HELSINKI JOURNEY TIME MONITORING SYSTEM

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INTRODUCTION

At the end of September 1998, Golden River Traffic were awarded a contract by the Finnish National Roads Administration (Finnra) to provide an Automatic Number Plate Reading (ANPR) based Journey Time Monitoring System (JTMS). The main purpose of this pilot system was to ascertain the suitability of ANPR technology under Finnish traffic and weather conditions. This paper describes the equipment, its installation, the system evaluation and future expansion options.

EQUIPMENT OVERVIEW

Journey times are measured by reading the registration marks of vehicles, using cameras installed on pedestrian and vehicle overbridges above the monitored carriageway, at approximately 5 to 7m height. Readings of the same registration mark at different monitoring points are then matched, from which transit times are calculated for each link.

Six ANPRs have been installed at three locations (“Outstations”) on Ring Road 1, which is a semicircular shaped urban motorway connecting the main exit roads of Helsinki capital area. A fourth system (the “Instation”) is installed at the Traffic Management Centre (TMC) in Pasila. A Communications Hub performs the matching of registration marks and the calculation of transit times for each of the routes. It is also used for setting up and monitoring the performance of each of the six outstations. The ANPRs and Communications Hub are linked by TCP/IP-based communications protocols running over the Integrated Services Digital Network (ISDN). Another instation PC provides a Graphical User Interface (GUI) for presenting the measurement data using a map of the Ring Road 1 network being monitored. The Communications Hub and GUI are linked by TCP/IP-based communications protocols running over Ethernet.

The Outstations and Instation are further described below. An overall system block diagram can be found in Figure 1.

Outstation

Each Outstation site has dual 2-lane carriageways, one running in each direction. One camera is mounted above each lane, pointing against the flow of traffic, so that registration marks can be read from the front of the vehicles in all cases.

Two Marksman 850s (M850s) are installed at each Outstation site in a well-ventilated (fan assisted) and heated cabinet. All the video signals for the site are brought to this housing. Each M850 is equipped with two frame grabbers and can therefore interface directly with two cameras. The ANPR software running on each machine extracts registration marks from the images grabbed and sends lists of registration marks (and the times at which they were observed) to the Communications Hub at regular intervals via the ISDN. The two ANPRs at each site are networked using Ethernet, so that only one of the machines requires a connection to the ISDN.

The Outstations consist of the following components:

P354 – The P354 Vehicle License Plate Capture System comprises a single unit for easy and low cost installation. Each unit incorporates a monochrome camera plus an Infra Red (IR) pulsed Light Emitting Diode (LED) illuminator, which compensates for sunlight and vehicle headlights. A single 6 way connector provides power, video and control interfaces. The unit is environmentally sealed to IP67 to protect against all weather conditions. The unit also includes an outer cover to reduce the effects of the sun and which also provides added protection against harsh weather conditions. The casing is an aluminum single casting with integral heat sinking and mounting point.

Camera Controller - This enables two P354 cameras to be controlled via a standard PC parallel port. The M850 ANPR software is therefore able to automatically adjust the gain and flash settings, in accordance with the changing ambient lighting conditions. The video signal from the camera is sent differentially and is transmitted over a screened twisted pair. The external sync and control signals are transmitted in the reverse direction to the video as common mode signals between the pair of video conductors and their screen. The Camera Controller enables the cable equalisation to be preset between 0 and 100m. The control pulses are then sent as data on the blank lines following the field sync interval.

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M850 – Industrial PC based ANPR containing a Pentium 233MHz MMX Central Processing Unit (CPU) fitted with 32MB of Random Access Memory (RAM). On-board parallel and Ethernet ports facilitate connection to the associated Camera Controller and local M850 respectively. Two frame grabbers each provide a single composite video input. One of the M850s at each site is fitted with an ISDN card for communicating to the Communications Hub.

The ANPR software runs under Linux, employing an X client for both local and remote configuration via any computer capable of running an X server. This X Windows based GUI is shown in Figure 2.

The screenshot also serves to demonstrate the type of images produced by the P354. Because it is only imaging in the IR, only retro-reflective objects (*e.g.* number plates) and headlamps can be seen in the image, unless the ambient lighting conditions are very bright. This makes reading at night no more difficult than during the daytime, which would not be the case with conventional CCTV cameras (especially those featuring an auto-iris).

Instation

A 350MHz Pentium II Windows NT workstation installed at the TMC in Pasila provides the user with a single point of access to the JTMS. All normal system operations, as well as control and configuration options, can be carried out from here.

The Instation comprises of two subsystems:

Communications Hub – A Celeron 350MHz PC running custom application software under Linux. It is configured to match registration marks sent over the ISDN by the Outstations, calculate transit times and log the matched observations to a disc file. It is also used to set up the Outstations, and for subsequent monitoring of them. The Communications Hub has an internal ISDN card, primarily for connecting to the ANPRs, but it also facilitates remote monitoring and diagnostics of the system. An Apache web server provides an intranet, which is accessible from the GUI PC, for controlling and configuring the JTMS.

GUI – Runs a Windows NT application that presents the measurement data in real time using a map of the Ring Road 1 network being monitored. The monitored links change colour according to the journey times and as they do so, a user definable audible alarm is sounded. The following data is overlaid onto the associated link being displayed on the map: average speed, standard deviation of speed, 5 and 95 percentiles of both speed and journey times. An internet browser facilitates access to Communications Hub functions.

The GUI application main window is shown in Figure 3 and provides the following menu options:

Links – Displays a table containing the traffic data for all the links. Data is printed with higher precision than is shown in the main window.

Limits – Allows assignment of colours, smoothing factors, upper and lower limits for speed bands. Each link can be individually configured.

A smoothing factor is applied to the average speeds and journey times displayed in the GUI main window and Links table. All standard deviations, 5 and 95 percentiles are calculated using raw data received from the Communications Hub. The average journey time is calculated as follows:

$$T_k = a\, t_k + (1 - a)\, T_{k-1}$$

where:

T_k = smoothed journey time after k observations;
t_k = real single journey time measurement after k observations;
T_{k-1} = smoothed journey time after k-1 observations;
a = smoothing factor alpha.

Print – Generates historical traffic data reports. These may be in the form of alphanumeric tables or graphical plots. The user is able to select the links, parameters, monitoring timescales, reporting intervals and report destination. All data is imported into Microsoft Excel, which enables the operator to generate custom reports with relative ease.

Faults – Displays the GUI PC's fault log. This is stored as a plain ASCII text file.

Legends – Key for the colour coding of the links. This uses the same scheme as is employed on the Finnra website at:

http://www.tieh.fi/alk/english/frames/liikenne-frame.html

The Communications Hub web server interface is shown in Figure 4 and provides the following menu options:

Status – Enables the operator to see the current status of the links and M850s. Link status information includes: distance, average speed, calling interval thresholds and the last time a journey was logged. M850 status information includes: calling interval and associated reason, time of last call and last successful call.

Journey Time Graphs – Plots raw journey times and speeds in real time for an individual link. A typical plot is shown in Figure 4.

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Timetable – Facilitates viewing and editing of the seven calling interval timetables. Each timetable specifies the M850 calling intervals for any number of user-definable time periods during a day.

Special Days – Allows the user to define dates that a particular timetable should be employed.

Weekdays – Allows the user to assign timetables to particular days of the week.

Route – Allows the user to define calling intervals for particular speed bands on individual links.

When there are multiple calling intervals defined for a link, then the Communications Hub will always use the shortest value currently valid. The reason a particular calling interval is in force can always be found via the Status option.

Floating – Enables a list of floating vehicles to be viewed or edited. The Communication Hub does not log any individual number plate readings, except for these floating vehicles, which enables the M850's ANPR performance to be monitored.

INSTALLATION

The JTMS was installed during the period November 1998 to February 1999. The Outstation sites are located around Helsinki's Ring Road 1, at Otaniemi, Konala and Pukinmäki. The distance between each site is 7.5km, making the total length of road being monitored 15km.

Cameras

In order to avoid the adverse weather conditions typically experienced during a Helsinki Winter, camera installation was scheduled for mid-November 1998. Nevertheless, temperatures still fell to –20ºC, making it practically impossible to safely touch any metal surfaces with bare hands! There was a lot of snow on the ground, although the roads had been cleared.

Traficon Oy, Finnra's consultants for the JTMS project, specified that the cameras had to be installed underneath the bridge deck. This was to avoid any possibility of the cameras being vandalised or tampered with. For this reason, it was considered unacceptable to mount the cameras off overbridge handrails and all cables were run inside permanent ducting.

The cameras were initially fitted with 50mm lenses with the aperture set to f/4. The cameras give a 4m horizontal field of view at 20m distance, which is ideal for ANPR applications. All 12 cameras were installed with these settings. An M850 and Camera Controller were used to ensure the cameras were correctly aligned.

All but one of the cameras were left unpowered for a month, until the next phase of the installation took place. A single M850 was installed at Otaniemi and connected to the camera via a stand-alone manual controller. The site was chosen because it was the only one to have ISDN communications available at this time. It enabled initial ANPR software testing to take place remotely from the UK.

By the time the next installations took place towards the end of December 1998, the temperatures had risen significantly above freezing. The combination of melting snow and rain lead to the vehicles and their number plates becoming very dirty. In fact, it appeared that the majority of number plates were unreadable by eye - let alone ANPR!

Back in the UK, some tests were carried out comparing the retro-reflectivity of UK number plates with those produced in Finland. It should be noted that in Finland, unlike in the UK, all number plates are produced by just one manufacturer – namely the Helsinki Prison! This means that there is more likely to be a standard build quality amongst all the plates in circulation. No italics or joined-up writing here! The tests seemed to suggest that the retro-reflectivity was about the same, but Finnish plates could be read at a greater angle than UK plates.

Experiments were also carried out to see what effect opening up the iris on the cameras had. This would obviously let more light in, but might also have had an adverse effect on the depth of focus. The lenses fitted to the P354s could have their aperture widened to f/1.8 maximum. This gives nearly five times the light intensity (power per unit area) on the image plane compared to when using the normal f/4 setting. There was no noticeable effect with regards to depth of focus at this setting. Another way of making the dirty number plates appear brighter was to change the lens itself. A 25mm lens was fitted with the aperture set to f/1.8, giving a 4m horizontal field of view at 10m distance. This gives nearly 20 times the original intensity on the image plane. The test plates were now brighter than ever, but by reducing the gain setting, the M850 could still compensate for any over exposure.

The third and final stage of equipment installation took place in mid February 1999. Unfortunately, temperatures had plummeted again. During the last few nights, temperatures had dropped to –30ºC. The first job was to take down all the cameras, which had to be done quickly, because in these temperatures the hydraulic fluid on the cherry picker could freeze up! No one could believe how dirty the front screens had got in the space of 3 months. It was hardly surprising the plates looked so dim, not only did the M850 have to cope with dirty plates, but it also had a thick layer of muddy deposits all over the camera screens. The sea air combined with salt from the road gritting had together formed the worst possible type of deposits. Salt water

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is known to attenuate the power of the IR light emitted from the illuminator.

It was decided to test the alternative camera configurations at the Konala site. One camera in each direction was fitted with a 50mm lens set to f/1.8. The other camera in each direction was fitted with a 25mm lens set to f/1.4. No attempt was made to clean the camera screens. This was deliberate, so that we could determine whether or not the adjustments would compensate for both the dirty plates and cameras. The results showed that it was nearly impossible to read the plates with the 50mm lens. A decision was made to fit all cameras with the 25mm lens set to f/1.8, as it was felt that too much light would be entering a clean camera configured as per the test setup. The changes were made, the cameras cleaned and reinstalled at all sites.

In order to slow down the build-up of dirt on the camera screens in the future, an extended hood has been designed. Rather than require the cameras to be taken down, this hood can be fitted in-situ without removing the existing short hood. At time of writing, a prototype had been built. Once this has been proved in the field, the production models can be manufactured and fitted to all 12 cameras.

Marksman 850s

All the six M850s were installed during December 1998. Each cabinet at a site has two 19" rack mounted shelves. The two M850s sit on the bottom shelf, whilst the associated controllers sit on the top shelf. The cabinets were provided by Finnra and feature both heating and forced ventilation systems.

The M850 employs no custom hardware, just off-the-shelf industrial PC components. By running the ANPR software under Linux (a free UNIX-like operating system), the M850 is a very reliable and cost-effective platform. It is fitting that Linux was developed by its author Linus Torvalds at the University of Helsinki! In the unlikely event of an M850 or Camera Controller failure, the affect on the overall JTMS operation has been minimised by feeding one camera from each carriageway into an M850.

Communications Hub

The Communications Hub was installed at the same time as the M850s. It was originally intended to interface the M850s to the Communications Hub via an existing Windows NT Remote Access Service (RAS) Server sitting on the Finnra network. However, configuration of the Microsoft system proved problematic, hence it was decided to make use of a spare ISDN line into the TMC at Pasila. This was connected directly to the Communications Hub and Instation to Oustation communications were duly established!

Graphical User Interface (GUI)

The GUI PC was the last part of the JTMS system to be installed during February 1999. The VGA output from this PC was connected via the Finnra video wall system at the TMC in Pasila. This enabled changes to the GUI requirements to be identified, so that its display could be optimised for use with the video wall. These modifications included increasing the thickness of the coloured bars overlaid on the links being monitored.

SYSTEM EVALUATION

Because of the long distances between the monitoring points in the Helsinki JTMS, there is no quick way of evaluating the performance of the system. If there were no junctions between monitoring points, then it would simply be a matter of comparing loop based traffic counts with the number of individual journey times logged. However, this would not take into account the state of the number plates, or whether or not a vehicle was straddling lanes.

The floating vehicles facility provides a method of programming in test vehicles into the JTMS, but this does not generate a big enough sample to be statistically significant. Golden River have previously employed video verifications to determine the accuracy of ANPR installations. This involves recording the output from the ANPR camera onto video cassette and logging the associated number plate readings to a text file. The recording can then be played back to manual enumerators, who compare their readings from the tape with that of the ANPR system. As yet, no such verifications have been employed in Helsinki. The M850 has been verified in the UK over a two hour survey with a confirmed ANPR accuracy of 86% for all vehicles (including those with dirty and/or unreadable plates).

One aspect of the system evaluation is the requirement for routine maintenance. Specifically, how often do the cameras need to be cleaned? Without extended hoods during winter months, the answer is probably at least once a month. It is envisaged that with the new hoods fitted, the cameras will only require one annual maintenance visit.

SYSTEM EXPANSION

Should the system evaluation prove successful, Finnra are initially planning to expand the number of measurement points to 40 and then 200. The current communications infrastructure would struggle to cope with this amount, as it would be impossible for all the M850s to call in at the required intervals without getting an engaged tone!

The JTMS is already capable of making use of the Internet, as opposed to direct dialing between the

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Outstation and Instation. The Communications Hub must be assigned a static IP address so that it can be made permanently available over the Internet. Finnra's existing Internet connection is not considered suitable for this purpose, so a new connection via a local Internet Service Provider (ISP) will be sought. The M850s would then dial a local ISP (instead of the Communications Hub) every time they want to call in. The data would then be sent via the Internet to the Communications Hub, thereby removing any potential bottlenecks in the communications infrastructure.

In the shorter term, it is intended that data from the JTMS will be made available to road users through local radio stations (FM or with RDS/TMC), through the Internet and on roadside Variable Message Signs (VMS).

Future real time uses of the data could include Automatic Incident Detection (AID), whereby journey times are fed into an algorithm which determines when an incident has occurred on the network. This method would rely on the fact that the journey times are being monitored over very short links, *e.g.* similar to the 500m distances employed between loop arrays on UK motorways. Another method would be to estimate when a vehicle is expected to arrive at a monitoring point and raise an alarm when it does not turn up.

Offline analysis of the JTMS data can be used for assessing the road network's performance and reliability monitoring. Before and after studies can be carried out for physical changes to the road network. Origin and destination surveys and/or turning movements surveys at junctions are all possible future uses of the journey time data.

By logging all the number plates to a database, further applications can be facilitated. The percentage of regular and non-regular users of a road is easily determined via database matching.

Other possible uses of the ANPR cameras are for enforcement purposes. Speed enforcement is an obvious application, as is stolen vehicle detection and bus lane enforcement. Any enforcement application would also require the installation of a colour context camera for identifying the vehicle type, make, colour and driver.

CONCLUSION

The Helsinki Journey Time Monitoring System has successfully employed Automatic Number Plate Recognition equipment in the depths of the Finnish Winter weather. In exhibiting both days of continual darkness and light, Helsinki offers some of the most rigorous test conditions in the World for ANPR technology.

Even specialist ANPR cameras had to be modified to cater for the extreme conditions. Longer hoods, shorter focal length lenses with wider apertures, are all required to be fitted to the cameras.

JTMS can provide a different form of data than traditional traffic monitoring equipment. This can be used for a variety of real time or off-line systems.

Advances in technology mean that expensive specialist hardware is no longer required as an ANPR platform. Industry standard off-the-shelf industrial PCs can be employed running freely available OS software. The only specialist component within the ANPR is the application software itself.

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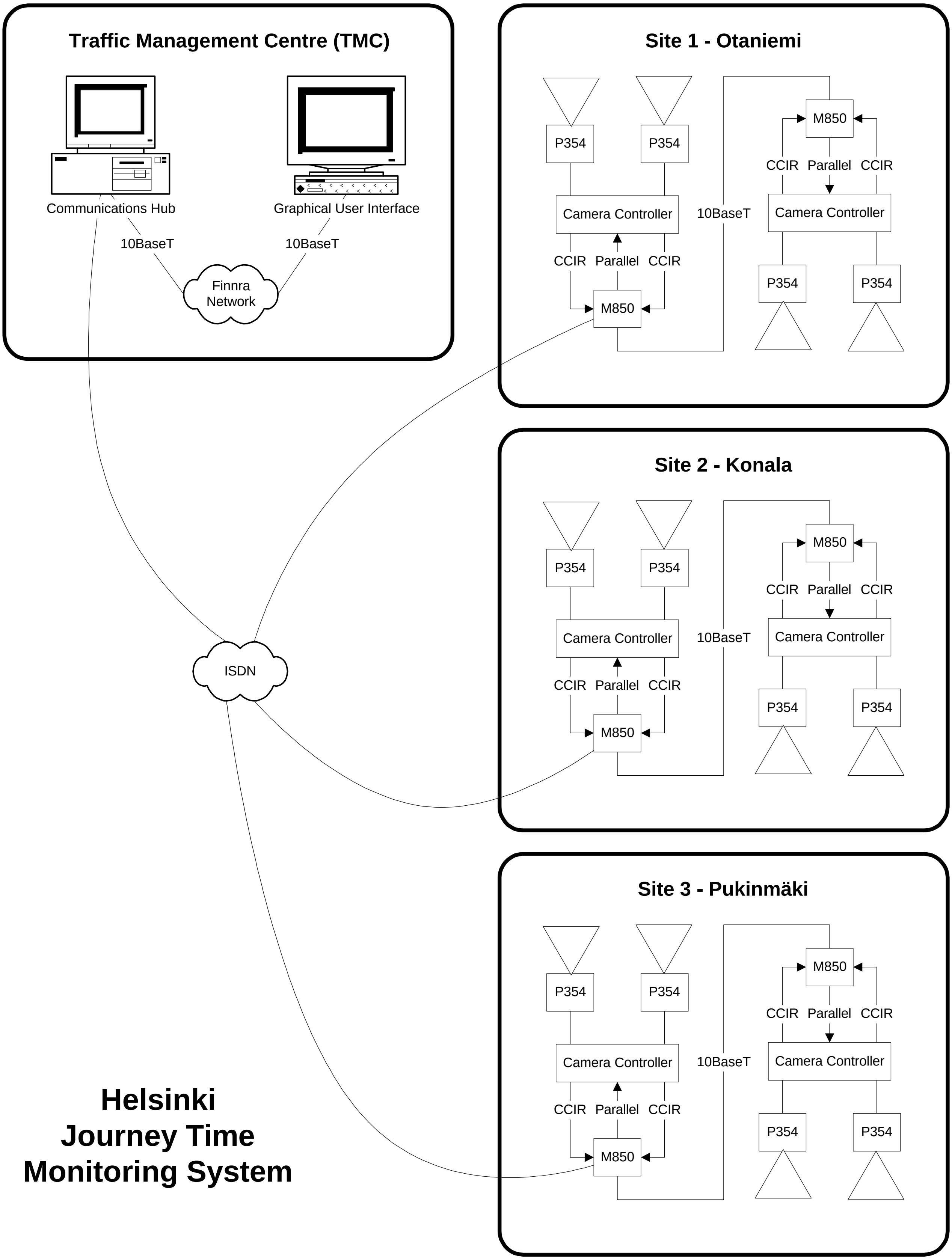

Figure 1 – Overall System Block Diagram

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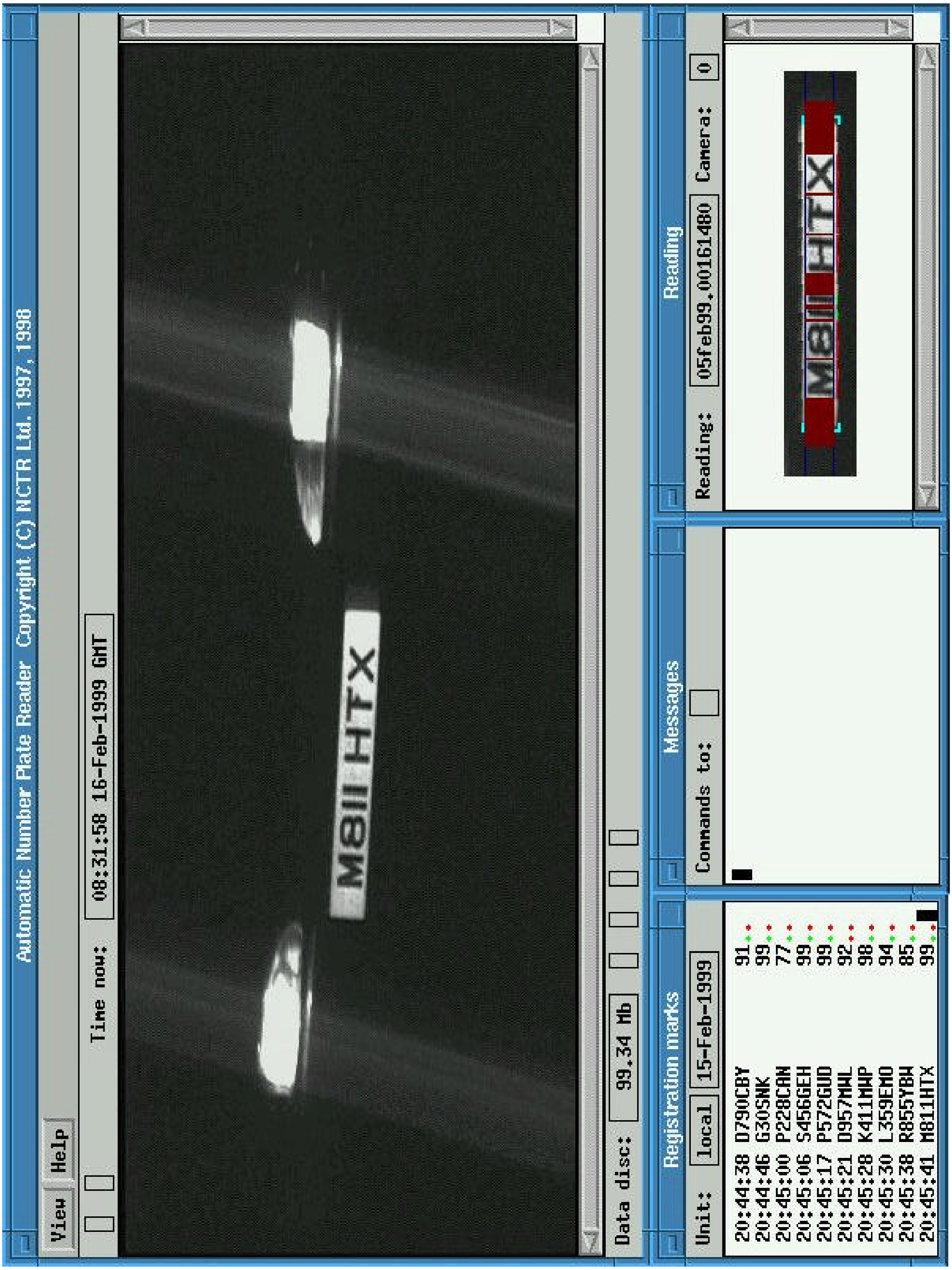

Figure 2 – Marksman 850 ANPR GUI

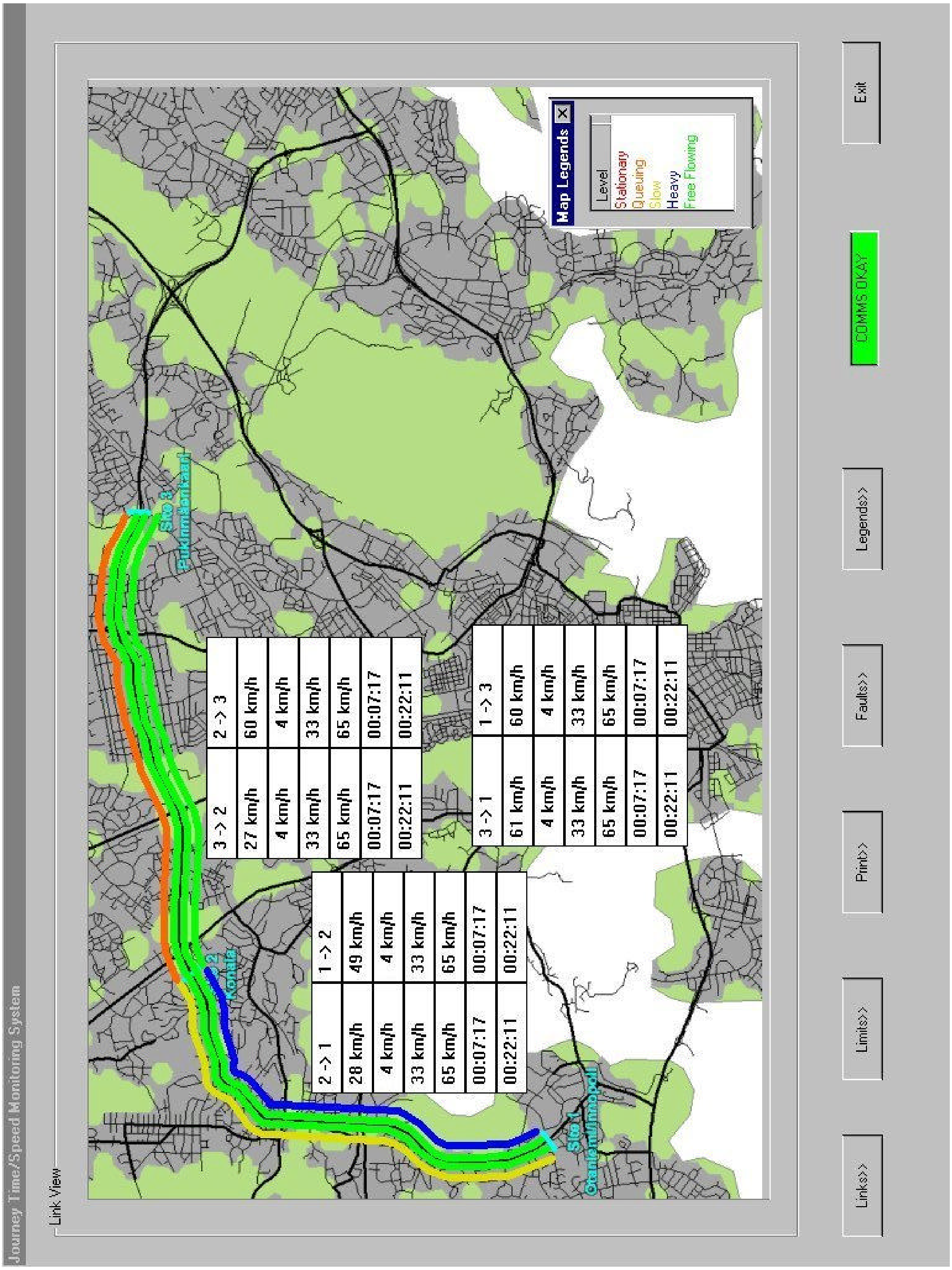

Figure 3 - GUI Main Window

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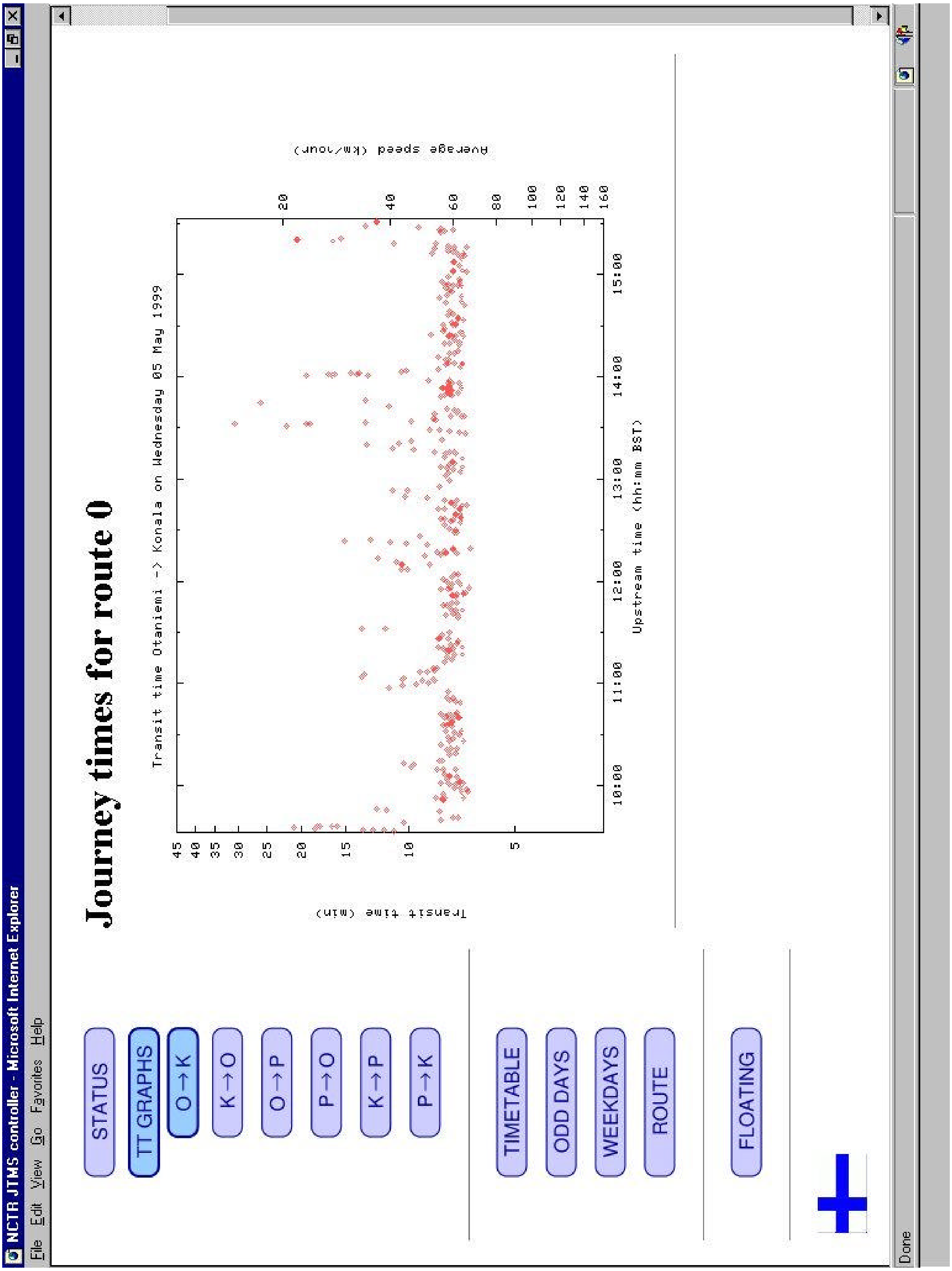

Figure 4 - Control Interface GUI