AUTOMATION OF TRAVEL TIMES CALCULATION IN THE NETHERLANDS.

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REAL-TIME TRAVEL TIMES

Real-time travel time information gives a better indication of motorway congestion conditions than queue lengths. Travel time information enables drivers to choose a better alternative route. It also provides useful input for traffic control by motorway managers.

Rijkswaterstaat (RWS) has carried out research in this field for many years and a number of field trials have taken place. This has resulted in the development of a new system, MoniBas, which uses the available loop data from the RWS traffic monitoring system to calculate travel times for the Dutch motorway network. The system is designed in a modular manner and can be expanded by new, additional, modules. MoniBas is operational since July 2001 and its output is now used by the Dutch national TIC.

RESULTS OF PREVIOUS RESEARCH

In the Netherlands, The development of models for the calculation of actual travel times and queue lengths started in the early nineties. Several queue length algorithms have since then been implemented in regional RWS Traffic Control Centres (TCC's) for stretches of road equipped with the Motorway Lane Signalling System.

An early model for the estimation of travel times was developed in the EU-project GERDIEN (1994).

A simplified, practical algorithm was made operational in 1997 for a geometrically simple road segment (A13). This system is still operating and the results are presented on a Dynamic Route Information Panel (DRIP) on the A13 near the Hague.

Further research to improve the algorithms was carried out in the ASTRIVAL project (AVV, 1997), in which offline software was developed and the algorithms were validated. The conclusions of the validation were:

– Results for completely monitored road sections are satisfying.
– Results for short, partially monitored road sections (e.g with an exit without detection loops) are less accurate.
– Long road sections that are only partially monitored give erroneous values, due to the fact that the number of vehicles within the section (see under 'Algorithms') cannot be estimated accurately enough.
– Special solutions had to be found for situations where no vehicle passages are detected at all: stationary traffic (V=0), quiet nightly hours and lane closures.

The ASTRIVAL software was adapted in the ASTRID-RT project (AVV, 2001) for operational real-time use in DRIP systems in the region of Utrecht. The geographical scope of this system is limited to a few short routes. Other RWS districts and the TIC (plan to) use the MoniBas output.

THE MONIBAS PROJECT

Rijkswaterstaat invests heavily in the improvement of traffic safety and a better utilisation of the motorway network. In recent years much effort has been put into the development or enhancement of systems for Dynamic Traffic Management (DTM). Some of these new DTM components are:

– Dynamic Route Information Panels (DRIP, a text variant of Variable Message Signs), managed by regional TCC's.
– Integrated operator interface and decision support systems in TCC's.
– Systems in the Traffic Information Centre (TIC-NL) for the automatic generation of traffic information messages.

In addition, the RWS monitoring system for the main motorway network is being expanded and improved. The purpose of this system is to collect, process and provide real-time traffic data for DTM applications as well as statistical and management applications.

The real-time ‘raw’ monitoring data are (minute-aggregated) data, collected by loop detectors, that provide only information about specific point locations in the traffic flow. Other, more 'longitudinal' quantities describing the flow, like queue lengths and travel times, have to be generated from these raw data, using advanced algorithms. Since the need for a 'centrally' operated and shared software application that provides this enhanced information was felt more and more in recent years, the MoniBas (MONItoring BASic applications) project was initiated to provide the required input to the abovementioned (and possibly other) DTM components.

AVV-Transport Research Centre is responsible for the project management, the system specifications and the operational implementation. The technical specifications and the software were realised by Logica and CGEY.

The project started in 1999 and was based on a phased approach, anticipating that the first operational results would lead to further improvements of the system and its algorithms.
During the realisation and testing of this MoniBas system, the (ASTRIVAL-) algorithms were further tested and improved, in particular for (not too long) partially monitored road sections and special situations like lane closures. The first version of MoniBas became operational just in time to provide a new TIC system with real-time travel times per road section (i.e. from a detection point to the next detection point).

THE RWS TRAFFIC MONITORING SYSTEM

Data collection on motorways in the Netherlands is performed as follows:

– Loop detectors are used to measure the speed and the intensity of flow in each lane (for details, see under 'Measuring Configuration').
– The data is collected by road side systems and sent each minute via intermediate systems and the RWS communication network (Vicnet) to the 7 regional MoniCa (MONItoring CASco) systems.
– These MoniCa systems are interconnected and exchange their information. In principal all data can be made available in each region.
– After some technical checks and pre-processing, MoniCa makes the results (in the form of so called ADY minute files) available for further applications via the ADY and AST servers.
– Systems like MoniBas then retrieve the data from these servers for further processing.

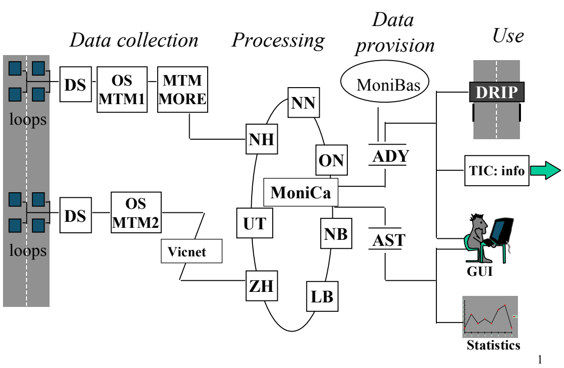

Figure 1: Data collection concept

The following dynamic data (per loop position and per minute), available on the ADY server, is used as input by MoniBas :

– Intensity of flow (veh/min)
– Speed (average per minute)
– Incident detection signal
– Detector status codes

TRAFFIC CONTROL ARCHITECTURE

MoniBas is one of the new central applications that fits in the Rijkswaterstaat 'AVB' Architecture for Traffic Control. This architecture is consistent with the European KAREN Architecture.
The AVB architecture allows the MoniBas output to be used on all levels: nationwide by the national TIC that provides general and standardized traffic information to a wide number of service providers, regionally by TCC's and also (mostly via a TCC) directly along the road (DRIPs).
The MoniBas system is built in a modular way and forms a framework for the implementation of various future algorithms that use the same basic monitoring data. An example is the calculation of the total vehicle hours lost in traffic congestion.

MONIBAS ARCHITECTURE

The designers were faced with the following requirements:

– The input format (= Monica output format) was fixed, the output format had to be fixed at an early stage to allow TIC-NL and other users to start the design of their systems.
– Algorithms will be improved continuously.
– Improvements and changes of algorithms or the implementation of new ones may not have an effect on the other algorithms.
– Extensions and updates of the road configuration database with all ‘static’ geometrical data about loop positions, exits etc. should be prepared off line. As this database is also implemented in user systems, the operational version should be exchanged at most a few times a year.
– New versions of the system or the road configuration database must be implemented with minimal disturbance of the normal operational conditions.

The MoniBas architecture has met these requirements as follows:
All (system)management functions are combined in the Kernel system. All more specific mathematical calculations are done by algorithms in calculation modules. New modules can be ‘plugged’ in without the need for changes in the kernel or other calculation modules. The kernel will only change when its environment dictates this or when new (managerial) capabilities are required.
The kernel has the following main processes:

– PreProc: gathers and reads the ADY files and prepares the dynamic data for use in the calculation modules. PreProc checks the data for consistency, and performs some limited (point level) correction or data completion in case of local or temporary (2 min, say) loss of data.

- Start-up procedures read and check the data from the road configuration database, and interpret and convert them when necessary for further internal use.
- PostProc: integrates the output from the calculation modules and exports, once per minute, an output file to the ADY server.
- BehProc: a maintenance module that takes care of housekeeping issues in the kernel.

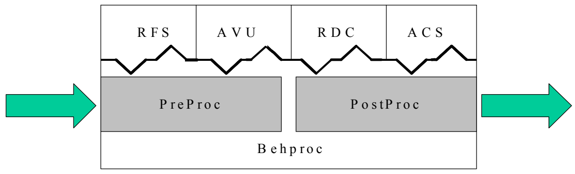

Figure 2: MoniBas Architecture

Plug-and-play approach

The 'plug-and-play' architecture makes it possible to develop the calculation modules on an as-needed basis. The specifications of the interface to the kernel are in principle fixed, so a new calculation module can be specified and built independently from other developments. At this moment the following modules are implemented or planned:

- RFS module: Travel times per road section and queue lengths (operational since July 2001)
- AVU module: Total vehicle hours lost (veh.hrs) and total distance travelled (veh.kms), per road section and per minute, hour, ...
- RDC module: Travel time day curves
- ACS module: Actual capacity estimation

Standardised output format

An output format has been specified which is similar to the DATEX (EDIFACT) format. The file is composed of several segment groups and segments. The segments contain identifying 'trigrams' and specific results generated by individual calculation modules. The segments groups and the segments are structured as shown in this branching diagram :

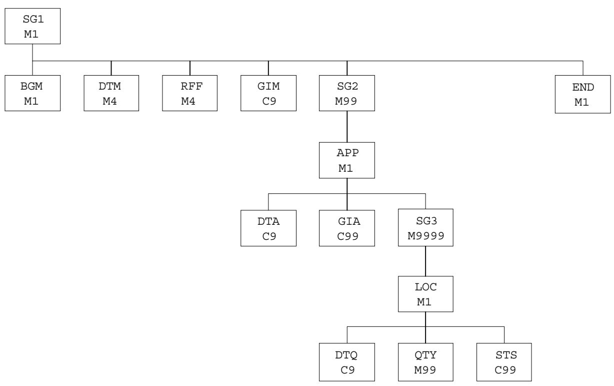

Figure 3: Branching diagram Output format

The trigrams BGM etc. are cf. the DATEX protocol. SG3/M9999 means that there can be output data for at least 1 and at most 9999 road sections, each represented by 1 LOC(ation) identifier, followed by maximally 99 values of the actual travel time and other quantities (QTY).
This approach makes it possible to add new segments later, containing data from new modules in such a way that existing user applications will disregard these segments and will function undisturbed.

ALGORITHMS

Brief description

The algorithms use the ADY-files as input, in particular the 1-minute intensity and speed data. To compensate for systematic counting errors, the intensities are corrected using filtering techniques.
Then the speeds at the up- and downstream measuring cross sections of a monitored road section are used to make a first estimate of the travel time over the road section:
$T_v = ½L/V_{in} + ½L/V_{out}$, where T is the estimated travel time, V = speed, and L = length of the section.
Various criteria are used to check continuously whether there is a congestion situation. Even congestion in the middle of a section (i.e. not near the detection loops) can be detected in this way, be it with a short delay.
If there is congestion, each minute *the number of vehicles* inside the road section is updated by :
$N(t+1) = N(t) + I_{in} – I_{out}$, where I = the intensity of total in-/outflow at time t. The initial value of N is the number of vehicles prior to the detection of the congestion. This value can in various ways be estimated reliably.
Next, $T_n = N(t) / I_{outav}$ is calculated, in which I_{outav} is a short term moving average of the downstream outflow, corrected for in- and outflows via on/off ramps. T_n can be considered as the *expected travel time* for vehicles that enter the road section at time t.
Using criteria based on tests and experience, a 'mix' of T_v and T_n is then taken as the best estimate for the travel time T. Under free flow conditions T_v is used. In case of severe congestion T_n has the largest weight, unless the road section is short (< 1 km) and the measured speeds are > 30 km/h. Then the weight of T_v in the mix is higher.

The *delay time* is the difference between T and the free flow travel time, where this last value can (optionally) be based on an estimate, a local speed limit (e.g. 100 km/h) or a recent or averaged value of T_v under free flow conditions.

The *queue length* (inside the road section) is calculated using $Q = (N - DL) / (D_q - D)$, where D_q and D represent the vehicle densities in the queue and outside the queue in the same road section. These densities are determined using heuristics (basic traffic flow diagram)

and/or the local values for I/V at the up- and downstream measuring cross sections.
In the situation that a queue does not yet cover one of the measuring cross sections (V_{in} and V_{out} both high), D_q can only roughly be estimated, causing Q to be initially less reliable than N or T (the relative error in N and T is usually smaller than 15%). This is only the case for short queues, and the absolute error in Q (0,5 - 1 km, in such a case) is then acceptable. As soon as a queue covers a measuring cross section, D_q and Q can be 'calibrated' and the position of the other end of the queue (head or tail) can be determined. If the measuring cross sections are close to each other, e.g. on roads where the Motorway Signalling System is installed, a queue length can of course be monitored more directly, with a maximum error of 500 m.

The description above sketches the principles of the calculation. In reality some values are calculated using a somewhat more complex algorithm. In case of missing data, alternative (and, of course, less accurate) approximations are used. When a complete measuring cross section should fail, in principle the two adjoining road sections could be merged automatically into a single, longer road section. This is not yet implemented.

Output Generated

Every minute, for each road section, the following output is generated by the RFS module in the first installed MoniBas version :

- *Congestion signal* when congestion occurs somewhere in the road section (reaction time 2 to 5 minutes). This is useful on motorways without Signalling System.
- *Number of vehicles* within the road section (in future possibly also per vehicle category).
- The *actual travel time* and *delay time* over the length of the road section (in future possibly also per vehicle category).
- The *queue length* within the road section.
- The position of the *head or the tail* of the queue, if it is located inside the road section and can be determined with some certainty.

In the next version of MoniBas probably output from the AVU and RDC modules will be added.

For routes or road segments consisting of a number of road sections, queue lengths, travel times, vehicle kilometres travelled etc., can of course be aggregated.

Measuring Configuration

The MoniBas algorithms require measuring cross sections (connected to a Monica system) up- and downstream of each motorway exit or entrance, and preferably also on the on or off ramp itself, certainly when these ramps are heavily used.
On motorways with Lane Signalling the existing detection configuration is dense enough, and only additional loops on some ramps have to be installed. Where such dense detection is not available, it is acceptable to use three measuring cross sections at each junction: one on the on ramp, one on the off ramp, and one on the motorway between the on and off ramp.
Special situations, like complex motorway junctions, need individual attention and may require more specific loop configurations.
For road sections without exits or entrances a maximum length (i.e. a maximum distance between detection points) of approx. 5 km is acceptable. For longer sections the algorithms become inaccurate and too slow to follow the actual situation on the road.

EVALUATION OF FIRST RESULTS

The output has been tested using a number of different methods:

- Plausibility approach: the results are compared with visual output from other systems that process the same input data into queue lengths or visualise the speed measured by the detection loops.
- Mathematical analysis and visualisation of the output resulting from synthesised data.
- Verification by processing (historical) data that can be associated with known travel times. These travel times were collected (with the use of probe cars) in previous or other projects.

At this moment MoniBas generates output for about 90% of the defined road sections. A full audit of the complete chain of information from the detection loops up to the TIC systems is planned. A first preliminary analysis has made clear that the missing output is caused by un-operational detection loops, road works or configuration problems in other systems.
In situations like complex junctions with 'open' (not fully monitored) road sections the output is not yet reliable enough. An update of the RFS algorithms is planned to solve or reduce these specific problems.
One of the Dutch traffic information providers already offers the travel time information as a pilot on its website.

THE FUTURE OF MONIBAS

The availability of travel time information will have an impact on the systems of service providers and motorway managers. RDS-TMC providers can use the ALERT-C or ALERT-PLUS protocol, others will have to start new developments. DRIP systems may have to be changed to present this new information

In next versions of the MoniBas system, the AVU, RDC and (later) ACS modules will be installed. It is to be expected that the AVU and RDC output will increasingly be used for offline incident analysis, evaluation of traffic control measures, and for general statistics. Aggregated indicators like total hours lost and kilometres travelled can also be used in a real time environment by traffic managers, to assess the actual overall performance of their road network.

Another possible extension consists of very short term predictions (under certain conditions, and several minutes ahead), e.g. a prognosis of the growth of a queue behind a lane closure. The MoniBas output will also be used as input for the BOSS system (a decision support and short term prediction model, being designed by RWS - AVV).

Concluding, the availability of travel times and other 'longitudinal' quantities on a nationwide scale will stimulate or enhance further applications, in the field of general traffic information as well as in traffic control.

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