

ROAD STANDARD

TRAFFIC ENGINEERING

USE OF MICRO- SIMULATION MODELS

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Danish Road Standard Committee

 Vejdirektoratet

FOREWORD

In 2007, the Road Standard Group for geometric design of roads and paths in open land established an ad hoc group to examine the basis for calculations using microsimulation. The ad hoc group was given the following terms of reference:

As a result of the widespread use of microsimulation models, an assessment is required of how these models deal with the basic situations in traffic flows, as described by the road standard proposal for capacity and service level, and how the parameters provided for in the road standard proposal are reflected by microsimulation. The ad hoc group is to prepare draft recommendations for the use of microsimulation models, taking into account the general implementation of simulation tasks and the calibration and parameter setting of models.

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The ad hoc group commenced work in November 2007. A literature study was carried out, the group's own knowledge and experience were presented and results of model testing conducted by the group members were included.

For reasons of time and resource consumption, it has been necessary to limit the booklet to include the current contents. Of course, a more detailed model description and discussion of parameter setting would be welcome, but this would require further tests, traffic measurements, etc. Hopefully, there will be a later opportunity to look into areas, if the use of the booklet shows a need for this. Furthermore, as microsimulation model tools continue to be developed and use and knowledge of them increase, it must be assumed that the road standard will need updating in future.

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1. INTRODUCTION

1.1 Background



Fig. 1.1. Microsimulation of traffic is a representation of real road networks and traffic flow in a detailed model.

Microsimulation illustrates the existing or planned reality in a detailed model. Microsimulation models of traffic includes the individual road network sections and intersections, traffic regulations and rules, as well as the individual road users with accurate positioning, properties, status, etc.

Since 2002, microsimulation has been a rapidly growing way to analyse traffic flow. However, so far, road standards concerned with calculation of capacity and service level have assumed that the model type used is at traffic flow level, also known as a macroscopic model.

Microsimulation tools used in Denmark have almost always been developed in other countries and therefore typically have inherent sub-models and parameters, which reflect experimental and measurement results made in the country of origin. This is one of the reasons why a particular need exists to take a critical approach to the original default setting of the tool models and parameters. It is also necessary to assess how analyses with microsimulation models are generally implemented from the commencement of a task to its completion. However, time and resources are often insufficient for such considerations in the day-to-day solution of tasks.

For this reason, the Road Standard Group for geometric design of roads and paths in open land assessed that a need exists for a described basis for using microsimulation models. Such basis would also allow for better documentation of the solution of tasks using this type of models, and this way, it will be possible for the requester to know the basis of solutions and recommendations.

1.2 Contents of this booklet

This booklet contains a Road Standard Proposal for the use of microsimulation models. This includes a general guideline on the use of microsimulation models for the analysis of road traffic, as well as more detailed instructions for calibration and parameter setting of microsimulation models.

A proposal for a reading guide has been inserted in section 1.5.

The guidelines in this booklet all have status as guides recommended to be followed.

The Road Standard Proposal attempts to clarify a number of important parameters in microsimulation models and establish links between the parameters used in microsimulation models and the fundamental parameters, which have been estimated for use in the traditional capacity models. Furthermore, a number of recommendations are made about the actual process of solving tasks when it is considered to use a microsimulation model in connection with traffic technical tasks.

The present version of the booklet focuses on simulation of motor traffic and not for example on pedestrian and bicycle traffic nor conditions in bus terminals, toll booths or similar.

It should be noted that although the ad-hoc group's task has been to consider microsimulation models in general, it has been impossible to avoid for the microsimulation models to bear the characteristics of one simulation tool, Vissim from the German company PTV AG. In recent years, this model tool has been almost the only tool used among consultants and road committees in Denmark, and Denmark therefore mainly has experience of Vissim-based models. This also applies to members of the ad hoc group. As long as the situation with Vissim as the dominant micromodel tool prevails, it is estimated, however, that the usefulness of the Road Standard Proposal increases by having strong references to Vissim.

1.3 Relation to other road standards

The booklet relates to the Road Standard Proposal for capacity and service level. This Road Standard contains proposals for parameters for capacity calculation and calculation of service level, and it is to a large extent based on research and studies of traffic in Denmark. As mentioned in section 1.1, it has, however, been assumed that the analysis is macroscopic, i.e. at traffic flow level, and it is on this basis that the use of model and parameters for the calculation of free sections and intersection is recommended in the previous Road Standard.

1.4 Purpose

In short, the purpose of this Road Standard is to contribute to successful implementation of analyses, using the microsimulation models. This means

that the requester received the best possible advice according to its needs and resources and that the model maker has solved the task in a rational manner.

The Road Standard provides both more general operational guidelines and more detailed guidelines for calibration, validation and parameter setting. This way, the Road Standard is to help the model maker and at the same time provide a basis for better clarification between the model maker and the requester. The Road Standard also aims to make it easier to ensure high quality and document a model that is used for a simulation task.

The target group of the Road Standard is therefore both the requester (such as the project manager or the person in charge of tasks in a road committee) and a contractor or model maker (e.g. consultant or specialist in a consultancy firm), but the more specific and model technical sections are, of course, targeted primarily at contractors.

However, the Road Standard can in no way replace the need for the developer of a microsimulation model having substantial technical knowledge about traffic and that such person also holds a theoretical and practical understanding of the situation to be modelled.

1.5 Reading guide

As mentioned, this Road Standard is targeted at both the requester, who wants clarification of a traffic situation in connection with a project, and the contractor, who provides advice on the use of the model, structures the model and conducts the necessary analyses using the model. The requester will typically need general information about problem solving by means of simulation models to be able to engage in a better dialogue on the solution of the task and to be able to interpret results better. On the other hand, the contractor may need relatively specific information about calibration and parameter setting in a model.

The part of the Road Standard specifically targeted at the contractor particularly bears the characteristics of the Vissim simulation tool. As mentioned, the aim has been to provide specific information about parameters, etc. However, the part of the Road Standard targeted at the requester is almost independent of the microsimulation tool used.

Requester

For the requester, special reference is made to chapters 2 and 3. Chapter 2 sets out the microsimulation models, model use and the overall procedure for solving tasks by means of microsimulation. Chapter 3 describes the traffic flow analysis process using microsimulation in more detail. In addition, the requester is recommended to read chapter 4, including Annex 7, on the control of simulation tasks.

Chapters 5 and 6 on calibration and parameter setting will not normally be of interest to the requester, but the initial sections of the chapters may be read.

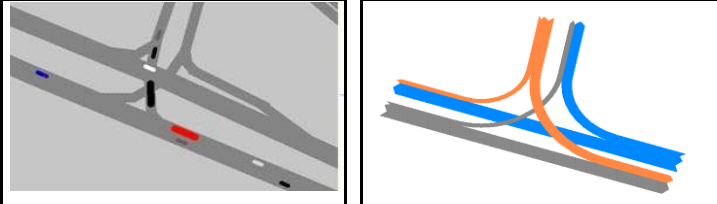
Contractor	For the contractor, the contents of chapter 2 and most of chapter 3 will most likely be familiar material. Contractors are recommended, however, to read and relate to the proposed control procedure in chapter 4 and Annex 7. Chapter 5 provides guidelines for calibration, and chapter 6 for setting of parameter values, and these chapters are particularly targeted at contractors.
Nomenclature	With regard to the terminology used, please refer to the list of nomenclature in Annex 1.

2. MICROSIMULATION

2.1 Model

Micro-/macroscopic analysis

When the traditional macroscopic capacity models are used for traffic flow, entire traffic flows are considered together, and both input and output in the model apply to traffic flows as a whole. Microsimulation, however, simulates the movement of the individual road users through a road network. Vehicles, including the driver, can be distinguished by means of the physical and technical differences of the vehicles (e.g. length, maximum speed, acceleration properties), characteristics of the drivers (e.g. driving style, acceleration and desired speed) and where in the network the vehicles currently are, their route in the road network and their individual speed. Important characteristics of micro- and macroscopic analyses of traffic flow on road sections are shown in figure 2.1.



Traffic data:	Microscopic analysis:	Macroscopic analysis:
Traffic flow	Time intervals between cars in seconds	Traffic intensity, cars per hour
Speed	Individual speeds	Average speeds
Density	Individual distances between cars in meters	Density, cars per lane-km

Fig. 2.1. Characteristics of micro- and macroscopic models for traffic flow analysis.

The microscopic models illustrate the movement of individual vehicles in a traffic flow in the form of their individual speeds and distances to other vehicles. The macroscopic models characterise a traffic flow as the traffic intensity in a calculation period, e.g. a peak hour, and at a free section a common average speed and traffic density for the calculation period. The result of the macro-models is normally available in the form of lists of mean values for the calculation period. The micro-models can usually also visualise traffic situations and calculate a number of other statistical values of selected variables.

Car-following

A central part of a microsimulation model is a sub-model for *car-following*, which is a behavioural model to control the movement of the vehicle in relation to other vehicles, e.g. for speed, acceleration, braking and distance to the front vehicle. In addition, there is built-in logic to select and change lane and a behavioural model based on critical interval (in Vissim known as gap time) to control how individual vehicles weave with or cross the general traffic flow. In addition, models typically exist to control traffic light signal systems, such as time- or traffic-controlled systems. Furthermore, a microsimulation model includes the possibility of flexible selection and collection of data for analysis, e.g. for driving times, queue lengths, average speeds and delays, for which both mean value and variation can be calculated.

Stochastic model

Microsimulation models are almost always stochastic models, i.e. the model has a built-in generator to extract random numbers, the probability of which follows the probability distribution, which have been entered in the model. The outcome of repeated calculations with the same model and the same input therefore varies, if the start figure used by the random number generator varies. This actually corresponds very well to the reality of traffic with its random day-to-day differences. To gain insight into an average or typical situation, it is therefore necessary to repeat a simulation a number of times with different sequences of random numbers, and furthermore observations should be obtained for the real traffic for several days of traffic in order to form a general picture of speed, delay and queues at the specific place.

In contrast, macroscopic models are almost always deterministic. Such a model is characterised by the fact that all calculations are determined on the basis of the initial conditions and the models and correlations entered in the system, and a calculation using the same input will always generate the same result, usually the mean value for the variable analysed.

In particular, the stochastic models make it possible to create highly comprehensive and detailed models. It is therefore often possible to analyse the interaction between traffic flows in different traffic systems (intersections, sections) on different partial sections and between different road users. In addition, signal programs in traffic-controlled signal systems and the related detector locations are simulated very realistically.

Finally, stochastic micromodels usually make it possible to visualise the traffic flow. This allows the model maker to control the operation of the model to some extent, and the recipient of the results will be in a better position to consider the analysed situation. This way, an analysis may for example be adjusted in the process and be better targeted at the issue to be assessed.

2.2 Opportunities and problems relating to microsimulation

Use

Traffic microsimulation is used for detailed analysis of traffic flow on road sections and in intersections or for analysis of conditions not normally included in the macroscopic models. This particularly applies in connection with calculation of the impact of traffic flow in one road system (partial section, intersection) on the traffic flow in surrounding parts of the road network to be able to make an overall analysis of a defined road network;

- study of signal programs and detector location in signal-controlled intersections with traffic management;
- analysis of road and traffic conditions which are not part of the macroscopic modelling tools available;
- study of the consequences of varying traffic influx during the peak period considered;
- need for knowledge of the entire distribution of the results for certain elements (quantiles in the distribution of e.g. travel time, queue lengths, average speeds) and not only of mean values;
- need for visualisation of traffic flow;

- analysis of congested situations where macroscopic models often do not give reliable results, and where it will also often be appropriate with more information than just mean values, which are normal the only type of result generated by macroscopic models.

A large detail also includes many parameters, and many data are required in the model, especially when large microsimulation models are to be created. It therefore usually requires much more work to conduct an analysis with a microsimulation model than with a macromodel. However, microsimulation makes it possible to choose a large or small degree of detail depending on the current task, and this way, resources can to some extent be adjusted to the task.

Credibility of result

A microsimulation model can therefore be very useful to solve tasks concerning traffic flow, but in order for the results to be credible the model structure and calibration must be in place. Input for traffic must also to a sufficient degree correspond to the situation to be analysed. If any of these conditions are not met, the simulation will generate inaccurate or erroneous results and might contribute to the wrong decisions.

The many options in the form of the choice of parameter values and their often complex effect in different sub-models may constitute a problem in the development of microsimulation models. The problem may also be that the modelling tools do not always receive sufficient documentation of the incoming models, procedures and parameters. Experience is therefore required to set up and calibrate models that reflect the desired situation sufficiently well. It should for example be ensured that the model generates the correct maximum traffic through a bottleneck, that weaving of traffic flows is realistic, that queues and delays in intersection approaches are correct in relation to the load of the intersection and that traffic speed on a section depends on traffic intensity in the same way as in reality.

The forecast for the traffic to be included in an analysis may also involve a great degree of uncertainty. This should be taken into consideration when results of the model are interpreted and when solving a task.

The problem with setting the model is smaller in a macromodel such as DanKap, where the setting options are considerably fewer and normally more transparent. It is important to note that the macroscopic models will only generate correct results, if their parameters are set to reflect traffic and road on the site of the analysis. The Road Standard parameter set in DanKap could therefore probably be considered as indicative of "normal Danish conditions", and if you are uncertain as to whether these parameters apply to current conditions in an analysis, a critical assessment must be made of the parameters and calibration and validation must be performed.

Section 3.1 includes a list of conditions for a particular task that would favour the use of micro- versus macroscopic analysis.

2.3 Definition of parameter and variable

Parameters A microsimulation model consists of sub-models, each of which uses a number of *parameters*. The parameters may for example control:

- Road user behaviour, e.g. duty to give way, desired speed, desired acceleration, desired deceleration, distance to the front vehicle and change of lane;
- Vehicle characteristics, e.g. acceleration and braking performance, dimensions, weight/power ratio of lorries;
- Special parameters in connection with the operation of simulations, e.g. time step, start value for random numbers, the number of repetitions made for each situation.

The parameters can be considered relatively fixed data, however, to a varying degree. Some parameters should be reviewed for each project, others are more general and some parameters should actually not be changed from the model tool default setting, unless you have very thorough knowledge of the operation of the model.

Variables In this Road Standard, the data which are very specific to a project or which are typically changed in connection with the project, e.g. traffic intensity and signal times, will be referred to as *variables*.

2.4 Procedure for solving tasks

A traffic analysis task will normally be solved according to a process as described below and shown in a simplified form in figure 2.2.

A task is typically initiated when the requester (e.g. a project manager in a road committee) needs to know the traffic flow of future traffic and/or at a scheduled road construction. The requester draws up a proposal for the task and specifies the need for results, as well as the data and resources that might be included in solving the task. The proposal is presented to the contractor (e.g. a specialist in consultancy firm), who assesses the proposal and provides advice with respect to the way of solving the task.

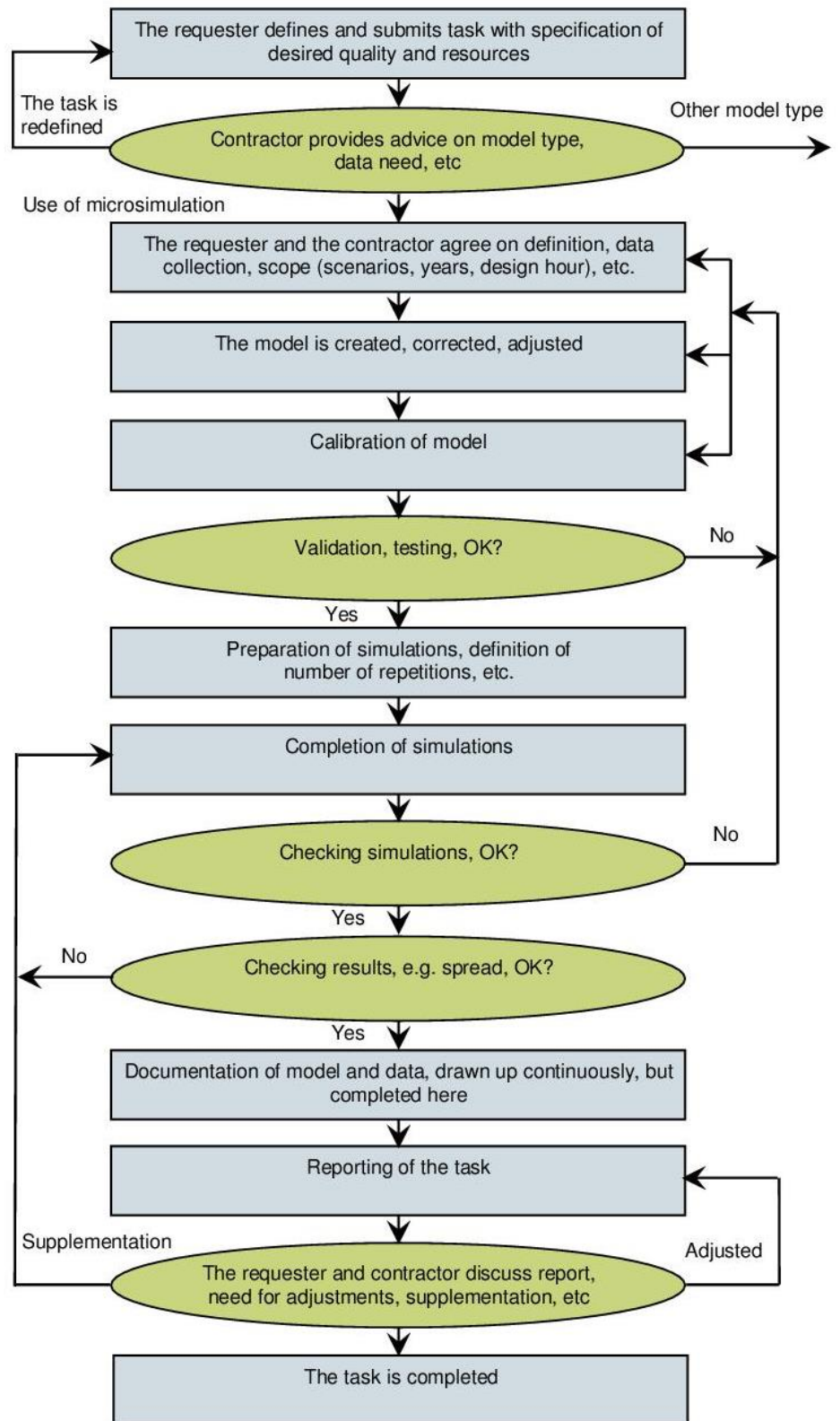


Fig. 2.2. Typical process for completion of traffic simulation task. * indicates various loopback options in the process depending on the outcome of the test or check.

The result of the initial advice may be that the task is most appropriately solved by means of a microsimulation model. A second option is that the contractor states a different model, such as a macroscopic model, or considers that the task type, need for results and the allocated resources do not match, and that the task should therefore be redefined.

If it is decided to create and use a microsimulation model, the requester and contractor must initially agree on the basis for the model and its use, e.g. by agreeing on the geographical limits of the model, the need for data and the extent of calculations in the form of scenarios, the year and hours of the year, for which the calculations are made. When this is resolved, the contractor can start creating the model based on the model tool, e.g. Vissim.

The completed model must undergo calibration with a view to adjusting individual model parameters in the best possible way. Then the calibrated model is tested and validated and is then tested on a real situation.

As can be seen from figure 2.2, an unsatisfactory outcome of validation and testing will result in renewed recalibration or a step further back in the process with model recreation or collection of required, additional data.

In theory, there is a risk that a given situation cannot be illustrated with the chosen microsimulation model. This will show if the model can not be calibrated properly, or if the calibration cannot make the model generally applicable within the task definition. The consequence would be erroneous results of the simulation of some of the situations covered by the task. It can then be concluded that the model is not able to illustrate the desired traffic situations and their interaction. In some cases, it is possible to revise the model with the microsimulation tool, but in rare cases, it can be concluded that the tool is not suitable for the particular type of task.

A satisfactory test and validation mean that the contractor can prepare for and perform the actual simulation of the situations described in the task specification. This includes an assessment or calculation of the number of required repetitions of the simulation. The simulations must be checked, and should results or situations occur which, despite the calibrated and validated model, are suspected to be erroneous or too inaccurate, the cause must be found. It may therefore be necessary to go back further in the process and revise the model or calibration, see fig 2.2.

As the last part of the process, the contractor draws up a report for the task. The report is the product delivered to the requester, and the report must therefore accurately describe conditions, delimitations, the traffic included and all relevant results. The model must also be documented for possible future use, use of results and to indicate the basis of the task as agreed by the requester and contractor. The documentation should normally be drawn up on an ongoing basis and be collected at last.

The task is completed when the report is presented to the requester.

2.5 Elements in the microsimulation model structure

The actual creation of a microsimulation model will typically include the following elements:

- a. Establishment of overall simulation parameters, including the start for the time specified during the simulation, the duration of each repetition in seconds, calculation interval for updating positions, etc.

- b. Loading of the individual vehicle characteristics, including the distribution of desired speed, type designation, etc.
- c. Establishment of traffic composition in terms of vehicle types.
- d. Loading of base map or orthophoto, and an accurate scale, i.e. the relationship between a distance in the model in the base map or orthophoto and the corresponding real distance.
- e. Determination and plotting of partial sections and the links between partial sections where it should be possible for traffic to drive (in Vissim "links" and "connectors").
- f. Static assignment: Entering of mean traffic intensity on sections at the model external boundaries, traffic intensity for light traffic, as well as the shares of turning/straight ahead traffic of total traffic at intersections. Dynamic assignment: Determination of routes for traffic based on the setup of OD matrices.
- g. Entering of duty to give way with identification of priorities, the location of the duty to give way and reduced speed as a result of the geometry.
- h. Signal control with time or traffic control, signal groups, possible detectors, duty to give way of turning traffic, etc.
- i. Determination of results collection (e.g. determine the sections for speed measurements, partial sections where travel times are measured or sections where the number of cars in queue is counted), settings for output, etc.
- j. Completion of the simulation.
- k. Control of simulation and results.

2.6 Model results

Generally, microsimulation models provide great flexibility in the creation of output. This applies to both choice of result variables in the form of e.g. travel times and queue lengths, and in choice of statistical processing, e.g. in the form of mean value, dispersion, median and the other quantiles in the distribution of a variable that can be extracted from the model.

Examples of choice of output are average speeds at user-defined locations, travel times between two user-defined points, queue lengths in selected approach roads, delays, traffic intensity at a specific place at different time intervals.

The model collects data, which can be post-processed in another tool, such as a spreadsheet. Results from the repetitions of the model can be collected here, and statistical analysis can be carried out.

However, it is important to be aware of special conditions which are linked to the results from a microsimulation model compared to the traditional macroscopic capacity models. As an example, the microsimulation model does not directly calculate capacity and load factor for sections and intersection approaches. However, microsimulation models are generally strong and flexible when it comes to calculation of travel time, delay and queue length. Please refer to section 3.9 for interpretation of results.

3. PERFORMING MICROSIMULATION ANALYSIS

3.1 Selecting model type

In the planning of a task, the requester and contractor must agree on objectives, resources and approach. One of the first things to be considered is what model type would be most appropriate to use.

<u>Microsimulation should typically be considered when:</u>	<u>Macroscopic model, when:</u>
<ul style="list-style-type: none">– multiple sections or inter-sections should be evaluated together– there is full clarity of the road design– a section or intersection has a special design– good and detailed traffic data are available– flexibility is needed to be able to select result variable or statistical processing– a detailed assessment is needed of detector location and signal program in traffic-controlled signal systems– a special need exists to analyse traffic flow under congested conditions	<ul style="list-style-type: none">– an isolated road section or an isolated intersection is to be evaluated– only a draft of the road has been drawn up– the road section or intersection is designed in the traditional way– traffic is available in the form of aggregate data and/or rough estimates– only results, such as average speed, average delay or load factor, are needed– a "first estimate" or rapid response is requested.

The outcome of these considerations and an assessment of which of these points are most important should be taken into account when deciding whether a microsimulation model is in fact the most appropriate model to use to solve the task, or whether the task may just as well – and in any case, faster and cheaper – be solved by using a macromodel based on e.g. DanKap. Initially, calculations could be made using a macroscopic model (DanKap) to obtain an estimate of the extent of the traffic problems and where and when the traffic problems particularly occur. Such calculations might be able to uncover the need for using microsimulation and target the work to the critical points.

3.2 Need for observations and data for real traffic flow

Large or small parts of the basis for input of traffic data in the simulation may be based on observations e.g. in the form of observed turn-flows at intersections that are projected for a future year, or data for e.g. the share of daily peak hours of the annual daily traffic, established directional distribution, measured variation of traffic intensity during a peak hour, etc.



The extent to which existing data can be used depends on the specific task. If for instance the task concerns reconstruction of an existing intersection and no other changes are assessed to occur in the road network and environment, the current traffic might be a good starting point for the determination of the traffic in the model, possibly in the form of projected

volumes of the individual turn flows during the design hour.

Conversely, if the task concerns a project in a road network, which does not yet exist, or if any future changes to the road network and the environment significantly affect traffic flow, then useful traffic data cannot immediately be obtained. In such cases, the basis for determining the amount of traffic is often the estimated annual day traffic or weekday traffic which should then be broken down to traffic for a short time interval, e.g. a peak hour, on which basis the project will be assessed. The task is typically to estimate the directional distribution for the relevant peak hour and to estimate the share of the peak hour of annual day traffic or weekday traffic.

Design hour

The design of roads is usually based on traffic loads during 30th or 100th highest hour of the year, but it is possible to choose to use other design hours. The Road Standard Proposal for capacity and service level and the guidelines of the Danish Road Directorate for traffic flow counts contain guidelines on how aggregate traffic figures can be used to provide traffic data for use in models for the design of road facilities seen from a capacity perspective.

Data for calibration

Observations and data from real traffic are also used to calibrate and validate microsimulation model. The data to be used for calibration and validation are discussed in sections 3.6 and 3.7 and will be studied in more detail in section 5.2.

Data for calibration and validation should as far as possible represent the road, which the model must reflect. However, this may be infeasible, because models are often used to analyse planned and non-existing road facilities. In many cases, it is therefore necessary to calibrate and validate the model solely on the basis of data from other comparable road facilities. In such cases, it may be possible to base the models on parameters known to be suitable for similar cases.

Traffic variation

It should be pointed out that the real and observable traffic is characterised by both systematic and random variations. The systematic variations are the recognised trends for e.g. traffic variation over the weeks of the year, over the hours of the day and within a peak hour where traffic increases, culminating in e.g. a 5- or 15-minute interval, and then decreases.

Also the weather impact on motor and engine and bicycle traffic and the effect of major events on traffic may be characterised as systematic changes in traffic volume. In the collection of traffic data, it is important to avoid situations where traffic differs systematically from the normal level or from the situation focused on.

If intersection or section counts are used, the periods during which traffic was counted should be assessed according to the normal distribution of traffic over a week and a year. The aim is to avoid accidental use of traffic figures, representing e.g. a period of the year with particularly little traffic. The procedure is for knowledge about traffic distribution to be obtained over weeks and years, typically in the form of adjustment factors as available in "Guide to traffic flow counts" and in "Road Standard Proposal for capacity and service level" (see chapter 7, references 2 and 3) for weekly weekdays. Then the adjustment factors can be used to correct the counts so as to represent the desired traffic load.

The random variations are day-to-day variations that cannot readily be explained. The random variations in traffic can only be taken into account if repeated observations are made of the same traffic situation.

In such case, it is important to be aware that intersection counts are often only performed for a single morning and afternoon peak period, and that special uncertainties may therefore be associated with such traffic figures. Conversely, if several observations exist of a variable, it must be decided, which value is to use, e.g. mean value, the greatest value or a value representing a given quantile.

Capacity demand

The traffic counted corresponds to the real traffic handled over the relevant counting section. If traffic data are to be used to assess the development of the current road facility, a target must be set for the actual demand for capacity. Demand is measured first and foremost as the actual traffic handled plus any increased queue length in the approach or in front of the bottleneck during the time interval counted. Therefore, intersection counts should include counting of queue lengths, and the actual traffic handled must be adjusted for the observed changes in queue lengths.

Demand for capacity may also include road users, who have so far chosen other routes, but who, after a capacity increase, are attracted by the road facility and should therefore be added to the traffic load. The extent of additional traffic as a capacity increase, can be estimated by means of a traffic model.

3.3 Loading traffic data into the model, static and dynamic assignment

There are two different methods of loading traffic data into a microsimulation model, - static and dynamic assignment. Fundamentally, there is no difference in the results generated by the model, no matter whether static or dynamic assignment is used, provided that traffic data are allocated similarly by the two methods. Dynamic assignment may, in addition to loading traffic data, also distribute traffic in a network, and the simulation model will then be a small traffic model. The type of assignment to be used depends to a large extent on the specific task and the data basis available for solving the task.

However, often static assignment is used for small simulation tasks where intersection counts are available for the relevant intersection. Static assignment may, however, in some situations give an unrealistic driving behaviour.

Dynamic assignment may advantageously be used for large simulation tasks where traffic model calculations have already been made, or where a traffic model already exists for the area and matrices are therefore available. Furthermore, only dynamic assignment with e.g. the Vissim model tool, makes it possible to choose a specific road in relation to the traffic load if there are one or more alternative routes, multi-lane sections or approach lanes to intersections.

Dynamic assignment also allows analysis of the effect of reconstructing an intersection on the basis of the load of other intersections in the model.

Static and dynamic assignment is discussed in detail in section 6.2.

3.4 Geographical scope of the model

When an increasing number of intersections and sections have to be included in a model, the need for data and model development costs increases.

In most microsimulation models, traffic at the boundaries of the model is generated randomly by a Poisson process. Often the vehicle arrivals do not, however, follow such a process in practice, because lack of overtaking opportunities, signal-controlled intersections, etc. may result in clustering of traffic. In addition, lack of capacity on the surrounding sections and intersections may result in traffic being fed towards the analysed road facilities. Finally, it is important that the model does result in congestion. That is why it may in some cases be necessary to include surrounding intersections and roads in the model, although these are not to be included in the analysis.

Thus, we must critically assess whether the nearest intersection – or parts of such intersections – and roads should be included in the model, especially with a view to the above-mentioned feeding and clustering from e.g. signal-controlled intersections. Neighbouring intersections should, however, only be loaded if this is of particular importance as this will complicate and make the model more expensive. If it is deemed necessary to load neighbouring intersections into the model, it should be considered modelling such intersections in a more simple way for the primary purpose of achieving the desired effect, such as clustering or feeding of traffic.

3.5 Temporal scope of the model

Calculation period both macro- and microscopic models include the effect of the randomly occurring variation of traffic over the analysed time period, e.g. a peak hour or a peak quarter of an hour. Furthermore, there is normally systematic variation in traffic during the time period covered by the analysis, e.g. build-up of a 15- or a 5-minute peak and then decreasing traffic during the peak period. However, in many macroscopic models, such as DanKap, systematic variation in traffic over the calculation period cannot be included. Neither is it possible in e.g. DanKap "to take over" a build-up queue from the previous time interval.

In a microscopic simulation model such as Vissim, the mean traffic

intensity may, however, be entered in short subintervals of e.g. 15 minutes or shorter, making it possible to allow for the effect of varying traffic over a peak period of one hour or more.

It is important to be aware that projection of traffic in relation to registered traffic may generally mean that the time interval with queues increases. To achieve the best comparison of results, it might therefore be appropriate generally to consider as large a time interval as would be necessary to assess the situation with most traffic properly.

Settling time

When determining the start time of the simulation, it is important to be aware of the settling time. *Settling time* is the time it takes for the model to build the start of the situation to be analysed. As general rule, settling time includes, as a minimum, the first vehicles running through the model, but the settling time may be longer. This is often the case, if queues existed at one or several places in model already before an analysed peak hour, had the previous time been included. It may thus be appropriate to start the simulation e.g. 15 or 30 minutes before. It is important to be careful not to include data from the settling time in statistics of the simulation results.

End time

End time must be at the end of the peak period considered, but if information is to be extracted from the analysis on a total delayed volume, the end time for simulation must be set for such a late time that queues no longer exist. It should also be noted that for congested situations, the largest queues will occur at a later time than the time with the most traffic in the model and will not decrease until the traffic influx towards a congested part of the road networks has fallen to its capacity.

3.6 Calibration of the model

Before a created model can be taken into use, the model must be calibrated. Calibration means the process in which an attempt is made to adapt the model to reality by adjusting the model parameters in the best possible way.

Calibration is based on the data available from observations of e.g. traffic volumes, queue lengths, speed measurements, etc. In most cases, the data therefore express, in an aggregate form, the diversity of road user behaviour. But for the basic behaviour of the individual road users, data are generally not available, and the observable data can rarely be compared directly with model parameters, e.g. in submodels for car-following, models for lane change or models for weaving manoeuvres. In addition, it is difficult to make an isolated study of the parameters that are linked to the respective submodels, as these models often interact to reach the final result.

The calibration process is therefore an iterative process, where the model maker gradually adjusts the individual parts of the model to obtain the best possible conformity with the observations of real traffic. For calibration, primarily the parameters, the setting of which the model maker is uncertain of in the current situation, are selected. As a starting point for the calibration, values can be used, which the model maker has previously used in similar situations, or the recommended default values in this Road Standard, see chapter 6. If none of these options are available, the model

tool default values must be used for the parameters.

Methods for calibration of a microsimulation model are described in chapter 5.

3.7 Validation

In the validation of a model it is examined how well the model fits with the observed reality. It is therefore a question of the overall correctness of the system in an observable situation, whereas calibration includes the correctness of the individual parameters seen in isolation. Validation must be carried out independently of the calibration and thereby for situations that have not also been used for calibration.

Validation is about recreating in the model a real situation for which measurements are available.

Validation must be regarded as a model check, but a satisfactory validation is not in itself a sufficient for a correct model. If the calibration is not correct, changes in variable, e.g. in traffic intensity, compared to the initial situation will lead to incorrect results.

Validation examines:

- Whether the correct traffic intensity is generated by the model definition;
- Whether the model and reality have roughly the same queue lengths in intersection approaches;
- Whether speed measurements actually correspond to the speeds at the same location in the model;
- Whether lane utilisation is approximately the same in the model and in reality if traffic data broken down by lanes are available.

3.8 Documentation

The documentation must serve as description of the technical basis for model and simulations.

In connection with reporting of a task, documentation must be prepared for the model used and its use for solving the task. The purpose of documenting the task is:

- for the requester and model maker to have a written basis for solving the task, which states what has been agreed with respect to data basis, parameter setting, definition, etc., and thereby it is documented that mutual understanding has been reached as to the task content and solution;
- for the requester to avoid doubt as to the basis for the analysis, and thus the applicability of results and how the results should be interpreted
- for the model maker to be able to recreate the model or go back at a later time to see how previous tasks have been solved.

The documentation may be included as part of the report prepared for the task, as an annex to the report or as a separate memo, which is referred to in the reporting of the task.

The documentation should state that the guidelines in this Road Standard have generally been followed if this is the case. But it is particularly important to state, if exceptions have been made and why. From the documentation, it should therefore be possible to recreate the parameter setting in the model.

Furthermore, the documentation must also briefly describe and possibly argue for the selected geographic and temporal scope of the model, see sections 3.4. and 3.5.

The documentation must account for the desired quality level and what the results can be used for, see section 5.1. In addition, the calibration and validation performed must be briefly described as set out in sections 3.6, 3.7 and chapter 5. The documentation must also specify the weaknesses, if any, of the model as a result of lack of knowledge, lack of data, lack of resources, etc.

In general, the documentation should allow recreation of the simulation by loading the analysis variable.

The documentation may also be accompanied by a completed checklist, see chapter 4.

3.9 Interpretation of results

3.9.1 Capacity and load factor

A microscopic model does not – as a macromodel – calculate capacity in an intersection approach or at a free section, and the load factor for a traffic flow in the approach or at the section will not be calculated. Therefore, it is not possible directly to determine the remaining capacity or the degree of congestion in a road facility.

To be able to assess the capacity and load, it is typically necessary to change the traffic intensity in the model, until the capacity limit occurs. An indication that the capacity limit has been reached, is that traffic builds up in the approach road or before the section which constitutes the bottleneck and that the queue length tends to increase over time until the traffic intensity decreases.

Traffic load may also be assessed on the basis of criteria laid down, such as the load, where the mean delay for a traffic flow changes from one value that is considered satisfactory, to an unsatisfactory value.

For the assessment of capacity and delay in models, where several road facilities in the form of intersections and partial sections are included, it is important to note that lack of capacity at one place in the model may feed traffic towards other parts of the model. In such cases, it may be difficult to determine the capacity of the individual road facility, and it may therefore be necessary to eliminate bottlenecks in the model to be able to analyse capacity elsewhere.

3.9.2 Delay, travel time and queue length

Delay and travel time are important values for the assessment of accessibility and service level for the road users. As already mentioned, microsimulation models usually provide good opportunities to define sections, where these values are measured. However, in respect of capacity, it is important to be aware of the interaction between parts of the road network in the model, where e.g. congestion in one place may result in less load in other places with the resulting consequences for delay in the individual places.

In the measurement of delay and travel time, it is important to be aware of the possible extent of queue when determining the sections between which travel time is measured.

It will always be interesting to see how often a queue length exceeds the critical length, e.g. from a ramp intersection to the motorway through lanes, from a stop or give way line in an intersection to the end of a turning lane or a queue that results in congestion from one intersection to another. Such results can be readily achieved in a typical microsimulation model.

3.9.3 Distribution of results from the model

As mentioned in section 2.1., microsimulation models are almost always stochastic models, where the model only provides one (random) outcome for the traffic flow during the considered calculation period. An overview of the general conditions for traffic flow during the calculation period can therefore be achieved only by repeating the model run with an unchanged set of variables, but by using different sequences of random numbers.

An immediate result in the form of, e.g. mean delay, average queue length and load factor will therefore not be provided as is the case with the macroscopic capacity models, which are usually deterministic models also known as "mean models".

With the stochastic models, it is necessary to estimate the values needed on the basis of the outcome of each repetition. A calculated value, such as the mean value for travel time for a traffic flow during the calculation period, will always be subject to uncertainty due to the fact that only a limited number of repetitions have been made. But by increasing the number of repetitions, this uncertainty will be reduced. In addition, use of the model always involves a systematic uncertainty in the outcome as a result of the fact that the parameters and submodels cannot be set so as to correspond perfectly to the real world.

A macroscopic model usually only generates mean values. By contrast, a stochastic model has a major advantage as it is possible to gain an overview of the entire variation (distribution) of the considered result variables, and for example to determine for how much of the time during the calculation period the queue length exceeds a critical length or for how long the travel time between two points is longer than a given time.

Repeated runs of the model should therefore provide a distribution of the result variables, which corresponds to reality and not just provide a mean value or median for the variables, which is close to the real corresponding values. For this to be the case, the parameter distributions entered in the model must be correct, and all factors associated with an uncertainty in the real world, or where there is a correlation must also be simulated with stochastic submodels where the correlation is included. For this reason, it is necessary to have thorough knowledge of the simulation tool, calibration and parameter setting, in order to be able to assess the correctness of e.g. quantiles estimated on the basis of a model.

3.9.4 Assessment of traffic flow on the basis of microsimulation model results

The solution of tasks by means of a microsimulation model involves an assessment of the result in relation to the current project, e.g. whether the calculated value for the traffic intensity of an approach, mean delay or x% - quantile for queue length is acceptable for the project, or whether a different solution should be considered.

No Danish guidelines are available for requirements for e.g. load factor, traffic density or mean delay. The assessment must be made individually for projects depending on the individual project size, type, the hours of the year for which the calculation has been made and which year the calculation represents in relation to e.g. the opening year of the facility. Furthermore, the assessment depends on how much uncertainty is associated with traffic data.

However, it should be mentioned that a frequently used practice has been to design a traffic facility for a capacity utilisation of 70% at the hour of the year and the future year which forms the basis of the design. But in many cases, it has also been decided to deviate from this.

Service level

The Road Standard proposal for capacity and service level describes the service level using the below variables

- Load factor (capacity utilisation) and mean travel times for sections.
- Mean delay for intersection approach.

The Road Standard Proposal for capacity and service level recommends that the value of these variables be used directly to communicate the service level.

Some foreign sources, e.g. Highway Capacity Manual 2000, HCM, define a classification of service levels into classes A to F, making it possible, to qualify or classify traffic conditions on the basis of the calculated values for e.g. delay, see annex 6. In HCM, as in the Danish Road Standard Proposal, mean delay provides the basis for service level at intersections, but other indicators, which form the basis of the classification of service level by section. *When agreements are made between the requester and contractor, HCM or other sources may therefore be used as a basis for qualification of traffic flows in intersections.*

Also in Denmark, efforts have been made to introduce classification and

qualification of calculated mean delay for intersection approaches. Table B6.3 in Annex 6 shows a proposal where the basis of the determination of intervals was peak hour traffic, and where the incorporated level designations A - F from HCM were used. The proposal has not been formally discussed or adopted, but *when agreements are made between a requester and a contractor, this form or an adapted version may be used*, if they want to qualify and communicate a calculation result using these designations.

Finally, reference may be made to the congestion definitions in Project Congestion 2000-

04. This is based on actual travel time and actual traffic density in relation to the free travel time and maximum traffic density. Free travel time is the travel time at low traffic load, and maximum traffic density is the highest density that can be reached for the section. The congestion definitions are set out in table 3.1. In respect of urban streets, the traffic density criterion will not be used.

	Actual travel time compared to free travel time	Actual density compared to maximum traffic
Negligible	$\geq 80\%$	$\geq 20\%$
Starting	$\geq 80\%$	$\geq 20\%$
High	$> 40\%$ and $< 80\%$	$> 33\%$ and $< 60\%$
Critical	$\geq 40\%$	$\geq 60\%$

Table 3.1. Congestion definitions according to Project Congestion.

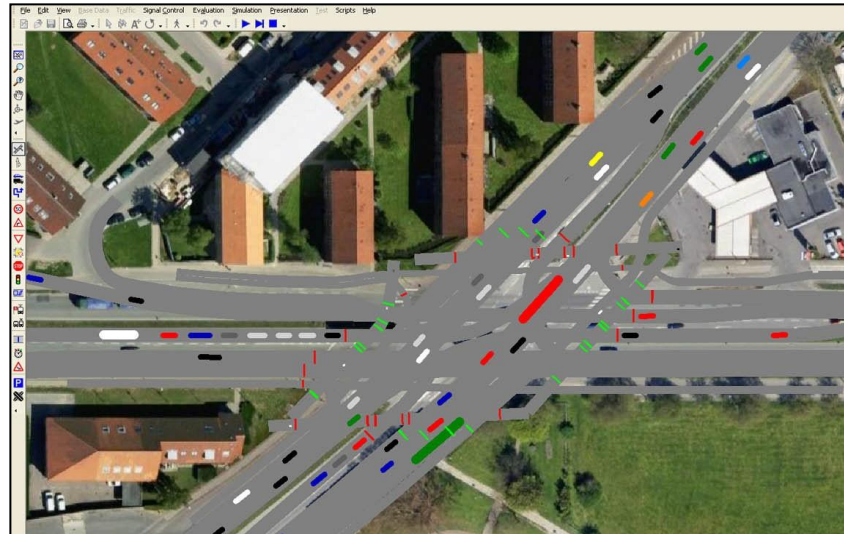
Guidelines

based on experience

Regardless of the above, the following guidelines based on experience may also be included in an evaluation of simulation results:

1. *Traffic load compared to the capacity of section and intersection approach.* At a high capacity utilisation of more than approx. 85%, a future traffic increase will soon result in much greater delay or reduction in section speed. If the calculation is has been made for an undivided peak hour, it is important to bear in mind that traffic during the most severely loaded quarter of an interval may come close to or exceed the capacity limit, if the capacity utilisation is calculated at 85% or more for the total peak hour.
2. *Delay in intersection approaches.* If the mean delay is calculated to over a period of about 60 seconds in an approach with duty to give way and over the cycle time for signal-controlled intersection approaches, a traffic increase or higher traffic load during a peak interval will typically result in a significant increase in mean delay.
3. *Queue length in critical approaches* , e.g. turning lane where a long queue may exceed the lane length and block the neighbour lane, or where a queue on a ramp may be critically long and result in a distance that is too short for exiting traffic to brake or even cause a risk of queue to a motorway through lane. Queue length is often assessed on the basis of the 5% quantile, i.e. , the queue length which is longer for only 5% of the time during the considered calculation period, which is e.g. a peak hour or a peak quarter.

Visual assessment



As mentioned above, it is almost always possible in a microsimulation model to gain a visual overview of traffic flows and thus become aware of any problematic locations and times for traffic flow. In any event, this problem areas found should be subject to deeper analysis.

3.10 Reporting of tasks

Not many guidelines are provided here on how the contractor should report a task. Advisers and others have fixed routines for this, and reporting will generally depend on the nature of the task.

However, in reports of tasks containing analyses of traffic situations, it is particularly important that the following is clearly stated for each analysis result:

- What road network has been analysed, i.e. clear reference to road proposals, development variant, source;
- What traffic is included, i.e. reference to scenario and source as well as years of traffic;
- What vehicle composition is included;
- For what hours of the year, the calculations have been made, e.g. the 30th or 100th highest hour of the year, morning or afternoon situation;
- How signals are modelled, e.g. time- or traffic-controlled and possibly a further description of signal programs.

4. SIMULATION TASK CONTROL

4.1 Systematic control

It is suggested that for microsimulation tasks, a systematic control be carried out for the overall solution of the task. The aim is mainly to ensure that the quality of the task solution is satisfactory, and to avoid any subsequent discrepancy between expectations of the requester for the results and implementation by the contractor of the task. In addition, the systematic control can contribute to creating an effective solution of the task and contribute to systematic knowledge gathering.

The control should include the preparation of the task, including dialogue between the requester and contractor and the agreements concluded with regard to the scope, definition and data basis of the task. In addition, the control should include the actual model creation and use of the model, including calibration and validation efforts, assessment of the simulation and the results, as well as an assessment of the need for the number of repetitions of model runs for each analysed situation. Finally, the control might include the efforts concerning documentation and reporting of the task.

4.2 Checklist

A draft checklist has been prepared as to facilitate systematic control of microsimulation tasks, see Annex 7. A list structured in a different way or with different content may of course also be used, if it is adequate for the process and result of a micro simulation task.

The checklist is primarily intended for the contractor, and it may constitute an important basis for the quality control before delivery of the task result to the requester. But the checklist may also be used as a list that will be provided to or reviewed together with the requester – in the same way as a workshop provides a checklist to the car owner after service of a car.

Furthermore, it is recommended that the contractor, at an early stage in the task solution, organises his work in accordance with the checklist to ensure that no gaps or unresolved issues are subsequently found in connection with used data, model creation and analysis.

5. CALIBRATION OF MICROSIMULATION MODEL

This chapter provides guidelines on calibration of a microsimulation model. The concrete examples of parameters are for a model created in Vissim.

Section 5.1. will begin with a description of calibration effort depending on the required quality of the study and of the result sensitivity depending on the model parameters. Then section 5.2 describes some model parameters, which may be the subject of calibration of different traffic situations. Section 5.3 describes in more detail a calibration effort which will typically be aimed at a relatively comprehensive model, and section 5.4 includes conditions concerning calibration of a smaller model.

5.1 Sensitivity and quality

The calibration of a parameter should initially study the importance of the parameters for the simulation result. A sensitivity analysis of the parameter will provide information about the intervals at which the parameter is of more or less importance for the outcome, and how the outcome can be influenced. On this basis, it will be possible, for example, to assess how critical the parameter is for the result, and thus how much of an effort should be made in the calibration of the parameter.

A sensitivity analysis is performed by keeping all parameters and variables constant, apart from the parameter whose sensitivity is examined.

The extent of the calibration effort should also be adapted to the quality expected from the analysis work. Quality requirements depend on e.g.

- what use of results is expected, e.g. whether the result is to be used directly in a detailed project where a high degree of accuracy is needed or whether it is to illustrate a draft situation;
- whether it is absolute values of the results are important or if what is needed are rather relative values for a number of alternatives;
- whether are major requirements exist for visualisation for decision-makers and other stakeholders, or whether the visualisation is only for the closest project staff;
- what traffic and infrastructure data are available;
- what resources have been allocated to the project.

The calibration efforts must be determined on the basis of the quality level set for the task.

The quality level for the simulation work must be set out in the reporting, e.g. by the requester clearly being told what the result can be used for and what it should not be used for.

5.2 Traffic situations and model parameters

In case of major discrepancy between simulation results and observations of real conditions, the parameters must be adjusted until conformity has been achieved. In the process, the user should distinguish between:

- Parameters which the contractor is certain of, and which therefore do not need adjustment;
- Parameters which the contractor is uncertain of, and which therefore may have to be adjusted.

The user should to the greatest possible extent reduce the number of parameters to be adjusted. Depending on the road facility to be analysed, adjustment of parameters which control or have an influence on the following conditions may be considered:

Motorway section:

- Distribution of specified time intervals
- Distribution of speeds
- Distribution of accelerations and decelerations
- Speed-flow relations
- Driver response time
- Critical gap in connection with lane change
- Mutual separation of the vehicles in connection with a slow-moving queue or stationary queue.

Signal-controlled intersection:

- Time loss at start and time of driving after end of green time
- Car-following time from when the queue starts to clear and between vehicles further back in the queue, which allows green time capacity to be estimated
- Critical gap for left turn

Duty to give way:

- Critical interval (in Vissim: gap time)
- Car-following time, i.e. the distance between cars in queue with duty to give way, which uses the same interval in the overall traffic flow

Calibration can be performed by either a "trial and error" method or by using an algorithmic-numerical approach, see below.

Table 5.1 below lists parameters for different traffic situations in a simulation model that can be calibrated on the basis of observations of traffic flow in a real situation, and which can then by comparing the situation with the model handling of the same situation be used in the calibration procedure.

Situation	Parameter in model	Data sets for model run and observations at calibration
Weaving	Car-following parameters (in Vissim particularly CC0, CC1, CC2 CC4, CC5)	Traffic intensity per lane, speed/flow relation for traffic in the weaving area, comparison with other models (e.g., Dan-Kap)
Route search (dynamic assignment)	Assignment parameters	Measured traffic intensity at the same locations for model and real world, traffic flows established in model and real world
Capacity of a lane	Car-following parameters, desired speed, desired acceleration and braking	Known values for capacity of lanes in the relevant road type (see Road Standard Proposal for capacity and service level) or observed capacity, standard or observed speed/flow-relation
Traffic flow at an at-grade intersection	Car-following parameters, signal parameters at signal-controlled intersections, critical interval for duty to give way	Observed capacities, queue lengths and delays, comparison with other models (e.g. DanKap)
Driving behaviour along a corridor	Car-following parameters, desired speed	Measured speed profiles in model and reality, e.g. by GPS data for vehicles
Capacity for a toll booth, etc.	Service times, car-following parameters	Measured delays and queue lengths

Table 5.1. Typical parameters and examples of data sets as basis for calibration of different situations.

Example 5.1:

The Vissim-based model assumes that CCO = 1.54 metres, which is the desired distance between stationary cars, and CC1 = 0.9 seconds, which is the parameter for the safety distance to the vehicle ahead. This means that a car driving at a speed of 100 km/h maintains a safety distance to the vehicle of:

$$\Delta = \frac{100 \text{ km/h}}{3.6} * 0.9 + 1.54 = 26.5 \text{ meter}$$

This distance can then be compared to the shortest measured time intervals for cars with the same speeds in real traffic.

A microsimulation tool such as Vissim contains a number of vehicle parameters which have typically been defined using distribution functions. It could e.g. be desired speed, desired acceleration, desired braking, weight/power ratio and length of vehicles. Distributions of desired speeds, accelerations and braking operations are analysed for free-running road users or for traffic situations with so low traffic load that it must be assumed that the individual road users have themselves been able to determine speed and acceleration/braking, see section 6.7.

Other parameters are particularly difficult to control and manage. This includes parameters that control the distance, which a driver of a vehicle wants to keep to a vehicle ahead. The shortest acceptable distance of a road user to a vehicle ahead in the same lane is of great importance for lane

capacity, and therefore, this safety distance must be more closely assessed in the event of discrepancies between capacity in model and reality. In a Vissim-based model, the parameters typically adjusted at calibration for safety distance are CC0 and CC1, see example 5.1. On the basis of existing or new registrations of passage times for vehicles in the same lane, it is therefore necessary to prepare and analyse distributions of time intervals for maintained traffic intensities, focusing particularly on situations near the capacity limit for model-calculated and real situations.

5.3 Calibration of large models

The calibration of a large model must as a minimum include calibration up against one data set for model runs and observations of real traffic conditions. The procedure for calibration is suggested as follows:

- Selection of data to be calibrated up against, see e.g. table 5.1.
- Assessment of the calibration reliability should be made using the "root-mean-square" value:

$$RMSE = \sqrt{\frac{1}{N} \cdot \sum_{n=11}^N (x_n^{sim} - x_n^{obs})^2}$$

or for the comparison of simulated and observed traffic intensity, known as the Geoffrey E. Havers value:

$$GEH = \sqrt{\frac{2(x^{sim} - x^{obs})^2}{x^{sim} + x^{obs}}}$$

where x is the selected calibration variable (such as traffic intensity, travel time, queue length, etc.), sim the simulated value and obs the corresponding observed/recorded value from a real situation. GEH can only be used for traffic intensity whereas $RMSE$ can be used for e.g. traffic intensity, travel time, queue length etc.

- As x_i^{sim} depends on the parameter set (p_1, p_2, \dots) in the simulation model, $RMSE$ and GEH will also depend on the parameter set. An optimum calibration provides a set of parameters (p_1, p_2, \dots) that minimises $RMSE$ and GEH .

Traffic intensity

GEH is used for calibration based on data sets for traffic intensity. The optimum calibration is achieved using the parameter set that minimises GEH . Furthermore, it is recommended that a calibration with GEH is performed so as to meet the requirements in table 5.2.

Criteria and measured data	Met
Traffic per hour, model versus registered	
<u>Individual links:</u> Within 100 vehicles/h for flow < 700 vehicles/h Within 15% for 700 vehicles/h < flow < 2700 vehicles/h Within 400 vehicles/h for flow > 2700 vehicles/h and $GEH < 5$ for link flow	> 85% of the cases
<u>Sum of flows for all links:</u> Within 5% and $GEH < 4$ for the sum of all links	<u>Total for all links</u>

Table 5.2. Examples of criteria and the degree of completion for calibration for traffic intensity.

Travel times

Following a comparison of the model-calculated and observed travel time, the parameters generating the lowest *RMSE* are selected. Furthermore, it is recommended that the variance between the model-calculated travel time and the observed travel time

- is less than 15% or less than 1 minute (if 15% of the travel time is greater than 1 minute) for more than 85% of the cases.

Optimum parameter set

The optimum value for the parameters can be defined using different methods.

If it is only necessary to adjust up to about three different parameters, this can be done by means of systematic testing, "trial and error" method. A more effective method is to use algorithms that seek to minimise the deviation - e.g. the Nelder-Mead or Simplex method by using evolutionary algorithms or by using simulated annealing. Common for these methods is that they are based on a set of parameters determined by the user. The algorithm-based optimisation methods are not described in more detail in this booklet.

When the above methods are used, a problem may in some cases occur which is known as "over-fitting" or noise. To make sure that this does not happen, several different data sets can be used for both calibration and validation.

Example 5.2:

This is an example of the use of *GEH* and *RMSE* in the calibration of Vissim-based model in terms of traffic intensity, where it is assumed that the conditions in table 5.2 must be met.

The table below shows the data set used in the example. Observed data consists of 10 traffic counts made within the model area. Simulation data shows the calculated data in 3 alternatives of a model. The difference between the alternatives is that parameter *CC0* has been adjusted.

The purpose of the calibration is that the model must comply with the conditions set out in table 5.2, i.e

1. $GEH < 5$ for 85% of individual links
2. $GEH < 4$ for the sum of all links
3. The other conditions laid down in the table of traffic flow volumes must be met

	Obs. (num vehicles)	Alt. 1 (num vehicles)	Alt. 1 <i>GEH</i>	Alt. 2 (num vehicles)	Alt. 2 <i>GEH</i>	Alt. 3 (num vehicles)	Alt. 3 <i>GEH</i>
Link no.		CC0 =2.0		CC0 =2.5		CC0 =3.0	
1	1000	950	1.60	950	1.60	950	1.60
2	1200	1100	2.95	1100	2.95	1100	2.95
3	1500	1350	3.97	1350	3.97	1350	3.97
4	1100	1400	8.49	1050	1.52	1050	1.52
5	900	1000	3.24	1000	3.24	1000	3.24
6	800	1200	12.65	1200	12.65	850	1.74
7	950	1200	7.62	1200	7.62	1000	1.60
8	1170	1170	0.00	1170	0.00	1170	0.00
9	1205	1100	3.09	1100	3.09	1100	3.09
10	1000	950	1.60	950	1.60	950	1.60
All	10825	11420	5.64	11070	2.34	10520	2.95

The table above states calculated *GEH* values for all links individually and collectively, as well as for all 3 simulation alternatives.

	Share of links where <i>GEH</i> <5
Alternative 1, CC0 =2.0	70%
Alternative 2, CC0 =2.5	80%
Alternative 3, CC0 =3.0	100%

The table above states the calculated proportion of individual links which comply with condition 1.

	<i>GEH</i> for the sum of all links
Alternative 1, CC0 =2.0	5.64
Alternative 2, CC0 =2.5	2.34
Alternative 3, CC0 =3.0	2.95

The table above states calculated *GEH* of the sum of all links in the simulation alternatives where condition 2 is that this must be less than 4.

The calculations show that all calibration requirements are met only in alternative 3.

	<i>RMSE</i>
Alternative 1, CC0 =2.0	193
Alternative 2, CC0 =2.5	168
Alternative 3, CC0 =3.0	81

The table shows the values of *RMSE*. These values can be used for control, and the selected alternative should have an *RMSE* among the lowest. It is found that alternative 3 gives the lowest *RMSE*.

For alternative 3, calculations show that the variances between the individual links' model-calculated and observed traffic numbers are all within 15%, see condition 3 and table 5.2 for traffic intensity between 700 and 2700 vehicles/hour. In addition, the variance is the sum links in model-calculated traffic compared to observed traffic within 5% (see table 5.2) in alternative 3, since $10520/10825 = 0.97$, i.e., the variance here is 3%.

For this example, alternative 3 is therefore selected with CC0 equal to 3.0 to deliver the best result for traffic intensity, and the parameter CC0 has been calibrated to 3.0. The example, however, does not guarantee that a higher parameter value, e.g. CC0 = 3.5 would not be better. We should, therefore, continue the calibration efforts.

5.4 Calibration of small models

Small models are described as models to simulate relatively small traffic systems. This could be a few or single intersections, ramps and ramp intersections at motorway approach systems, parking areas, toll booths, etc.

In small models, a scenario should first be modelled that reflects the reality of a situation which can be observed.

For calibration of small models, the "trial and error" method is used, where driving records, travel times and other visual observations are used to make the model reflect the reality. It is not necessary to use the same mathematical calibration as for large models. This is due to the fact that small models are usually easily manageable. But if there is doubt as to the complexity of the model, a mathematical approach should always be used.

If changes are to be simulated in future or new scenarios, the same parameters must be used as those in the basic scenario.

6. SETTING PARAMETER VALUES

6.1 General

Microsimulation models are typically extensive and detailed. The models have many options to control road user behaviour, vehicle performance and signal operation. The current parameter setting which controls the submodels may have a significant impact on the outcome of a simulation task, and it is therefore important to be aware of the parameter setting.

Simulation tools come with default values for the parameters, and often they do not reflect Danish traffic conditions. In order to be representative of Danish traffic, it may therefore be necessary to change some parameter values, whereas others may remain unchanged. It is also important to be aware that different traffic flow conditions in the same country may result in a need for different parameter setting.

It may be a major problem for the user of microsimulation models to set parameters appropriately because the models are often large and complex. It requires experience and knowledge to understand what parameters are of importance for a given part of the model, and then to set the parameters optimally. Users may therefore be too inclined to use the model tool default values for parameters or to make an irrational calibration for the purpose of setting parameters. Reference is made to chapter 5 on calibration of simulation models.

This chapter provides guidelines for setting the important parameters. The guidelines include the parameters for:

- Allocation of traffic by roads and routes in the model, also known as "traffic assignment";
- Road user behaviour in the context of "car-following";
- Lane change behaviour;
- Duty to give way behaviour;
- Traffic flow in signal-controlled intersections;
- Vehicle and driver characteristics; and
- Special parameters related to the actual simulation.

As mentioned, the Vissim simulation tool has proved to be the predominant platform for creating microsimulation models for road traffic in Denmark, and Vissim is therefore used as the basis for the guidelines for setting parameters. When the following sections mention parameter *default values*, these are the "factory settings", i.e. the value of the parameter, when the program is received from the supplier.

Note that Vissim operates with two fundamentally different behaviour models for "car-following", lane change and traffic flow weaving. The models are known as Wiedemann 74 and Wiedemann 99. Wiedemann 74 is used mainly for urban traffic whereas Wiedemann 99 is for motorway traffic, but Wiedemann 74 is recommended for situations with traffic flow weaving on motorways. Parameter setting is presented in both of these Wiedemann models.

6.2 Assignment, static and dynamic

Vissim has are two basic route selection models called static and dynamic assignment.

6.2.1 Static assignment

In static assignment, the route for vehicles is determined statically by either route selection or choice of direction.

The mean number of vehicles broken down by vehicle type and time must be established for all incoming roads in the model boundaries. For each intersection, either a percentage or an absolute breakdown of traffic between turning movements in the intersection. Subsequently, it is possible to compose the routes for each intersection to routes, which cover the vehicle route through the entire network. It is possible to have different traffic intensity, route, and distribution of vehicle types in different time intervals.

6.2.1.1 Advantages of static assignment

Static assignment is easy to use, even for new users of Vissim, as it is a simple way to build the route selection, and the model route selection is easy to understand and explain.

For small models with only a few intersections, it will normally be less resource demanding and faster to create a model with static assignment than with dynamic assignment.

6.2.1.2 Disadvantages of static assignment

Vehicles that "enter" the model, do not know their route through road network. A vehicle is not assigned a route until the point at which it passes the first defined route in the road network. The vehicle has then been assigned a route and will complete this route. But if the route for example is defined only for one intersection, the vehicle will only have information on how the route is through this particular intersection, and not on the route for driving through the rest of the road network. When the current route has been completed, the vehicle will therefore have to search for a new route.

In models containing roads with more than one lane in each direction, the disadvantage of this method of route assignment is that without combined routes describing the entire route of the vehicle through the road network, no information is available for the vehicle on how it should position itself in relation to subsequent intersections. This does not reflect the reality of the situation, where drivers would normally choose the lane most appropriate for subsequent intersections. But this is not possible in the model because the vehicle only knows its current route which may end immediately after an intersection. Only when the vehicle has completed the current route and is assigned a new, will the vehicle receive information about its further route and about whether the vehicle is to continue straight ahead or turn right or left at the next intersection.

In static assignment, a vehicle, to which no route has been assigned, may

therefore behave inappropriately with regard to the choice of lane, and this may lead to unfavourable lane change, even if the distance between the routes is very short. The result of static assignment modelling may therefore be unrealistic lane change which is commonly seen in such Vissim models.

If the routes are not defined until the vehicle reaches an intersection, and the routes are subsequently combined so that the routes cover several intersections or the entire route through the road network, it is difficult to change the distribution of routes for a single intersection.

If the model has two or more alternative routes between two points, the number of vehicles choosing each route must be specified in advance. It is not possible to have Vissim distribute the vehicles according to the actual conditions.

6.2.1.3 When can static assignment be used

Static assignment should primarily be used for small models, i.e., models that contain a small number of signal-controlled intersections, one-lane roundabouts and priority intersections. The model should not contain multi-lane sections, multi-lane roundabouts or the need for dynamic selection between several alternative routes.

6.2.2 Dynamic assignment

In dynamic assignment, traffic input and route selection are based on established OD matrices. Routes are generated by dynamic assignment as a cost is assigned to each route in each OD pair.

Vissim includes cost factors such as:

- Travel length
- Travel time
- Costs of specific "links"

The latter is used for modelling of factors such as toll roads or similar.

On this basis, the model selects the route involving the lowest costs. This is done through a series of iterations (simulations), until a certain convergence criterion has been met.

The convergence criterion may depend on the following:

- Travel time on a route
- Travel time on a sub-route in/between intersections
- Number of vehicles on sub-routes in/between intersections

An example of a process for the route selection in dynamic assignment is shown in figure 6.1. In principle, route selection in dynamic assignment works in a traffic model.

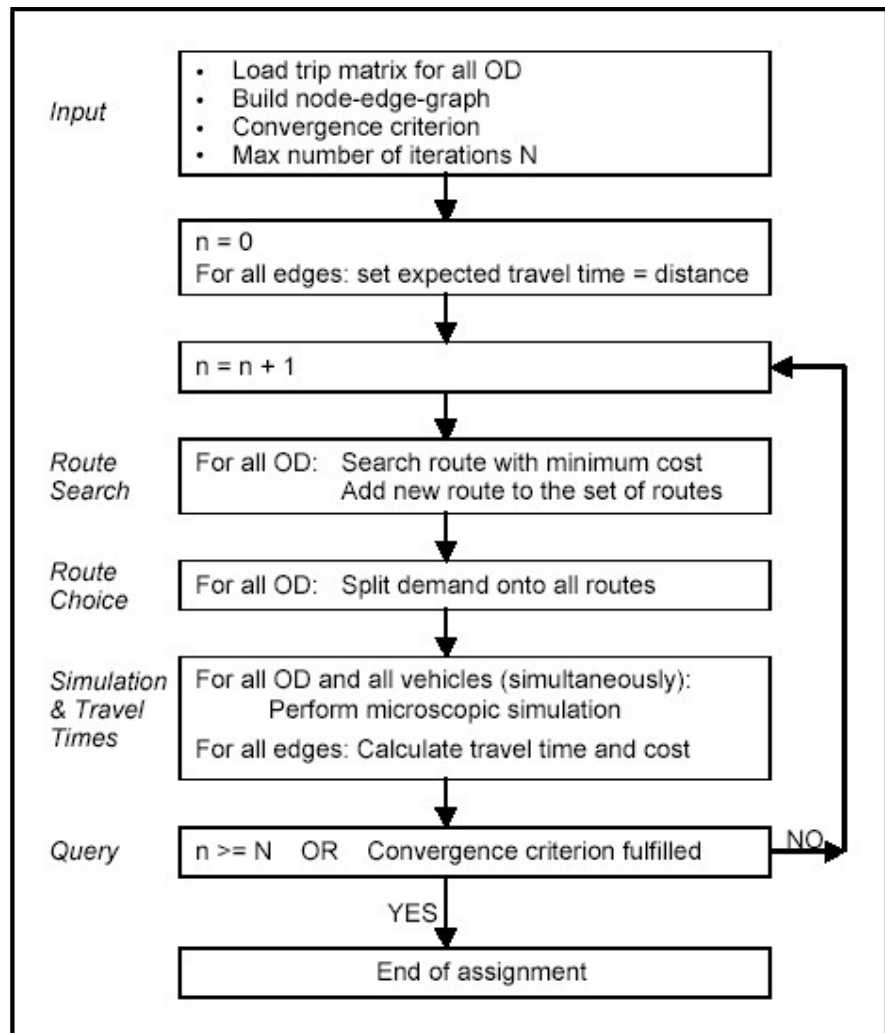


Fig. 6.1 The process for the route selection in dynamic assignment in Vissim.

6.2.2.1 Advantages of dynamic assignment

In dynamic assignment, vehicles always know their route through the road network in advance and are therefore always able to choose the most appropriate lane in the road network, meaning that the behaviour of the vehicles in the model can easier reflect reality.

In the process, Vissim finds all routes in road network and the cost of the routes. The model is then able to assign to the vehicles the optimum route through the road network where two or more alternative routes exist between two points.

If traffic level or traffic distribution is to be changed, it is quick and easy to change the matrices in a matrix tool (e.g. a traffic model tool).

If complete traffic model calculations have been performed for scenarios, it is easy to transfer the matrices for these scenarios directly from the traffic model to Vissim.

If the model covers more than one intersection, a traffic model can be used for the entire area to calibrate a matrix, which is adapted to the traffic flow counts. As a result, any differences between counts in the individual intersections will be offset.

6.2.2.2 Disadvantages of dynamic assignment

As the routes in dynamic assignment are not pre-defined, it may take some time to calibrate the route selection. It is particularly time-consuming if several routes have almost the same cost, and it is therefore difficult for the model to choose between routes and thus have difficulties meeting the convergence criterion. Vissim can, however, tell what routes do not converge. But in any event, calibration may take longer than in static assignment.

For less experienced users of Vissim, or users who are not used to working with traffic models, it might be difficult to understand the logic behind the route selection, and this increases the risk of improper use of dynamic assignment.

If the user does not have access to a traffic model tool to generate the matrices, the development of matrices may be cumbersome for large models with several intersections.

6.2.2.3 When can dynamic assignment be used

Dynamic assignment can be used for all model types, but it is particularly advantageous for large or complex models. Models containing multi-lane sections, multi-lane roundabouts, motorway sections or other sections with multiple lanes in each direction should use dynamic assignment. Generally, dynamic assignment may advantageously be used if the model contains a route selection or if traffic model calculations are available.

6.3 Car-following behaviour

Microsimulation models typically describe car-following models using behaviour parameters, representing the various aspects within the following four different driving modes:

- free-driving,
- approaching,
- following,
- braking.

These modes are modelled in Vissim using the Wiedemann 99 or Wiedemann 74 model for car-following.



6.3.1 Parameters related to car-following in Wiedemann 99

Vissim's Wiedemann 99 model includes ten behaviour parameters called CC0-CC9. The parameters are described in more detail in table 6.1.

Table 6.1 shows the default values for the parameters CC0-CC9 and a relevant interval based on experience within which the parameters CC0,

CC1 and CC2 will often be. In practice, these are generally the parameters that would need to be adjusted. For the other CC parameters a special basis is required to change the default values.

In addition to CC0-CC9, a number of other parameters exist with respect to car-following behaviour. These are:

- Look ahead distance and look back distance (number of metres a road user is able to see and react to vehicles ahead and back),
- Observed vehicles (number of vehicles ahead (or network elements) to which a reaction is seen),
- Temporary lack of attention (length of time and likelihood of inattention).

Generally, it is important to be careful when changing the default values for all of the CC0-CC9 Wiedemann 99 parameters as their effect and the interdependence for the car-following model are complex.

In several studies, attempts have been made to map how e.g. changes in CC0-CC9 affect the simulation results. The results indicate that the simulated capacity for a road section depends to a large extent on the selected parameter values. In particular CC0, CC1 and CC2, seen in isolation, influence the capacity in the simulated traffic flow, but several of the CC0-CC9 parameters have strong interdependence, which affects the outcome of a simulation.

Parameter	Default	Relevant range	Comments
CC0 (Stand still dist.)	1.5 m	1 – 3 m	Describes the desired distance between stationary vehicles.
CC1 (Headway time)	0.9 sec.	0.9 – 1.2 sec.	Describes time gap to the vehicle ahead. At a given speed, v is the safety distance given by $dx_safe = CC0 + CC1 * v,$ where v is measured in m/s. The model defines the safety distance as the minimum distance the driver will keep to the vehicle ahead. This value has a major impact on capacity.
CC2 (Following variation)	4 m	4 – 8 m	Describes a length oscillation or the extra distance in relation to the safety distance required by the driver before he will drive closer to the vehicle ahead.
CC3 (Threshold for entering Following)	- 8	--	Describes when deceleration starts, i.e. when the driver recognises a slower moving vehicle ahead. CC3 defines when the deceleration starts in seconds before the safety distance is reached.

Parameter	Default	Relevant range	Comments
CC4 and CC5 (Following threshold)	-0.35 and 0.35	--	Describes speed differences in the Following process. The lower the value, the greater the sensitivity when the car ahead decelerates or accelerates. A small value means that the vehicles are closely paired. CC4 and CC5 are used for both negative and positive speed change.
CC6 (Speed dependency of oscillation)	11.44	--	Describes the influence of distance on speed oscillation in the Following process. At the value 0, there is no dependency. The higher the value, the higher the speed oscillation at increasing distance.
CC7 (Oscillation acceleration)	0.25 m/s ²	--	Describes the actual acceleration in the oscillation process.
CC8 (Standstill acceleration)	3.5 m/s ²	--	Describes the desired acceleration when starting up after standstill, limited by the desired acceleration for the individual vehicle type.
CC9 (Acceleration at 80 km/h)	1.5 m/s ²	--	Describes acceleration at 80 km/h.

Table 6.1. Behaviour parameters CC0-CC9 for car-following in Vissim Wiedemann 99 model, - where no values are given for relevant range, the default values should normally be used unless a special basis exists for choosing an alternative value.

Observed vehicles

Generally for "driving behaviour", the number of "observed vehicles" must be changed from default value of 2 to a value of 4, 5 or more. This is due to the fact that all elements of the model are seen as vehicles, meaning that e.g. a stop line or changed speed is perceived as a "vehicle". If the default value cannot be changed, the vehicles may e.g. drive through a red light.

Look ahead/back distance and Temporary lack of attention

The parameters for "look ahead/back distance" and "temporary lack of attention" should not normally be changed from the default values for these parameters.

Model parameters

No clear recommendation can be given for parameter setting for CC0-CC9 in the Vissim Wiedemann 99 model. The optimum setting of the parameters will vary depending on the actual situation. That is why focus should be on calibration and validation in connection with parameter setting for CC0-CC9, particularly CC0, CC1 and CC2.

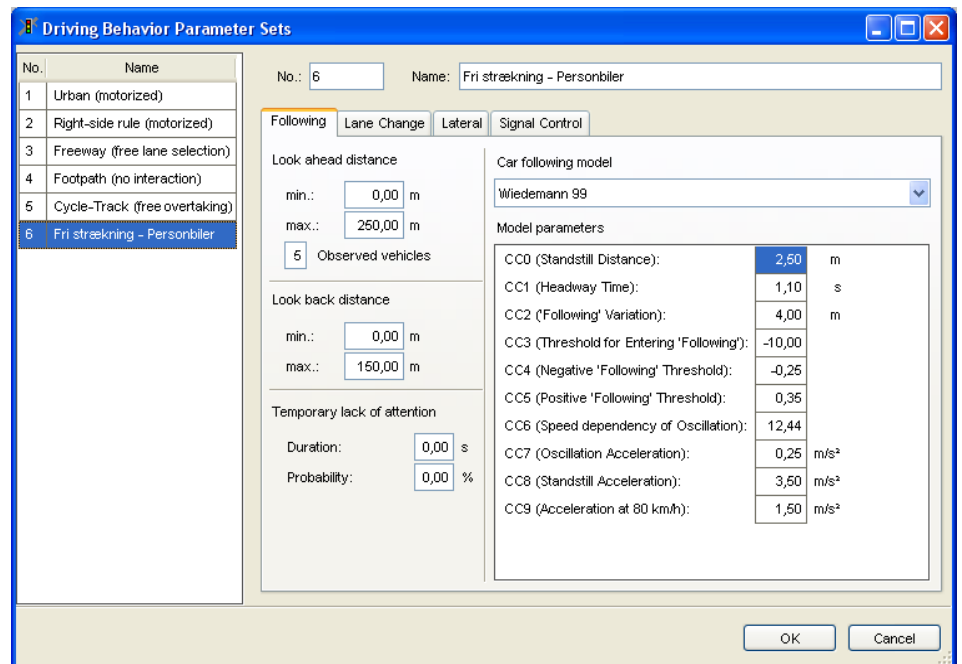
The section below gives a few examples of *indicative* parameter setting, which, in connection with the preparation of this Road Standard, has been tested on measured traffic intensity on a motorway section. The analyses completed do not fully cover all model parameters, but they have given a reasonable result, and the parameter setting is therefore shown in the tables below. These parameters are also based on studies conducted by PTV,

which is the supplier of Vissim, in connection with the ongoing development of the program.

Free section motorway

As mentioned, Wiedemann 99 is usually used for simulation of traffic on motorways, and this model has a preference for using the right lane. However, experience shows that traffic on Danish motorways is not always simulated realistically with the default values for the parameters for CC0-CC9, see table 6.1. Figures 6.2 and 6.3 show examples values, which have, in some cases, proved to result in a more realistic simulation.

Figures 6.2 and 6.3 shows that several changes have been made from the default values, and for some of the parameters, major changes have been made to the values. In connection with the parameter setting for a free section, it is important to distinguish between passenger cars (car) and heavy goods vehicles (HGV). The difference is in the CC1 value, which is why it is necessary to create a "driving behaviour" for the passenger cars/vans and heavy goods vehicles. The reason why the value is lower for heavy goods vehicles, is that they typically travel in convoys on the motorways. The lower CC1 value means that the HGVs drive so closely, that passenger cars do not normally break the convoy, which is often the case in real traffic



* CC1 = 1.0-1.1 for commuter traffic, CC1= 1.1-1.2 for other situations

Figure 6.2. Indicative values for car-following parameters in Wiedemann 99 for passenger cars.

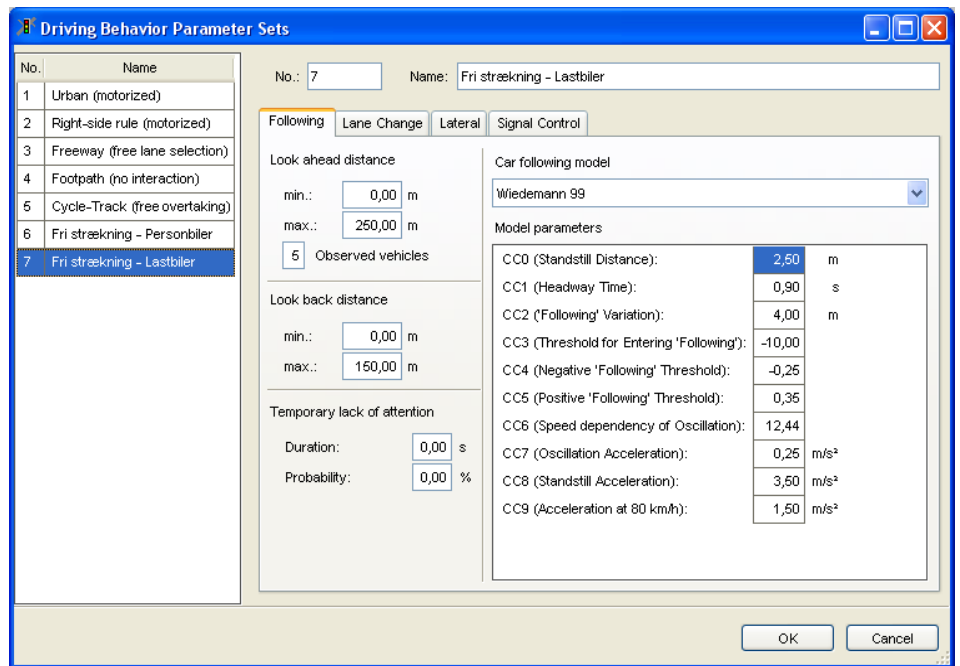


Figure 6.3. Indicative values for car-following parameters in Wiedemann 99 for heavy goods vehicles.

6.3.2 Parameters related to car-following in Wiedemann 74

For urban traffic and on roads with weaving of traffic flows, the Wiedemann 74 model is most commonly used for car-following. The sections with weaving traffic could be a result of weaving of two motorways, of a narrowing from 3 to 2 lanes where traffic will be handled through weaving or of weaving of traffic from a ramp. In these areas, the road user behaves in a different way than on the other section as particularly attention is greater and smaller distances to the other traffic is often accepted. These situations have proved to be more readily handled in Wiedemann 74 than Wiedemann 99.

In the car-following model, the parameter "observed vehicles" is normally set at 4 or more as described in section 6.3.1.

Average standstill distance is normally set at 2.5 metres.

6.4 Lane change behaviour

6.4.1 Parameters relating to lane change in Wiedemann 99

Lane change behaviour is indicated using parameters describing e.g. safety distance and a more or less aggressive lane change behaviour.

In Vissim, an important parameter for weaving manoeuvres is the "Safety Distance Reduction Factor", which is a key factor for how much the safety distance to vehicles ahead and behind can be reduced in connection with lane change. The default is 0.6, which means a reduction in the safety distance to 60% of the distance under normal conditions.

Figures 6.4 and 6.5 show indicative values for lane change of passenger cars and heavy goods vehicles. Some values have been adjusted compared to the default values. The values shown in the figures, means that road users in the model will be slightly more "aggressive" compared to the default values, and this has proved to result in a more realistic traffic flow in many cases.

The reason for the difference between passenger cars and heavy goods vehicles in the field "two slower lane if collision time above" in the figures 6.4 and 6.5 above, is that it must be ensured that the model quickly makes trucks pull into the right lane after overtaking, which is considered realistic in most cases.

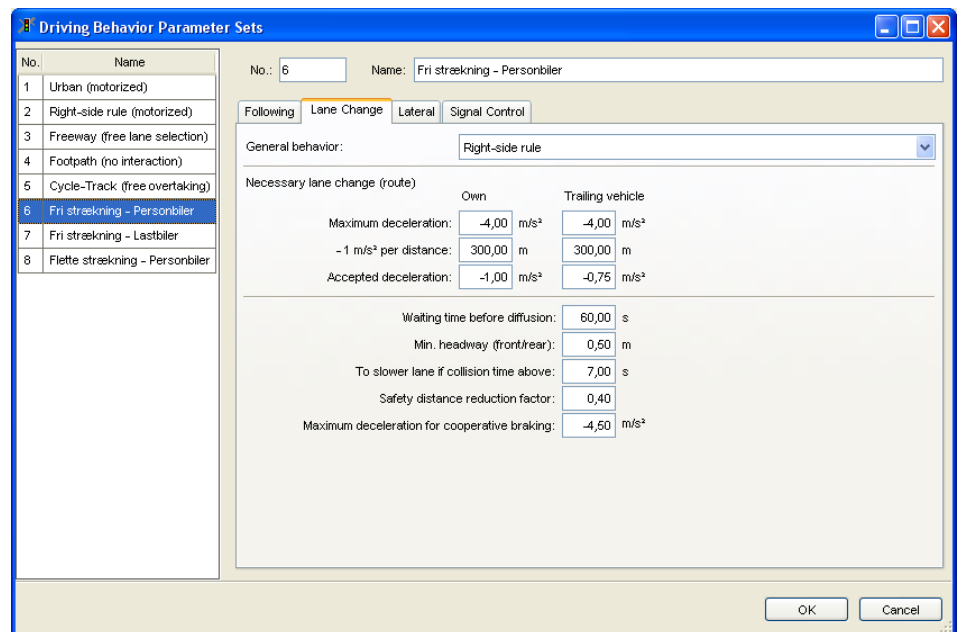


Fig. 6.4. Indicative values for passenger cars of lane change parameters in Wiedemann 99.

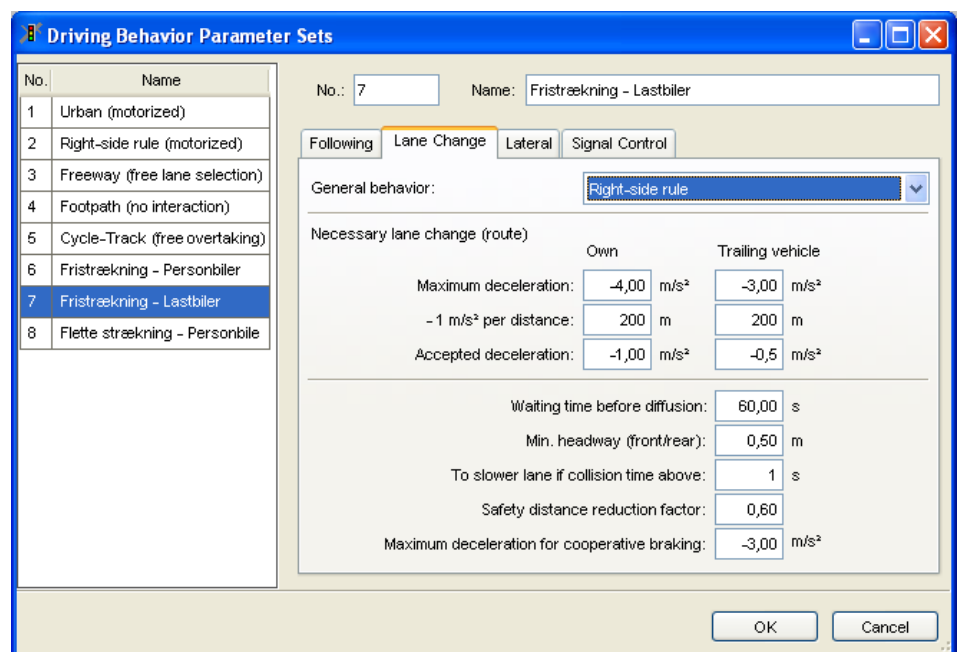


Fig. 6.5. Indicative values for heavy goods vehicles of the lane change parameters in Wiedemann 99 .

6.4.2 Indicative parameter setting for weaving in Wiedemann 74.

Figure 6.6 shows proposed default values. Contrary to Wiedemann 99, Wiedemann 74 does not make a distinction between passenger cars and heavy goods vehicles. The values are adjusted from the default values. The values in the figure make the road users in the model slightly more "aggressive" compared to a model based on the default parameters.

No.	Name
1	Urban (motorized)
2	Right-side rule (motorized)
3	Freeway (free lane selection)
4	Footpath (no interaction)
5	Cycle-Track (free overtaking)
6	Fristrækning - Personbiler
7	Fristrækning - Lastbiler
8	Flette strækning

No.: 8 Name: Flette strækning

Following Lane Change Lateral Signal Control

General behavior: Free Lane Selection

Necessary lane change (route)

	Own	Trailing vehicle
Maximum deceleration:	-4,00 m/s ²	-4,00 m/s ²
-1 m/s ² per distance:	300,00 m	300,00 m
Accepted deceleration:	-1,50 m/s ²	-1,00 m/s ²

Waiting time before diffusion: 60,00 s

Min. headway (front/rear): 0,20 m

To slower lane if collision time above: 0,00 s

Safety distance reduction factor: 0,20

Maximum deceleration for cooperative braking: -4,50 m/s²

OK Cancel

Fig. 6.6. Indicative values for lane change parameters in Wiedemann 74.

If the parameter values shown here do not provide realistic weaving of traffic, e.g. if the traffic in the model does not match the counted traffic, the parameters must be adjusted until conformity is achieved. As an example, it is possible to make weaving more or less "aggressive" by adjusting maximum deceleration between -6.00 and -9.00. In specific cases, values for maximum deceleration of -7 and -8 proved to give good results.

6.5 Parameters for duty to give way

Traffic flow in priority intersections and roundabouts, as well as unbound turning flows in signal-controlled intersections depends to a wide extent on road users' duty to give way to main traffic flows. To model the duty to give way in Vissim, two different methods can be used. One method uses "conflict markers" and stop lines whereas the other uses "conflict areas".



The following sets out guidelines for how duty to give way situations can be modelled properly in Vissim using the two methods, and guidelines are provided for parameter setting. The parameter setting for duties to give way is highly dependent on the individual situation where e.g. geometry, traffic volumes, etc. play a major role for capacity and for the final result. Therefore, it is important to emphasise that the proposed values for parameter setting for duties to give way must be used critically, and that the used values should be calibrated and validated against registrations in the "field" to the extent this is possible, see section 5.2. In cases where no observations of actual traffic flow are available, the simulation results can be related to similar data obtained from models in the Road Standard Proposal for capacity and service and from the DanKap model.

6.5.1 Modelling of duty to give way in Vissim with "stop line" and conflict marker

Modelling of duty to give way using the stop line and conflict marker method is based on what is known as the gap time theory. This assumes that a certain minimum time interval must exist between two vehicles in the overall traffic flow, before the road user with the duty to give way will continue driving and cross the give way line. This minimum time interval is known as the critical interval and is measured in seconds, see figure 6.7. In Vissim model tool, the critical interval measured from the rear end of a vehicle to the front of the following vehicle is called *gap time*.

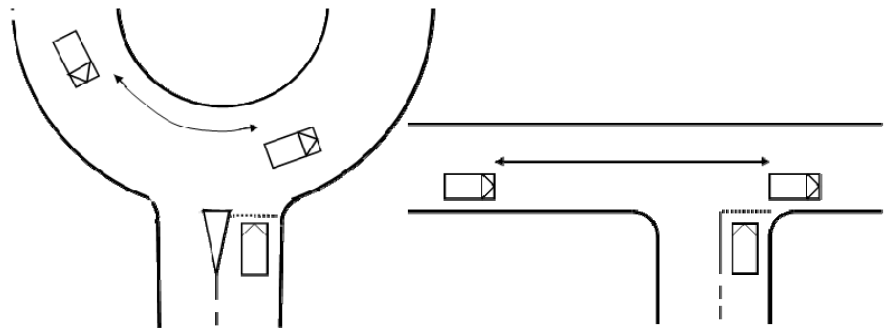


Fig. 6.7. Critical gap, in Vissim known as *gap time*, shown with arrow for road users with duty to give way in a roundabout and on a side road in a priority intersection.

In addition to gap time, Vissim also uses the parameter *minimal headway*. Minimum headway is a given section in the conflict area where no other road users must be if the road user with duty to give way is to continue into the intersection. The parameter *minimal headway* typically covers the conflict area and is used to ensure that the road user with duty to give way does not continue into a lane containing a queue or slow-moving traffic. Here, headway is measured in metres, see figure 6.8.

In practice, this type of duty to give way is modelled by inserting a stop line in the model at a location where the vehicle with duty to give way is required to stop to observe its duty to give way. In addition to the stop line, one or more conflict markers should be entered to which some conditions for gap time and minimal headway should be assigned. The conditions for critical interval (gap time) and minimal headway must be

met before the vehicle with duty to give way continues and crosses the give way line.

As mentioned, the reason for specifying a *minimum headway* is to be able to handle cases with queues or slow-moving traffic in the main traffic flow. In such cases, the *gap time* parameter is not sufficient as the only criterion, and therefore, *minimal headway* is added as a critical distance in metres.

Figure 6.8 shows an example of how duties to give way can be entered in the model.

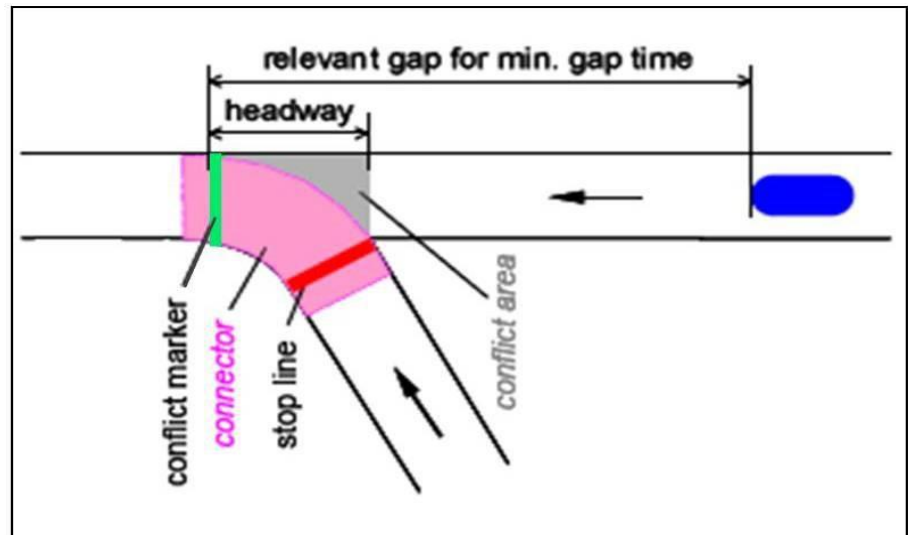


Figure 6.8. Modelling of duty to give way in Vissim with stop line and conflict marker.

Frequently used values

The most important parameter for modelling duties to give way using stop lines and conflict markers is gap time. Tables 6.2 to 6.4 show some general intervals for the gap time as well as a default value estimated as a "weighted" average of values found relevant in the specific cases.

If the default value is used, it must be noted, however, that it should only be used with great caution, as e.g. gap time, is highly dependent on the physical conditions and the general traffic load in the area. In each case, the model maker must therefore make a careful assessment of the value assigned to the *gap time* parameter and the extent to which it is considered necessary and possible to calibrate and validate the model up against field recordings. See also sections 3.7 and 5.2 for calibration and validation

Roundabouts Vissim – DanKap

Furthermore, a comparison has been made of the parameters used in the Road Standard Proposal for capacity and service level and in DanKap, see Annex 4. Figure B4.4 in Annex 4 shows that the value of 3.2 sec. for gap time in a one-lane approach can, according to table 6.3, be assumed to result in about the same capacity as DanKap with a critical interval of 5.1 sec. if the circulating flow has a medium traffic intensity, equivalent to approximately 6-800 pcu/hour.

Gap time: Priority intersections in Vissim

Passenger cars:				
Traffic flow ► Opposite traffic ▼	Primary road: Turning left	Secondary road: Turning left	Secondary road: road:	Secondary road: Turning right
from the right or oncoming	[3.0 – 5.0 sec.] 4.5 sec.	[4.0 – 6.0 sec.] 5.5 sec.	[4.0 – 5.5 sec.] 5.0 sec.	
from the left		[3.0 – 4.5 sec.] 4.5 sec.	[3.5 – 4.5 sec.] 4.0 sec.	[3.5 – 5.5 sec.] 5.0 sec.
Heavy goods vehicles:				
Traffic flow ► Opposite traffic ▼	Primary road: Turning left	Secondary road: Turning left	Secondary road: road:	Secondary road: Turning right
from the right or oncoming	[3.5 – 5.5 sec.] 5.0 sec.	[4.5 – 6.5 sec.] 6.0 sec.	[4.0 – 6.0 sec.] 5.5 sec.	
from the left		[3.5 – 5.5 sec.] 5.0 sec.	[3.5 – 5.0 sec.] 4.5 sec.	[4.0 – 6.0 sec.] 5.5 sec.

Table 6.2. Interval specified in square brackets for frequently used gap times and proposed "standard" gap time for priority intersections in Vissim.

Gap time: Roundabouts in Vissim

Passenger cars:			
Traffic flow ► Opposite traffic ▼	Traffic in 1-lane approach	Left lane in 2-lane approach	Right lane in 2-lane approach
Circulating traffic	[2.5 – 4.5 sec.] 3.2 sec.	2.7 / 2.6 sec.	1.8 / 2.6
Heavy goods vehicles:			
Traffic flow ► Opposite traffic ▼	Traffic in 1-lane approach	Left lane in 2-lane approach	Right lane in 2-lane approach
Circulating traffic	[3.5 – 5.5 sec.] 4.0 sec.	3.7 / 3.6 sec.	2.8 / 3.6 sec.

Table 6.3. Interval specified in square brackets for frequently used gap times and proposed "standard" gap time for roundabouts in Vissim. For the 2-lane approaches, the first figure is the proposed value for duty to give way to traffic in the left-hand circulating lane and the second figure is the value for duty to give way to traffic in the right-hand circulating lane.

Gap time: Signal-controlled intersections in Vissim

Passenger cars:	
Traffic flow ► Opposite traffic ▼	Left-turning vehicles with
Oncoming	[3.0 – 4.5 sec.] 4.0 sec.
Heavy goods vehicles:	
Traffic flow ► Opposite traffic ▼	Left-turning vehicles with
Oncoming	[3.5 – 5.0 sec.] 4.5 sec.

Table 6.4. Interval in square brackets for frequently used gap times, as well as "standard" gap time for left-turning vehicles with duty to give way in signal-controlled intersections in Vissim.

Priority intersections

Vissim – DanKap

A study has been carried out of capacity for right- and left-turning vehicles from side roads and left-turning vehicles from primary roads in priority three-leg intersections. Reference is made to the diagrams in figure B4.1, .2 and .3 in annex 4.

A comparison between the Road Standard Proposal for capacity and service level and Vissim shows that frequently used values for gap time, see table 6.2, give results consistent with the Road Standard Proposal particularly where the overall traffic flow has great intensity – more than approx. 1500 pcu/hour for both directions in total, when left-turning vehicles with duty to give way are coming from the side way – more than approx. 700 pcu/hour for traffic from the left turning right from the side way – and more than approx. 1100 for oncoming traffic turning left from the primary road. At a lower overall traffic intensity, higher gap time values are required in Vissim than shown in table 6.2. to ensure consistent capacity in relation to the Road Standard Proposal and thus DanKap.

Minimal headway

The minimal headway value depends to a large extent on the duty to give way situation modelled and on the geometric conditions. Often, the minimal headway value will be between 5 and 10 metres in Vissim. The determination of the minimal headway value is often based on a visual inspection of traffic flows in the simulation model.

6.5.2 Modelling of duty to give way in Vissim with conflict areas

Modelling of duty to give way using the method with conflict areas in Vissim is an alternative to duties to give way using stop lines and conflict marker. The method using conflict markers is the method recommended by the supplier of Vissim, PTV AG, for most cases as this is a more simple way of defining duties to give way and as this results in more rational driver behaviour.

Modelling using conflict areas in Vissim saves time creating a model, but greater efforts are required for calibration. In 2010, the method is relatively new, and no values based on experience have yet been obtained for parameters to control duty to give way situations modelled in this way. Below is a short guide to modelling with conflict areas in Vissim.

Description

When a vehicle with duty to give way encounters a conflict area, the model observes the vehicles in the main flow, and a decision is made about what it will take for the vehicle to choose to move through the conflict area. Subsequently, the model calculates the acceleration profile allowing the vehicle to pass the conflict area. The calculations also take into account the situation after the conflict area, e.g. that the vehicle might have to stop or slow down due to other vehicles, or that several other conflict areas are located immediately after this conflict area. This may result in the vehicle needing more time to pass the conflict area than first intended, and thus, the decision as to whether the conflict area can be passed, may be amended.

When the method using conflict areas is used to model duty to give way, cars in the main flow will also react to the conflict area. This is not the case if duties to give way are modelled using stop lines and conflict markers. If a vehicle with duty to give way is unable to pass the conflict area without affecting traffic in the main flow, the cars in the main flow will brake or stop in order not to hit the crossing car. If a queue is formed through a conflict area, e.g. from a nearby signal system, cars in the main flow will not attempt to stop in the conflict area. This way crossing traffic will not be blocked.

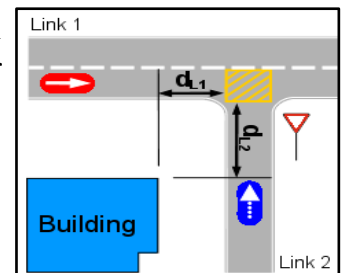
All vehicles, both road users with a duty to give way and cars in the main flow, will avoid driving into the conflict area if no space is available after conflict area to leave the conflict area completely.

Parameters

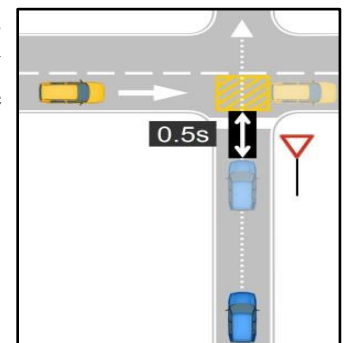
As mentioned, no systematically obtained values based on experience are available for parameter setting for duty to give way modelled using conflict areas in Vissim. Calibration is therefore particularly important to ensure that models with conflict areas can handle a maximum traffic corresponding to the observed capacity in a real situation.

The following parameters can be changed for each conflict area:

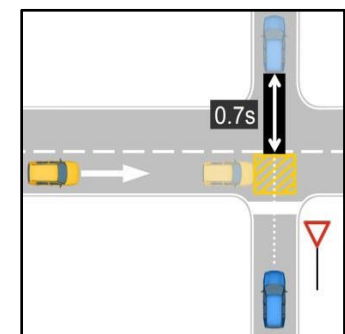
- Visibility is the maximum distance of when the driver can see the cars on the other roads included in the conflict area.



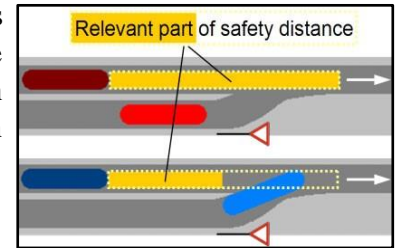
- Front Gap is the minimum gap in seconds between the rear of the car on the priority road and the front of the car on the side road, from which there is duty to give way.



- Rear Gap is the minimum gap in seconds between the rear of the car from the side way with duty to give way and the front of the car on the priority road. This parameter is used only for driving straight ahead from the side road.



- Safety distance factor. The value is multiplied by the safety distance normally selected to a car on the main road. The parameter is only used in weaving conflicts.



- Additional stopping distance. The distance the cars must keep to the conflict area when they stop (only from side ways with a duty to give way).
- Avoid blocking. Is a percentage of the cars in the main flow which would give way if a queue builds up and thus allow the traffic from the side road to pass the conflict area. The default value for this parameter is 100%, but it should probably be set lower to illustrate road user behaviour in practice.

The default values for the conflict areas in Vissim are shown in table 6.5.

	Li	Visibilit Link 1	Link	Visibility Link 2 [Front Gap [Rear Gap	Safety Di Factor	Additional Stop Distance	Observe adjacent l	Anticipat Routes	Avoi Bloc
▶	1	100	2	100	0.5	0.5	1.5	0	<input type="checkbox"/>	0	1
	1	100	4	100	0.5	0.5	1.5	0	<input type="checkbox"/>	0	1
	2	100	3	100	0.5	0.5	1.5	0	<input type="checkbox"/>	0	1
	3	100	4	100	0.5	0.5	1.5	0	<input type="checkbox"/>	0	1

show all possible Conflict Areas in Node:

Number of Conflict Areas: 4

OK Cancel

Table 6.5. Default values in Vissim used to determine conflict areas.

Traffic in exits

As described in the Road Standard Proposal for capacity and service level, exiting traffic in the same road branch as the considered approach may reduce the capacity of the approach in a roundabout. This is attributable to the fact that the road users with duty to give way are hesitant when driving into the roundabout because they are uncertain of whether the main traffic continues or takes the exit. In Vissim, the conflict areas are to a certain extent able to take account of this effect, because with the parameter "Anticipate routes", it is possible to indicate a share of road users from the sideways who watch the route of the overall traffic.

6.6 Parameters for traffic flow in signal-controlled intersections

Signals systems can be simulated as time- or traffic-controlled systems and may coordinated with other signal systems. In general, the creation of a signal system in a microsimulation model must follow the Road Standard for traffic signals.

In respect of the geometry of intersections, and particularly long turning lanes, it must be considered whether the model should use separate links or part of a multi-lane link. Also, with regard to turning movement, it must be ensured that road users lower speed.



To obtain a realistic traffic flow through signal-controlled intersections, the acceleration of the vehicles is important, see section 6.7.4. In addition, car-following parameters play a role for the simulation, see section 6.3. For turning traffic without bound left- or right-turn, gap times for duty to give way to oncoming cars or pedestrians/cyclists are of crucial importance, see section 6.5.

The Road Standard Proposal for capacity and service sets out a set of passage times across the stop line for traffic flows in signal-controlled intersections. Annex 5 sets out additional measurements of passage times to which reference might also be made in the calibration and control of a created model. However, it is important to calibrate, to the extent possible, the model according to local conditions to ensure that the model passage times correspond to the passage times on the spot. This is done for example by exploring how many cars can be handled during green time in reality and in the model.

It is also important that stop lines in the model are placed correctly, and that the space available generally corresponds to reality in order to achieve the correct clearance times and not least that the number of unbound left-turning vehicles that have entered the intersection and turns after the end of the green time corresponds to real situation.

Models based on Vissim tend to start vehicles early when the signal changes to green. However, this is offset by the fact that the vehicles are typically also stopped earlier after the end of the green time than in real traffic. These differences will often offset each other, and normally, it is not necessary to change these parameters. In general, however, it is important ensure in the calibration and validation that the green time is used in the same way as in real traffic.

6.7 Parameters for vehicle and driver characteristics

The actual vehicles in a microsimulation model will typically be characterised by parameters such as vehicle length and weight/power ratio.

The combination of vehicles and drivers can e.g. be characterised using parameters for desired speed and desired acceleration and deceleration.

Vehicles can be divided into vehicle types, such as passenger cars, vans, heavy goods vehicles with and without trailers, and for each type, the parameters will typically be described by distributions in the form of frequency or distribution functions.



Distribution of lengths, desired speeds and desired accelerations/decelerations must be made on the basis of observations on the roads similar to the road network to be modelled. Desired speeds and desired accelerations/decelerations are collected under conditions with low traffic intensity, where the road users can drive freely without being bound or restricted by other traffic.

6.7.1. Vehicle lengths

Vehicle lengths play a particular role for the vehicles' consumption of space on the road. In a microsimulation tool such as Vissim, a number of vehicle types, each with a specific length as determined by the user, can be specified for each vehicle category.

It is important to note that major difference is to be expected in the distribution of vehicle lengths for traffic on the different road types. Particularly motorways and other major roads typically used for long-distance traffic have many long vehicles, i.e. heavy goods vehicles with trailers or semi-trailers. For roads with more local and regional traffic, the average vehicle length of heavy goods vehicles is usually less.

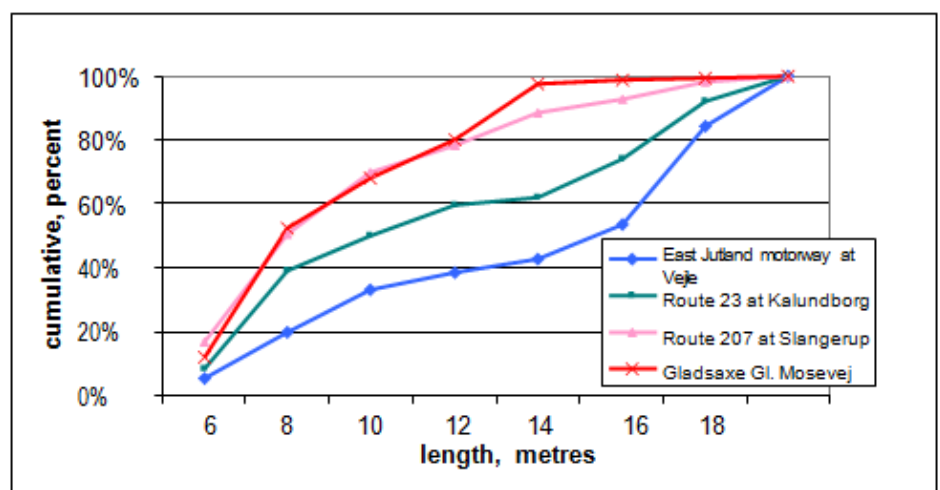


Fig. 6.9. Examples of measured length distribution of vehicles longer than 5.8 metres.

Fig. 6.9 shows examples of measured distributions of lengths of all vehicles longer than 5.8 metres. Measurements have only been included for the daytime hours 6 am to 6 pm. The figure shows a clear difference in the distribution of lengths from the East Jutland motorway with many long vehicles to the national road towards Kalundborg, the regional road at

Slangerup and to the small local road in Gladsaxe with only few vehicles over 12 metres.

6.7.2. HGV power/weight distribution

HGV acceleration and deceleration characteristics on a level road and by rises and falls in road profile depend largely on the weight/power ratio for the vehicles.

Vissim generates HGV characteristics stochastically based on entered weight and power distributions as those two distributions are regarded as independent of each other. All combinations of power and weight may therefore occur according to the distributions, also heavy HGVs with low power and light HGVs with high power, unless the group of HGVs is divided into defined groups representing power and weight ranges. From extracted values in the weight and effect distributions a power/weight ratio is calculated for each HGV, which is crucial for acceleration and deceleration performance. Vissim only uses weight and power distributions only in connection with HGVs.

Fig. 6.10 shows weight distributions for HGVs based on measurements of actual vehicle weight made on roads in urban areas, regional roads and motorways.

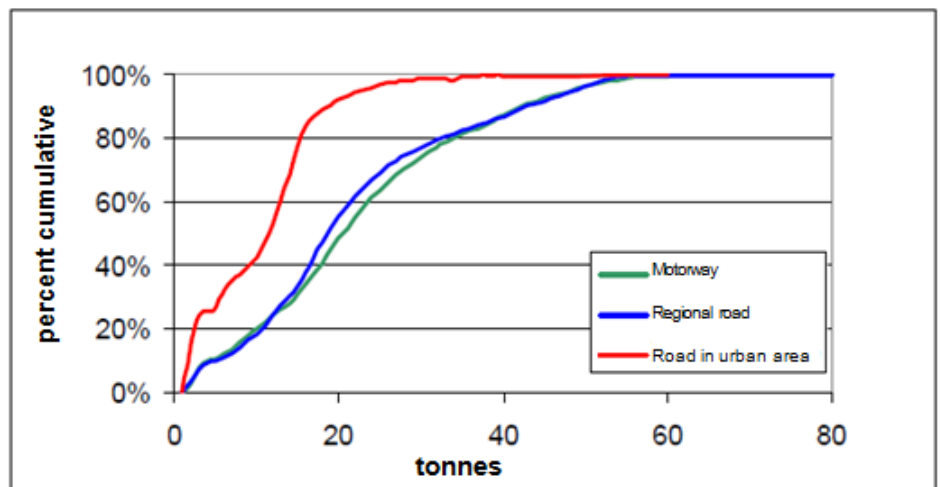


Fig. 6.10. An example of distribution of actual vehicle weight for HGVs as an average of measurements on four motorways sections, three regional road sections and two sections on roads in urban area.

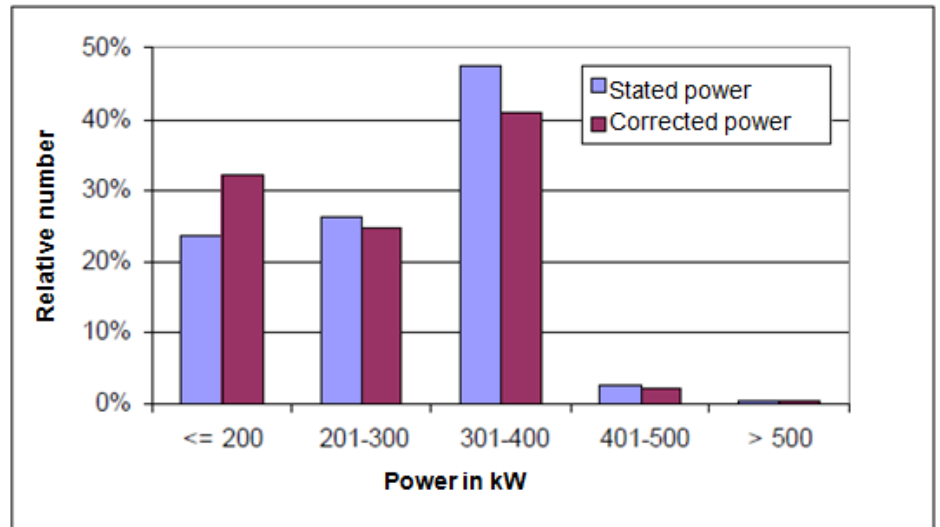


Fig. 6.11. Engine power distribution for Danish HGVs as at 31 December 2009, stated power and calculated power after correction according to gross weight. (source: Statistics Denmark).

Fig. 6.11 shows the distribution of HGV engine power. The distribution of the stated effect is shown for Danish lorries as at 31 December 2009 according to Statistics Denmark. Engine power, however, is only registered for later HGV models, and no information is therefore available for a large proportion of the HGVs. In an attempt to estimate a distribution, which better represents all HGVs, adjustments have been made for the gross weight distribution for all HGVs relative to the gross weight distribution for HGVs with stated power. However, it is important to be aware that the adjusted power distributions are subject to uncertainty, and that generally the distribution must be expected to vary for vehicles travelling in different ways and places.

6.7.3. Desired speeds

It is important to specify, in the model, the distribution of desired speeds for each incoming vehicle.

The desired speed depends particularly on allowable speed for the road on which the vehicle is travelling. When determining desired speeds in the simulation model, it is, however, important to aware that systematic differences may exist depending on the specific road section in respect of layout, design, surroundings, etc, as well as of weekday, time of day and the traffic flow on the road at the particular time, such as home-work traffic, long-distance traffic or leisure traffic.

If speed measurements are available for the simulated road sections or comparable road sections, these measurements can be used for periods of low traffic and preferably also for the same weekdays and times as included by the simulation. If not, it is necessary to perform speed measurements, but this will often be rather resource-intensive.

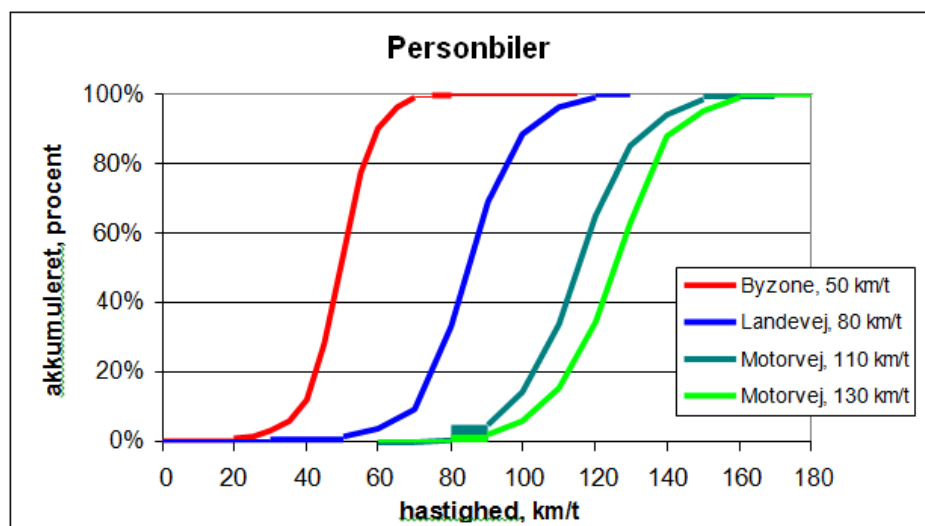


Fig. 6.12. Average for different road types of measured desired speeds for passenger cars.

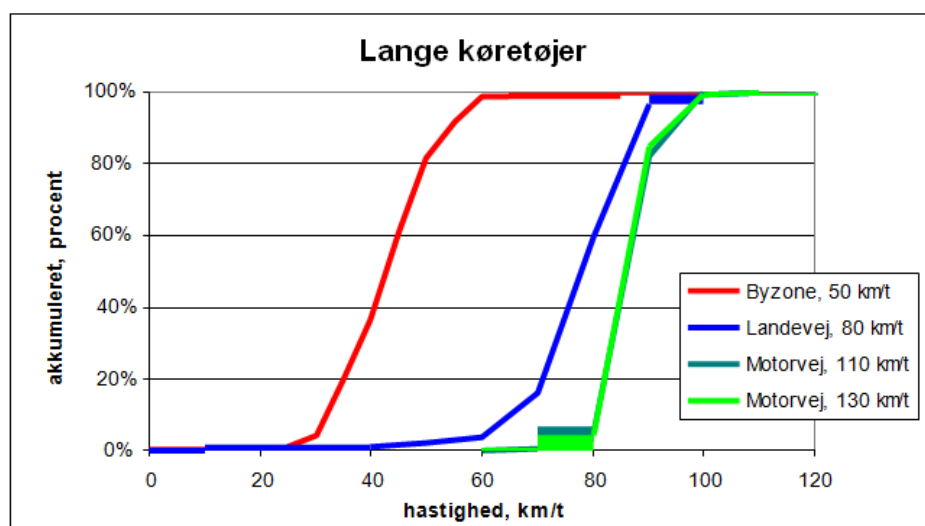


Fig. 6.13. Average for different road types of measured desired speeds for long vehicles.

Figures 6.12 and 6.13 show the distribution of measured desired speeds for passenger cars and long vehicles, respectively. For each of the four types of roads, the measurements have been made for five sections, and the figures show the total distribution for each type. The figures are shown in Annex 2 in tabular form.

Annex 2 also shows the measurements for each of the five roads included in the charts in figures 6.12 and 6.13 for each road type. The charts in Annex 2 can be considered as examples of measurements of desired speeds for roads with different speed limits. The measurements are shown as cumulative frequency for the desired speed.

6.7.4. Desired accelerations and decelerations

Road users adapt speed by accelerating or decelerating with a value adapted to the instantaneous speed, the situation, the vehicle and the behaviour of road user as such. Such a value is called the desired acceleration or deceleration, and it plays a major role for traffic flow and capacity for free sections and at intersections.

The Vissim model tool assigns graphs to each vehicle type, representing the mean value of desired acceleration and deceleration of the instantaneous speed.

In practice, it is difficult to measure road users' desired accelerations and decelerations. However, figure 6.14 below shows the result in the form of mean value of measured acceleration for passenger cars, and figure 6.15 shows the measured deceleration. Some of the measurements are divided into the permitted speed on the road where the acceleration or deceleration took place. Apart from the graphs of accelerations of cross-sectional measurements of speed on ramps, the measurements only represent acceleration and deceleration processes where drivers did not have to adapt their driving to a vehicle ahead.

However, it is important to be aware that many of the runs, on which is the illustrations of acceleration and deceleration are based, were made under experimental conditions which might give other (presumably lower) values than for general road users not covered by an experiment. This does not, however, apply to the accelerations recorded by cross-sectional measurements of speeds on ramps.

The figures also show Vissim's default distribution of acceleration and deceleration for passenger cars.

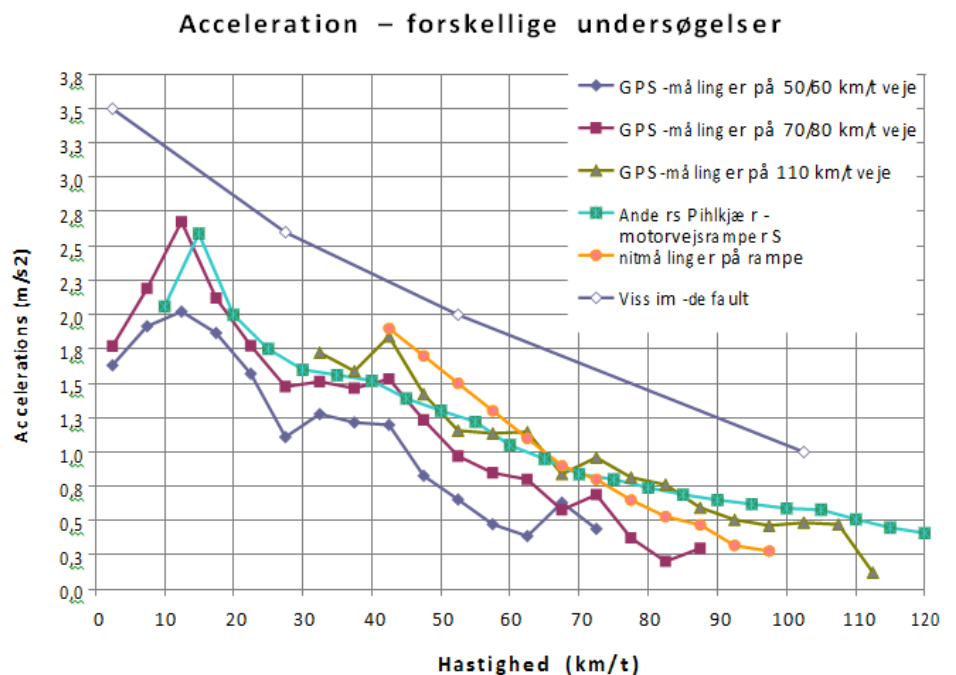


Fig. 6.14. Measured accelerations for passenger cars and default distribution in Vissim.

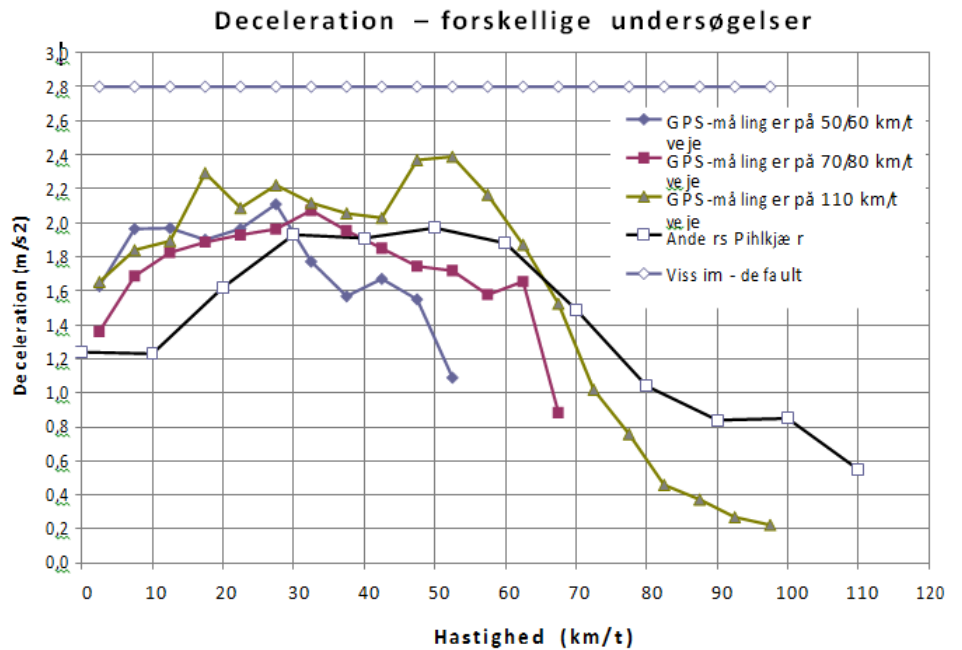


Fig. 6.15. Measured decelerations for passenger cars and default distribution in Vissim.

6.8 Special parameters

The special parameters include parameters relating to the more technical part of the simulation. The following sections describe the initial value for random number generator, length of time step and how many times the model runs need to be repeated, in order to obtain adequate certainty in the establishment of the key values to be estimated using the model.

6.8.1. Random number generator

In the simulation, based on an initial value, the model tool random number generator creates a sequence of random numbers which are added to the distributions of stochastic variables, and thus have an impact on the result of the simulation.

Simulations that use the same input, and where the value of the random number generator is the same, will always lead to the same results, and a situation can be recreated.

6.8.2. Size of time step

For each time step, the position of all vehicles is recalculated. With a short time step, frequent updating will take place, resulting in better accuracy of the simulation, but the smaller the time step, the slower the actual model runs as the extent of calculations increases.

In Vissim, the time step is determined as the number of times the vehicle positions are updated every second. This value can be set between 1 and 10, corresponding to time steps between 1 and 0.1 seconds. The manual of Vissim recommends at least 3 updates per second. Experience shows that, in practice, the user should select 10 updates per second, which normally does not provide problems with a modern computer.

6.8.3. The number of model repetitions

If a stochastic model is used to analyse a critical variable, such as a particular queue length, travel time or traffic flow intensity, there is a risk that the result generated by one simulation is very far from the actual average for the relevant variable. To obtain an insight into the distribution of outcome of the critical variables, including an estimate of the mean value of these variables, the simulation must be repeated a number of times.

The same is also applicable to the collection of data for the real situations. Reality is not more correctly described than it must be considered to involve a significant streak of coincidence, i.e. day-to-day variations exist, even under conditions that immediately seem the same. Therefore, real-life actual queue lengths, speeds, traffic flow intensities, etc. must be observed over several days under what appears to be the same conditions to provide a general picture of these variables.

The ideally designed and calibrated model of a traffic flow situation does not only provide the same mean value as that found in similar real-life situation, but also provides the same spread and the same quantiles in the distribution of the measured values as under real conditions. In addition, the same requirements should be made for the number of repeated simulations and observations, respectively, in the model and in real-life to determine the values of the considered variables.

To allow for the variation of the simulation results, it seems to be "tradition" that the simulation of a situation for analysis is repeated, so that a total of between 10 and 20 repetitions are available. In addition, experience shows that more repetitions should be made for simulations of high-load traffic situations than for situations will load. If significant variation in result variables is established, several repetitions must also be made. With the processing power of modern computers, it will normally not be a major problem in terms of time to repeat the model run several times.

Calculated number

However, it is always possible to make a statistical estimate of the number of repetitions required to achieve adequate certainty in the determination of the analysis result. The following method based on the mean value of a selected result variable can be used to determine both the number of simulations with the stochastic model during "production run" and during calibration, and actually also to determine the number of observations in real conditions. The method statement generally illustrates the work with results generated by outcomes of tests involving stochastic elements, which is normally the case with microsimulation models runs.

1. A critical result variable is selected, e.g. average travel time, queue length or traffic intensity, for a specific time interval, e.g. a peak hour.
2. An allowed margin of error must be set for the result variable. The margin of error, also known as the confidence interval, is the size of the range within which the actual mean value will most likely be.

Determining the range of this interval may depend on the nature of the task. If, for example, the task is about fine-tuning of signal

systems etc., a narrow confidence interval will be required to achieve confidence in the calculated differences. If the task is about comparing significantly different designs of a traffic handling system or about classifying the results of an analysis into relatively rough categories, specification of a broader confidence interval will be sufficient. If a small confidence interval is set, more repetitions of the model will be required than for a large interval.

The size of the margin of error/confidence interval, K , may, for example be given as a fraction ε of the mean value of the result variable, e.g. +/-5% of mean travel time.

3. A confidence level must be set which expresses the probability that the true (unknown) mean value is within the margin of error/ confidence interval in relation to the estimated average value of the simulation.

It is common to choose a confidence level of 95%, i.e. the probability that the true mean value is outside the margin of error in relation to the calculated mean value is accepted to be $\alpha = 100 - 95 = 5\%$. Higher or lower confidence levels may be chosen, where higher confidence levels will require a higher number of repetitions, and fewer repetitions require a lower number of repetitions, but the certainty of the mean value estimate will be less.

4. It is proposed that initially 5-6 simulations or observations be carried out where outcome of the result variable is recorded.
5. Based on the repetitions of the simulation or the observations made, a calculation is made of the result variable standard deviation, S :

$$S = \sqrt{\frac{\sum (x_i - \bar{X})^2}{N - 1}}$$

Where X_i is the i^{th} outcome of the result variable of the total number of N repetitions, and

$$\bar{X} = \frac{\sum x_i}{N}$$

is the mean value of the N outcomes of result variable.

6. It should now be established whether sufficient repetitions have been made or whether more are needed. For this purpose, the following formula should be used to determine the necessary number of repetitions, N' , based on the previous N repetitions for which the standard deviation is provisionally intended:

$$N' = \left(\frac{2 \cdot S \cdot t_{N'-1}(1-\alpha/2)}{K} \right)^2 = \left(\frac{S \cdot t_{N'-1}(1-\alpha/2)}{\bar{X} \cdot \varepsilon} \right)^2$$

where α is the selected probability that the true mean value is outside of the confidence interval K , see step 3. $t_{N'-1}(1-\alpha/2)$ is $(1-\alpha/2)$ - quantile in the t -distribution with $N'-1$ degrees of freedom, and the value can be looked up in a statistical table. As mentioned in step 2, ε is the proportion of the result variable mean value included in the

margin of error, and the error of margin will then be $\pm X \cdot \varepsilon$, and the overall confidence interval $K = 2 \cdot X \cdot \varepsilon$, but K may also be determined in a different manner.

Note that the calculation of the number of necessary repetitions using the above formula requires an iterative process, where the calculated N' on the left-hand side is brought to correspond to the right-hand side value of N' , which is used to look up t distribution.

7. If the calculated value N' is less than or equal to the total number of repetitions N already performed, the established criteria for confidence interval and confidence level are considered to have been met by the estimate of the mean value of the critical result variable.

If, on the other hand N' is greater than N , then it is necessary to carry out more repetitions and continue with step 5 where a new mean value and standard deviation will be calculated on the basis of the additional repetitions, and then a recalculation is made of the formula in step 6 to determine whether a sufficient number of repetitions have now been made.

Table 6.6 shows the solution to the above formula for the calculation of the minimum number of repetitions based on the desired confidence interval and confidence level.

In cases of more critical variables where a specific accuracy in estimation must be ensured, the necessary number of repetitions must be ensured for each of the critical variable.

It is important to note that the method is only suitable to determine the number of repetitions required to achieve a specified certainty in connection with *mean value* and not in connection with other statistical values, e.g. quantiles in distributions or variance.

At least 10 repetitions

Note that irrespective of the result of the above calculations or table lookups, it is recommended that *at least 10 or 15 repetitions are always carried out.*

C/S	Confidence level	Min. number of
0.5	99%	110
	95%	64
	90%	46
1.0	99%	31
	95%	18
	90%	13
1.5	99%	16
	95%	10
	90%	7
2.0	99%	11
	95%	7
	90%	5

Table 6.6. Calculated minimum number of repetitions of a model to achieve a confidence level of 90, 95, or 99%, and at different relationships between the selected confidence interval, K , and a calculated standard deviation, S .

Example:

Re 1) In a specific task, focus is on travel time between two given points. The travel time is selected as the critical result variable on the basis of which the number of required repetitions must be determined.

Re 2) Based on the nature of the task, it is decided to set the margin of error/confidence interval at + /-5% of mean travel time, i.e. $\varepsilon = 0.05$.

Re 3) The confidence level is set at 95%.

Re. 4) Initially, five repetitions are carried out with a simulation model, resulting in the following critical mean travel times in seconds: 125, 120, 120, 116, 132.

Re 5) Based on the five repetitions using the formulas in step 5, the mean value of the travel times are calculated at 122.6 sec. and the standard deviation is calculated at 6.2 sec.

Re 6) Defined and found values are inserted in the formula as shown in step 6:

$$N' = \left(\frac{6.2 \cdot 2.776}{122.6 \cdot 0.05} \right)^2 = 7.9$$

where $t_{5-1}(1-0.05/2) = t_4(0.975) = 2.776$ according to table lookups of t distribution. At a few iterations, a need for $N' = 7$ repetitions is calculated.

Re 7) Since a minimum number of repetitions are calculated which are greater than the previous five, another three repetitions of the model will be made, as it is decided to make one additional repetition in relation to the calculated minimum number. The results for mean travel time are: 129, 117 and 122 sec. Continue to step 5.

Re 5) Based on the total of eight repetitions, the mean value is 122.6 sec. and the standard deviation is 5.7 sec.

Re 6) Values are inserted in the formula to determine the required number of repetitions. Iteration gives $N' = 6$.

Re 7) A number of repetitions greater than the smallest calculated number of 6 have now been performed and the criteria set for accuracy of the selected critical result variable have therefore been met.

With a confidence interval of + /- 5%, i.e. a total of 10% of mean travel time, which is calculated at 122.6 sec., the confidence interval is $122.6 \cdot 0.10 = 12.3$ sec. Initially, the standard deviation is calculated at 6.2 sec. The confidence interval divided by the standard deviation, C/S, is therefore $12.27/6.2 \approx 2.0$. At the selected confidence level of 95%, table 6.6 provides that at least 7 repetitions of the model must be made.

As outlined in this section, however, at least 10 or 15 repetitions should always be carried out of a stochastic microsimulation model.

7. REFERENCES

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ANNEXES

Annex 1. Nomenclature

Assignment	Traffic assignment is the way in which traffic is distributed on roads and routes in the model road network. In static assignment, traffic distribution in the network is constant. In dynamic assignment, traffic is distributed on roads and routes over time according to the current costs of the trip.
DanKap	PC program developed in conjunction with Road Standard Proposal for capacity and service level. Calculations of capacity and service level are based on the same models and parameters as described in the Road Standard Proposal. It is a statistical model at macroscopic level
Default value	The value of a parameter when a microsimulation software is first installed after delivery, - the equivalent of a "factory setting"
Deterministic process	Course of events which only depends on the initial conditions and determined contexts, and where the course does not change by repeating model calculation under unchanged conditions
Assignment	Traffic assignment is the way in which traffic is distributed on roads and routes in the model road network. In static assignment, traffic distribution in the network is constant. In dynamic assignment, traffic is distributed on roads and routes over time according to the current costs of the trip.
DanKap	PC program developed in conjunction with Road Standard Proposal for capacity and service level. Calculations of capacity and service level are based on the same models and parameters as described in the Road Standard Proposal. It is a statistical model at macroscopic level
Default value	The value of a parameter when a microsimulation software is first installed after delivery, - the equivalent of a "factory setting"
Gap (time)	Gap or gap time is the time gap between the rear end of one vehicle and the front end of the following vehicle in a traffic flow measured in seconds. In this Road Standard, it is used in connection with the Vissim microsimulation tool in the sense "critical interval"
Headway	Distance in metres between the front of a vehicle and front of the following vehicle in the same lane (note that in other traffic contexts headway is often the time gap in seconds from vehicle to vehicle)
Critical interval	The minimum time interval in seconds required between vehicles in a main traffic flow for a road user with a duty to give way to drive into the intersection.
Macroscopic model	Model that illustrates the overall connections in a process - for traffic flow models, entire traffic flows and the interaction between traffic flows are typically modelled.
Microscopic model	Model which illustrates the individual elements of a process - traffic flow models typically show the individual road users the traffic flows and the interaction between the road users
Contractor	In this Road Standard, a contractor is the person who solves a micro simulation task by creating a model and conducting analyses etc., typically an adviser
Requester	In this Road Standard, the requester is the person who wants an illustration of traffic situations. The requester may be a project manager or the person in charge of a specific task in a road administration

Parameter	In this Road Standard, parameters are the data which are firmly attached to a submodel and which usually have a specific value for a project after calibration
Passage time	The time interval between passage of the front of a vehicle to the front of the following vehicle, e.g. when crossing a stop line or give way line at an intersection
Simulation	Imitation or representation of real events, mechanisms or processes, - in a model that simulates traffic flow, traffic may for instance be shown in a stochastic model such as Vissim or in a statistical model such as DanKap
Simulation tool	Software acquired for the purpose of creating simulation models. Vissim is an example of a simulation tool
Default value	A parameter value which, according to this Road Standard, can be used as the basis for calibration or – with care – be used directly in a model in cases where a value adapted to the current task cannot be specified. The default value can be the same as or different from the parameter default value.
Stochastic process	Random course of events which varies from time to time of the model calculation, even though the conditions otherwise remain unchanged.
Time step	Time interval between updates of the simulated situation in a model, - in traffic simulation, the acceleration, speed and position on the carriageway are recalculated after every time step, and decision routines are activated after every time step.
Road user	Vehicle (passenger car, van, bus, HGV, cyclist) or pedestrian
Variable	In this Road Standard, variables are the data which are specific to a project or which typically change in connection with the project. Variables can be traffic intensities, cycle times of signal programs, etc

Annex 2. Measured desired speeds

Desired speeds for roads with speed limits of 50, 80, 110 and 130 km/h have been set for five sections. The measurements have been carried out as average speed measurements for freely moving vehicles, where a time gap of at least 7 seconds exists to the vehicle ahead of and behind the vehicle. For these situations, it is found that road-users have themselves been able to choose the speed, and therefore, these speeds can be interpreted as the *desired speeds* of road users.

Passenger – cars/vans				
Speed, km/h	Road in urban area, 50 km/h	Regional road, 80 km/h	Motorway, 110 km/h	Motorway, 130 km/h
0	0	0	0	0
20	1	0	0	0
40	12	1	0	0
60	90	4	0	0
80	100	33	1	0
100	100	89	14	6
120	100	100	65	34
140	100	100	94	88
160	100	100	99	99
180	100	100	100	100

Table B2.1. The percentage of passenger cars/vans measured at a speed below the speed stated in the left column, total for 5 sections on each of the four road types.

Long vehicles longer than 8 metres on urban and regional roads, longer than 12 metres on motorways				
Speed, km/h	Road in urban area, 50 km/h	Regional road, 80 km/h	Motorway, 110 km/h	Motorway, 130 km/h
0	0	0	0	0
20	2	0	0	0
40	36	1	0	0
60	98	4	0	0
80	100	60	5	4
90	100	97	85	85
100	100	100	100	100

Table B2.2. The percentage of long vehicles measured at a speed below the speed stated in the left column, total for 5 sections on each of the four road types.

Tables B2.1 and B2.2 are tabular versions of figures 6.12 and 6.13 in section 5.7.3. Figures B2.1-B2.8 show the results for each of the measured sections for passenger cars/vans and large vehicles. The measurements for large vehicles longer than 8 metres for urban areas area and roads with speed limit of 80 km/h, and longer than 12.5 metres for motorways.

However, it is important to note that the five sections for each of the speed categories are not equally geographically distributed across the country, particularly not for roads with speed limits of 50 and 80 km/h. Data come from a couple of weekdays in 2008 or 2009 and represent the entire day. Certain road types have a limited number of large vehicles.

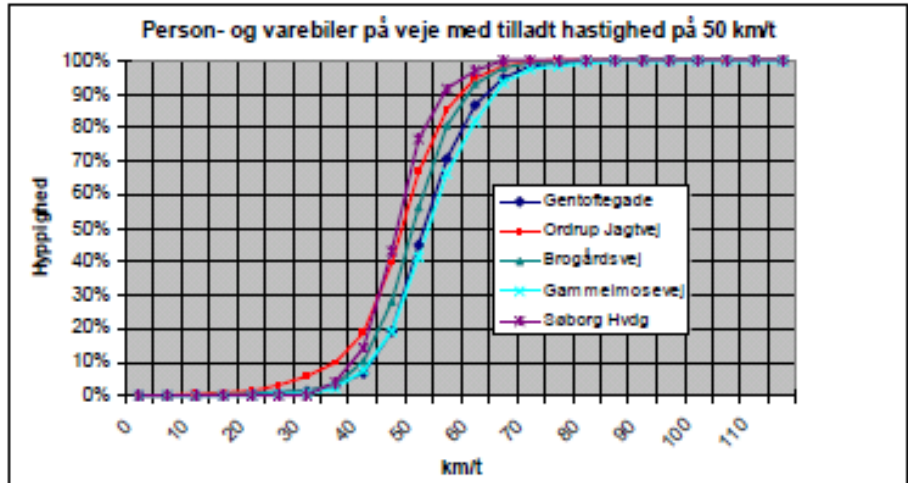


Fig. B2.1. Passenger cars and vans at 50 km/h speed limits.

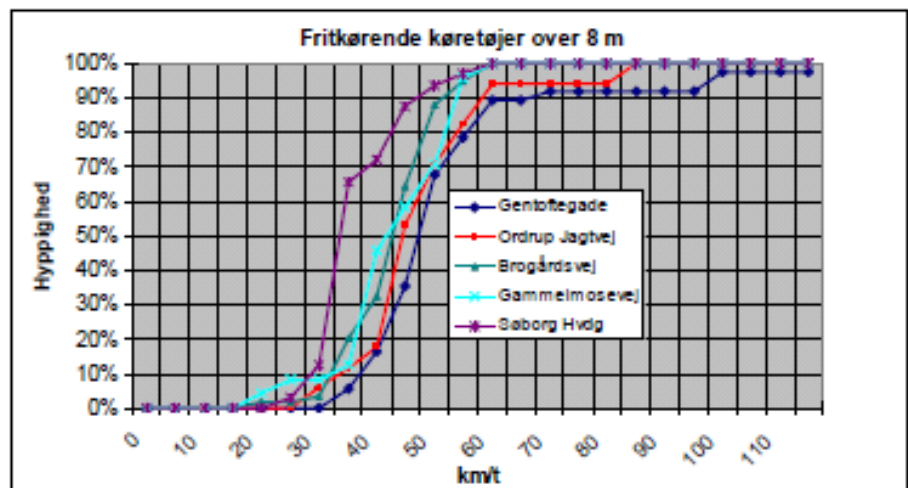


Fig. B2.2. Vehicles longer than 8 metres at 50 km/h speed limits

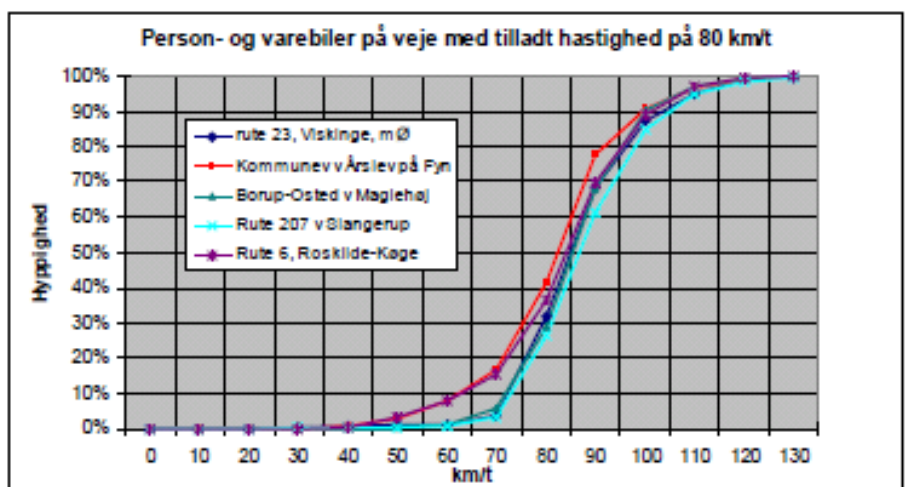


Fig. B2.3. Passenger cars and vans at 80 km/h. speed limits

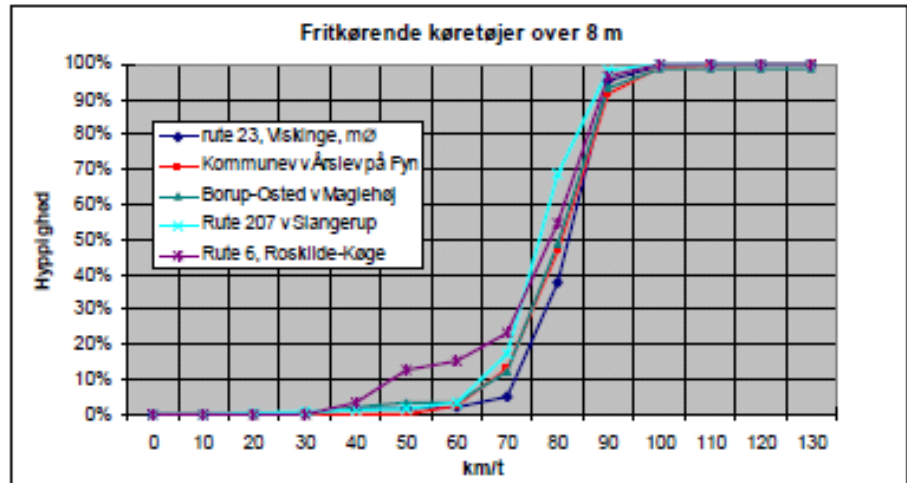


Fig. B2.4. Vehicles longer than 8 metres at 80 km/h speed limits for passenger cars.

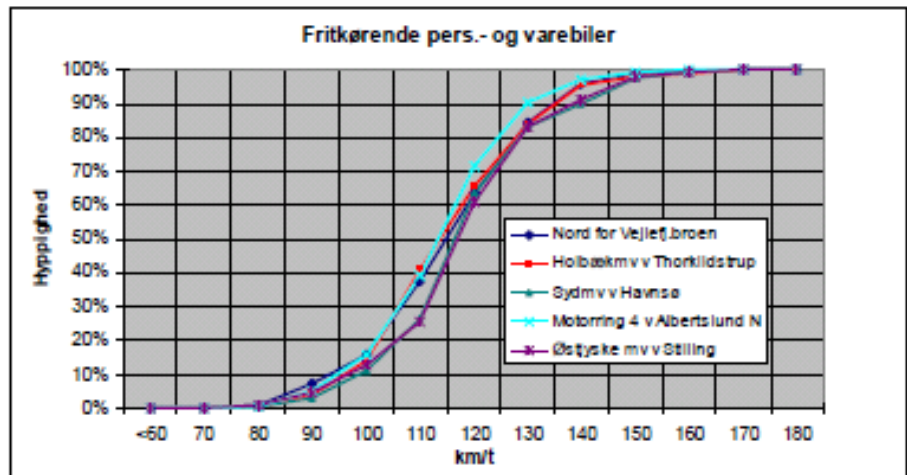


Fig. B2.5. Passenger cars and vans at 110 km/h. speed limits

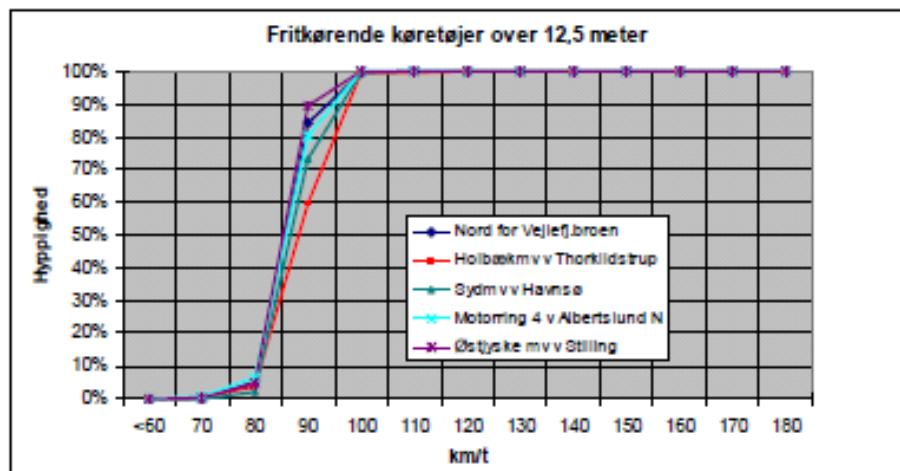


Fig. B2.6. Vehicles longer than 12.5 metres at 110 km/h speed limits for passenger cars.

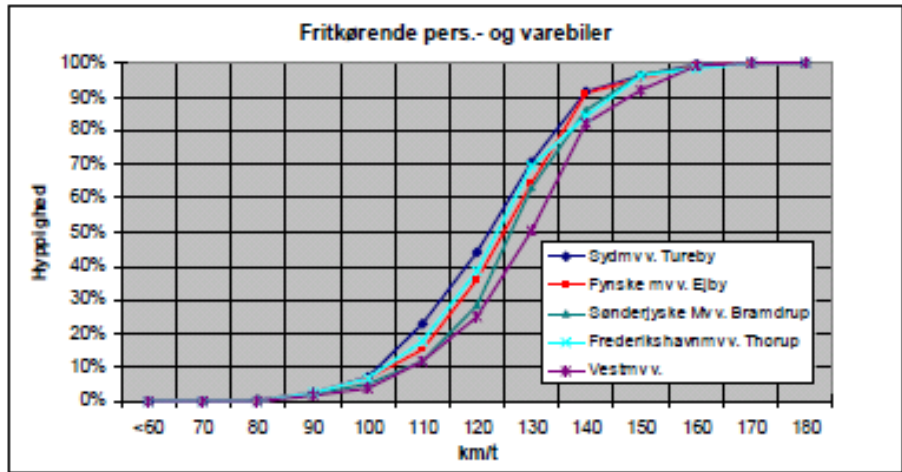


Fig. B2.7. Passenger cars and vans at 130 km/h speed limits

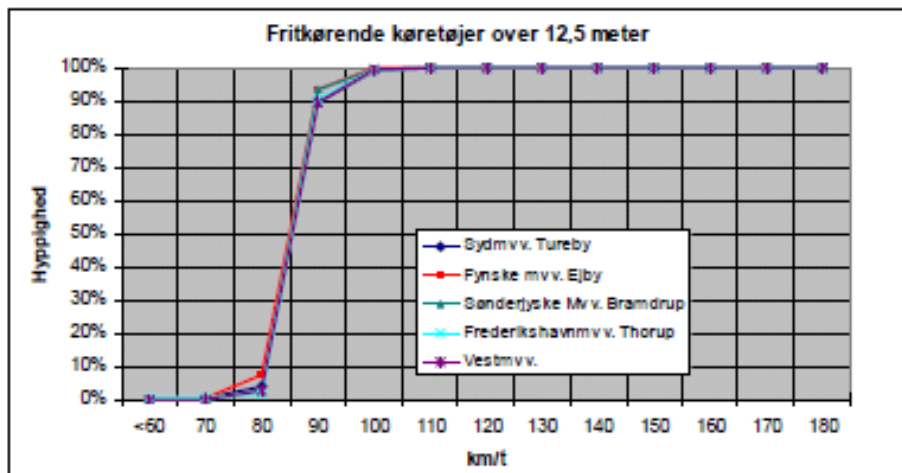


Fig. B2.8. Vehicles longer than 12,5 m at 130 km/h speed limit for passenger cars.

Annex 3. Measured desired accelerations and decelerations

Data presented in 6.7.4 are based GPS measurements from test runs (chapter 7 reference 6) and from test in Northern Jutland with the "spar på farten" (cut speed) campaign (reference 7). It is important to note that data measured under such conditions may differ systematically from normal conditions, but still the data are considered appropriate to assess level and trends for desired acceleration and deceleration during normal driving.

To be able to assess acceleration values when driving through signal-controlled intersections, the new Danish acceleration curves, which are based on the above measurements, have been added to Vissim. In addition, a published Swedish acceleration curve from 2004 and default acceleration curve from Vissim v. 5.0 have been added. A section has been simulated with a signal-controlled system, and passage time for passenger cars has been calculated in relation to green time.

The result of the simulation can be seen in figure B3. The figure shows that Danish acceleration curves are better than the foreign ones at reflecting the Danish measured passage times of 1.7-1.8 sec/passenger car.

Figure 6.14 in section 6.7.4 also includes sectional measurements of acceleration on raps, and these are relatively close to the curves from the GPS measurements, including the measurements from the test in North Jutland (Pihlkjær, motorway ramps).

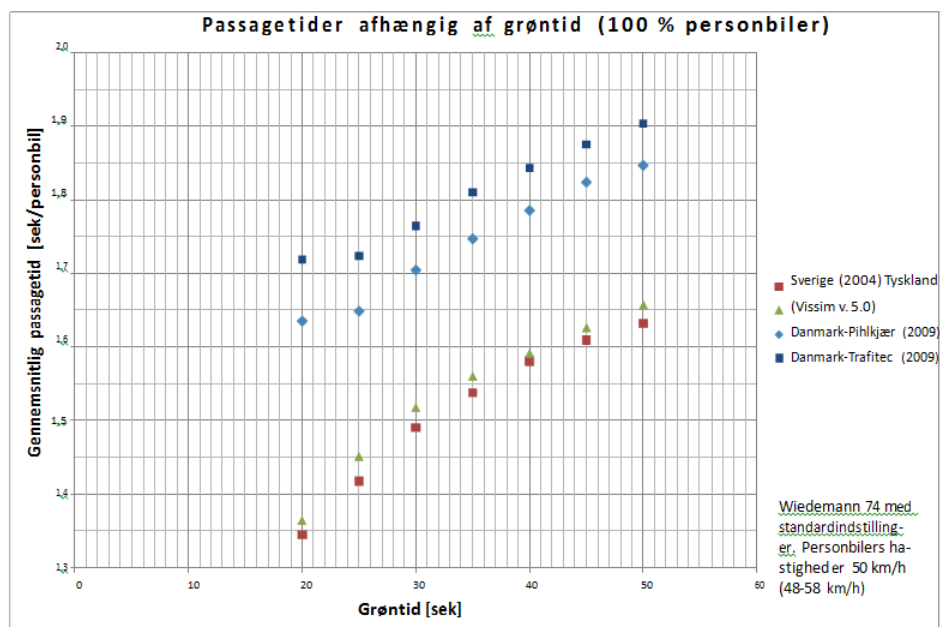


Figure B3. Passage times for passenger cars depending on green time and deceleration and acceleration values.

However, additional measurements of acceleration and deceleration are necessary. Until these studies are completed, acceleration and deceleration curves for the purpose of microsimulation may be based on the illustrations in figures 6.14 and 6.15 in section 6.7.4.

Annex 4. Comparison of calculated results for duty to give way in Vissim and DanKap

In connection with the drafting of this Road Standard, a number of studies were conducted of how much traffic can be handled in priority intersections and roundabouts in Vissim and DanKap, respectively. The studies were conducted at various traffic intensities and at various critical intervals (gap times). Results from the studies show that, at a critical time interval, such as at mean intensity in the main traffic flow which gives nearly the same capacity in Vissim and DanKap, Vissim generally handles most traffic at low traffic intensities and DanKap handles most traffic at high intensities in the main traffic flow.

In studies of priority intersections, focus has been on handled traffic in the traffic flow with duty to give way in the form of right- and left-turns from the secondary road and left turns from the priority road. All traffic flows are calculated for a three-leg intersection with one-lane approaches and exits. An extract of the results for right turns from a secondary road is shown in figure B4.1, for left turn from a secondary road in figure B4.2 and for left turn from a priority road in figure B4.3.

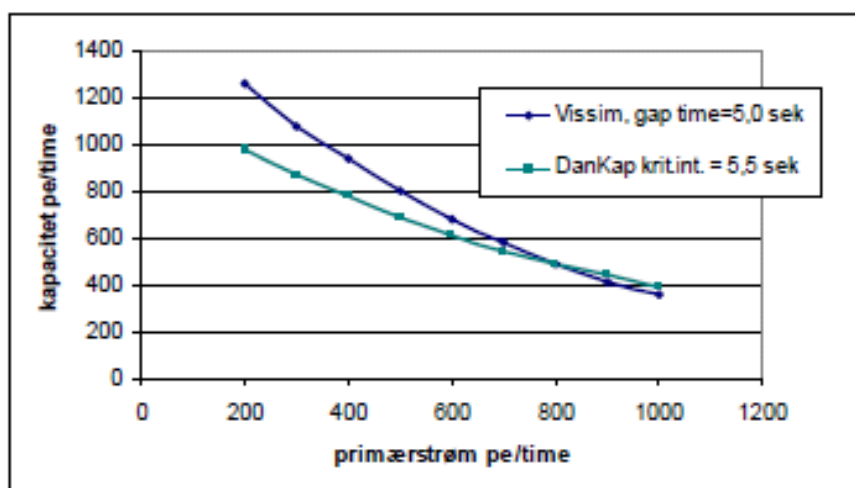


Fig. B4.1. Right turn from secondary road

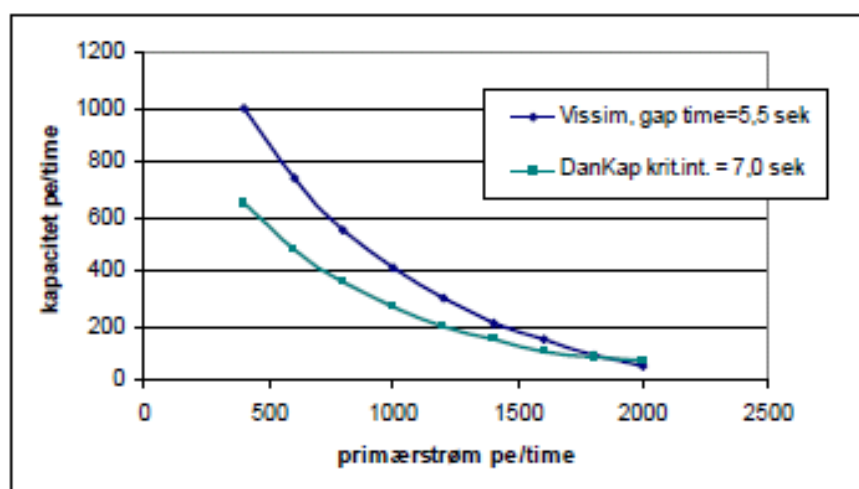


Fig. B4.2. Left turn from secondary road. In Vissim, the gap time for priority traffic from the left is 1 sec. less than stated.

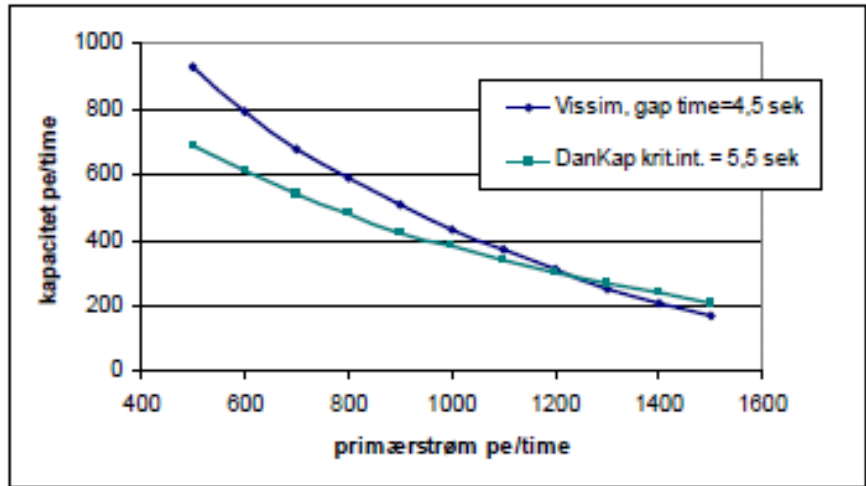


Fig. B4.3. Left turn from priority road.

A comparison has also been made of calculated results for a one-lane roundabout in Vissim and DanKap. The results of this study are shown in figure B4.4, where the capacity of an approach is shown relative to the amount of circulating traffic. A critical interval is used for a Vissim-based model of 3.2 sec (gap time) and for DanKap of 5.1 sec, which gives approximately the same results at medium traffic intensity (about 700 vehicles/hour) in the main traffic flow. A critical interval of 5.1 sec is recommended in Road Standard Proposal for capacity and service level for one-lane approaches to roundabouts in urban areas.

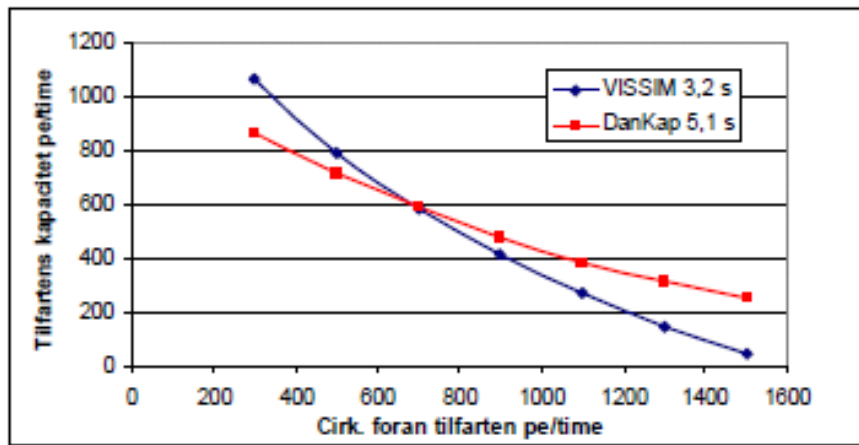


Figure B4.4. Capacity in an approach lane in a one-lane roundabout in DanKap with a critical interval of 5.1 sec. and Vissim, where the critical interval (gap time) is set at 3.2 sec. The blue line shows the simulated results from Vissim, while the red line shows the results from DanKap.

In the evaluation of the above, it is important not to consider results from the Road Standard Proposal for capacity and service level or DanKap as "the true values". The Road Standard Proposal and DanKap are considered to be best calibrated at a medium main traffic flow, and the simple statistical model in the Road Standard Proposal and DanKap have recognised weaknesses which might lead to inaccurate results at high traffic intensity in the main traffic flow. The Road Standard Proposal's and DanKap's relatively low capacity at low traffic intensity in the main traffic flow is attributable to the fact that the entered passage time may not correspond to traffic behaviour at low traffic load in the flow to which there is a duty to give way.

Annex 5. Passage times in signal-controlled intersections

Reference is made to the Road Standard Proposal for capacity and service level for the section on signal-controlled intersections. In addition, it should be added that during the period from the autumn of 2005 to the spring of 2006, the Danish Road Directorate carried out an analysis of car-following times (passage times) at large signal-controlled intersections in the Copenhagen region (chapter 7 reference 4). In this analysis, the average passage time for the straight-ahead driving vehicles, excluding HGVs and busses, is calculated at the following:

- Left lane: 1.68 sec.
- Left lane and long green time: 1.75-2.30 sec.
- Right lane: 1.82 sec.
- Right lane and long green time: 1.80-2.30 sec.

The times are not significantly different than previous values in the Road Standard Proposal for capacity and service level in connection with the calculation of capacity in signal-controlled intersections. The Road Standard Proposal states a general passage time for the straight-ahead driving vehicles of 1.8 sec.

A passage time of 1.8 sec. is equivalent to the passage times calculated in Vissim on the basis of GPS-measured deceleration and acceleration values, see fig. B3 in Annex 3.

Annex 6. Qualification of traffic flow

The tables below show the proposals of different sources for service levels A – F for intersections with duty to give way and signal control.

	HCM 2000	Germ an	Norway SINTEF	Denmark Road
Service level	Delay sec/vehicl	Delay sec/vehicl	Delay sec/vehicl	Delay sec/pcu
A	0-10	0-10	0-6	0-12
B	11-15	11-15	6-15	12-18
C	16-25	16-25	15-30	18-24
D	26-35	26-45	30-60	24-36
E	36-50	> 45	60-120	36-72
F	>50	---	>120	>72

Table B6.1. Service levels of different sources in intersections with duty to give way.

	HCM 2000	Germ an	Norway SINTEF	Denmark Road
Service level	Delay sec/vehicl	Delay sec/vehicl	Delay sec/vehicl	Delay sec/pcu
A	0-10	≤25	0-5	0-12
B	11-20	26-40	5-15	12-18
C	21-35	41-60	15-25	18-24
D	36-55	61-80	25-40	24-36
E	56-80	81-100	40-60	36-72
F	>80	> 100	>60	>72

Table B6.2. Service levels of different sources in signal-controlled intersections.

Table B6.3 below shows a proposal with values, which are in most cases about or between the above values in tables B6.1 and B6.2. The service level resulting from table B6.3, is to be regarded as applicable to hourly traffic. If traffic is considered for a peak quarter, arguments could be made in favour of a slightly longer delay as limit between the service levels. In signal-controlled intersections with cycle times longer than 100 sec., the limit between service level E and F could be raised to the cycle time.

Service level	Mean delay sec per vehicle	
	Priority intersection	Signal-controlled
A	≤10	≤10
B	11-15	11-20
C	16-25	21-35
D	26-50	36-60
E	51-70	61-100
F	>70	>100

Table B6.3. Proposed service level for intersections with duty to give way and for signal-controlled intersections.

Annex 7. Draft checklist

Checklist for microsimulation task

Task:	
Requester:	Adviser:
Simulation tool:	Date:

A. Preparation	Has arguments been provided that is relevant to use microsimulation to solve the task?	OK
	Have a quality level corresponding to the nature of the task, available data, resources, etc. been agreed with the requester?	OK
	Has it been considered whether relevant data can (relatively easy) be obtained which might improve the task solution?	OK
	Has agreement been made with the requester about the hours to be analysed?	OK
	Have the selected geographical definition of the model and the consequences of this been assessed?	OK
	Has it been considered whether special circumstances relating to the task speak in favour of changing the value of certain parameters	OK
	Have relevant calibration efforts been considered?	OK
	Have relevant validation efforts been considered?	OK
B. Modelling	Have calibration and validation been completed?	OK
	Has the simulation been checked visually and have any incorrect situations been corrected (e.g. collisions, unnatural stops, poor choice of lane, incorrect weaving, signal program errors, etc.)?	OK
	May additional assumptions be made and may parameters be adjusted – and if so, what are the consequences?	OK
	Is the time frame (i.e. settling time and end time) of the task reasonable – and has it been checked whether it should be adjusted?	OK
	Are results of model runs regarded as reasonable, and has the reason for any unexpected results been examined?	OK
	Number of completed repetitions, possibly determined on the basis of spread found for the results?	Number:
C. Reporting	Does the report clearly specify what road network (proposal, source), what traffic situation (scenario, source), what time of the year, what vehicle composition and what signal programs the results represent?	OK
	Has documentation been prepared, and is it included in the report or is reference made to it?	OK
	Has it been checked that the report answers the questions asked in the task/agreed with the requester?	OK
	Have any surprising results of the analysis been commented on?	OK
	Has an account been given of any important adjustments, corrections or assumptions made during the preparation or analysis which are important for the reader – even if these are included in the documentation?	OK

Colophon

Title: Microsimulation

Date: June 2010

Editor: Danish Road Directorate, Danish Road Standard Committee

Photo:

Drawings:

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