When’s the next bus coming?

TRITAPT management system for bus and tram services
With no hard data on route times to go on, bus companies find it impossible to optimise their timetables. The result is that buses arrive needlessly late, and in some cases even pass their stops ahead of schedule, which is even more frustrating to waiting passengers. ‘I was at the bus stop on time, but the bus had already left.’

Transport engineer Theo Muller and his colleague Peter Knoppers of TU Delft have developed a measuring and analysis system for bus trip times that makes it possible to optimise the timetable. Long-term field tests at Eindhoven prove that the system does indeed help bus drivers to stick to their schedule.

Travelling by public transport will often take up to twice as long as going by car. An analysis by Delft transport engineer Kees van Goeveerden shows that even a slight reduction in public transport travelling time will entice a relatively large number of people to take the bus or train. So it’s worth going to the trouble to improve the timetable to ensure that travelling by public transport takes less time. It will help to increase public transport’s market share in relation to private transport.

At the Civil Engineering sub faculty of Delft University, researchers have been working since the nineteen-seventies on a system that enables them to quantify the quality of public transport by bus. In the first place, the analysis system helps buses (or rather their drivers) to stick to their timetables. In addition, it provides bus company management with hard data about the quality of the service, the number of passengers, the number of kilometres they travel, and the total number of kilometres all passengers together have travelled by bus. Bus trip analysis systems are rapidly gaining in importance. Bus companies increasingly need hard data to demonstrate their performance. The ultimate purpose of it all is to increase the market segment of public transport. The means of achieving this is to provide better services by improving timetables.

**Commercial applications**

‘This was our first on-board computer. It dates from 1979.’ Transport engineer Theo Muller shows a box the size of a desktop PC, with a display. Next to it is a smaller box with sixteen buttons on it.

‘To use the system, students would take the button boxes onto the buses,’ Muller explains, ‘and press one button when the bus reached a stop, a different button when an accident had occurred, or if they got stuck in a traffic jam. A cassette tape in the on-board computer stores the recorded trip data transmitted by the handheld terminal. This enabled us to gather information manually about how close the buses were sticking to their timetables. What’s more, the box proved to be...’
Muller lectures in dynamic traffic and transport management at the faculty of Civil Engineering. He is also the head of the Traffic & Transportation Research Laboratory. The primitive system lying on his table has contributed to 25 years of development that culminated in TRITAPT, which stands for TRIp Time Analysis in Public Transport. It is a fully automatic system for analysing public transport trip times. The system, which is unique in the world, is now ready for commercial application.

Detection loops
TRITAPT consists of four components. The first is a location system that determines the exact position of the bus. Technically speaking, this often involves a number of selective detection loops built into the road surface, but it could equally well be done using infrared beacons or a GPS-based system. In the Netherlands, detection loops are the most commonly used system, since they can already be found at most road intersections where they control the traffic lights. A detection loop is in fact a coil with a couple of turns that acts as a kind of wireless transmitter. Modern loop systems, known as Vecom loops, look like stylised figures of eight. A couple of times per second, the loop emits a signal. When the receiver (transponder) in the bus detects this signal, it responds by transmitting a message containing an 18-bits code to indicate the type of vehicle, and for buses and trams, the route and trip number. The loop then sends its own identification back to the bus. Most systems use a entry call loop located time-wise about twenty to thirty seconds in front of the stop line at the traffic lights, and a second, call-out, loop immediately before or after the stop line. These loops are used to control the traffic light system. In some cases these include special traffic lights for buses, but buses can also be given priority in normal traffic. In urban settings, the TRITAPT system uses the traffic control detection loops already built into the road surface to control traffic lights. In rural areas, there may be too few loops in the road, and an additional investment will be required to add loops.

The second component required for TRITAPT is an on-board computer which can be used to monitor such actions as doors opening and closing (using door switches) and current speed (using a drive shaft rev counter). A counter mechanism connected to the doorsteps can also keep track of the number of passengers getting on or off. With these technical means, the necessary trip data can be collected. All a bus driver has to do is enter his route and trip numbers, and select the appropriate route at the point of departure. Once en route, the on-board computer can show the driver how much he is behind or ahead of schedule. If the trip information is not entered into the computer before leaving, the bus will not be given priority at traffic lights. Although the on-board computer is capable of storing information for an entire week, it normally transmits the raw data to a central computer at the depot at the end of the day, again using Vecom loops.

The buses used by the Hermes transport company in Eindhoven have all been fitted with on-board computers supplied by Peek Traffic (formerly Philips). At the start of each trip, the driver enters the route and trip numbers. The computer automatically registers the trip data and notifies the driver and control equipment at intersections of any deviations from the timetable.

At the start of each trip, the bus passes an induction loop that transmits the route descriptions and timetables to enable the computer to calculate locations and punctuality deviations en route.
An answer to every question
The third component of TRITAPT is trip recognition program, which processes the input data into information about individual trips. The data show at what time a certain bus was at which location, and how much behind schedule it was at that point. From the event data, the program extracts the times at which the bus arrived at and departed from each stop. In cases where the bus passed a stop without pulling over, the software uses interpolation to estimate the time at which the bus drove past.

The fourth and last TRITAPT component is the program that analyses the quality and effectiveness of a large set of bus trips on the basis of every trip monitored on a certain route. The program is capable of instantly displaying in graphical form practically any statistical material. After analysis of the available data, the program devised by Muller and Knoppers offers a proposal for an improved timetable that does not require more manpower or equipment, but will allow more passengers to be transported thanks to improved quality. It can also make sure that the numbers of passengers are more evenly distributed over consecutive trips. For the best possible statistical analysis, the program requires at least fifty observations of any given trip. Of course, it still takes a bit of common sense to filter out such things as days on which road works or special events disrupted the timetable. The program has been made user-friendly enough to enable the bus company itself to produce all the statistics it may need.

‘We developed TRITAPT with only three people, first with Prof. Hakkesteegt, then with Peter Knoppers. Peter is a marvellous programmer. Sadly, writing software comes much lower on the appreciation scale than producing publications, but he makes it possible for me to publish. People like that are indispensable.’

Muller shows on his computer the different types of information the program can supply. He displays a chart showing trip data.

‘This shows us that at the end of their route, all the buses suddenly run ahead of schedule. This was done on purpose by the bus company, so the management would be able to say, see, all our buses got to their destination on time. Of course, this is not the right way to ensure that the buses were actually running according to their schedules.’

The registration system can also generate slight errors. Muller clicks on a diagram that shows that for a certain trip, the total number of people getting onto the bus is lower than the number who got off.

‘It’s as if several babies had been born en route. In this case something must have gone wrong with the automatic counting system missing a few people getting on or off the bus, probably due to the fact that at busy stops a number of people were standing together on the steps and so were counted as one. We have developed a corrective algorithm for this kind of measuring error.’

Satisfied customers, satisfied drivers
Most of the experience with TRITAPT has been gained by the Hermes bus company at Eindhoven, where the exchange of data between the on-board computer and control equipment takes place by means of a transponder fitted to the bus chassis and a detection loop (interrogator) built into the road surface.

The bus driver enjoys a considerable degree of autonomy, with central control intervening only in the event of accidents, breakdowns, etc. Contact with the drivers is established by means of mobile radio.
system has been in use since 1997. At Eindhoven, the TRITAPT analyses were used to improve the timetables so the buses could run exactly to schedule, which makes for satisfied customers as well as satisfied drivers. ‘The punctuality curve changed into a straight line once the timetable had been modified using our analysis system’, Muller states. This means that buses are now only a constant, but small, margin away from the ideal trip. ‘This is exactly how it should be. On average, the buses run one minute late, but that is because they must on no account depart from their stops ahead of schedule. One minute is perfectly acceptable in the circumstances. A good timetable should never cause a bus to leave early,’ Muller explains, ‘because it would unnecessarily extend passengers’ waiting times.’ Nobody likes to queue ten minutes in advance for a bus that arrives every ten minutes. On the other hand, a ten-minute wait for a late-night service that runs every two hours is not a problem. Suppose the bus is ahead of schedule and leaves early, a passenger missing it would have to wait two hours. If they can be certain the bus will not be leaving early, passengers do not have to arrive at the bus stop ten minutes in advance.

Shifts
In The Hague, the htm transport company has been using TRITAPT since 2001. Much interest has also been shown by companies in Germany and the United States. In Boston, Mineapolis and Portland bus companies are now experimenting with TRITAPT within a trb funded transportation research program on the use of apc (Automatic Passenger Counter) and avl (Automatic Vehicle Location system) data. According to Muller, TRITAPT is miles ahead of systems in other countries. No other system offers the extensive analysis options featured by the system from Delft. A major selling point of TRITAPT is that it can offer suggestions to improve timetables in shifts. Current thinking among some bus companies still has it that a rigid round-the-clock timetable is in the interests of passengers, so they will know for example that their bus is always scheduled to arrive at ten minutes past the hour or half hour. ‘Passengers are not completely stupid,’ Muller says, ‘and they know all too well that the bus will be late during the rush hour. So they will adapt by taking an earlier bus in order to arrive at the station in time to catch their train.’

The number one buses in Eindhoven were also used for the initial experiments with the conditional priority system. A number of road intersections feature special bus traffic lights. The on-board computer knows whether the bus is running slow or fast. If a bus is behind schedule when approaching the set of traffic lights, the on-board computer will request priority. In most cases, the bus will be able to continue on its way without stopping, and so make good its delay. If the bus is running ahead of schedule, the on-board computer will not request priority, and the bus will just have to wait its turn. This has the added advantage that the

The individual, average punctuality deviations provide a good measure of the quality of the timetable and the standard deviation of the quality of the service. The black line starting at 1 indicates the mean deviation from the timetable. The blue lines give an indication of the punctuality deviation range. At the top is a bus running about 6 minutes fast at 11.26 p.m. This was probably because the driver was in a hurry to get home.

Different periods of the day require different trip times in order to enable each trip to be completed on schedule, taking into account traffic volumes en route. Based on such data, TRITAPT provides planners with an indication of the route times required for each period.

TRITAPT gives the mean ‘production’ in passenger kilometres for each trip on a certain day. This information is important to the transport company because it is used to calculate government public transport subsidies.
normal traffic lights cycle is not disrupted unless absolutely necessary.
‘You can slow down a bus, but you cannot speed it up, or you would create an unsafe situation’, Muller says. Throughout their route these buses seldom are more than sixty seconds late or thirty seconds early. The system to give priority to «stragglers» proved to be so popular that drivers were not allowed to take a number one bus for more than half a day, simply to keep them from being spoilt. Driving a number one bus was a cushy job, with the system automatically making sure that the bus would stay on schedule. On other routes, drivers constantly had to check their driving in order to stick to the timetable.

Essential cooperation
It is essential that drivers and planners as well as the management are involved in TRITAPT. Cooperation has to involve everybody. The TRITAPT system in itself cannot improve a service. The system can help, but it requires the commitment of all the parties involved. So what would a bus company have to pay for a system like this? Muller: ‘Transport companies pay a limited, one-off fee for the software, which includes the right to updates. The money is used to help cover the cost of our research. In fact it covers only a fraction of the total research and development cost of the TRITAPT project. The analysis is left to the transport company. If they have any questions, they can come to us and we will see if there is a way to satisfy their requirements. And if we want, we can study the data produced by the system.’

In towns without the system, timetables are often still laboriously composed in the old-fashioned, manual way, according to Muller.
‘What they do is to put someone on a bus to ride along and look at a watch at every stop to keep track of the schedule manually. Of course, this is not the way to go about it if you want statistically reliable trip times.’

During a different field test in Eindhoven, the researchers also noted some rather engaging effects on personal behaviour.
‘Some of the drivers were collecting the printouts of their trips after analysis, so they could show them off to their family to prove how accurately they had followed the timetable. At long last they had solid proof of how good they were at their profession. On the other hand, some people tore up their printouts. Those were probably the ones whose trip times did not match the timetables closely enough.’

Hard figures may enable you to see how bus drivers perform en route, but isn’t there a risk of creating a «Big Brother» effect?
‘The initial purpose of the system,’ Muller says, ‘is not to check on the performance of individual drivers. It all really depends on the policy of the transport company. Of course, companies will discuss the results with drivers in groups in order to improve their attitude. It is simply a means of optimising the timetable and monitoring quality. The drivers can complete their trips without the stress, and their customers get the best possible product. A supermarket manager does not like
to see his check-out staff sitting idle when customers are waiting to be served. And, of course, the public transport sector can increase its market share considerably just by making their buses run closer to schedule.

For more information please contact Ir. Theo Muller, phone +31 15 278 5288, e-mail theo.muller@ct.tudelft.nl, or Ir. Peter Knoppers, phone +31 15 278 2762, e-mail http://www.delftoutlook.tudelft.nl/info/mailto.html

Regiolab Delft - How do motorists select their route?

To find out how road users determine what route to take, Muller and his colleagues set up the RegioLab Delft project. This is a traffic detection and analysis system that shows which changes in routes occur as a result of, for example, tailbacks or modifications to the infrastructure. The measurements are designed to provide insight into the way road users respond to information about traffic conditions, such as messages shown on gantry displays over motorways and broadcast traffic information. Muller says this information is required so that this kind of behaviour can be properly anticipated and the right set of dynamic traffic management measures can be taken.

The intensity and speed of traffic in the RegioLab Delft area (the area bordered by Gouda, The Hague, Naaldwijk, and Rotterdam) are measured using detectors at traffic lights and along motorways, as well as number of cameras along the Kruithuisweg ring road in Delft. The researchers look at the routes motorists take and how their choices are affected if an unforeseen event like an accident occurs. At that point, many motorists will resort to rat-running. In the corridor next to Muller’s office a monitor shows the live status of traffic flows in the designated area. Using recent measurements, Muller demonstrates how a tailback starts to build up after an accident. It shows how even ninety minutes after the cause of the tailback has been removed, the effects of the tailback can be felt at great distances from the source.

Regiolab Delft started in Delft in 1996 as the Stadslab (Citylab) project. In 2000 this grew into the larger Regiolab project. The data comes from three different road authorities: the Ministry of Transport for the national roads, the province of Zuid Holland for the regional roads, and the town of Delft for the local roads. Each of these three authorities has its own particular set of interests and political agenda. If something is to be done about the effects of tailbacks on a number of roads, all three parties involved will have to cooperate. Finding out how motorists pick one route instead of another is not an easy matter. The psychological aspects are difficult to grasp. Where one person prefers a longer route without traffic lights, another may take the shorter...
route that includes traffic lights, while others simply like to drive past the house of their lover. Still little is known about the many considerations that play a part in the route choice process. However, Regiolab Delft can at least provide hard data showing how many cars are coming past which point

Traffic control design

In addition to tritapt and Regiolab Delft, Muller and Knoppers are working on a third major project, vrogen, a traffic control system generator. Users will be able to create a graphical representation of any type of three- or four-branch road intersections they like on their pcs. Each lane can be assigned to be a car, bus, bicycle and pedestrian lanes. A roundabout can be use instead of an intersection.

The vrogen program was created to analyse every possible sequence in the control structure. The graphical representation also shows in which area conflicts will occur. The calculations take place using a conflict matrix, which is a special traffic engineering tool that indicates which conflicts exist between the different traffic flows and how long they take to clear. This requires an estimate of the crossing times of each of the various traffic components, as well as the anticipated volumes and capacities of the traffic flows.

VROGEN offers two main advantages over similar existing programs. In the first place, according to Muller the program not only takes into account the main conflict group (the busiest conflicting traffic flows), but also any parallel flows that sometimes require a little extra green light time.

Current software systems too often produce a branch-by-branch solution, in which for example the west branch is first given the green light, followed by the north branch, the east branch, and the south branch.

In many situations it is much more efficient to allow oncoming, parallel traffic flows to move at the same time.

A second advantage is that vrogen allows users to generate a traffic control system without themselves having to do any programming. All they have to do is concentrate on the control tactics. Any change in the control tactics can be converted into a new control program in a matter of seconds, and evaluated by means of a simulation. vrogen is capable of adapting very flexibly to situations in which some of the lanes remain empty of traffic, by keeping close track of which lanes have, and which have not, been given their turn to go. In the interest of traffic safety, it can also give the green light a few seconds ahead to cyclists and pedestrians, so motorists turning off will be given sufficient warning before crossing cyclist’s and pedestrian’s path.

The province of Zuid Holland has been using the program since 2001 to analyse such complex traffic situations. Although the vrogen program has been developed as a teaching tool for students in traffic control, the latest version of the program has been
modified such that it is now able to find the optimum solution even for these rather complex situations.

The size of each circle indicates the volume of the traffic flow, and its colour the speed (green is fast, red is slow).
The Regiolab Delft map shows the locations of vehicle recognition cameras (circles) and detection points (squares) along the motorway network.
Vehicle recognition camera alongside a Regiolab Delft road section.

The registration number is taken from the images of individual cars and sent, in encoded form, to the Traffic Engineering Laboratory. The encoding scheme ensures that the data cannot be traced back to individual vehicles. The information is used to calculate the travel time and to determine the routes of vehicles coming from the A4 and travelling through Delft to the A13 and other destinations.

**TRAFFIC CONTROL DESIGN**

The graphical design environment of VRIGEN offers the user a relatively simple method of laying out a complex intersection, selecting a control structure, calculating the effects, and indicating control tactics. The result is a fully programmed traffic control system.
The consistency of the programmed control system can be checked in a test environment using programs such as TRAFCOD or C-COL.

In addition to providing the visualisation, the traffic control system generated by VRIGEN can be linked to a microsimulation program (e.g. VISSIM) to enable the quality properties (waiting times, number of stops, travel time between two points in the network) of the control system to be analyzed. The total system from design to evaluation is used by students as an introduction to the subject of Traffic Control Systems.