Appendix: Multilane Free Flow System Analysis

The Multilane Free Flow System can be divided into Roadside and Vehicle Equipment. In this chapter Roadside and Vehicle Equipment will be explained and then the functional description of the whole system.

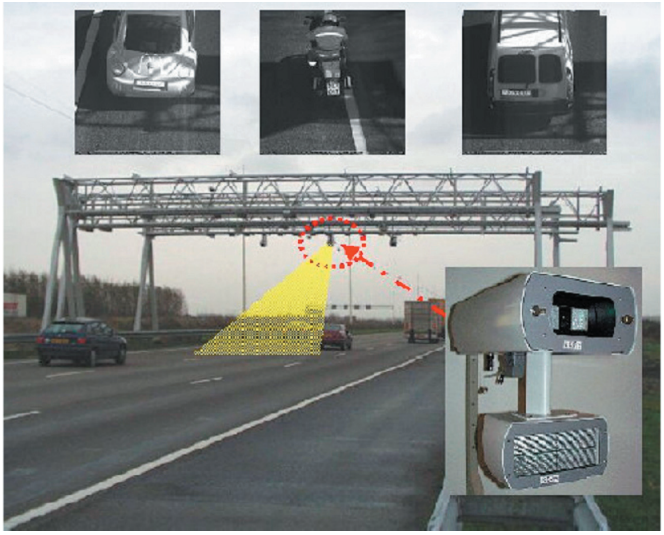
A. Roadside and Vehicle Equipment

The **Vehicle Equipment** is basically the so-called tag or OBU (On board Unit).The OBU is the unit responsible for secure way with the Radio Communication System at the respective toll collection point and is located inside the vehicle. It is activated by the Radio Communication System at the toll collection point. The data transmission is performed through reflection and modulation of the microwave frequency carrier sent by the Radio Communication System.

The **Roadside equipment** is formed by:

1. **Radio Communication System**, formed by transmitters (TX) and receivers (RX) located at the gantry. Both types of antennas are designed for automatic registration, identification and debiting of vehicles carrying a Transponder.
2. **Video Registration System**, including Vehicle Registration units. The VR Units are mounted in poles or at gantries. The Video Registration System comprises the Video Registration units mounted in the poles in case of 2 lanes per direction, or at a gantry in case of more than 2 lanes per direction. The VR units for each lane contain CPU, Heater, Camera with lens and IR flash. The IR-flash is placed close to the camera to utilize the retro reflective properties of the vehicle licence plate. Clear images of the licence plate can therefore be taken under different weather and light conditions.

   The enforcement camera will take a picture based in a triggering signal originating from the Vehicle Detection System (this system will be explained in the next point). This image is then stored on Toll Plaza Computer (included in the Coordination System which will be explained afterwards).



3. **Vehicle Detection and Classification System.** The system consists of a Detection computer placed in the cabinet and a set of gantry mounted laser scanners.

   The Detection Computer receives data from the Single Beam Laser Scanners.

   It has 3 serial ports that make it possible to connect up to 3 scanners so that a software module combines the information from the various single-beam laser scanners. In a Multilane environment this is sufficient to cover 3-4 lanes.

   The Single Beam Laser Scanner is an infrared laser. The measurement principle is based on time of flight. The laser emits a light pulse and then measures the time it takes before a reflected light signal is received. From the known speed of light the distance to the object can then be calculated.

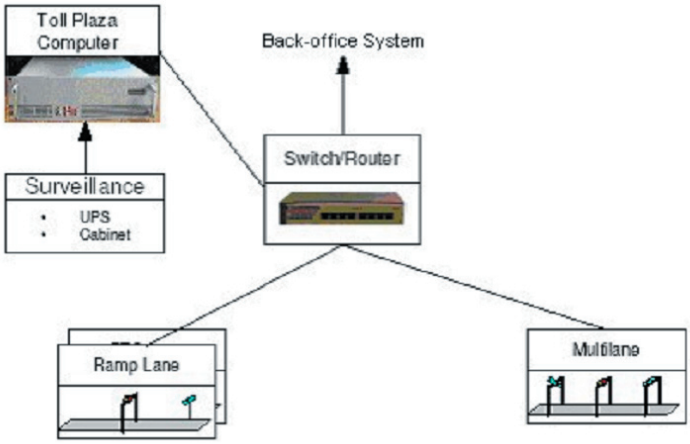
   As an option dual-beam laser scanners can be included instead of single beam laser scanners. Dual-beam laser scanners consist of two laser beams that are very close. Thus, these scanners are able to measure the speed and the length of the vehicle as well as the rest of measures taken by the single beam laser scanner.

4. **Coordination System**.This system is located in the cabinet equipment. All units at the toll

plaza/toll ramp level communicate over the local area network. The toll plaza is controlled by the Toll Plaza Computer that, in addition to acting as a file-server for the different lanes, can also monitor common features for all lanes, like the Uninterruptible Power Supply (UPS), surveillance of the cabinet where the equipment is installed and so on.

B. Back Office System.

The back office system (also called central system) is responsible for receiving the transactions from the toll



plazas. The system will also be responsible for monitoring the plazas. The back office system has the following main building blocks:

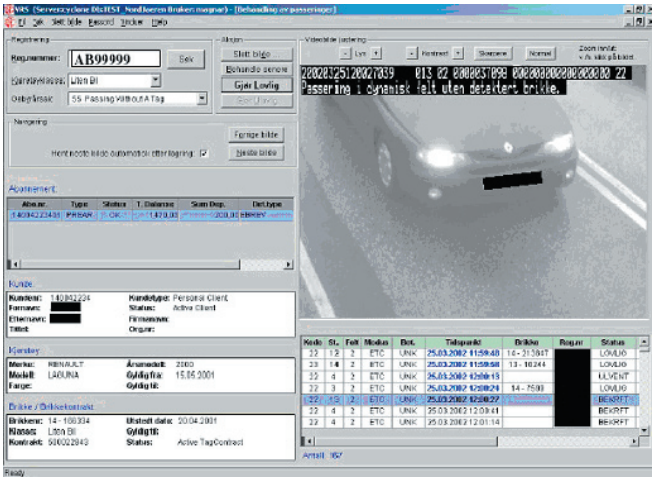
- **Database for storing the transactions (Client database):** The Central System Database is the core of the system, and all information is stored in it. Data integrity is enforced through the use of the database constraints. In addition to the pure storage of data, substantial data processing logic is also present in the CS database, in the form of Stored Procedures.

  Stored Procedures are used to perform all data manipulations in the database: To handle transactions, picture information, payment/banking status information, user security and so on. All software applications access the CS Database through use of Stored Procedures. This acts as a security mechanism, whereby casual alteration of the database data is prevented – and only authorized data manipulations encoded in the Stored Procedures are allowed.

- **Software for analyzing the video images: The Video Retrieval System:** The *Video Retrieval System* (VRS) application is the Back Office application that provides an interface to the enforcement/violation data and images stored in the back office system. It is responsible for allowing Enforcement/Violation data to be examined and correctly classified for processing.

  The Enforcement system handles transactions from the toll system that are marked as 'exceptions'. These are transactions relating to non-payment, vehicle classification violations, etc. Video pictures arriving at the back office system are stored as distinct image files on the server disk. The Video Retrieval System application is equipped to zoom in any part of the picture and adjust light and contrast if needed.

- **Software for billing the users including interface**



  to external parties. This software consists of the following applications:

  - The *Banking/Payment System* is the Back Office Subsystem responsible for communication and integration with third party banking and payment systems. This subsystem is closely coupled to processing auto-refill transactions requests between Client Accounts and the Back Office System.

  - The *Tag Contract Administration* (TCA) application is the Back Office application that provides an interface to the creation and management of Clients and their associated data throughout their life cycle in the system.

- The *Mailing House* (MH) application is the Back Office application that provides an interface for the management and handling of OBUs and any accessories to a Clients Account as part of the OBU issuing process.

- **Software for monitoring the status of the toll plazas.** This application is the Back Office application that provides:

  - **Handling of alarms and incidents:** Alarms and incidents will continuously be updated to the screen. The operator must acknowledge the alarms with high priority.

  - **Monitoring /configuring lanes:** The state of the primary equipment can be monitored and manipulated. Sampling tests can be defined.

  - **Passages:** It is possible to search in all vehicle passages available in the system. The search parameters can be time, lane, operator, direction, vehicle class, passing type and credit card type defined by the operator. Using a query in the database, a report will list the rows from the transaction database, based on search parameters given by the operator. All fields in the transaction database (passing-table) are available for this search. Date and time is one of the search parameters in the search. The operator can enter a start date, and end date and time in addition to other search parameters. In addition to being presented on the screen, the output from the search can be directed to a printer or as a file to Excel.

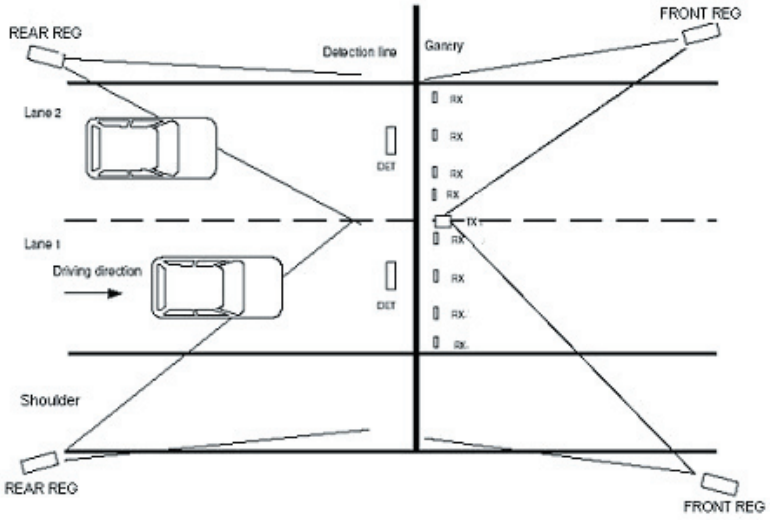
  - **Shift reports:** An overview of all the shift reports can be listed using defined search criteria.

C. Functional Description.

As the vehicle enters the detection line, the laser scanners (DET sensors in Figure below) will detect it, and the front enforcement camera (FRONT REG units in Figure below) will be triggered. The vehicle remains detected until it leaves the detection line. As the vehicle leaves the detection line, the rear enforcement camera (REAR REG units in Figure below) will be triggered, and a transaction is generated for that vehicle.

Simultaneously as the vehicle is passing over the detection line, the communication system (Transmitter, TX unit in the Figure below, and Receivers, RX units in the Figure below) will communicate with the vehicle's tag, and it is possible to match the correct tag to the correct vehicle.

The general layout for a two-lane Multilane system is presented in the figure below.

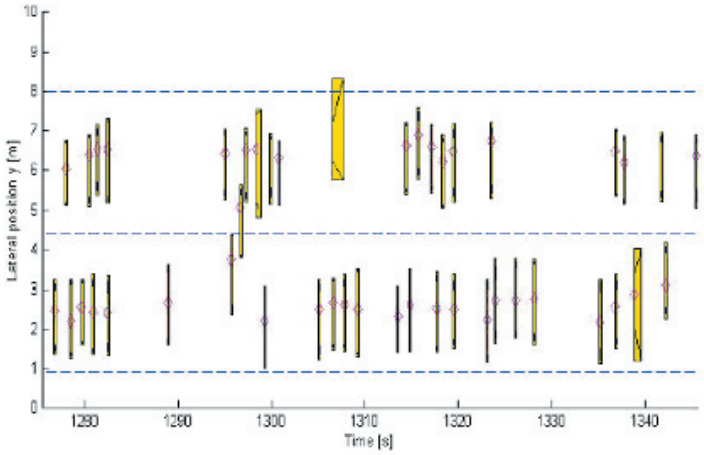


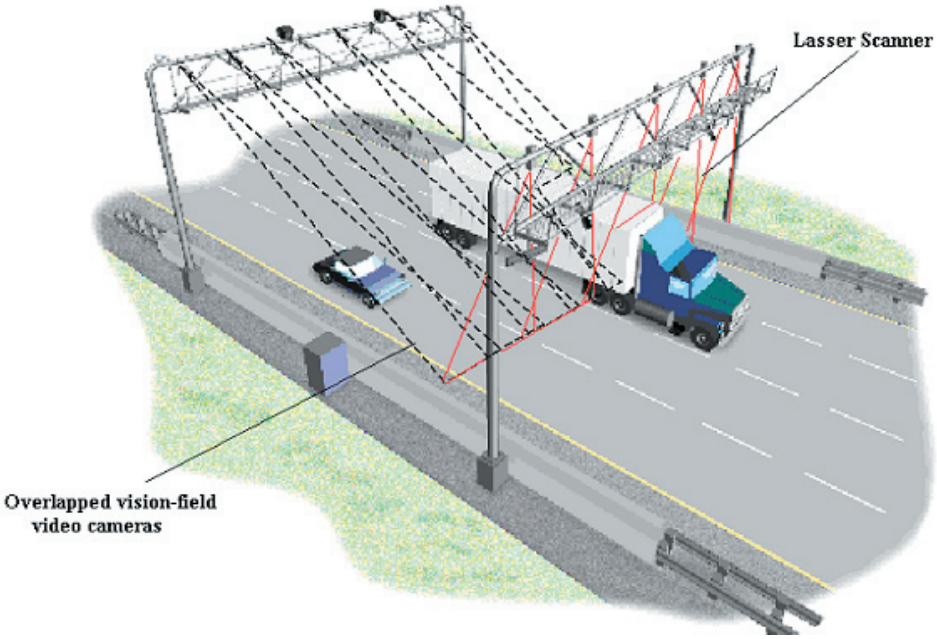
The OBU communication is not directly triggered by the detection system, and hence needs to be matched based on time comparison between the detection and communication system besides the lateral position information of the both the OBU and the vehicle.

The matching between the OBU and the vehicle will then be based on a comparison in time of which vehicles remained in the vehicle sensor systems zone while the reported OBU was there (OBU´s maximum point of communication is located close to the detection line defined by the vehicle sensor system) and which of these vehicles reported is closest to the reported OBU coordinates (a comparison in space).

In a Multilane system with more than 2 lanes per direction, the only difference is that front enforcement cameras are placed at one gantry and rear enforcement cameras are placed at another gantry. Poles cannot be

used be with more than two lanes because the pictures of the cameras would not be enough good for the OCR process.





D. Security.

The data exchange between toll plaza and the central system can be encrypted. In addition, in order to prevent manipulations of the enforcement images, these images can be equipped with an electronic signature that is a function of the information in the image in the camera. Hence, if the images are later manipulated by for example modifying the vehicle license plate number on the image the electronic signature will no longer be valid.