for some schemes microsimulation models are not required. Microsimulation models are only required if operations of vehicles are influenced. E.g. for road pricing measures, using microsimulation might not be very efficient or useful.

Bullet 5: True, especially for adapting driver behaviour and route choice behaviour (e.g. for dynamic route guidance). Anything that influences operations of vehicles can be added to the model, outside or inside cars.

Threats

Threats
1. Micro-simulations may require a phenomenal amount of input data at a very detailed level. 2. Large range of input parameters and potential modelling issues often require expert advice, developer support and reliance on default values. 3. Fully calibrated and validated micro-simulation models are very (if not prohibitively) time intensive to set-up for large areas. Calibration is usually confined to selection of key input parameters. Validation is usually limited to data collection for key links or regions. 4. Impressive visualisation of results may lead to overconfidence in unreliable data.

Bullet 1: PTV state that although this is true in most cases, micro-simulations will not *necessarily* required a phenomenal amount of input data.

Bullet 2: PTV do not agree with this threat at micro-simulation especially. This holds for all model types, and can better be listed as a weakness.

Bullet 3: Data required for calibration might be hard to get (such as gap acceptance distributions).

Bullet 4: This is true, the modeller should explain the results. If the input for the micro-simulation model is trusted, the outcome should be trusted too (although people tend to focus on outliers (such as a Porsches driving at 200 km/h)).

PTV like to add a threat: the validation of micro-simulation models can be split up into two parts: the macroscopic network results and the microscopic vehicle behaviour. Both should be validated!

Part 2: Traffic model development

Not explicitly discussed, is covered in other parts of the interview

Part 3: Market forecast and expected future practice

In 2010, micro-simulation models will probably look more or less the same. However, they will probably be applied much more. Also, they might be applied to increasing network sizes due to the expected increase in computation power. Furthermore, using certain dynamic traffic management measures in the networks will become available as an option to insert at a certain location (instead of studying the measures themselves as is now often done).

Part 4: Noise related possibilities

Microsimulation models are not used a lot for noise regulation studies nowadays. Most traffic noise forecasts are based on static assignments.

B.9 Peter Sykes - SIAS (Microsimulation)

The following text is based on an interview with Peter Sykes of transport planning consultants SIAS Ltd., conducted on 25th November 2004, and on information contained within the "Paramics 2004 Reference Manual". Within the text Peter has been referred to as 'the Developer'.

Introduction:

Paramics is an advanced traffic microsimulation and analysis suite, with a pedigree dating back to the 1980's. The name Paramics is an acronym derived from *Microscopic Simulation on Parallel Computers*, though versions of the software run acceptably on typical desktop PC platforms. The Paramics software has arisen through collaboration between the software specialists Quadstone and transportation engineers SIAS. Whilst the collaboration between these two partners subsequently ended in the late 90s, both companies maintain their own versions of the software, derived from the same fundamental core. Through agreement, at the time of writing, SIAS controls marketing and sales within the UK, whilst Quadstone distributes to the US market.

SIAS' Paramics has been widely distributed to Local Authorities and consultants in Scotland, England and Wales, with modelled schemes including:

- Considerable portions of the major road network in Scotland have been modelled. This includes the Forth TRIPS area, which spans half of West Lothian, the Edinburgh bypass and half of Fife. The cities of Edinburgh and Aberdeen have also been modelled.
- There are many Paramics models of areas of the UK – SIAS has worked on well over 100 commissions and most consulting companies use Paramics. For example, a Paramics network has been set up for a 15 mile area around the centre of Plymouth. IMAGINE partners Leicester City Council are also using Paramics in conjunction with their own TRIPS network.

In continental Europe, a Dutch consultant has used Paramics to model the road network of Limberg province. Internationally, Paramics has been used in cities from Toronto to Tokyo.

Part 1: Assessment (SWOT) of model type

Strengths:

The developer agreed with the majority of the strengths listed in the analysis, and demonstrated the flexibility of system using a number of case studies.

Strengths

1. Traffic parameters vary, both spatially along road links, and temporally.
2. Modelling at incredibly detailed levels is possible. It is relatively easy to gain vehicle speed and acceleration information, broken down by user class from a micro-simulation. For noise assessment a variety of aggregation procedures could be undertaken, e.g:
    a. Use instantaneous vehicle parameters to calculate emissions, then assign emissions to a section of road.
    b. Use aggregate vehicle parameters for a given road section/time period to produce noise emissions.
3. Modelling of a wide variety of traffic schemes possible.
4. Modelling of short-term transient events (e.g. incidents or in-peak congestion).
5. Micro-simulation packages often include very powerful network editing, visualisation and post-processing tools.

Regarding individual points:

1. The developer agreed that spatial and temporal variation of traffic parameters are readily available at the area, link and node levels of the model. Spatial resolution down to individual link sections in the ten meter length would also be feasible – with the caveat that obviously the volume of data generated would increase. The Paramics suite already contains a very powerful post-processing statistics module, the Data Analysis Tool (DAT), which provides a DataBase Management System (DBMS) which allows for the querying, filtering and spatial selection of results, visualisation of output, calculation of descriptive statistics based on the output of multiple runs, as well as a variety of mathematical operation on data. Datasets may be large (i.e. 100s of MB) but this was felt to be little problem in an age of rapidly increasing storage space.
2. Information on instantaneous parameters for individual vehicles may be obtained directly through the model GUI, or saved in .csv files for later analysis. In the current software version, up to 256 vehicle categories may be used, each linked to an engine model with its own emission factors. Therefore it would not be a great stretch to include an instantaneous sound power model for engine noise. The developer observed that there was a requirement for road surface type description within the model, as there has been no previous demand for such a feature. The developer stated that the facility to input such a feature could be implemented without too much difficulty, as long as there was adequate data to make the feature useful.
3. The developer felt that the modelling of innovative traffic management schemes, such as those that dynamically evolve (e.g. variable speed limits or lane utilisation changes) was a staple feature of microsimulation.
4. As with point 3. the developer agreed that the modelling of transient events was a major strength in microsimulation.
5. The developer felt strongly that advanced visualisation tools were a key element in both ensuring the correct calibration of a model, instilling confidence in modelling results, and “selling” a particular scheme to the general public and relevant authorities. With regards to network editing, Paramics contains an easy-to-use GUI, and the developer felt that a primary method in ensuring quality results was the ability to easily edit road geometry to correctly reflect the real world. As mentioned in point 1. above, Paramics already contains an advanced post-processing system in the DAT.

Weaknesses:

The developer disagreed with a number of the listed weaknesses, stating that a number were probably based on particular situations associated with particular modelling packages, or on scenarios that an experienced, qualified consultant would strive to avoid.

Weaknesses

1. Model accuracy depends on initial assignment of flows – possibly from an independent model.
2. Modelling may take a long time and will involve multiple simulation runs.
3. For accurate geographic mapping and modelling links need to be defined with more precision than is typical in static or DTA models.
4. Stability of models may depend on selection of a particular value of time step (usually 0.5 – 1 second). This may not be appropriate for noise modelling.
5. Selection of different time steps may alter results (e.g. fine time steps of under <0.25 seconds may not significantly alter aggregate parameters, but could the affect the distribution of accelerations produced).
6. Output speeds from micro-simulations often depend on the “desired speeds” set for individual links (tendency for non-following vehicles to remain at the desired speed).
7. Boundary conditions and/or selection of network cordoning affects modelling.
8. Specific algorithms, rules or parameter values used in a given package targeted at one member state may not be transferable to other member states.
9. Micro-level results require aggregation for large-scale and/or GIS use.

Regarding individual points:

1. The developer stated that modelling will always be dependent on the quality of the input data. Using direct traffic counts, spanning many links, over multiple time periods would obviously be preferable to deriving flows from limited O-D matrix/assignment model data. Paramics does contain its own Matrix Estimation (ME) module to derive ODs from existing Paramics matrices, observed data and roadside survey data. As an example the Paramics Edinburgh City centre model meets the UK DMRB (Design Manual for Roads and Bridges) requirement of 95% of flows having a GEH statistic of <5. The model also include the correct flow restrictions and signal plan changes based on time of day.
2. The developer felt that with the ubiquity of computing power this point was becoming irrelevant as batch processes could be run on multiple computer systems, with data collated an analysed from a central system. Paramics already has a Batch Simulation Module (BSM) that allows model operation without GUI/visualisation features, with statistical analysis of results through the DAT module. Depending on the size of the network and traffic volumes, microsimulation models routinely run very much faster than real-time.
3. The developer suggested that the overall data requirements for microsimulation were comparable to static or dynamic models. Geographic data requirements for microsimulation in terms of the position of road kerbs (similar to noise mapping requirements) will be mitigated by model integration with large geographical datasets (e.g. the UK Ordnance Survey’s MasterMap Topographical and Integrated Transport Network layers). Generally the developer felt that DBMS would make the transfer of geographical information into the model far simpler and quicker in the future.
4. The developer acknowledged that microsimulation models were stable with time steps smaller than human reaction time (approx 1 second). A value of 0.5 seconds was suggested as an optimal time step.
5. Experience with model validation has shown that whilst microsimulation may produce acceleration profiles that are somewhat smoothed when compared to real-world monitored profiles, they are comparable. It was therefore felt that in a properly calibrated

and validated model this point was a non-issue. Using aggregate data, minor variations would be lost.

6. The developer suggested that a tendency of a model to produce non-following vehicles at only the desired speed showed either a problem with the particular model used, or a lack of understanding of correct calibration/validation procedures. In Paramics many elements of vehicle behaviour (e.g. desired speed, gap acceptance etc.) are controlled by user defined distributions of driver “aggression” and “awareness” factors – with the default settings allowing vehicles to possibly exceed posted speed limits.
7. The developer felt that this was an irrelevant statement, and an issue that was not confined to microsimulation models. The initial process of studying and defining the correct network area by the consultant should eliminate any such problems. The developer cited one example where incorrect network cordoning lead to a lack of route choice and erroneous results, which were readily identifiable during analysis. Links on the boundary of simulation areas, where vehicles enter and exit the simulation, should be treated with caution as a matter of course.

   Not so much “correct network areas” as an area appropriate to the task you are addressing with the model. Budget comes into this too!

8. The Paramics model already contains a number of default rules categories and driver “aggression” and “awareness” distributions, developed for specific countries. It was felt that this comment should be levelled at traditional assignment models, and wasn’t
9. The developer stated that the consideration of the need for aggregation as a weakness was in contradiction with one of the main strengths of microsimulation, that of being able to work at a fundamentally detailed level.

Opportunities:

Opportunities
1. The running speed and spatial scope of micro-simulations is improving all the time as computing power increases. 2. Variety of traffic schemes that may be modelled is increasing – vibrant research area. 3. Micro-simulation models offer possibly the best method for assessing future ITS and in-vehicle systems. 4. Micro-simulation models have been directly linked to on-street UTC systems such as SCOOT, SCATS or UTOPIA and on-street detector systems. 5. Possibility to add further parameters to the model through additional research, (e.g. time-of-day or weather dependent parameters affecting driving characteristics).

The developer agreed with the opportunities as listed, whilst elaborating on a number of concepts to improve running time and spatial scope of microsimulation models, including the ability to use distributed or parallel computing for very large scale modelling, or particular techniques to remove some of the computation burden for route choice in urban areas. The developer felt that the suggestion of “micro-modelling for micro-areas” was outdated, as already evidenced by the existing number of regional networks available.

One additional feature available in Paramics, at extra computational cost, is the use of driver waypoints to give a more realistic representation of the driver’s route choice, and hence a more accurate model.

On the subject of traffic signal control, the developer stated that Paramics is already capable of modelling Vehicle Actuated (VA) signals, linking to SCATS or SCOOT systems and utilising data from on-street detectors. Feedback loops between SCOOT and Paramics systems have already been achieved.

Looking to the future the developer envisaged a time where hooks would be provided in the code for third parties to supply their own algorithms to the model, for example to define different car following or gap acceptance algorithms. This would be of benefit to the research community and of potential relevance for noise modelling. Initial work is already being done to allow third parties to provide visual basic code to determine how drivers react to VMS signs within the model.

The developer states…

> *"Two facilities are available here – one is an API; tightly coupled to the simulation appropriate for the micro decisions drivers make i.e lane choice car following …. However its tight coupling makes it hard to use. The other is our control interface based on SNMP – loosely coupled and apprpriate for the messages drivers receive from traffic signals VMS signs, broadcasts etc. This was the M42 demo you saw. We can teach a client to use this in 2 days."*

Threats:

Threats
1. Micro-simulations may require a phenomenal amount of input data at a very detailed level.
2. Large range of input parameters and potential modelling issues often require expert advice, developer support and reliance on default values.
3. Fully calibrated and validated micro-simulation models are very (if not prohibitively) time intensive to set-up for large areas. Calibration is usually confined to selection of key input parameters. Validation is usually limited to data collection for key links or regions.
4. Impressive visualisation of results may lead to overconfidence in unreliable data.

The developer agreed with one of the stated threats, whilst disagreeing with the others. Specifically:

1. The developer felt that this statement was incorrect, and that input requirements were not that different from traditional traffic assignment models. The use of the word "phenomenal" was too strong. Again the statement that the quality of all modelling is dependent on the quality of input was made.
2. The developer envisaged microsimulation package becoming more user-friendly in the future, with online advice, assistance and "wizards" being directly available to an operator to aid the setup of network geometry, and to advise on default parameter values. The developer suggested that the threat statement was based on an old fashioned mentality.
3. The developer strongly suggested that the use of good visualisation tools greatly mitigated the problem of network calibration in microsimulation models, making it easy for a trained traffic engineer to identify and remedy problem areas (e.g. those exhibiting excess queuing). As a first course of action, manipulation of link geometry, stopline positions, queuing locations and turning points may be done directly through the GUI, to alter junction capacities, before the need to change underlying model parameter values is ever explored. Given the expanding scope of models, focus has shifted from such micro-calibration and validation, on to calibration of regional "level of service" parameters. Alternately, journey time along selected routes could be used for calibration purposes.
4. The developer agreed that it was possible to convince people in unreliable data through impressive visualisations, though felt that it was more probable that such visualisations

would allow the rapid identification of potential problems and inspire confidence in actual results.

Part 2: Traffic model development

During the course of the interview, the developer raised a number of issues with regard to microsimulation in general, as well as commenting on the structure of the IMAGINE approach to segregating traffic models into four categories.

The developer felt that cellular transmission models should be treated as a separate, distinct category from microsimulation, which considers the driver-vehicle combination as the fundamental unit within the simulation.

Part 3: Market forecast and expected future practice

The developer strongly posed the argument that in the future it will become easier for end users to set-up and maintain microsimulation models, with software providing more intuitive feedback and assistance. Development will parallel general development of the technology industry. Technologies start as the preserve of the experts, but develop to being readily accessible, with knowledge of intricate details not being required.

Larger networks will be developed as microsimulation models adapt to use client-server architectures, batch operations or grid computing. (The example of the successful SETI-at-home software, which processes work units downloaded by general Internet users PCs as part of a larger effort) was given as one possible approach to allow multiple runs and sensitivity testing for future microsimulation models).

Part 4: Noise related possibilities

The developer felt that the required levels of accuracy in terms of vehicle flow and speed for noise modelling were achievable, provided that input data was available of sufficient resolution and quality.

The developer felt that a noise model, such as the suggested HARMONOISE vehicle source model, could be readily integrated into the simulation software at either the individual vehicle level, or at a more aggregate sub-link/link/node level, providing adequate advice on aggregation methods and implementation were given from projects such as IMAGINE. Alternately, output .csv files from Paramics could be used directly by any third party program to calculate emissions in any way deemed suitable.

It was noted that the Paramics suite already contains a pollution module that allows output of pollution levels at a link or node level, as well as providing output and visualisations of pollutants across a grid through a limited dispersion model. The developer suggested that, whilst it was understood that the summation of noise levels was logarithmic in nature, the possibility existed to potentially utilise existing functionality in noise modelling (see end).

The general concept of a “button” to transfer data direct from the Data Analysis Tool of Paramics to any future noise emission/propagation model was perfectly feasible. However, development of such a feature in the DAT would more than likely be driven by funding being available through a specific project. Whilst SIAS does maintain strategic goals for the Paramics software as a whole, day-to-day development tends to be driven by the needs, desires and feedback of individual users and from specific projects. Incremental software updates are released perhaps once or twice per year.

A demonstration of the Paramics DAT module was also made, showing the output of air pollutant emission levels directly from a cordoned area of a network. A reduced screenshot of the operation is given below (Figure 16):

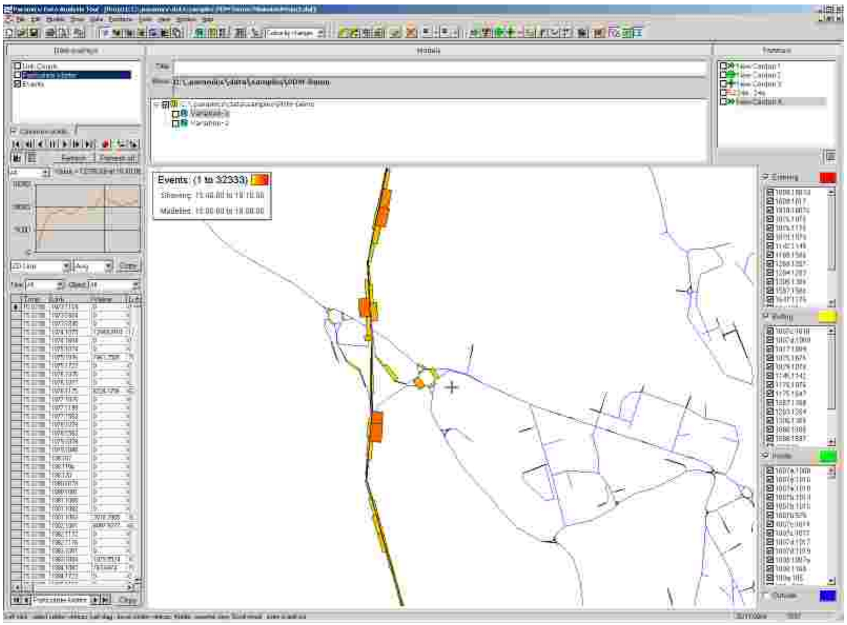


Figure 16 Screenshot of Paramics DAT module showing link based pollution emissions output

B.10 Jaime Barceló (Microsimulation)

Interview with **Jaime Barceló** (Professor at the Technical University of Barcelona, model developer at Transport Simulation Systems (TSS))

This interview was carried out as part of the Interactive traffic model developer workshop.
Date: October 21, 2004
Location: ITS Congress, Nagoya, Japan.

General notes

- Jaime is a developer and a user of AIMSUN
- TSS is the company that develops and markets AIMSUN
- AIMSUN has over 350 licensees all over the world. Jaime estimates that there are 1000-2000 users (many licenses are for multiple users). AIMSUN has an estimated 25-30% of the market share. Other major models are Paramics and VISSIM.
- Licenses:
  - 60-65% professional consultancies
  - 20-25% governmental / administrative agencies, municipalities (large cities like Stockholm, Barcelona, but also smaller cities like Sheffield, Leeds, Florence, Perugia, The Hague agglomeration), and some national agencies or large regions
  - rest universities and research institutes

Part 1: Assessment (SWOT) of model type

Jaime basically agrees with the SWOT except for some items in the weaknesses and threats.

Strengths and opportunities

Jaime agrees with the strengths and opportunities given below, *and adds a strength*.

Strengths

1. Traffic parameters vary, both spatially along road links, and temporally.
2. Modelling at incredibly detailed levels is possible. It is relatively easy to gain vehicle speed and acceleration information, broken down by user class from a micro-simulation. For noise assessment a variety of aggregation procedures could be undertaken, e.g:
   a. Use instantaneous vehicle parameters to calculate emissions, then assign emissions to a section of road.
   b. Use aggregate vehicle parameters for a given road section/time period to produce noise emissions.
3. Modelling of a wide variety of traffic schemes possible.
4. Modelling of short-term transient events (e.g. incidents or in-peak congestion).
5. Micro-simulation packages often include very powerful network editing, visualisation and post-processing tools.
6. *The powerful visualisation tools can help in the calibration and validation process*

Jaime adds a line to bullet 1 and has added TUC to the on-street UTC systems:

Opportunities

1. The running speed and spatial scope of micro-simulations is improving all the time as computing power increases, *and software engineering and data structures become more efficient.*
2. Variety of traffic schemes that may be modelled is increasing – vibrant research area.
3. Micro-simulation models offer possibly the best method for assessing future ITS and in-vehicle systems.
4. Micro-simulation models have been directly linked to on-street UTC systems such as *TUC*, SCOOT, SCATS or UTOPIA and on-street detector systems.
5. Possibility to add further parameters to the model through additional research, (e.g. time-of-day or weather dependent parameters affecting driving characteristics).

Weaknesses

There are some weaknesses that Jaime (strongly) disagrees with (see below for weaknesses and Jaime's remarks).

Weaknesses

1. Model accuracy depends on initial assignment of flows – possibly from an independent model.
2. Modelling may take a long time and will involve multiple simulation runs.
3. For accurate geographic mapping and modelling links need to be defined with more precision than is typical in static or DTA models.
4. Stability of models may depend on selection of a particular value of time step (usually 0.5 – 1 second). This may not be appropriate for noise modelling.
5. Selection of different time steps may alter results (e.g. fine time steps of under <0.25 seconds may not significantly alter aggregate parameters, but could the affect the distribution of accelerations produced).
6. Output speeds from micro-simulations often depend on the "desired speeds" set for individual links (tendency for non-following vehicles to remain at the desired speed).
7. Boundary conditions and/or selection of network cordoning affects modelling.
8. Specific algorithms, rules or parameter values used in a given package targeted at one member state may not be transferable to other member states.
9. Micro-level results require aggregation for large-scale and/or GIS use.

Remarks:

- Some weaknesses are no longer true in Jaime's opinion:
  - bullet 1 & 2 are in some ways contradictory
  - bullet 1 is true for other models too, so this is a general weakness of traffic models – "garbage in = garbage out". The accuracy of input data, especially for route based models, and the OD matrices are the weak points of micro-simulation models.
  - It is not the modelling that takes a long time – building the model takes a long time and the stochastic nature of the models means multiple runs are needed but this true for all simulation models and does not have to be considered a weakness. All modellers have to deal with the trade-off between complexity and how realistic the results can be.
- Bullet 3: Jaime has seen a lot of improvement in the past few years (and expects more improvement in the coming years) in user interfaces. This will make building the model easier and quicker.
- Jaime strongly disagrees with bullets 5, 6 and 7: calibration means to find which values of the parameters are suitable in the particular situation, in order to get, for instance, flows that are close enough to reality; calibration and validation are always context dependent! It is therefore natural (and in Jaime's opinion not a weakness) that modelling is affected by varying time steps, desired speeds and boundary conditions, but the role of calibration and validation is precisely to ensure that the selection of a particular model is the right one. With

regard to bullet 8: again, it is the values of the parameters that can be different for different countries – the same underlying mechanisms and thus parameters apply.
- Jaime does recognise that the availability of data for calibration is still often a problem.
- Regarding bullet 9: this is true but this is made easier by using API's (application program interface). Bullet 9 can in fact also be seen as a strength! Again it comes down to the trade-off between complexity and how realistic the output can be.

Threats

There are also some threats that Jaime disagrees with (see below for threats and Jaime's remarks).

Threats
1. Micro-simulations may require a phenomenal amount of input data at a very detailed level.
2. Large range of input parameters and potential modelling issues often require expert advice, developer support and reliance on default values.
3. Fully calibrated and validated micro-simulation models are very (if not prohibitively) time intensive to set-up for large areas. Calibration is usually confined to selection of key input parameters. Validation is usually limited to data collection for key links or regions.
4. Impressive visualisation of results may lead to overconfidence in unreliable data.

Remarks
- Bullet 1: Jaime finds 'phenomenal' too strong a word. It would be more appropriate to use 'data-intensive'. But tools and methods for data processing are becoming better and easier to use. According to Jaime, even if it is not yet widespread, the trend is that authorities are going to use more sophisticated instruments. Data fusion is an important item, needed to generate useful sets of data from the many sources of data. These data can be used for micro-simulation models as well as for numerous other purposes. This makes micro-simulation viable. Jaime is of the opinion that we are still far from the ideal situation but things are going better all the time.
- Bullet 3: in Jaime's eyes, this is no longer correct: calibration and validation are a function of availability of data and the size of the area. So 'prohibitively' does not seem to apply any longer.
- Bullet 4: misuse of a model is always possible!

<u>Part 2: Traffic model development</u>

Many projects are carried out annually with AIMSUN and TSS regularly receives feedback on the model:
- concerning the accuracy of the internal model, and
- concerning the usability:
  - building and manipulation of models (much progress in the past years, still going on: data exchange is becoming much easier, model building will become easier)
  - validation, calibration, conducting experiments (Jaime notes that (semi)automatic calibration is not easy and is not ready for use yet, but there is much improvement in helping users calibrate and validate the model, which is still the biggest task)

In Jaime's opinion, all developers work along similar lines.

The use of micro-simulation is increasing (growth rate not slowing down yet) and improvements will continue to be made in the coming years.

Problems that cities have: budget and technical personnel. Jaime's personal perception is that most agencies subcontract the building of models to consultants. Cities interested in noise maps will probably contract consultants to build the model. He expects more and more consultants will use micro-simulation.

Modelling technique:
As well as other improvements already mentioned, the modelling techniques (e.g. car following model, route assignment) also improves. This is reflected, for instance, by the number of papers dealing with micro-simulation (core models) at the 2005 TRB conference. Also, in the USA, the FHWA are running a programme called NGSIM ('next generation of simulation models').

The increased use of micro-simulation models also ensures (future) improvements in all areas.

Measures
Regarding measures: micro-simulation is, by itself, not suitable for modelling all types of measures - as are none of the other model types. The solution is not to develop a single model that can do everything (attempts to do this, e.g. TRANS/MS, have failed). The trend is to combine different model types (because traffic modelling questions are getting more detailed). The next generation of AIMSUN incorporates, for instance, macroscopic modelling.
To the question whether in the future studies will include more sensitivity analyses (as one single answer is always wrong), Jaime answers that he does see this happen more and more.

Input
Regarding input, two aspects can be mentioned:
1. What is the use of the model, and what data is therefore needed?
2. Is data available?

Micro-simulation models have traditionally been used for congestion analysis. This means that simulations are usually carried out for peak periods and OD matrices are available for those periods only. But OD matrices for the different periods can be obtained from the same data on which the peak period matrices are based (household travel surveys) and resulting traffic flows can be matched to traffic counts that in many cases are also available for other periods than the peak period only. In Jaime's opinion, if the customers start asking for this, the consultants will soon (learn to) do this. Current trends support this: cities are implementing more and more traffic management systems so more data will be available.

<u>Part 3: Market forecast and expected future practice</u>

See general remarks (in summary: micro-simulation will be used more in the future, by consultants as well as authorities).

<u>Part 4: Noise related possibilities</u>

Jaime knows of a firm in New Zealand that has developed an environmental model (for emission of pollutants) for use with AIMSUN. He is not aware of any noise models that were developed for use with AIMSUN. But a noise model can be connected with AIMSUN in the same way as other models are connected. There is already a 3-D environment for AIMSUN that could be useful.