TALLINN RING ROAD E265 ITS

ITS study of the dynamic traffic management of kilometres 0–30 of the Tallinn ring road (national road no. 11) and of the truck park

REPUBLIC OF ESTONIA
ROAD ADMINISTRATION

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Introduction

Tallinn ring road E265 ITS is a project for establishing dynamic traffic management and a smart truck park. In the course of the project, intelligent transport systems (ITS) for traffic management, monitoring, and notification of road users will be installed on kilometres 0–30 of the Tallinn ring road which is included in the TEN-T network, and a smart (intelligent and secure) truck park will be built. The Tallinn ring road will be equipped with information boards as well as variable speed limit and warning signs which are already familiar to road users. There will also be traffic counters, an accident detection system, road weather stations, and traffic cameras. Novel solutions used will include a system for re-routing traffic and V2I/I2V (vehicle to infrastructure/infrastructure to vehicle) devices which will be used for communication between the vehicle and the infrastructure. The V2I/I2V communication systems will increase the driver's awareness of potential hazards and will help to reduce the likelihood of traffic accidents, resulting in a safer traffic environment. This technology will also increase the efficiency of traffic, providing warnings about traffic jams ahead and allowing to choose alternative routes, thereby ensuring environmentally friendlier journeys. Although there are similar tools in the form of Waze, Google, and other applications available today, this technology will cut out the human link and the vehicle will independently obtain information for decision-making. A smart truck parking area for 100 trucks will also be built by the Tallinn ring road between the city of Tallinn and Veneküla (km 1.5).

The aim of this study is to provide a detailed overview to identify the selection of the equipment/solutions required for dynamic traffic management on kilometres 0–30 of the Tallinn ring road and for the parking system of the truck park. The most optimal solution which would be integrated to the traffic management centre of the Road Administration will be suggested for each type of equipment.

The study is divided into seven sections by the ITSs:

1. the traffic monitoring system;
2. the V2I/I2V (vehicle to infrastructure/infrastructure to vehicle) communication equipment;
3. the automatic barrier gate system for re-routing (ABGS);
4. the barrier control system and parking sensors for the truck park;
5. the re-routing scenarios;

6. information exchange between the traffic management centre of the Road Administration and the Tallinn traffic light control centre;
7. the architecture and interoperability of the ITS solution.

1. Traffic Monitoring System (TMS)

Purpose

The Traffic Monitoring System is a data acquisition solution. It is a combination of hardware and software tools, the aim of which is to use the data collected and events identified in real time to provide an overview that is as true-to-life and operational as possible of what is happening at the monitored points on the roads or sections of the road and to provide high-quality basic data for future calculations, planning, forecasting, analyses, and decision-making. The output of the system is the following data:

- Basic data – the basic values collected about each vehicle: time stamp, speed, length, direction, lane, and class. Some of the sensors also provide the mass, width, number of axles, and 3D image of the vehicle. The basic data is used to calculate interval data in the sensor or in the computer controlling the sensor.
- Aggregated interval and event data – number and classification of vehicles, separation distance between the vehicles, average speed and changes in the speed, the occupation level of the road in the specified period, and any incidents. Based on the aggregated and event data, the input is calculated for the TMC, as well as directly for the vehicles through the V2I/I2V sensors about any changes on the road (e.g. changes in the weather, congestions, accidents, etc.). The Road Administration will issue information for the application of the automatic barrier gate system for re-routing (ABGS) where detours are not possible or are unreasonably long on the day.

Open data. The system of the Road Administration will not be collecting data which would directly or indirectly enable the identification of persons. Therefore, the data should be available through the Estonian Open Government Data Portal, which would allow third parties to use the data.

Various technologies

The selection of solutions of the Road Administration is relatively broad with various technologies for obtaining data in use. From the technological perspective, the solutions may be divided into two larger groups: those which measure the data at a certain point and those which do this on a certain section. This has no impact on the counting data but, in the case of an event, the technologies which measure the data on a section are clearly advantageous.

The technologies which are referred to provide an example are from the manufacturers who gave the widest selection and the most detailed information about their solutions.

1.1. Radar sensors

Active devices operating in the microwave range which measure the speed, distance, direction, and shape of an object based on the reflections of the radio waves emitted to the surrounding area by the devices themselves. Divided in two based on the positioning: forward-firing and side-firing devices.
Operating at the frequencies of 24 GHz or 77 GHz.
Manufacturers: SmartMicro, Icoms, Geolux, ImageSensing, Wavetronix

1.1.1. Smartmicro UMRR-12 type 48 Forward+ forward-firing radar sensor

A 24 GHz Doppler radar which can simultaneously monitor up to ten lanes and 256 road users, maximum technical detection distance:

- trucks 300 m
- passenger cars 200 m
- motorbikes 130 m
- pedestrians 90 m

Figure 1.1 Smartmicro UMRR-12 radar

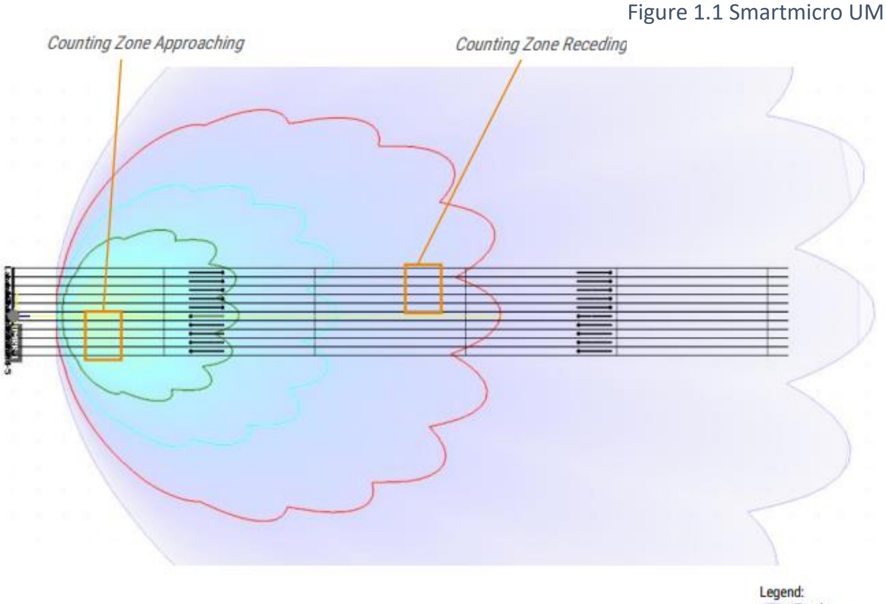


Figure 1.2 The detection areas and counting zones of Smartmicro UMRR-12 in the case of different road users.

This radar model is available in three different settings:

- Forward+ – traffic monitoring and counting
- Stop+Advance – a setting which is used for intersections, U-turns, left turns, etc. which detects the vehicles behind the stop line, waiting for turns and arriving to wait for turns
- Enforcement /RL – detection of speeding and ignoring the red light, which functions with a certified measuring accuracy

Typical devices and assembly in the counting and incident detection regime

Optimal values, possible ranges in the brackets:

- Installation height: 6 m (1–10 m)
- Position of the sensor with respect to the centre line of the road: 10° (–25°...+25°)
- Reading distance for approaching lanes: 30 m (20–90 m)
- Reading distance for opposing lanes: 120 m (70–130 m)
- Road user counting accuracy: > 95%
- Road user classification accuracy: > 80%
- Classification: pedestrian, bicycle, motorbike, passenger car, van, truck/bus, long truck.
- Duration of the scanning cycle: 75 ms or 13 times per second

Aggregated data: number of vehicles, occupation, average speed, 85th percentile speed, separation distance, road users in the oncoming lane.

Operation in dark conditions and under the influence of weather conditions

The radar sensor is immune to changes in the light conditions and is not impacted by weather conditions.

Installation method and positioning

The radar sensor is installed to a pole, console, portal, or other structure at the height of 1–10 metres. It is advisable to install it at least at the height of 6 m to minimise the amount of inaccurate counting data arising from vehicles being concealed by other vehicles. The angle between the centre line of the radar beams and the centre line of the road may not exceed 25° in the place of installation.

Communication interfaces and protocols

Ethernet 10/100 Mbps (in development), CAN v.2.0 passive, RS485 full duplex, Smartmicro Transport Protocol.

Interfacing with other systems

The manufacturer provides the software for setup and maintenance which advisably enables management of up to 20 devices in one installation. A software tool which would be installed in the industrial controller computer included in the radar solution must be developed for collecting and processing counting and event data. This would ensure flexibility and possibility for local connection of the systems, if necessary.

Need for regular maintenance

The device is maintenance-free.

Compliance

EN 300 440 (EVS-EN 300 440 Short-range devices (SRD); radio equipment to be used in the 1 GHz to 40 GHz frequency range; harmonised standard covering the essential requirements of article 3.2 of Directive 2014/53/EU).

Costs

The cost of the UMMR 12 Type 48 Forward+ device with five years of product support is approximately €6,000

1.1.2. ImageSensing RTMS Echo side-firing radar sensor

A 24 GHz Doppler radar which covers up to twelve lanes and monitors the road crosswise, maximum technical detection distance up to 76 m. The RTMS Echo is equipped with a GPS receiver which synchronises time and provides the accurate location of the radar.

Aggregated data through the Echo API

- Classification based on the length of the vehicles, 8 classes
- Vehicle speed
- Number of vehicles
- Average speed
- 85th percentile speed
- Separation distance
- Details of each vehicle: time stamp, speed, length, direction, class

Figure 1.3 ImageSensing RTMS Echo radar

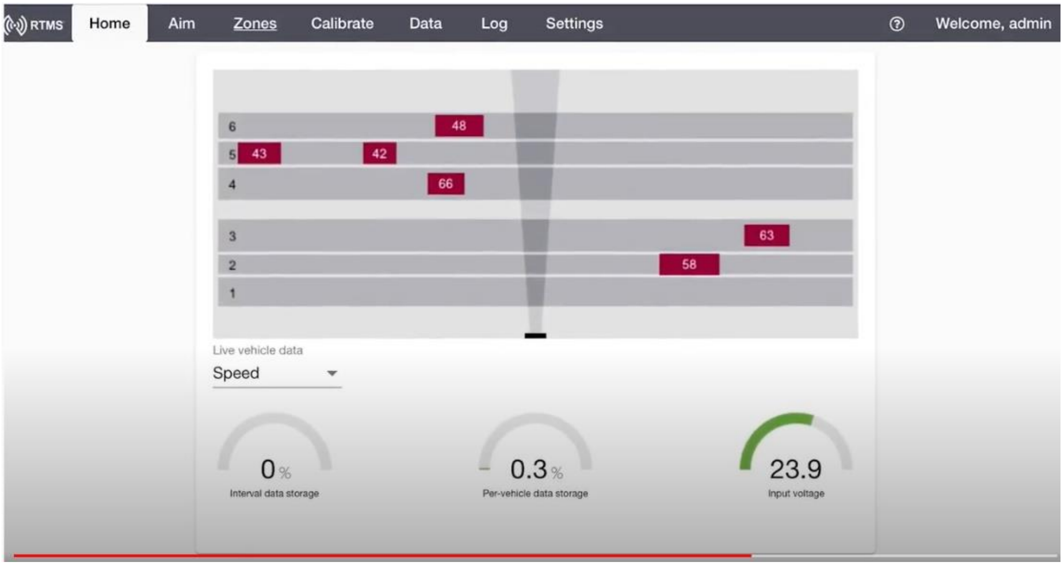


Figure 1.4 ImageSensing RTMS Echo administration interface

Additional software

In addition to the radars, ImageSensing also provides central IntelliTraffiQ server software, which enables the following:

- an interactive map application with real-time sensor information;
- a sensor administration module;
- a speed map;
- a database module;
- detection of road users in the oncoming lane;
- travelling time information;
- administration of the users of the software;
- an analysis and reporting module.

Operation in dark conditions and under the influence of weather conditions

The radar sensor is immune to changes in the light conditions and is not impacted by weather conditions.

Installation method and positioning

The radar sensor is installed to a pole or a console at the height of 5–10 metres. The height depends on the distance between the radar and the farthest monitored lane. The RTMS Echo radar cannot be installed directly on the portal due to potential disturbances. The RTMS Echo radar must be located on a pole which is installed at least 2.5 m from the portal or installed to a beam which is attached to the portal and is horizontally aimed sideways (see Figure 1.5).

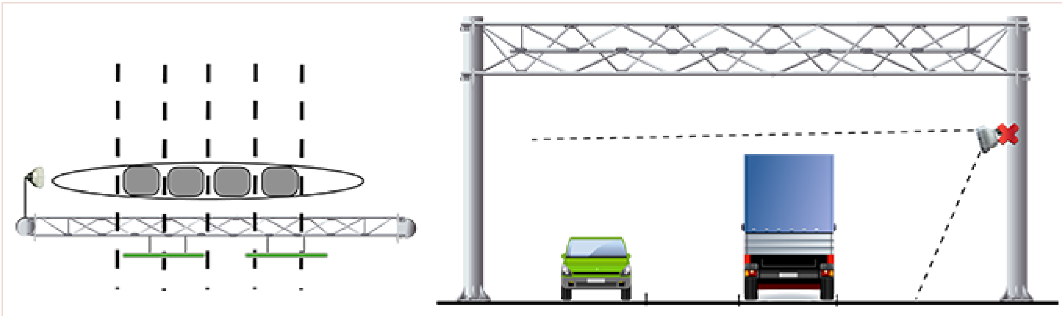


Figure 1.5 Positioning and detection area of the RTMS Echo radar in the case of a portal

Communication interfaces and protocols

Ethernet 10/100 Mbps, WiFi.

Interfacing with other systems

The RTMS Echo is equipped with an integrated online administration tool. There is an Echo API machine interface for information exchange. As an optional additional product, the manufacturer also offers the ImageSensing IntelliTraffiQ central administration and data acquisition solution for the management of ImageSensing RMTS Echo and other radar models of the same manufacturer.

Need for regular maintenance

The device is maintenance-free.

Compliance

EN 300 440 (EVS-EN 300 440 Short-range devices (SRD); radio equipment to be used in the 1 GHz to 40 GHz frequency range; harmonised standard covering the essential requirements of article 3.2 of Directive 2014/53/EU).

Costs

The cost of the ImageSensing RTMS Echo device is:	€6,000 + VAT
The IntelliTraffiQ Core server software licence for 25 sensors:	€36,000 + VAT
The IntelliTraffiQ Wrong Way Module licence for 25 sensors:	€14,400 + VAT

1.1.3. Wavetronic SmartSensor HD side-firing radar sensor

A 24 GHz Doppler radar which covers up to 22 lanes monitoring the road crosswise and the maximum technical detection distance of which is up to 76 m.

Figure 1.6 Wavetronix SmartSensor HD radar

Aggregated data through the Wavetronix protocol

- Classification based on the length of the vehicles, 8 classes
- Vehicle speed
- Number of vehicles
- Average speed
- 85th percentile speed
- Separation distance
- Details of each vehicle: time stamp, speed, length, direction

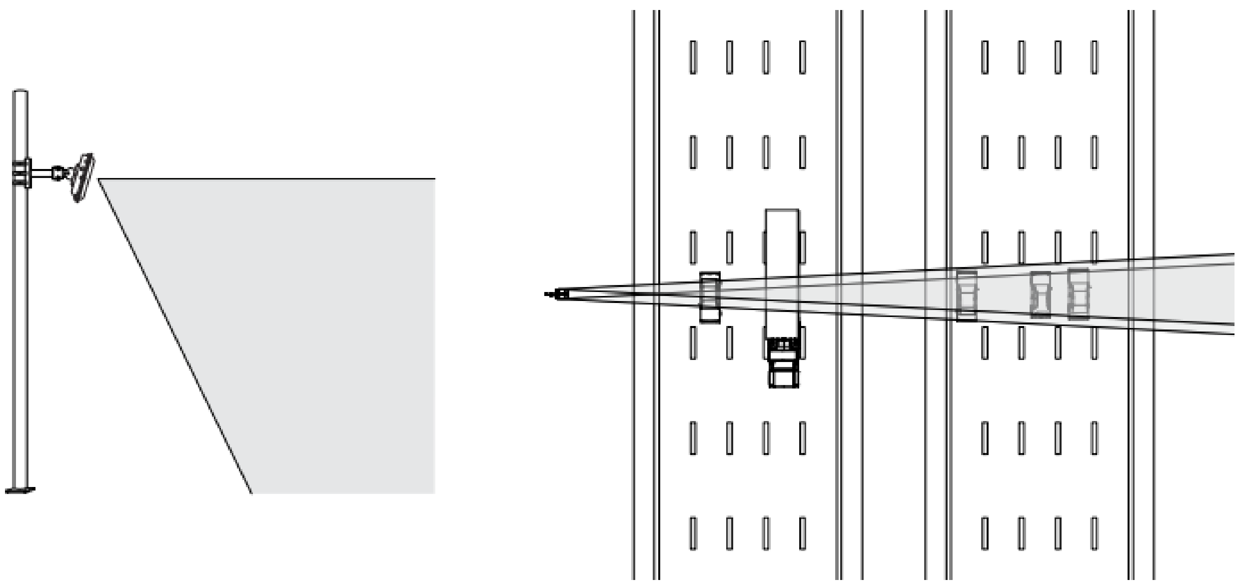


Figure 1.7 Side and top views of the Wavetronix SmartSensor HD

Operation in dark conditions and under the influence of weather conditions

The radar sensor is immune to changes in the light conditions and is not impacted by weather conditions.

Installation method and positioning

The radar sensor is installed to a pole or a console at the height of 5–12 metres. The height depends on the distance between the radar and the closest monitored lane. This radar cannot be installed on the portal due to potential disturbances. The radar must be located on a pole which is ideally installed at least

9 m from the portal or installed to a beam/boom which is attached to the portal and is horizontally aimed sideways.

Communication interfaces and protocols

RS232, RS485.

Interfacing with other systems

Wavetronix SmartSensor HD requires a local controller computer or RS232/485 – an Ethernet converter through which the communication is organised. A software tool must be developed for collecting and processing counting and event data.

Need for regular maintenance

The device is maintenance-free.

Compliance

EN 300 440 (EVS-EN 300 440 Short-range devices (SRD); radio equipment to be used in the 1 GHz to 40 GHz frequency range; harmonised standard covering the essential requirements of article 3.2 of Directive 2014/53/EU).

Costs

The cost of the Wavetronix SmartSensor HD device is €6,500 + VAT

1.2. Induction and piezoelectric sensors

Sensors which are usually installed in the pavement. In the case of induction sensors, the electric changes in the induction loop which are caused by the metal parts of the passing vehicle are measured and the vehicle class is determined and the speed and other information are calculated based on the signature and duration of the change. In the case of piezoelectric sensors, the change in the electric signal is caused by the mass of the vehicle by compressing the sensor. Thus, piezoelectric sensors can also be used for measuring the masses of moving vehicles, among other things. Manufacturers: Kistler, CaTraffic, Q-Free, ViaVDS

1.2.1. Kistler KiTraffic Statistics System

Figure 1.8 The Kistler KiTraffic controller

The combined induction loop and piezoelectric sensor enable to measure the mass of the vehicle in addition to the regular counting data. Measured data: vehicle speed, vehicle length, separation distance, road users in the oncoming lane.

Classification of vehicles: Euro-13, 13 classes + 1 unidentified.

Detection of the mass of a vehicle: total weight, differences between the masses of the left/right side, axle loads, number of axles, wheelbase.

Operation in dark conditions and under the influence of weather conditions

The induction and piezo sensors are immune to any impacts of light or weather conditions.

Installation method and positioning

The sensors are installed in the pavement. See Figure 1.9 for the manufacturer's scheme of the positions of the sensors in one lane.

Communication interfaces and protocols

Ethernet 10/100 Mbps, RS485 full duplex.

Interfacing with other systems

The manufacturer has developed the RESTful API. There are DIO outputs for controlling the devices locally. Online administration interface.

Need for regular maintenance

The solution requires annual inspection and maintenance.

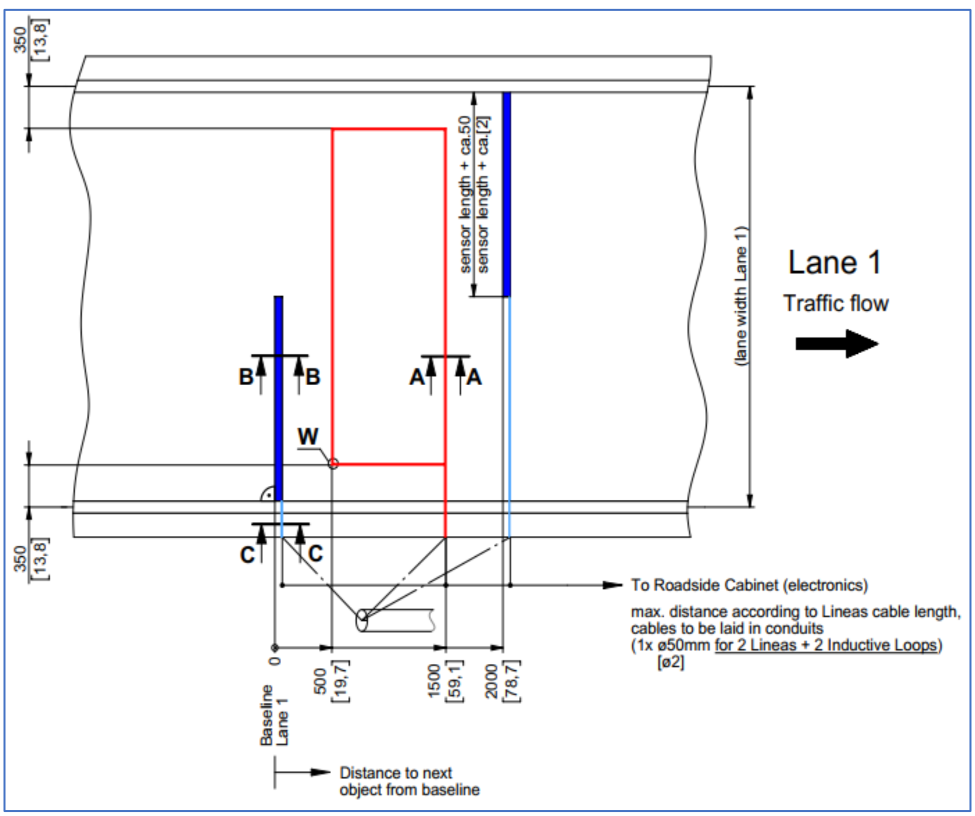


Figure 1.9 Positioning of the *KiTraffic* sensors in one lane

Costs: The cost of one set of devices in the case of 2 + 2 counting points is approximately €55,000

1.2.2. Vialis ViaVDS

An induction sensor-based counting and incident detection solution which is primarily designed for fully covering sections of a road with incident detection capability.

Classification of vehicles: 6 classes

Added to the selection as the sensor system for the fully automatic version of the systems for re-routing to be installed in the section between the traffic junctions of Jüri and Kurna, which enables full detection of incidents and counting of vehicles.

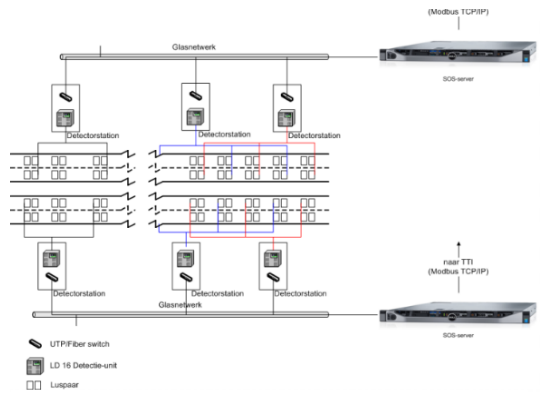


Figure 1.10 The Vialis ViaVDS solution

Operation in dark conditions and under the influence of weather conditions

The induction sensors are immune to any impacts of light or weather conditions.

Installation method and positioning

The sensors are installed in the pavement.

Communication interfaces and protocols

Ethernet 10/100 Mbps, TCPIP.

Interfacing with other systems

The manufacturer supplies control servers, over which the system is interfaced with other systems.

Need for regular maintenance

The solution requires annual inspection and maintenance.

Costs

The cost of the set of equipment for fully covering the section of the road between the junctions of Jüri and Kurna (approx. 3.5 km) is approximately €550,000

1.3. Video-based machine vision solutions

Software-based analytical tools which run in video surveillance cameras or the servers of the traffic management centre and process and analyse the video flows of the video surveillance cameras.

Manufacturers of server-based data processing solutions or solutions which run in video surveillance cameras: Citilog/Axis, Aitek/Axis, and Sprinx Technologies/Hanwha Techwin.

Manufacturers of solutions with centralised data processing: Telegra, DataFromSky, IntuVision, GoodVision, IntelliVision, TrafficVision, etc. This list is a small selection of the best-known manufacturers, as the number of the companies and start-ups which offer server-based automatic traffic analysis and counting solutions has increased explosively after the marketing of the TensorFlow and Yolo machine learning and machine vision libraries. The solutions with centralised data processing lack the required autonomous functioning if the connection with the traffic management centre is interrupted. Therefore, these solutions will not be described in detail.

1.3.1. Citilog SmartCam-AID

Citilog's software-based machine vision solutions for traffic counting and event detection which run in video surveillance cameras. AXIS's video surveillance cameras are used as hardware platforms. In addition to the usual video surveillance functionality, the cameras offer an integration environment for third parties for the creation of analytics and machine vision applications in any functionality. All Axis camera models with at an at least Artpec-5 processor can be used. Fixed, rotating, and thermal cameras can be used.

The following information is determined for each vehicle: vehicle class (3 classes by default: up to 6 m, 6–12 m, and over 12 m vehicles), vehicle speed, separation distance.

Calculated data: number of vehicles per lane, average speed per lane, separation distance in milliseconds of each lane, occupation rate of the lanes.

Figure 1.11 A Citilog SmartCam-AID screenshot

Detection of events

The SmartCam-Aid software enables automatic detection of the following events:

- stopped vehicle in the case of smooth traffic;
- stopped vehicle in the case of heavy traffic;
- slowing of the traffic, congestion;
- incorrect driving direction;
- slow vehicle;

- pedestrian.

In the event of using in a tunnel, the following can be determined in addition to the information listed above:

- debris/objects on the lanes;
- deterioration of visibility which is primarily caused by smoke, dust, or a fire.

Table 1.1 Default occupation levels provided by the solution

Level	Criterion: occupation of the lane + average speed
0	< 50%
1	≥ 50%
2	≥ 50% + average speed ≤ (speed limit + 10 km/h) / 2
3	≥ 50% + average speed ≤ 20km/h
4	≥ 50% + average speed ≤ 10km/h

Operation in dark conditions and under the influence of weather conditions

If cameras with a high sensitivity to light are used, the solution will work smoothly whether or not there are street lights and irrespective of the changing light conditions over 24 hours. However, weather conditions affect the field of vision of the cameras which, in turn, impacts the functioning of the software. It is advisable to use cameras with a high sensitivity to light, fog filters, and image stabilisers. The Citilog software uses the CT-ADL Citilog Applied Deep Learning in-depth learning algorithm for the prevention of false alarms arising from severe weather conditions and/or light conditions.

Installation and positioning

The camera must be installed above the lanes. In order to obtain accurate counting results, the camera must be installed on the centre line of one of the lanes.

Communication interfaces and protocols

TCPIP, Ethernet 10/100Mpbs. RSTP video flow and XML data flow.

Interfacing with other systems

The administration interfaces of the camera and the counting software are web-based. The IO outputs, RS422/485, or IP interfaces of the Axis cameras enable sending commands to other systems for performing pre-determined operations, for applying settings, for activation, etc. in the case of occurrence of events.

Need for regular maintenance

If the lens of a video surveillance camera gets dirty, it must be cleaned.

Costs

The cost of the Citilog cameras and software licences in 2 + 2 occasions (2 cameras) is €6,000

1.4. LIDAR sensors

Lidar measures reflections of the laser beam impulses from objects, forming point cloud images of objects.

1.4.1. Lidar sensor Sick TIC102

A device with two lidar modules for monitoring one lane. There are two types of the TIC102: a control device which includes a control computer and network switch in addition to two lidar modules. The master device can be connected to up to three slaves. Thus, four lanes can be monitored irrespective of the direction of the traffic. TIC102 is equipped with a weather-proof metal casing.

The following information is issued for each vehicle detected: length, width, height, speed, 3D image, and vehicle class.

There can be up to 30 vehicle classes. TLS 8+1 is used by default.

There is no separate detection of road users in the oncoming lane; theoretically, however, those moving in the opposite direction can be detected based on negative speed readings.

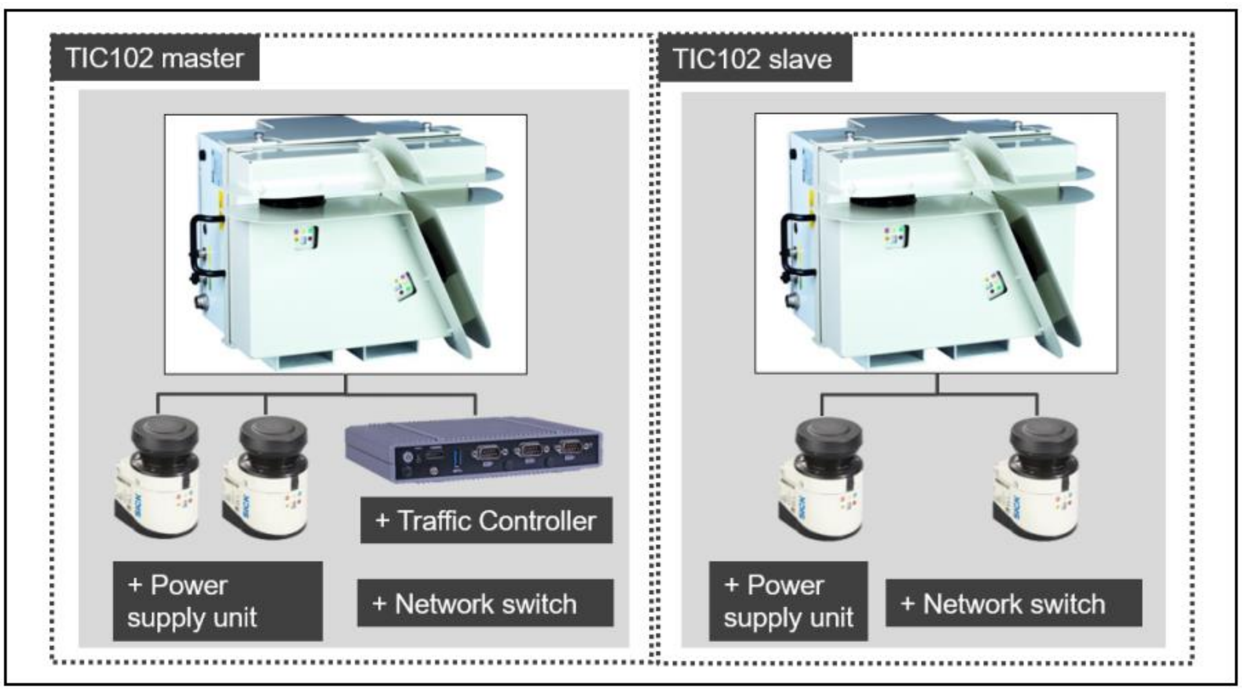


Figure 1.12 The Sick TIC102 equipment types and assemblies

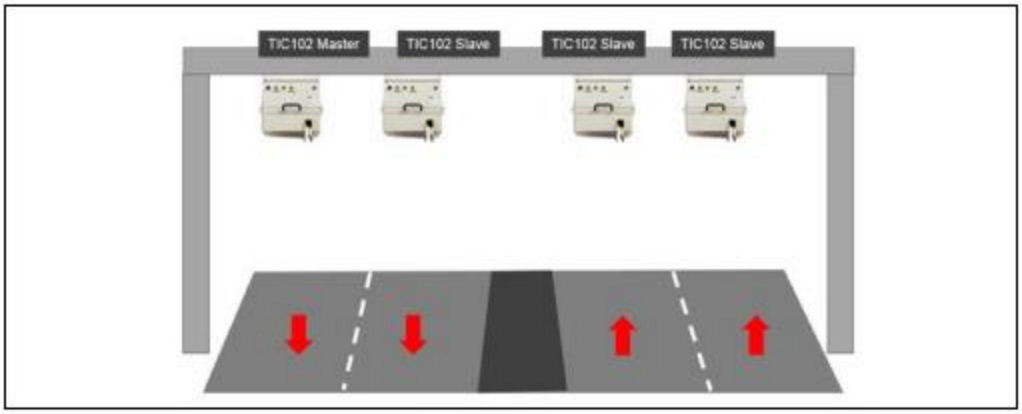


Figure 1.13 Positioning of the Sick TIC102 over lanes

Installation and positioning

One TIC102 device above each lane.

Communication interfaces and protocols

TCPIP, Ethernet.

Interfacing with other systems

Each set of devices comes with a control computer which analyses and saves the data from the sensor modules and is equipped with a web-based administration interface. An API is used for communicating data to third systems.

Need for regular maintenance

The devices do not require regular maintenance, but must be cleaned of dust and mud which settle on the optical surfaces when necessary.

Safety

Laser class 1, (IEC 60825-1:2014) safe for eyes.

Costs

The cost of a Sick TIC102 master device with a five-year warranty is €15,000 + VAT

The cost of a Sick TIC102 slave with five-year warranty is €12,000 + VAT

1.4.2. Lidar sensor Sick TIC501

A device with one lidar module for monitoring up to two same-direction lanes. The TIC501 set of devices includes a control computer which must be installed in a roadside equipment cabinet. One additional device per every two lanes is required for expanding the system. A TIC501 control set + one additional sensor are required for a 2 + 2 cross-section. The TIC501 is less accurate in the detection of vehicle speed and length due being equipped with only one measuring sensor module. The system cannot function if there is a congestion with standstill traffic under the system.

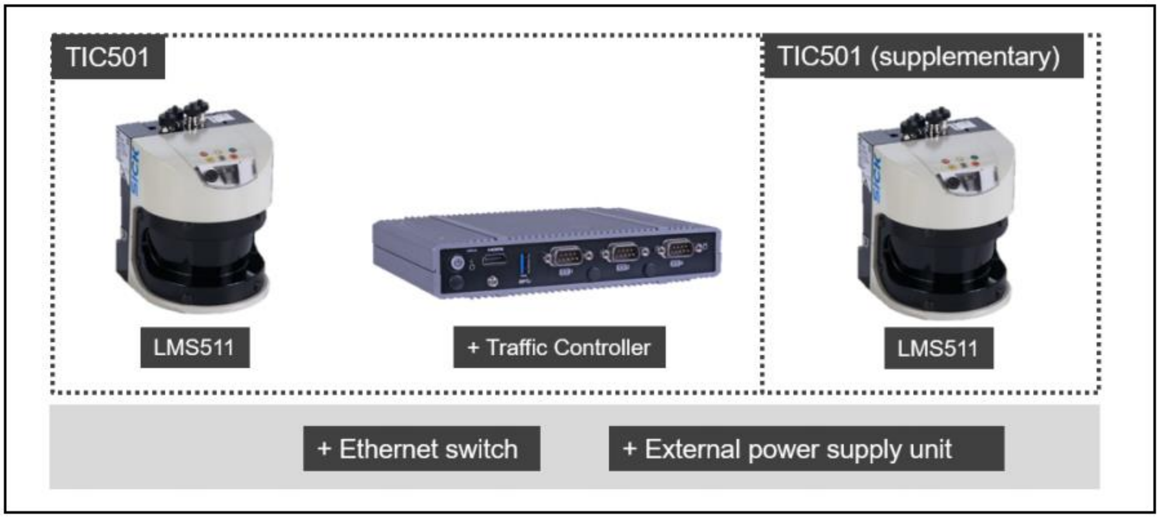


Figure 1.14 The Sick TIC501 set of devices

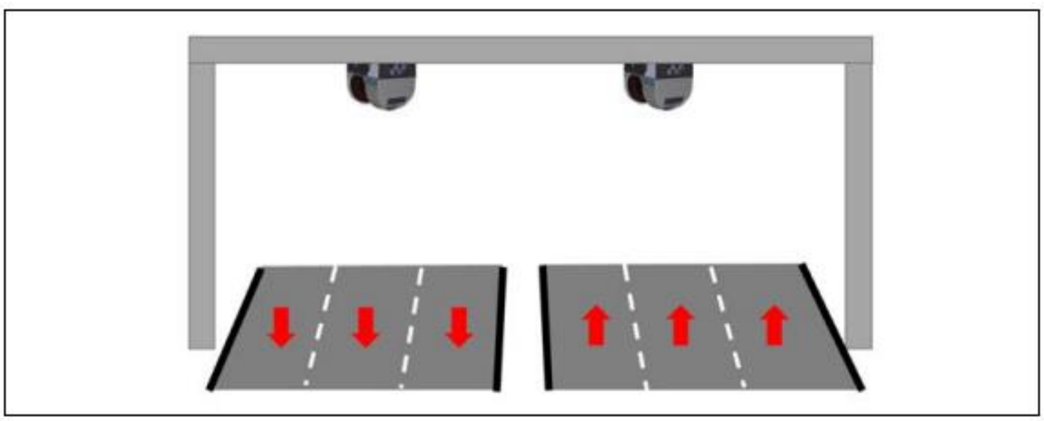


Figure 1.15 Positioning of the Sick TIC501 over lanes

The following information is issued for each vehicle detected: length, width, height, speed, 3D image, and vehicle class.

There can be up to 30 vehicle classes. TLS 8+1 is used by default.

There is no separate detection of road users in the oncoming lane; theoretically, however, those moving in the opposite direction can be detected based on negative speed readings.

Installation and positioning

Advisably, one TIC501 device for up to two same-direction lanes.

Communication interfaces and protocols

TCPIP, Ethernet.

Interfacing with other systems

Each set of devices comes with a control computer which analyses and saves the data from the sensor modules and is equipped with a web-based administration interface. An API is used for communicating data to third systems.

Need for regular maintenance

The devices do not require regular maintenance, but must be cleaned of dust and mud which settle on the optical surfaces when necessary.

Safety

Laser class 1, (IEC 60825-1:2014) safe for eyes.

Costs

The cost of a Sick TIC501 control device with a five-year warranty is: €11,000 + VAT
The cost of a Sick TIC501 supplementary device with a five-year warranty is €10,700 + VAT

1.5. Multisensors

This category includes sensors in which several different technologies are combined. The person who conducted the study only has information about one manufacturer: ADEC.

1.5.1 Adec Technologies TDC-3

The Adec TDC-3 sensor combines three different technologies for counting vehicles. A microwave radar, an infrared curtain, and an ultrasound sensor ensure an accurate result, providing a similar number of vehicle classes with the induction sensors. Based on the number of vehicle classes, the selection of models ranges from 2+0, 2+1, 5+1 to 8+1 (8 classes plus one unidentified).

The following information is determined for each vehicle: vehicle class, speed, separation distance with the vehicle in front, vehicle length, position of the vehicle on the lane (right, centre, or left). Detection of events: road user in the oncoming lane, standing vehicle under the sensor which is interpreted as a congestion.

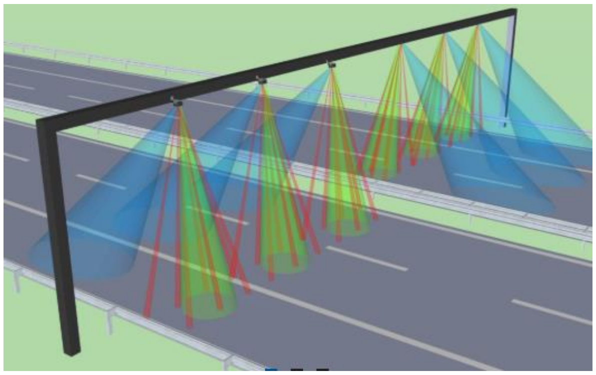


Figure 1.17 Positioning of the Adec TDC-3 sensors

Figure 1.16 Adec TDC-3 sensor

Operation in dark conditions and under the influence of weather conditions

The sensor is immune to any impacts of light or weather conditions.

Installation and positioning

One device above the centre line of each lane.

Communication interfaces and protocols

RS485 half duplex. Adec communication protocol.

Interfacing with other systems

A local controller computer is required for communicating with the devices. The manufacturer provides the software required for calibrating the devices. A software tool must be developed for managing the device and collecting counting and event data.

Need for regular maintenance

The device is maintenance-free.

Cost per counting point

The cost of a TDC3-8 device with fixing elements and with a five-year product support period is €2,500.

Table 1.2 Comparison of the technical features of the TMS devices

	Radar sensor			Induction and piezo		Video-based	Lidar		Multisensor
	Smartmicro UMRR-12 Type 48	ImageSensing RTMS Echo	Wavetronix SmartSensor HD	Kistler KiTraffic	CaTraffic Blackcat Compact	Citilog SmartCam-AID	Sick TIC102	Sick TIC501	Adec TDC-3
Number of classes	7	8, adjustable based on vehicle length	8, adjustable based on vehicle length	13	6/13	3	Up to 30 TLS 8+1	Up to 30 TLS 8+1	Up to 8+1
Counting accuracy	> 95%	> 95%	> 95%	> 99%	> 99%	> 95%	> 99%	> 99%	> 99%
Change in average speed	Yes [1]	Yes [1]	Yes [1]	Yes [1]	Yes, software	Yes	Yes [1]	Yes [1]	Yes [1]
Level of occupancy	Yes	Yes	Yes	Yes [1]	Yes, software	Yes	Yes [1]	Yes [1]	Yes [1]
Incident detection	Yes	No	No	No	No	Yes	No	No	No
Wrong Way Driver	Yes	Yes, through central software	Yes [2]	No	No	Yes	Yes [2]	Yes [2]	Yes
Motorbike detection	Yes	Yes	Yes	Yes	Yes	Yes [3]	Yes	Yes	Yes [3]
Pedestrian and cyclist detection	Yes	No	No	No	No	Yes [4]	No	No	No
Length of the section of road monitored per one counting point	Up to 250 m	Cross-section only	Cross-section only	Cross-section only	Cross-section only	100–200 m depending on the plan and camera lens	Cross-section only	Cross-section only	Cross-section only
Autonomous collection of the data in a buffer in the event of interruption of the connection with the TMC	Yes, up to 1 month	The data of 1 million vehicles	Yes, 2–3 h	The data of 3 million vehicles	The data of 400 million vehicles	At least 1 month	Yes	Yes	Yes [1]
Installation method	By/above the road, 1–10 m from the surface of the road	By the road, 5–10 m from the surface of the road	By the road, 5–12 m from the surface of the road	In the pavement	In the pavement	Above the road, in the middle of the lanes running in one direction	Above the road, over each lane	Above the road, in the middle of the lanes running in one direction	Above the road, over each lane

Table 1.2 Comparison of the technical features of the TMS devices (continues)

	Radar sensor			Induction and piezo		Video-based	Lidar		Multisensor
	Smartmicro UMRR-12 Type 48	ImageSensing RTMS Echo	Wavetronix SmartSensor HD	Kistler KiTraffic	CaTraffic Blackcat Compact	Citilog SmartCam-AID	Sick TIC102	Sick TIC501	Adec TDC-3
Access to basic data	Yes	Yes	Yes	Yes	No, encrypted	Yes	Yes	Yes	Yes
Interfaces and communication protocol	RS485, Ethernet, open protocol	Ethernet, WiFi, API	RS232/RS485, open protocol	Ethernet, API	Ethernet, closed protocol	Ethernet, open protocol, XML	Ethernet, API	Ethernet, API	RS485, open protocol
Installable to the structure of the VMS	Yes	Yes, in the case of a console	Yes, in the case of a console	No	No	Yes, in the case of a portal	Yes, in the case of a portal	Yes, in the case of a portal	Yes, in the case of a portal
Cost of the device before value added tax	€6,000 + VAT	€5,500 + VAT	€6,500 + VAT	set	–	Axis camera €1,500–2,000 + VAT depending on the model	–	–	€2,500 + VAT
Cost of the software licence(s) before VAT	–	€36,000 + VAT [5]	–	–	–	SmartCam-AID licence €2,000	–	–	–
Length of the warranty period	5	3	3	5	2	5	5	5	5
Number of devices required in the case of the 2 + 2 cross-section	1	1	1	1 set (1 central device, 8 sensors)	1 set (1 central device, 8 loops)	2 (1 per driving direction)	1 set (1 controlling sensor and 3 sensors)	2 (1 per driving direction)	4
The cost of the equipment required for the 2 + 2 cross-section includes the cost of a five-year warranty period and product support (for hardware and software)	€6,000 + VAT	€5,500 + VAT	€6,500 + VAT	€45,000 + VAT	€4,000 + VAT	€7,000–8,000 + VAT	€46,000 + VAT	€22,000 + VAT	€12,500 + VAT

The CaTraffic Blackcat Compact is the currently used solution, which was included in the table for comparison

[1] – functionality through an application which must be developed which would communicate with the sensors and calculate values.

[2] – road users in the oncoming lane are not detected directly but as the values of the speed readings will be negative, these road users can be identified based on the data at a later date

[3] – Motorbikes are counted but the counting data are added to the passenger car classes

[4] – Pedestrians are detected as incidents

[5] – Central administration software for up to 25 radars

1.6. Interfacing with the systems of the Road Administration

For the system to function, the sensors must be interfaced with the central systems of the Road Administration. It is important for the sensors to issue two types of data:

- basic data is important for future analysing and will be stored in a data storage;
- aggregated data and events – real-time overview of the situation on the roads.

The above-mentioned manufacturers differ greatly by the administration software provided. Some offer sensor systems with a software solution and graphic interfaces which are designed for use in the traffic management centre; others, however, are only focused on the development and manufacturing of the sensors and allow the client the freedom for developing and shaping their own environments. Of the above-mentioned manufacturers, ImageSensing and Citilog have their own administration solutions. The others use an API or open protocol for interfacing. It should be specified that all manufacturers provide the software required for setting up and launching the sensors but this software lacks the capacity for relaying the data flows to the systems of the Road Administration or this capacity is limited. If the manufacturer only offers open protocol, it is necessary to develop an interface of the protocol which would be capable of exchanging data with the sensors and performing calculations with the basic data, if necessary, to obtain aggregated data. The cost of the development of the software protocol interface which is approached as a one-time investment by nature will depend on the sensors, the manufacturer's existing software solutions, the protocol, and the functionality. Based on the experience of the person who conducted the study in developing an Adec TDC-3 software interface, the estimated volume of the work may range from 100 to 1,000 hours of development. An API must also be interfaced with other systems, but the volume of the work is smaller compared to creating protocol support. In order to determine the actual cost, a preliminary analysis of the interfacing must be performed based on a specific sensor, the tools supplied by the manufacturer, and the user's needs.

1.7. Cost

An estimated investment in the case of 2 + 2 counting points: equipment with a 5-year warranty period, accessories (surge protectors, serial-Ethernet converters, etc.), installation and adjustment. In the case of this project, it is presumed that the devices will be installed on existing structures and/or in an equipment cabinet and that the communication system with the traffic management centre has been created. The investment does not include the cost of one-time interfacing with the systems of the Road Administration.

Table 1.3 Comparison of the advantages and disadvantages of the TMS devices

	Investment per counting point	**Maintenance costs**	**Expected lifetime**	**Advantages**	**Disadvantages**
Smartmicro UMRR-12 Type 48	€10,000 + VAT	None	10 years	For monitoring up to 250-metre sections of road, detection of road users in the oncoming lane and incidents, detection of pedestrians and cyclists	No video feed for visual monitoring
ImageSensing RTMS Echo	€9,500 + VAT [1,2]	None	10 years	Integrated GPS, API	Cannot be installed directly on the portal
Wavetronix SmartSensor HD	€10,500 + VAT [1]	None	10 years		Cannot be installed directly on the portal
Kistler KiTraffic	€57,000 + VAT	Expenses arising from the wearing of the pavement [3]	10 years	Measures the mass of vehicles, identifies the number of axles	Installed in the pavement Cost. Need for maintenance
Catraffic BlackCat Compact [4]	€8,000 + VAT	Expenses arising from the wearing of the pavement	10 years	cheap	Encrypted basic data, need for maintenance
Citilog SmartCam-AID	€11,000 + VAT	None	10 years	The option to use road cameras, no need for traffic cameras as video feed is also provided, an AID system	Low number of vehicle classes
Sick TIC102	€61,000 + VAT	None	10 years	Accuracy, 3D image	Cost
Sick TIC501	€30,000 + VAT	None	10 years	Accuracy, 3D image	Cost
Adec TDC-3	€17,000 + VAT	None	10 years	Accuracy, has been used in Estonia for 9 years	

[1] – does not include the cost and installation of the pole or a beam protruding from the portal which are required for the installation of the device.

[2] – does not include central administration software.

[3] – as the installation depth of the Kistler KiTraffic-u sensors is 2 cm, annual maintenance and re-installation of the sensors may be required due to the wearing of the pavement.

[4] – The CaTraffic Blackcat Compact is the currently used solution, which was included in the table for comparison.

1.8. Summary

In the opinion of the author of the study, the Smartmicro UMRR-12 Type 48 radar sensor clearly stands out in the comparison of various technologies, costs, functionalities, and uses due to the following features:

- It is the most flexible solution from the perspective of installation – it can be installed on a console, pole, or portal and thus enables to fully use the existing structures.
- The only sensor which can detect and count cyclists and pedestrians.
- Offers classification of road users into seven classes and detects wrong way drivers and incident detection.

- No maintenance costs and the equipment can be used for at least 10 years.
- Based on the cost of the investment for 2 + 2 installation places, in the same range with the currently used CaTraffic Blackcat Compact equipment.
- Universal – this radar model is available in three different settings for different application scenarios.
- The manufacturer is about to issue an improved version of the same model which is equipped with an integrated video sensor within the next six months. In addition to the counting data, the outputs of the model include a video feed similar to the feed from road cameras which would enable the employees of the traffic management centre to obtain visual proof of incidents.

2. V2I/I2V roadside units and frequency bands thereof

Purpose

C-ITS or Cooperative Intelligent Transport Systems are independently functioning solutions but in the event of another similar system or other systems happening to be in the communication radius, the systems are capable of automatically co-functioning as one unified system, exchanging and communicating all information available to them with all separate systems which have interconnected with one another. In the near future, almost all new vehicles sold, irrespective of the type (passenger car, van, truck), will be equipped with this system. There will also be respective roadside units by the road for sending and exchanging information which will communicate with the vehicles. The area of application of the roadside units will be extremely wide, ranging from the communication of warning messages issued by the traffic management centre, e.g. about slippery roads, traffic accidents, etc., to relaying payments for using the infrastructure, for example. A common communication protocol is required for communication between the systems. The aim of the study is to describe and compare the possible frequency bands of V2I/I2V roadside units and then suggest the frequency bands which could be taken into use in Estonia, taking into consideration the current and future local and global market conditions. The manufacturers of automatic and communication technology have split into two groups. There are currently two competing technologies available in the world: ETSI-G5 (IEEE802.11p/DSRC) and C-V2X. Both technologies will be described in detail below.

2.1. The technologies

ETSI ITS-G5

ETSI ITS-G5 is a WiFi-type communication standard used in the European Union which was developed for mutual communication between vehicles and for communication between the roadside infrastructure and vehicles. ETSI ITS-G5 is based on the international IEEE 802.11p standard. The DSRC standard used in North America which can be deemed the sister version of the ETSI ITS-G5 is also based on IEEE 802.11p, but there are also differences between the two.

ETSI ITS-G5 is only designed for communication with an interface of the direct communication type and with an operating frequency of 5.9 GHz.

The maximum functioning range of the ETSI ITS-G5 ranges from 1,000 to 2,000 m depending on forward visibility. Car2Car Communication Consortium (C2C-CC) is the umbrella organisation of the automatic and telecommunication technology manufacturers who favour IEEE 802.11p: https://www.car-2-car.org/

The first car manufacturer on the Estonian market with a passenger car model which is equipped with the accessories which enable the so-called 'car-to-car' and 'car-to-infrastructure' communication is Volkswagen with its new eighth-generation Golf model.

The IEEE has also began developing a new communication standard which should replace the current 802.11p in the future, while also ensuring retrospective interoperability. The new standard is called 802.11bd and has two operating frequency ranges: 5.9 GHz and 60 GHz.

Taking into consideration the facts that it took approximately ten years from developing the previous standard to the first vehicle equipped with this standard reaching the Estonian market, it may take a similar amount of time until the new standard will be used in practice. Thus, if the IEEE sticks to its plans and the new 802.11bd standard will be approved as scheduled, i.e. in December 2021, the first vehicles which support the standard can probably only be expected on the Estonian market in 2030 or later. The work of the IEEE802.11bd working group can be monitored under the following link: http://www.ieee802.org/11/Reports/tgbd_update.htm

C-V2X

While development of the IEEE802.11p standard began in 2004, the C-V2X was launched in 2016 and the founding members, including BMW, Daimler, Audi, Ericsson, Intel, Nokia, Qualcomm, and Huawei, established an umbrella organisation called the 5G Automotive Association (5GAA) to develop the standard https://5gaa.org/. By the time of preparing the study, most of the manufacturers of automatic and telecommunication technologies have already joined the organisation.

Unlike the technologies which are based on IEEE802.11p, the C-V2X has two independent connection interfaces: A PC5 short-distance direct connection interface similar to the IEEE802.11p standard and the mobile operators' UU interface, which will be functioning over the 5G mobile network.

The operating frequency of the PC5 C-V2X short-distance direct connection interface is also 5.9 GHz, similarly to ETSI-G5.

The functioning range of the direct connection is also similar, with the functioning distance ranging from 1,000 to 2,000 m depending on the forward visibility.

Interoperability of ETSI ITS-G5 and C-V2X

As a result of the field tests conducted by ETSI and 5GAA in December 2019, the ITS-G5 and C-V2X technologies are currently compatible in the extent of 95%. https://5gaa.org/news/etsi-5gaa-c-v2x-testing-event-in-europe-confirms-high-level-of-interoperability/ Taking into consideration the efforts made, it may be presumed that ETSI ITS-G5 and C-V2X will be capable for interoperability in the future and that vehicles and the roadside infrastructure will be able to communicate with one another smoothly irrespective of the type of technologies used.

2.2. Roadside units and software and the costs

As the I2V/V2I has been standardised, the roadside units of different manufacturers are not very different from the functional perspective. The physical appearance of the roadside units is also similar. The differences mainly concern the accessories, such as the antennae used, and the software solutions offered is also different.

Cohda Wireless

Offers two roadside unit models, of which one is only ETSI ITS-G5 and the other a dual ETSI ITS-G5/C-V2X version. Regarding software tools, Cohda only offers a kit of message application development tools.

Figure 2.1 Cohda's roadside units MK5 RSU and MK6 RSU EVK

Costs

- The cost of the Cohda MK5 RSU (ETSI ITS-G5): €3,500 + VAT
- The cost of the Cohda MK6C RSU EVK (ETSI ITS-G5/C-V2X, for development): €4,000 + VAT
- The cost of the SDK (ETSI ITS-G5) software development kit: €4,500 + VAT per workstation
- The cost of the SDK (C-V2X) software development kit: €4,500 + VAT per workstation
- 5-day on-site training of the Cohda V2I/I2V system for five people: €9,500 + VAT

  Exclusive of the trainer's travel, accommodation, and other costs.

Commsignia

The product selection of Commsignia also includes only ETSI ITS-G5 and ETSI ITS-G5/C-V2X models. The software selection includes a central administration solution which is also capable of managing the roadside units of other manufacturers. A DATEX II ver. 2.3 interface is available as an accessory.

Figure 2.2 A Commsignia RS-4 roadside unit

Costs

- The cost of the Commsignia ITS-RS4M (ETSI ITS-G5): €5,600 + VAT
- The cost of the Commsignia ITS-RS4D (ETSI ITS-G5/C-V2X): €6,700 + VAT
- The administration software with the SDK: €2,300 + VAT per roadside unit

Siemens

Like Commsignia, Siemens also offers roadside units, as well as a central administration solution.

Figure 2.3 Siemens SiTraffic RSU

Costs

- The cost of Siemens SiTraffic RSU (ETSI ITS-G5): €5,500 + VAT
- The administration software (includes licences for 25 roadside units and for operating the hardware solution): €290,000 + VAT
- The administration software with an extension licence for every following roadside unit: €250
- Installation and launch of the solution and training: €55,000

Comparison

Table 2.1 Comparison of roadside units and software

	Cohda MK5 RSU	Cohda MK6 RSU EVK	Commsignia ITS-RS4M	Commsignia ITS-RS4D	Siemens SiTraffic RSU
Type	ITS-G5	ITS-G5/C-V2X	ITS-G5	ITS-G5/C-V2X	ITS-G5
Cost of one device	€3,500 + VAT	€4,000 + VAT	€5,600 + VAT	€6,700 + VAT	€5,500 + VAT
Required number of roadside units for 99% coverage, initial assessment	22	22	30	30	25
System development kit (SDK)	€4,500 + VAT	€4,500 + VAT	–	–	–
Administration software	–	–	€2,300 + VAT [1]	€2,300 + VAT [1]	€290,000 + VAT [2]
Training costs	€9,500 + VAT	€9,500 + VAT	–	–	€55,000 + VAT [3]
Total investment based on initial assessment	€91,000 + VAT [4]	€102,000 + VAT [4]	€237,000 + VAT	€270,000 + VAT	€482,500 + VAT

[1] – One licence per each roadside unit, includes SDK

[2] – Administrative software with SDK and with licences for 25 roadside units, €250 + VAT for each additional roadside unit licence

[3] – Includes the launch of and training for the roadside units and administration software

[4] – Does not include the development of administration software

2.3. The suitable I2V/V2I technology in the framework of the E265 in the current and future perspective

Irrespective of other differences, at the time of conducting the study, both technologies use the same operating frequency – 5.9 GHz.

Unlike the C-V2X technology, which is still in the development stage, ETSI ITS-G5 is a ready-made and tested standard which has been approved in the European Union. While the first vehicle equipped with the ITS-G5 technology is already available in Estonia in the form of Volkswagen Golf 8, it remains unknown for now if and when the first vehicles with the C-V2X technology will be launched in Estonia. C-V2X is largely backed by the commercial interests of the companies which provide telecommunication technologies and services, as only the C-V2X technology provides an opportunity for them to have their share of the huge commercial potential of connected vehicles through the UU interface.

It is currently almost impossible to predict which technology will prevail. Roadside unit manufacturers were also not able to predict this in the conversations held with them. It is clear that the tug-of-war has significantly decelerated the implementation of the I2V/V2I technology and, due to the general lack of information, many car manufacturers are not prepared to take the risk of choosing yet, as the investment in the application of either technology would be huge. On the other hand, large investments have been made in the United States in the development of the DSRC (IEEE802.11p) network on highways and it can be presumed that they will not allow writing off the investments which they have made in the infrastructure. The infrastructure which has been built in Europe so far is also mostly ETSI ITS-G5-based. It is likely that both technologies will exist in parallel, enabling interoperability with one another, but making the devices as well as the software more expensive. Roadside units which support both technologies are available in the market but they are mainly designed for development purposes because C-V2X is still being developed and different versions of C-V2X may not be interoperable. From the technological perspective, there will be two options for the selection of roadside units: only ETSI ITS-G5 or a roadside unit which supports the combination of ETSI ITS-G5/C-V2X.

In a situation where it is currently impossible to forecast whether or not C-V2X will exist in parallel with ETSI ITS-G5, we recommend the following action plan:

- Making preparations based on the combined ETSI ITS-G5/C-V2X roadside units
- Making the technological selection immediately before purchasing the roadside units

Below, there is a list of roadside unit (RSU) manufacturers whose product selection already includes models which support both technologies or who are planning to launch such models. This list is certainly not complete and only reflects the situation at the time of conducting the study based on information which is publicly available on the internet. These companies are: Kapsch, Commsignia, Cohda, LaCroix, Savari, Swarco, Siemens.

2.3.1. Installation places within the framework of the E265 ITS project and the coverage

The number of roadside units required to achieve full coverage is different in the case of different manufacturers. We proceeded based on the need to ensure full, i.e. 99% coverage which can be achieved by using approx. 22–35 units, depending on the manufacturer. Even though the radius of the technical coverage area of a roadside unit is 2–2.5 km, the actual radius ranges from 300 to 1,000 m. This is mainly due to physical obstacles (forests, bridges, ramps, metal structures, etc.), as direct vision is required in the case of the 5.9 GHz frequency.

Thus, in order to achieve the best reception, the installation instructions of the units should be read in the course of designing, as these instructions usually suggest the most optimal installation places and methods. For example, some manufacturers advise to prefer installing the units on a horizontal beam to achieve better reception. It would be even better if the manufacturers themselves would provide the

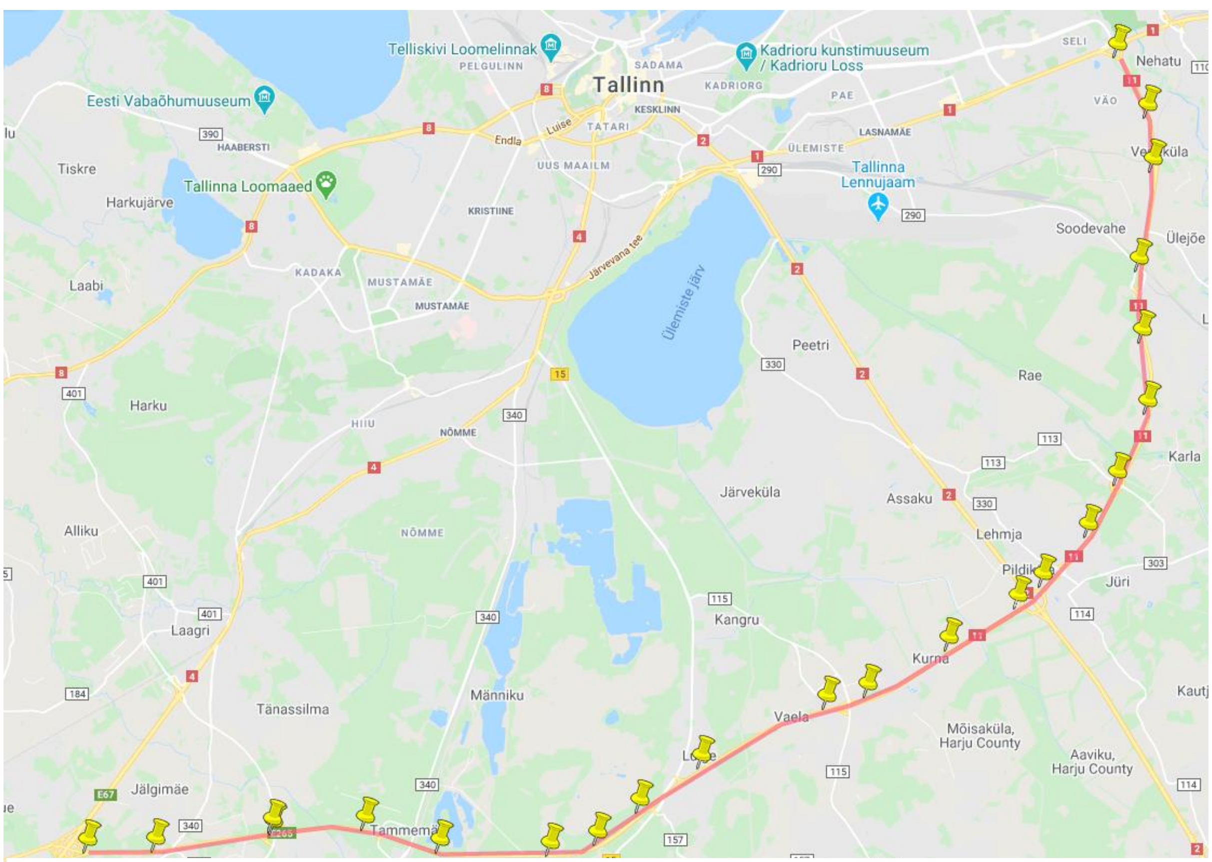


Figure 2.4 Cohda's initial estimation for the layout of the roadside units for 99% coverage

initial estimation of the number of terminals required for 99% coverage. The Google Earth and Street View map applications are sufficient for providing an initial estimation. Figure 2.2 shows an example of one manufacturer's initial estimation for the layout of the roadside units.

In the event of selecting partial coverage, the selection should be made based on the information shared with road users and the information received from road users, and the urgency of this information. As the area in question is mainly a 110 km/h area, every 30 m gap in the coverage translates to approx. 1 second of time. In order to determine the optimal coverage, the working group should study the documents listed below and use this information to develop the composition of the applications used in Estonia and the information transmitted and received:

- Definitions of the notification and warning applications of ETSI TS 101 539-1, ETSI TS 101 539-2, ETSI TS 101 539-3
- C-ROAD Harmonized C-ITS Specifications for Europe – Release 1.7

2.3.2. I2V/V2I software layer

The software layer required for the functioning of the I2V/V2I may be conditionally divided in two:

- SDK – software development kit for message applications

  In order to use the roadside units to send messages or warnings to vehicles (such as 'Road construction', 'Parked vehicle', 'Speed limit', etc.), an application must be created for each message or warning which defines the extent and direction of the impacted area, the time frame, the message to be displayed to the driver, the parameters to be sent to the vehicle, etc. For coding and testing such applications, it would also be necessary to purchase the software development kit (SDK) of the specific manufacturer, in addition to the roadside units. In most cases, the SDK is licensed by workstation and initially, one licence would be required.

- Administration software

  The purpose of the administration software is to manage the information which is sent to roadside units and received from the units and to exchange information with other systems. Setting up the roadside units, updating the software, and monitoring can be performed centrally. The software also provides a graphic overview of the locations of the units and of the active settings. The administration software supplied by the manufacturer includes the SDK which is required for coding message applications.

2.3.3. The C-Roads organisation

C-Roads is a platform which brings together European road operators and respective agencies and which is involved with the harmonisation of applying C-ITS in the European Union. They have also developed an infrastructure of roadside units in cooperation with car manufacturers and the specifications for the interoperability capability of the information sent to vehicles through the infrastructure. The uniform specifications are required to ensure that the roadside infrastructure and vehicles are able to understand the content of the information exchanged uniformly all over Europe. Therefore, it is important for the Road Administration to

join C-Roads. The website of C-Roads: https://www.c-roads.eu/platform.html

3. Automatic barrier gate system for re-routing (ABGS)

Description of the current situation

A 2 + 2 section with separated directions of traffic has been constructed in the Jüri-Kurna section of the E265 Tallinn ring road. In a situation where a traffic accident may close one of the directions of traffic for several hours, it is necessary to either provide detours or organise traffic in the oncoming lane on a 1 + 1 road. There are two options for detours in this section:

- Northern detour by the streets of the city of Tallinn – it is not possible to re-route heavy vehicles to the streets of Tallinn.
- Southern detour by national roads – the detour is several dozen kilometres long.

Figure 3.1 Potential re-routing places on the Tallinn ring road

Taking into consideration the above, the most optimal solution is reorganising of the traffic in the oncoming lane by using the 1 + 1 regime.

3.1. Re-routing solutions

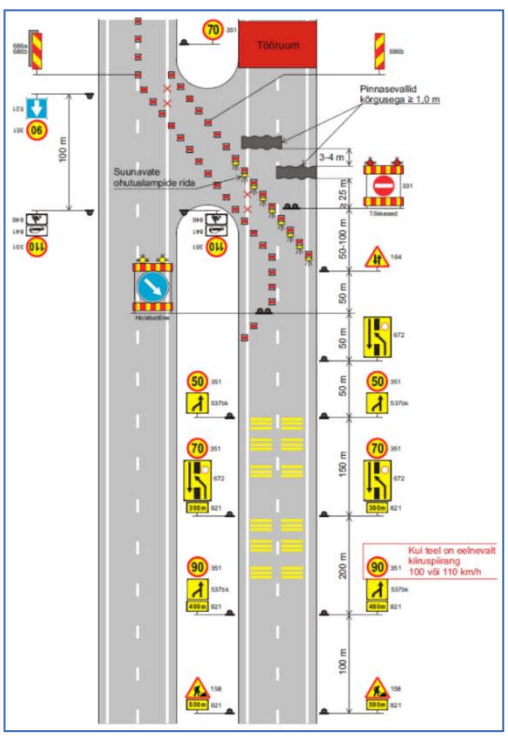
Below, we will be describing the potential solutions and analysing the suitability of the solutions in the Estonian conditions. The aim of the study is to find a solution which would be safe for the road users and economically feasible and which would enable to direct the traffic in the case of an accident.

The operations which follow a traffic accident should be divided in four different groups:

a) Detection of the accident
b) Notifying road users and calming the traffic
c) Entwining the traffic
d) Directing vehicles physically

This section of the study focuses on points c and d.

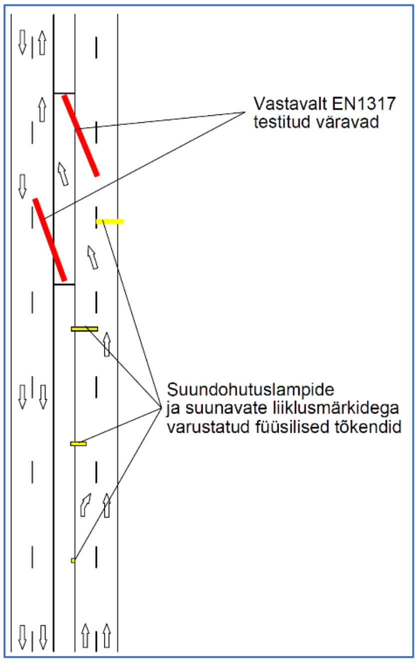
When a traffic accident has been detected and speed limits have been applied to calm the traffic, the traffic must be directed to one lane. The fundamental solution must be compliant with the requirements for temporary traffic control (Regulation no. 43 of the Minister of Economic Affairs and Infrastructure of 13 July 2018) and with figure 17 in Annex 2 which involves first directing the traffic to the first lane and then performing the rounding.



/joonise tekst/
Pinnasevallid kõrgusega ≥ 1,0 m – ≥ 1.0 m embankments
Suunavate ohutuslampide rida – Line of directing safety lights
Kui teel on eelnevalt kiiruspiirang 100 või 110 km/h – In the case of a speed limit of 100 or 110 km/h on the road before the site

Figure 3.2 Closing a direction of traffic with a dividing strip on the road. Beginning of the closed section.

As the installing of temporary traffic signs is time-consuming, the solutions to be built must be as similar as possible to the solution provided in the figure. In order to provide a solution, physical barriers have been used which are equipped with road signs and flashing electric safety lamps. The physical barriers with directing signs ensure that all road users understand that they must line up on one lane and this rules out potential misunderstandings by lining up on the oncoming lane.



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Vastavalt EN1371 testitud väravad – Gates tested pursuant to EN1317

Suundohutuslampide ja… – Physical barriers which are equipped with directing safety lights and directing traffic signs

Figure 3.3 Schematic calming of the traffic before the rounding

Under normal circumstances, the physical barriers are kept behind the safety barrier and do not constitute an additional hazard for the road users.

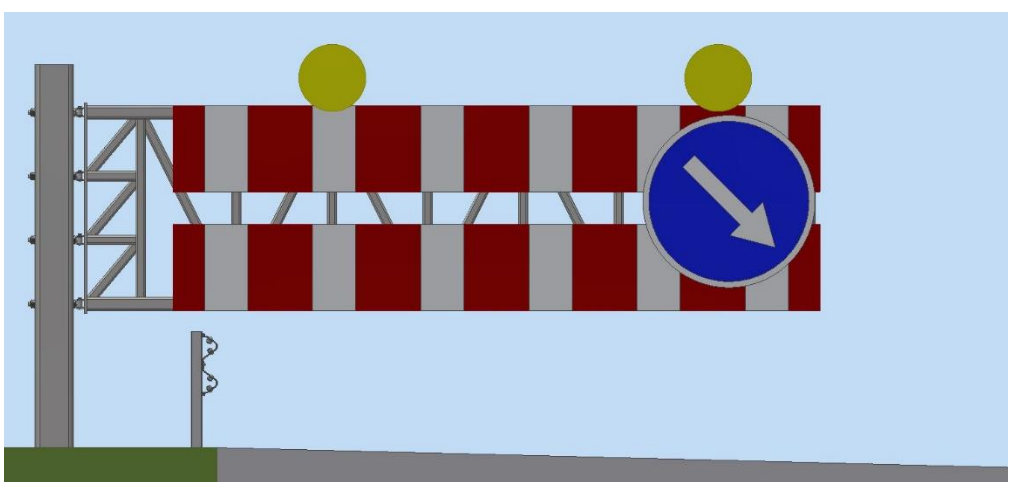


Figure 3.4 A physical barrier which is equipped with road signs and safety lamps

One potential solution is a lattice barrier which is either kept in the upright position (and lowered on the road with the help of an engine) or in a horizontal position (and turned to block the road manually).

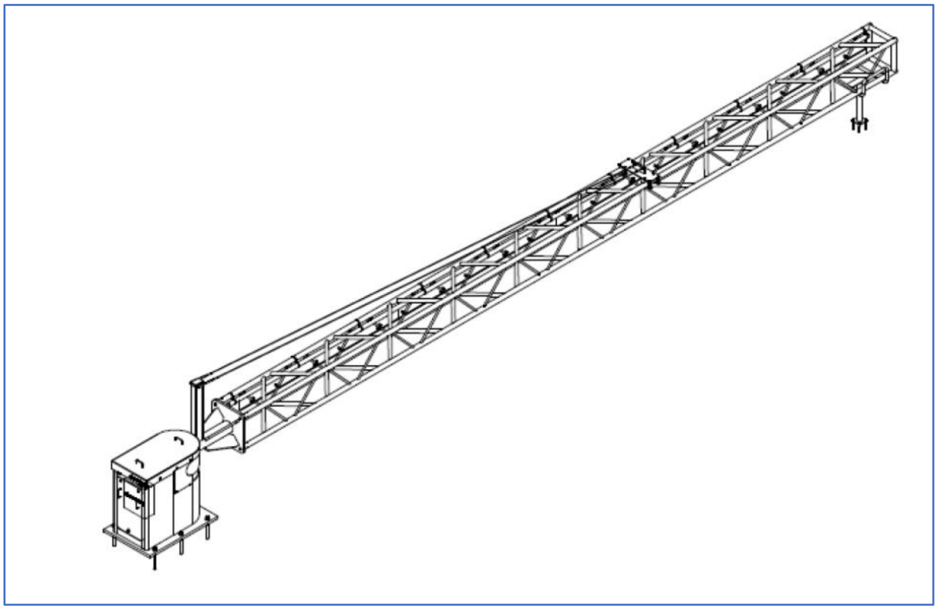


Figure 3.5 Potential gate solution

Figure 3.6 Automatic solutions developed by Rusthoven Verkeerstechniek B.V.

After directing the traffic to one lane, it must be re-routed further to the oncoming lane by using a paved re-routing lane which has been prepared for this purpose. The gate solution must be comprehensible for the road users and suitable for physical re-routing of the traffic and the structure of the gates must be suitable for re-routing the traffic to the oncoming lane in the direction from Jüri to Kurna, as well as in the direction from Kurna to Jüri.

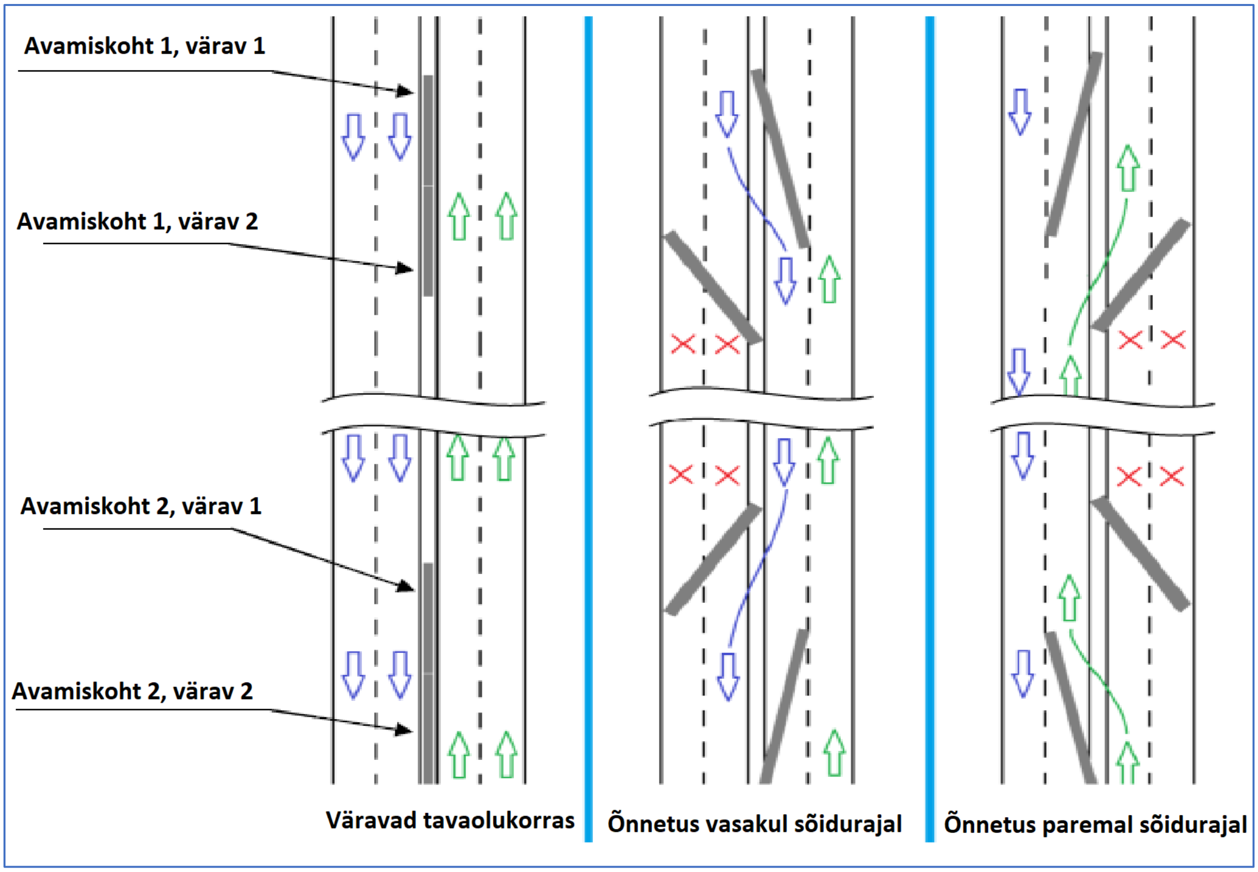


Figure 3.7 The gates to be installed must enable closing and opening of the right as well as the left lane

/joonise tekst/

Avamiskoht, värav – Opening point, gate

Väravad tavaolukorras – Gates under normal circumstances

Õnnetus vasakul sõidurajal – An accident in the left lane

Õnnetus paremal sõidurajal – An accident in the right lane

As both the physical barriers and the gates are turned physically to block the road for vehicles, traffic safety must be ensured after opening them and the process of opening should be performed in the following order:

a) One lane is closed in the direction of traffic with no accident
    a. Opening the barriers should begin from farther away and move in the direction of the gates to make sure that no additional traffic hazards are created
b) The physical barriers and gates of the direction of traffic in which the accident occurred are opened

a. The vehicles which have been caught in the congestion must be controlled and instructed when opening the gates and barriers to make sure that they do not get in the way of opening the gates and barriers

In opening the barriers and gates, it is always necessary to make sure that the opening would not damage any vehicles which have been caught in the congestion. The gates and barriers of the direction of traffic in which the accident occurred are reached from the oncoming lane from which one lane has been removed. In winter conditions, the companies in charge of maintenance of the roads must keep the gates and barriers free of snow so that opening the gates and barriers is not prevented by snow or ice.

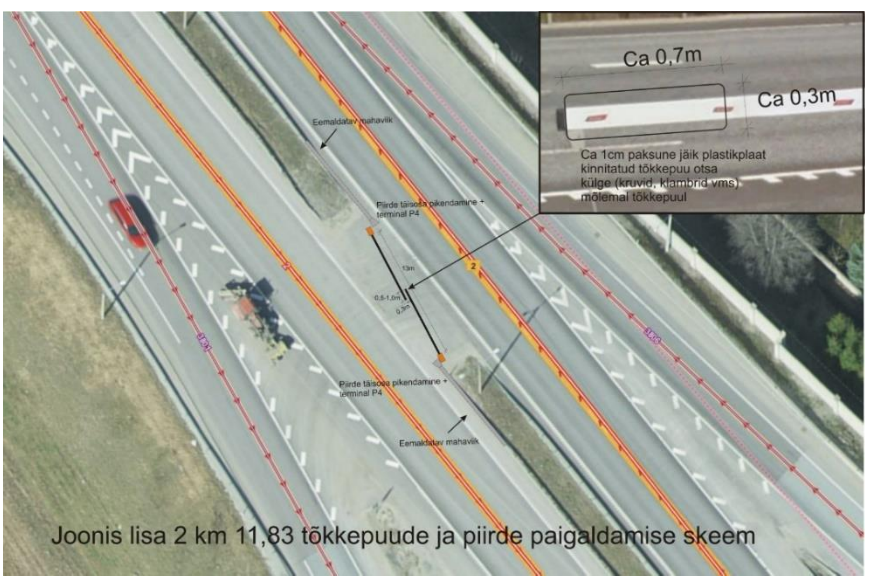
Solutions in which the physical barriers are opened within the dividing strip are used as gates. A selection of potential solutions is provided below.

3.2. Lifting systems

Regular lifting barriers are widely used in the Estonian 2 + 2 roads. Using such barriers is certainly the most cost-efficient solution, but also the most hazardous one.

Figure 3.8 Installed barriers in the Mäo traffic junction

The Road Administration has recently attempted to make the solution safer by issuing requirements based on which the barriers should be installed so that they are tilted away from the direction of traffic, but the safety of using barriers in such installations remains unproven and, in practice, we can only be sure of the safety/lack of safety thereof after first traffic accidents.



/joonise tekst/

Ca 2 cm paksune… - Approx. 1 cm thick rigid plastic sheets attached to the ends of both barriers (with screws, brackets, etc.);
Eemaldatav mahaviik – Removable exit;
Piirde täisosa pikendamine + terminal P4 – Extension of the full section of the barrier + roadside unit P4;
Joonis lisa 2 km 11,83 tõkkepuude ja piirde paigaldamise skeem – Drawing, Annex 2, km 11.83, barrier boom and barrier installation scheme

Figure 3.9 The requirement of the Road Administration for the placement of barriers

3.3. Sliding systems

a) The gate systems which are used in Scandinavia. This is also an untested solution and therefore it is not possible to rely on the safety of these systems

Figure 3.10 The sliding gate system in the Juuliku traffic junction

b) A sliding gate system which is compliant with the H2W5 requirements

Figure 3.11 A sliding gate system of the French manufacturer Aximum which has been tested based on the requirements of EN1317.

3.4. Side-opening systems

Gates for re-routing traffic are widely used worldwide. Most of them have been tested and such gates are also widely available in the European market (and are therefore compliant with the requirements of EN1317). Most manufacturers only offer mechanical gates, which can be opened by two people in 5–10 minutes. A few manufacturers are prepared to equip their solutions with electric engines, if necessary, but these solutions are quite expensive due to the low demand.

Figure 3.12 A side-opening gate system by the French company Aximum

Figure 3.13 A side-opening gate system of the Spanish company Duero

3.5. Comprehensive solutions

The Dutch company SPIE is offering a solution in which the booms and gates are opened automatically after an accident to calm the traffic. In the case of this solution, a human must decide on site whether or not it is necessary to open the gates and make sure that the process of opening the gates is safe for the road users. Once the safety has been ensured, it is possible to re-route the entire traffic automatically.

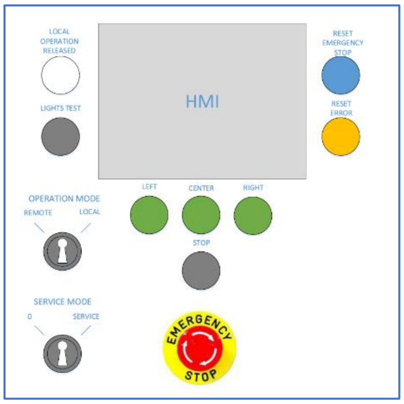


Figure 3.14 Remote control for launching the system

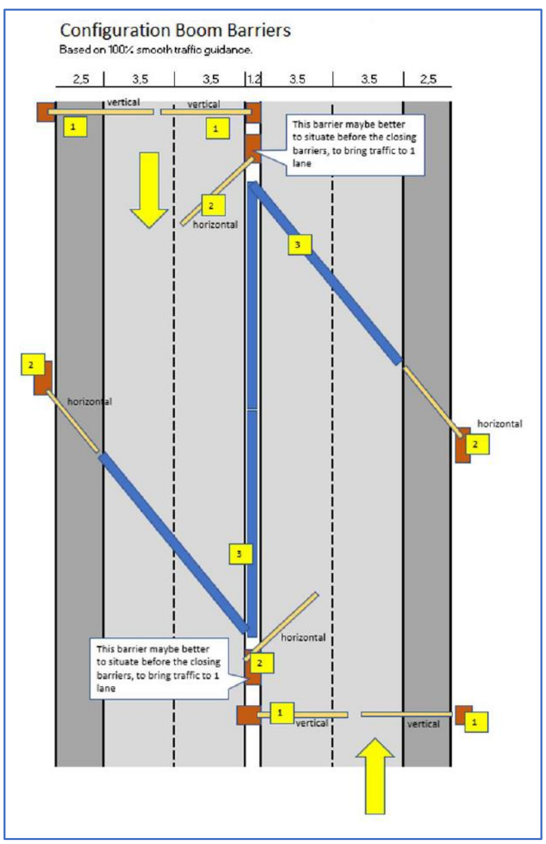


Figure 3.15 The SPIE VEVA3 gate system

3.6. Costs and comparison of the systems

Table 3.1 Costs of the equipment

Solution	Number of suppliers of the solution in the market	Cost, pc.	Advantages	Disadvantages
Physical barriers (manual)	more than 10	€9,500 + VAT	the price	requires physical force for opening
Physical barriers (automatic)	at least 1	€48,000 + VAT	easily openable	high price
Barriers	more than 10	€8,000 + VAT	the price	create an additional hazard in the event of an accident
Retractable	at least 1	€25,000 + VAT	easily openable	No re-routing function, safety not proven
Retractable, EN1317	at least 1	€45,000 + VAT	easily openable and safe	No re-routing function
Side-opening (manual), EN1317	at least 5	€55,000 + VAT	numerous suppliers, safe	two people required for opening
Side-opening (automatic), EN1317	at least 2	€250,000 + VAT	convenient and easy to open	the price

Table 3.2 Cost of the equipment in the system

Article	pc. Per system	Cost
Physical barriers (manual)	8	€76,000 + VAT
Physical barriers (automatic)	8	€384,000 + VAT
Barriers	2	€16,000 + VAT
Retractable	2	€50,000 + VAT
Retractable, EN1317	2	€90,000 + VAT
Side-opening (manual), EN1317	2	€110,000 + VAT
Side-opening (automatic), EN1317	2	€500,000 + VAT

Table 3.3 Costs of the systems

System	Cost of the system
Physical barriers (manual) + barrier booms	€92,000 + VAT
Physical barriers (manual) + side-opening manual gates, EN1317	€186,000 + VAT
Physical barriers (automatic) + side-opening automatic gates, EN 1317	€884,000 + VAT
An intelligent full solution which includes automation as well as electrical solutions	€2,500,000 + VAT

3.7. Summary of the ABGS

We considered various possible solutions in the study and analysed the suitability thereof for the Jüri-Kurna section of the E265 Tallinn ring road. From the perspective of traffic safety, solutions which have been tested based on the EN1317 standard should certainly be preferred. The testing ensures that the products are safe and will not create an additional hazard for the road users. From the economic perspective alone, unsafe solutions might be preferred, but if such solutions are chosen, it must be kept in mind that the cost-efficiency is being achieved at the expense of traffic safety.

From the perspective of suitability for the conditions, solutions which can be used for physically re-routing the traffic should be preferred. The safest option from the perspective of traffic safety is a solution in which the traffic management system directs the road user physically in the required direction and the road user will have no freedom in choosing their driving direction or trajectory.

Based on the above, we advise to use manual, side-opening gates which have been tested based on EN1317 in a combination of physically openable barriers within the framework of this project.

4. Truck park barrier system and parking sensors

Purpose

The aim of the truck park barrier system is to ensure that the park can only be accessed by trucks and emergency vehicles (incl. maintenance vehicles and waste removal). The parking sensors are used for detecting whether or not individual parking spaces are occupied.

The vehicles which can enter the truck park:

- Trucks, i.e. users of the truck park, for parking
- Emergency vehicles: police, ambulance, rescue service
- Maintenance vehicles. These are mostly lorries (waste removal) or vans. Winter-time maintenance vehicles, usually in the form of wheeled tractors with frontal loaders which are widely used in car parks, may be an exception.

As the truck park to be constructed within the framework of the E265 project will be closed by barriers, the task can be solved without using parking sensors. Parking sensors are also described below because it may become necessary to monitor the occupancy of individual parking spaces.

4.1. Potential solutions for controlling the barriers to grant access to the truck park for trucks

Sick TIC102 lidar sensor and ANPR camera

Lidar sensors can profile and identify various types of vehicles. Identification data can be used to create a barrier control logic so that the barriers are only opened when a truck has been identified. The accuracy of the Sick TIC102 is 99%. In order to create unique IDs for trucks and calculate parking time based on the ID, video surveillance cameras with automatic number plate recognition (ANPR) which identify the number plates of the trucks must also be installed. Another purpose of number plate identification is checking based on a number plate list who else are permitted into the truck park in addition to trucks. This enables granting access to emergency and maintenance vehicles.

In the case of using this combined solution (lidar + number plate identification), there is no direct need for separate monitoring of the occupancy of the parking spaces with sensors. By installing a lidar with an ANPR camera to the entry and only a camera to the exit, we can obtain enough information to always have an overview of the number of trucks parked and the parking times. Statistical data about all parking events is also available. In addition to the hardware, it would also be necessary to develop software which would control the devices and collect and connect the data.

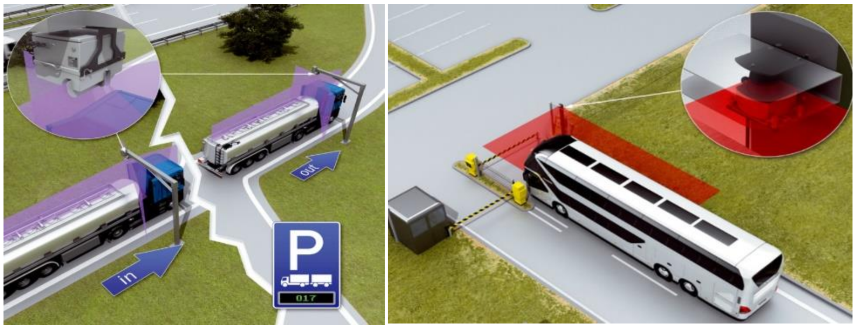


Figure 4.1 Using a lidar sensor for identifying vehicles and allowing vehicles into the truck park

FF Group CaMMRa

Similarly to the previous solution, the components of this solution also include a video surveillance camera which is equipped with a more capable machine vision solution and is capable of detecting much more information about a vehicle in addition to reading the number plate. The FFGroup CaMMRa is an edge processing software for analysing traffic and vehicles which functions with the help of Axis's video surveillance cameras. CaMMRa can identify the time of day, direction, number plate, issuing country of the number plate, as well as the manufacturer, make, type, and colour of the vehicle.

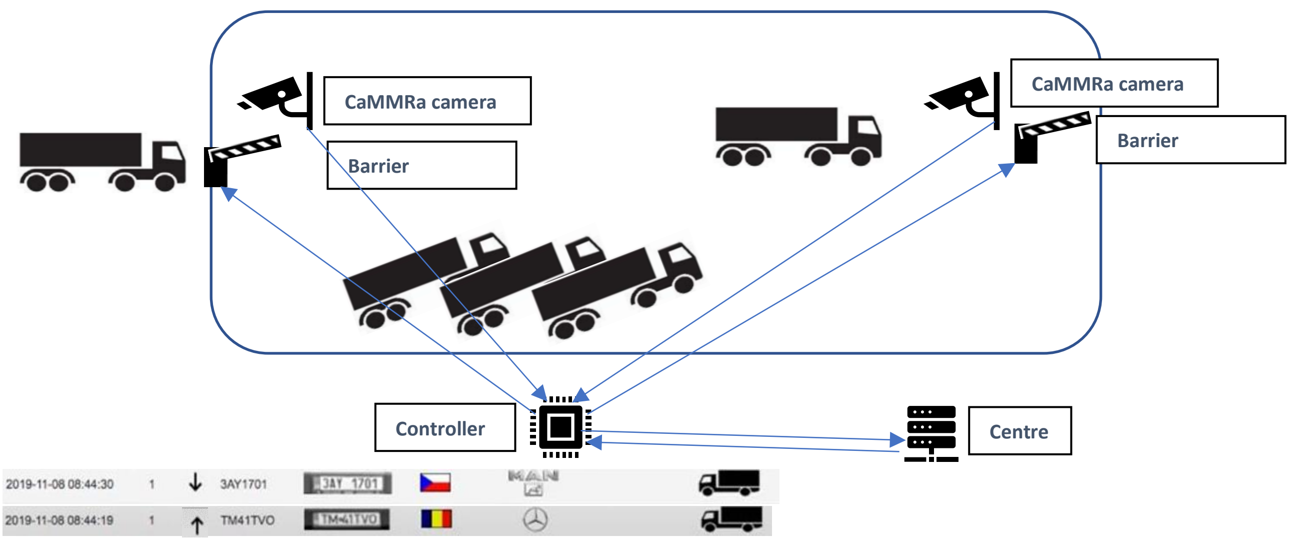


Figure 4.2 The option of a car park solution with truck and number plate detection

The information listed above is sufficient to ensure that only trucks are granted access to the truck park. Emergency and maintenance vehicles are granted access to the truck park through a list of authorised number plates. Thus, the camera analyses the number plate as well as the vehicle and access is granted if there is a match for the number plate detected in the list or if a truck is identified.

The number plate is a unique indicator for the calculation of the duration of the parking, as well as the general occupancy of the truck park. For the functioning of the truck park, two cameras are required with the CaMMRa software – one for the entry and the other for the exit. An API is used for integration with other systems. There is no car park administration software available for this solution yet.

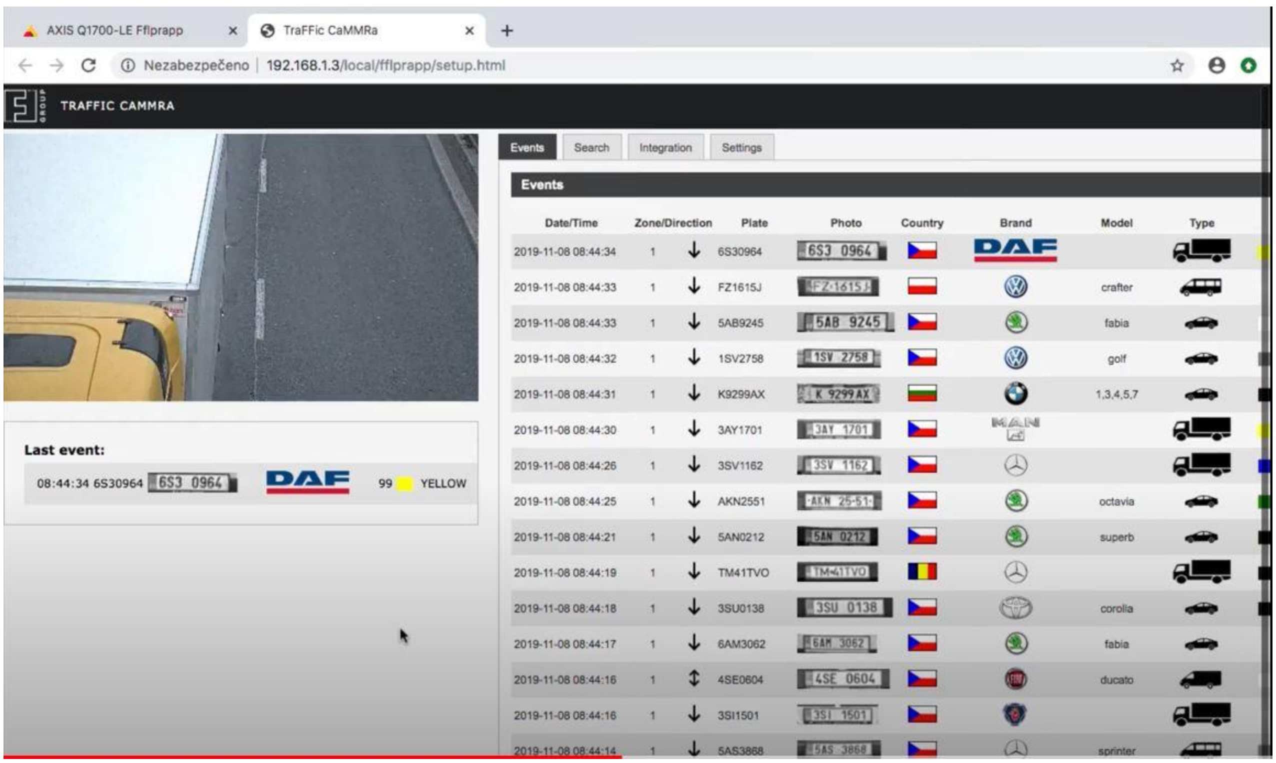


Figure 4.3 Screenshot of the CaMMRa software

CaMMRa can also be fully integrated with the Milestone Xprotect video surveillance cameras and enables searching vehicles from video recordings based on the number plate, colour, type, manufacturer, make, or country of origin.

In order to ensure the functioning of the number plate recognition system, the number plate must be clean and readable. Thus, information about the need to clean the number plate must be displayed at the entry to the truck park in several different languages.

Table 4.1 Comparison and costs of barrier control systems

	Lidar Sick TIC102 + ANPR Axis P1445-LE LPR	**CaMMRa licence + Axis Q1700-LE**
Accuracy	99%/95%	96%
Detects	Vehicle type, number plate, profile, length	Vehicle type, number plate, manufacturer, colour
The cost of one set of entry/exit detection equipment and software with a five-year warranty period [1]	€19,000 + VAT	€,9000 + VAT
Installation, calibration, tuning	€7,000 + VAT	€3,000 + VAT
Maintenance of detection devices	no	no
Cost of administration software development	–	–

[1] – includes detection devices, controller hardware, IO modules, communication devices, and an equipment cabinet

Administration software

A list of the tasks which must be fulfilled by the local administration software. The administration software runs in the local controller and performs the following operations:

- Accumulates the detection data received from the cameras and lidars and controls the barriers based on the pre-determined scenario (upon detection of a truck -> permission of entry; the number plate has a match in the permitted list -> permission of entry).
- Counts incoming and outgoing trucks and calculates the occupancy rate of the truck park.
- A list of active parking events and durations of the parking events including detailed information.
- Statistical data of parking by the duration, number plates, manufacturers, countries of origin.
- Provides real-time input to the TMC about the occupancy of the truck park and this data is, in turn, sent over the variable sign control module to the variable sign which displays the number of vacancies in the truck park.
- The video feed from the cameras is sent directly to the Milestone VMS.
- Provides real-time input to the Tark Tee application about whether the truck park is opened and about the number of vacancies.

4.2. Parking sensors

Overview

The selection of potential solutions for a car park is wide, but the majority are designed for using in parking buildings or underground car parks.

By the manufacturer, the solutions can be divided in two: suppliers of comprehensive solutions and suppliers of parking sensors alone. Sensors alone are supplied by the manufacturers who use IoT communication solutions in their sensors. This is due to the fact that the IoT is becoming the standard and the functioning of a parking solution does not depend on all components of the solution being supplied by the same manufacturer. This provides an opportunity to use the sensors which are suitable for a specific installation without being dependent on the narrow selection of one specific manufacturer. Based on the vehicle detection method, the sensors can be classified as follows:

Video-based machine vision solutions

A software solution which functions based on the administration server and analyses video flows from video surveillance cameras. The advantage of this solution is that if there are already designed video

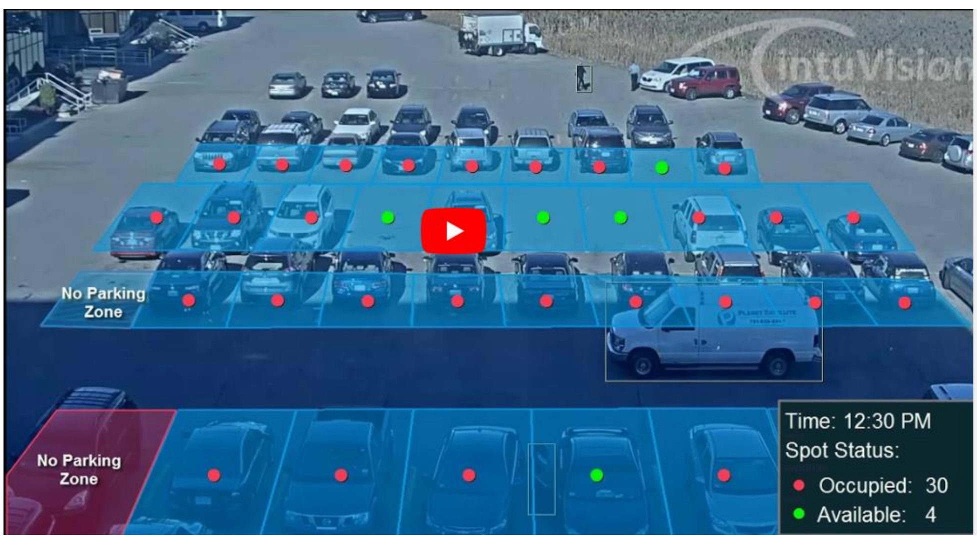


Figure 4.4 Screenshot of Intuvision

surveillance cameras for the car park for security reasons, the same video flow can be used for determining the occupancy of the car park. The video surveillance and car park projects must be coordinated in advance to ensure that the layout of the cameras enables fulfilling both of the functions. If it is planned to equip the car park with street lights, the system for detecting parking spaces should also be coordinated with the lighting plan to make maximum use of the poles to be installed for the lights, as well as the power supply, if possible.

If there is no video surveillance designed, it would not be reasonable to use a video processing-based solution, as it calls for a local infrastructure, power supply, and communication solution. It would also be necessary to install poles of sufficient thickness and height to ensure a stable feed and prevent swaying caused by wind. In order to prevent any trucks being concealed by other trucks, the cameras must be installed as high as possible. Functioning of video processing-based solutions in dark conditions and the need for illumination should also be assessed.

Magnetic, radar, infrared, or combined magnetic/radar sensors with autonomous power supply which are installed on the surface or sunk into the surface

Figure 4.5 Various IoT sensors, Wuhan Turbo, Parkdroid, Bosch, and Mobilisis

The selection is extremely wide and the technological development of the sensors has been rapid. The cost of the sensors ranges from €120 to €400. All these sensors are similar by nature, using lithium thionyl chloride batteries which are usually of a high energy density and which tolerate low operating temperatures for autonomous power supply.

Various detection and communication methods

The most common detection method is the magnetic method which is combined with the infrared or radar method by some manufacturers. A combination of the magnetic and radar solutions would be the most reliable in the Estonian conditions, in which the snow and ice which may cover the sensor may interfere with the infrared detection.

There are two possible communication methods:

- Sensors which operate at the frequency of 868 MHz, use the manufacturer's closed protocol, and require a local supporting infrastructure in the form of signal concentrators in the form of central and communication devices of the car park. An administration server is also required which is either located in the client's server resource or in the cloud.
- The IoT communication, which is divided in three: NB-IoT, LoraWan, and SigFox. The first is a communication standard with a low energy consumption which functions over the regular mobile network and the remaining two are separate operator networks for communication between the

IoT devices and the car park administration server. As IoT means open standards or protocols, it is possible to use third-party solutions for the car park administration server solution or to develop the required administration solution. At the time of conducting the study, the coverage of NB-IoT is significantly wider than the coverage of the other two.

Installation of IoT sensors

Figure 4.6 Installation methods of IoT sensors: same sensor, installed on the surface or fully sunken

IoT sensors can usually be installed on the surface or the sensors may be sunk into the surface. The solutions provided by different manufacturers may, however, call for different installation methods due to the detection technologies used in the sensor. For example, infrared-based sensors cannot be fully sunk and covered

4.2.1. Intuvision video-based car park solution

A server-based solution which analyses the video flows from video surveillance cameras and determines the occupancy of the car park. One camera can monitor the parking spaces for up to five trucks; thus, twenty video surveillance cameras are required for a 100-space truck park, plus the supporting infrastructure and installation on structures. Server resources are also required for processing of videos.

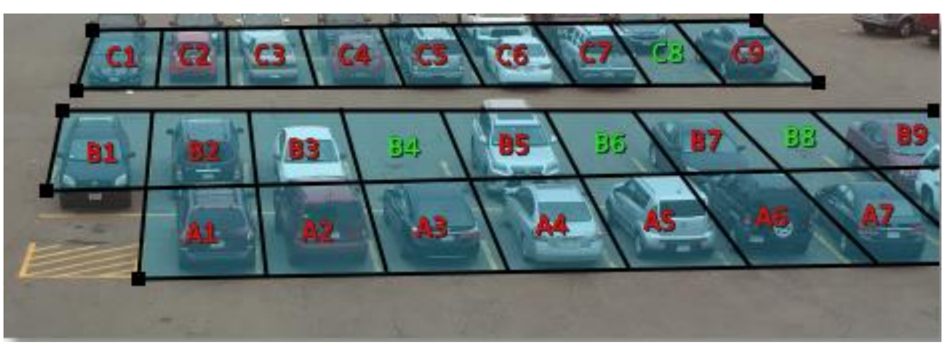


Figure 4.7 Screenshot of Intuvison

The software includes an administration, statistics, and real-time information module, as well as an API for information exchange with other systems.

The service-based cumulative cost of the licence for one camera for five years is: €1850 + VAT

4.2.2. Mobilisis IoT comprehensive solution with sensors

The sensors used in the Mobilisis solution are NB-IoT sensors with autonomous power supply which can be fully sunk and are completely immune to any means and methods of winter-time road maintenance. The sensors communicate their statuses to the administration server at the data centre of the service provider over the NB-IoT network. The sensors do not require permanent power supply. The software includes an administration, statistics, and real-time information module, as well as an API for information exchange with other systems.

The cost of a Mobilisis parking sensor: €475 + VAT

The cumulative cost of the five-year service licence of the Mobilisis parking administration system for one sensor: €160 + VAT

4.3. Comparison and the most optimal solution

Maintenance and operating costs

The service life of the video surveillance cameras which can be used as the sensors of a video-based car park solution is at least 10 years and there are no direct operating costs involved. The manufacturer has also not prescribed any maintenance operations, but dirt must be removed from the optical surfaces of the shells when necessary.

The service life of the IoT sensors depends on the service life of the battery, which is usually 5–7 years. No need for scheduled maintenance prescribed by the manufacturer. Annual inspections are required, though, to make sure that the sensors are properly in place. Communication costs will be added as direct operating costs. In the case of NB-IoT, each sensor must be equipped with its own SIM card, which must be installed in the sensor. Depending on the operator, the monthly communication cost per device ranges from €1.19 to €1.58, which amounts to €3.57–4.74 per month and €42.84–56.88 per year per parking space for one truck.

NB-IoT and the coverage thereof

NB-IoT or Narrowband Internet of Things is designed for the communication of small machine-readable messages, thereat, the lowest possible energy consumption per communication session is important to allow the sensors to operate for years. The NB-IoT network will soon cover all of Estonia with the exception of the areas by the border of Russia due to the lack of an agreement for coordination of frequencies with the latter. Of mobile operators, the coverage of Elisa's NB-IoT area is 95% and the coverage of Telia's area is shown on the drawing next to the text. It is, however, important to make sure that the nearest mobile antenna with NB-IoT capacity is located within 3–5 km from the truck park. This is required because the sensors are installed in the pavement which restricts the signal, as well as to avoid excessive energy consumption during the communication session which may significantly reduce the service life of the sensor.

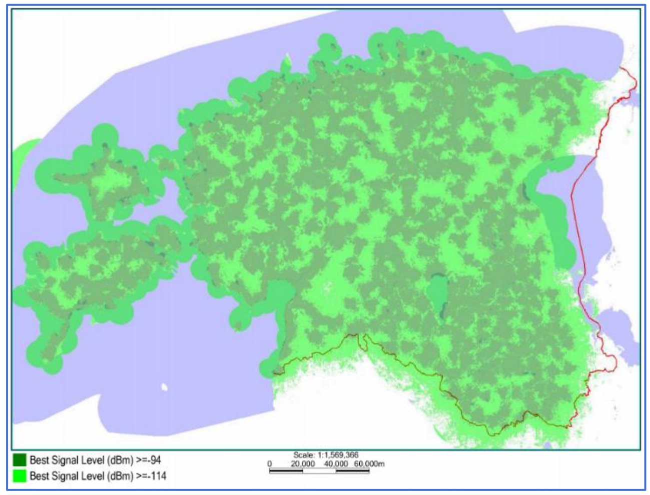


Figure 4.8 Telia's NB-IoT area. Source: telia.ee

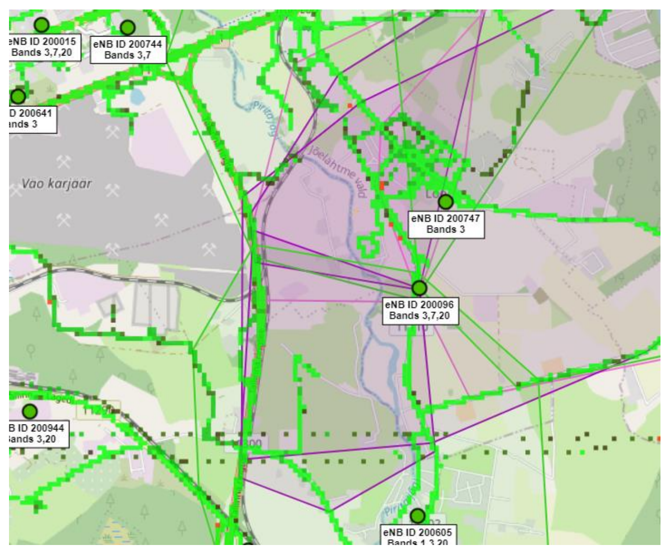


Figure 4.9 The antennae of Telia and the cell settings of the nearest transmitter in the Veneküla area. Source: cellmapper.net

Table 4.2 Comparison of parking solutions and sensors

	Intuvision	Mobilisis	Wuhan Turbo	Parkdroid	Bosch Smart Parking	Libelium
Type	Comprehensive video-based solution	Comprehensive IoT-based solution	IoT sensor	IoT sensor	IoT sensor	IoT sensor
Number of sensors for a 100-space truck park	20 cameras	300	300	300	300	300
Sensor lifetime	10 years	5–7 years	7 years	5–7 years	5 years	10 years
Cost of one sensor	€800 + VAT	€475 + VAT	€150 + VAT	€120 + VAT	€210 + VAT	€200 + VAT
Total cost of the sensors	€16,000 + VAT	€142,500 + VAT	€45,000 + VAT	€36,000 + VAT	€63,000 + VAT	€51,000 + VAT
Cost of the software for 5 years in total:	€37,000 + VAT	€48,000 + VAT [1]	–[2]	–[2]	–[2]	–[2]
Cost of the solution	€53,000 + VAT	€190,500 + VAT	€45,000 + VAT [3]	€36,000 + VAT [3]	€63,000 + VAT [3]	€51,000 + VAT [3]

[1] – software as a service

[2] – administration software must be developed

[3] – exclusive of the cost of administration software

The most optimal solution

Based on the features and the cost, the most optimal option would be to use a combined solution of sensors which are available in the market and an administration software which is specifically developed for the project. This would provide flexibility and freedom in using the sensors and enable to include barrier control systems, as well as parking sensors under the same management system. This approach will ensure the possibility to decide in the process of implementing future car park projects, if there is no permanent power supply, whether to build the permanent power supply or use IoT sensors. As the development of the sensors is rapid and the selection wide, the criteria which the sensors should be complaint with are described below.

Requirements arising from the Estonian weather conditions

- Low temperatures of up to –30°C
- High temperatures – the surface temperature of the pavement may reach +50...+60 °C in summer.
- Ingress protection: at least class IP67.
- Functioning if the sensor is covered with snow, sleet, ice, etc.
- The sensors must be resistant to winter-time maintenance of the road, including removal of snow irrespective of the type of the plough (for example, machines which are equipped with a frontal loader are usually used for snow removal in car parks).

Other requirements

Due to the lengths of the trucks, three sensors must be used per one parking space to identify trucks with no trailers.

Sensor

A combined magnetic/radar sensor. In addition to the two status messages sent by the sensor which may be conditionally referred to as ‘Occupied’ and ‘Vacant’, it is important that the sensor sends a so-called report of the condition of the device, confirming that the device is functional and specifying the battery level at least once in 24 hours.

The administration server is used for processing and storing of the data received from truck parks, statistical analysis of the data, transferring the data to third systems, and serving the data from the platform (PC, tablet, phone) irrespective of the web-based administration or user interface used.

In the case of using IoT sensors, the administration software runs on the basis of the server resources and performs the following operations:

- Accumulation of the sensor data from different truck parks.
- Counting the occupied and vacant parking spaces and calculating the occupancy.
- Counting active parking events and the duration of these events with detailed information.
- Real-time graphic overview of the truck park.
- Statistical data about parking duration.
- Provides real-time input to the TMC about the occupancy of the truck park which is in turn sent over the variable sign administration module to the variable sign which shows the number of vacancies in the truck park.
- Provides real-time input to the Tark Tee application about whether the truck park is opened and the number of vacancies.

Functioning scheme of the solution

The barrier solution and the IoT parking sensor solution can be controlled together irrespective of their technical differences. This is necessary because some car parks may require the application of both systems. Figure 4.10 shows a simplified overview of the common functioning scheme.

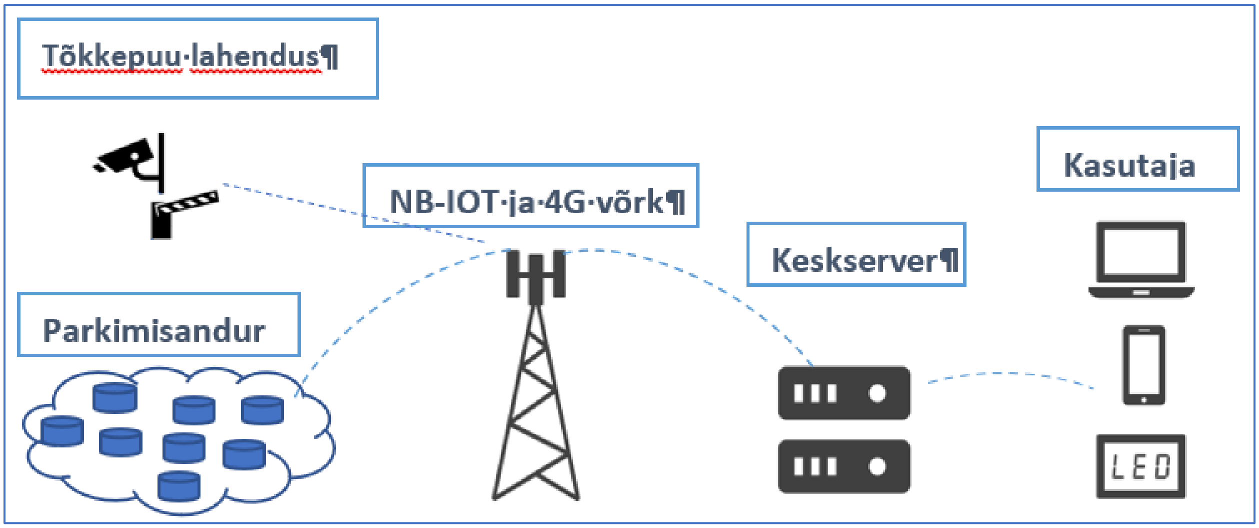


Figure 4.10 The functioning scheme of the IoT parking sensor-based solution and the barrier solution

/joonise tekst/

Tõkkepuu lahendus – Barrier solution

Parkimisandur – Parking sensor

NB-IoT ja 4G võrk – NB-IoT and 4G network

keskserver – Central server

kasutaja – User

5. Traffic re-routing scenario

The traffic re-routing solution is designed for implementation on the Tallinn ring road if it is required to re-route the traffic to one lane for some reason. The scenario is technology-neutral which means that it does not depend on the technological solution used for re-routing. This is also due to the fact that there are already several different types of gate solutions installed on the Tallinn ring road and one more new type will probably be added in the section between Jüri and Kurna. The traffic re-routing scenario should be one part of the overall set of incident detection, classification, and handling rules. Irrespective of the technical solution selected, from the perspective of traffic safety, the most hazardous period is the period of application of the systems, e.g. the period in which the gates are being opened or moved to the opened position, thus, respective authorised person(s) must be present by the gates during the application of the solution and actually open the gates, making sure that it is safe to do so. The authorised persons on site and the TMC must be able to communicate. The decision to re-route the traffic is also made by the authorised persons on-site based on the situation and need and depending on the location, applying the available technical means.

A dynamic scenario

On the basis of the new traffic monitoring system which will be installed on the Tallinn ring road and which will enable real-time monitoring of traffic flows, as well as on the basis of the pilot project nature of the E265 ITS project, we encourage the contracting entity to implement and introduce a novel dynamic re-routing scenario. In the case of a dynamic scenario, the locations of the means of traffic management which are used to notify road users of an incident which has occurred, re-routing, and any speed limits established (VMS, I2V, etc.) are not inflexibly pre-determined, but dynamic impact zones are used based on the impact of the incident on the normal traffic flow and road users receive information and orders based on the zones. A dynamic scenario also allows taking into consideration the time when the incident which calls for re-routing occurs, for example, in the case of an incident which has occurred during the busy hours in the evening, it is likely that the impact affects the entire ring road and information and orders must also be provided in the entire extent of the ring road. On the other hand, the impact of a night-time incident is barely noticeable and, in this case, any traffic management measures are only required in the immediate vicinity of the detour.

Impact and zones of an incident

Deviation of the traffic flows in the entire extent of the ring road is determined based on the long-term average indicators of regular traffic flows at the site of the incident and the ring road is divided into zones accordingly.

Red – gridlock due to an incident, etc.

Orange – regular traffic seriously disturbed

Yellow – medium impact

Green – marginal or no impact

The aim is to visualise the impact of the incident and the progress of the incident in time, which would facilitate making changes in the later analysis phase and simulate different situations if the required tools become available in the future. Naturally, this calls for saving detailed information about the situation before, during, and after the incident.

Zone-specific messages and orders

Green zone

- messages via the IVS-EVFT and the VMS information board: ‘TRAFFIC ACCIDENT IN … KM’

Yellow zone

- messages via the HLN-AZ, IVS-EVFT, and VMS information board: ‘TRAFFIC ACCIDENT IN … KM’ ‘CONGESTION OF UP TO 5 min’
- orders via the IVS DSLI and VSL speed ‘….’ km/h
- warning via the VWS: ‘TRAFFIC ACCIDENT’

Orange zone

- messages via the HLN-AZ, IVS-EVFT, and VMS information board: ‘TRAFFIC ACCIDENT IN … KM’ ‘CONGESTION OF UP TO 15 min’ ‘ADVISABLE DETOUR VIA ………’
- orders via the IVS DSLI and VSL speed ‘….’ km/h
- warning via the VWS: ‘TRAFFIC ACCIDENT’

Red zone

- messages via the HLN-AZ, IVS-EVFT, and VMS information board: ‘TRAFFIC ACCIDENT … KM’ ‘CONGESTION OF UP TO 15 min’ ‘…….. DIRECTION CLOSED’
- orders via the IVS-DSLI and VSL speed ‘….’ km/h
- orders via the IVS-DLM for changing the lane
- warning via the VWS: ‘TRAFFIC ACCIDENT’
- re-routing warning on the nearest WVS ‘TWO-WAY TRAFFIC’
- orders via the LCS for changing the lane

I2V definitions:

- IVS – In-vehicle Signage
    - EVFT – Embedded VMS ‘Free Text’
    - DSLI – Dynamic Speed Limit Information
    - DLM – Dynamic Lane Management
- HLN – Hazardous Location Notification
    - AZ – Accident Zone

Description of the process

1. General incident detection, classification, and handling (in a simplified form)
    a) a change in the speed of the traffic flow – the speed limit is lowered based on the developed scenarios and depending on the extent of the change
    b) it is determined whether and what type of an incident has occurred (with the help of cameras, through the Emergency Response Centre, etc.) – if an incident has occurred which calls for intervention by the Rescue Board/the police, the process continues with section 2 of the scheme. If not, regular traffic management scenarios are applied
2. Classification of re-routing of traffic
    a) The TMC lowers the speed limit, VWS is used, the respective information is displayed on the information board, and all of the above is repeated in the I2V system

b) the rescue vehicle/police/maintenance vehicle arrives at the site and, after assessment of the situation on site, a decision is made on whether or not it is necessary to close the direction of traffic
c) if the direction of traffic must be closed, the following process is performed:
    a. a decision is made on who will perform the operations and the TMC is notified
c) The TMC implements the re-routing measures in the respective section, lowering the speed limit in both directions further and displaying the respective information about the re-routing (with the VMSs and I2V messages applied simultaneously)
d) depending on the technical solution. If the physical barriers are equipped with lights, the lights are set to flash
e) If there are physical barriers, the barriers are taken into use
    a. from the farthest barrier to the barrier which is closest to the gate
f) an authorised person makes sure that the situation is safe, that no one is driving in the other lane, and that the gates can be opened safely
g) the free gate (the gate which should be used by the vehicles caught in the congestion to turn back to their lane) is opened first
h) then, the gate at which the vehicles are standing is opened
i) it is made sure that the traffic is functioning and the traffic is regulated to eliminate the congestion, if necessary
j) the vehicles which are stuck in the accident zone are also regulated back to the traffic flow (some will probably have to reverse)
k) The TMC will monitor the traffic flows on the entire ring road for the entire duration of the active period and adjust the speed limits, if necessary, and display information on the entire ring road or in specific sections to ensure smooth traffic and to prevent excessive queues at the ends of the detour
l) after responding to/liquidation of the incident, the original traffic management is restored in reverse order (first in the direction of traffic which was involved in the accident and then in the other direction)
m) a person who is present on-site makes sure that the gate system has been completely deactivated and notifies the TMC who will apply the traffic management scenarios appropriate for normal conditions

3. Post-incident analysis and implementation of improvements

6. The possibilities for cross-usage of the data of the traffic management centre of the Road Administration and the automated data of the Tallinn traffic light control centre for more efficient controlling of the incoming and outgoing traffic flows of the Tallinn ring road

The purpose is to improve the management of the incoming and outgoing traffic flows of the Tallinn ring road by mutual exchange of information. In order to analyse the possibilities for cross-usage of the data of the traffic management centre of the Road Administration and the automated data of the Tallinn traffic light control centre, we started from the capability of the Tallinn traffic light control centre and the information collected by the centre.

The Tallinn traffic light control centre mainly focuses on monitoring intersections and ensuring the permeability thereof. The situation at the intersections is also monitored via video surveillance cameras which are the main tools for detecting and saving the incidents which occur at intersections. Even though some traffic light controllers also enable unlimited counting and classification of vehicles, there is a separate network of traffic monitoring sensors in Tallinn for monitoring traffic flows which covers the most important traffic junctions in Tallinn. The central traffic light control solution used in Tallinn is the Swarco Omnia software, which is primarily used as a traffic light controller monitoring tool. In parallel, the old Omnivue software is used for monitoring the previous generation of traffic light controllers. In a limited extent, Swarco Omnia is also used for adaptive traffic management on Reidi road, which was opened last year. There are currently no plans for extension of the adaptive traffic management based on Swarco Omnia; the centre is examining which tools are used elsewhere in the world and how. For a traffic monitoring solution, Adec TDC-3 sensors are used. These are devices which are installed above the road and ensure a similar counting accuracy and number of vehicle classes to induction loops. At each monitoring point, there is a local controller which controls the local sensors, collects monitoring data from the sensors, and sends the data to the central server at an interval of 60 seconds. The monitoring data is currently only used for preparing analyses and summaries at a later date.

From the perspective of the traffic management centre of the Road Administration, it is important to receive real-time information from the monitoring points on the border of the city of Tallinn to manage the traffic flows which enter the Tallinn ring road.

In the end of 2019, monitoring points were built on the main roads entering the city of Tallinn which count and classify the vehicles entering or exiting Tallinn. These monitoring points are also based on Adec TDC-3 sensors which enable the acquisition of accurate and reliable data. Seven of these monitoring points are located on the roads which lead directly to the Tallinn ring road: Pärnu highway, Männiku road, Viljandi highway, Tartu highway, Suur-Sõjamäe, Peterburi road, and Laagna road.

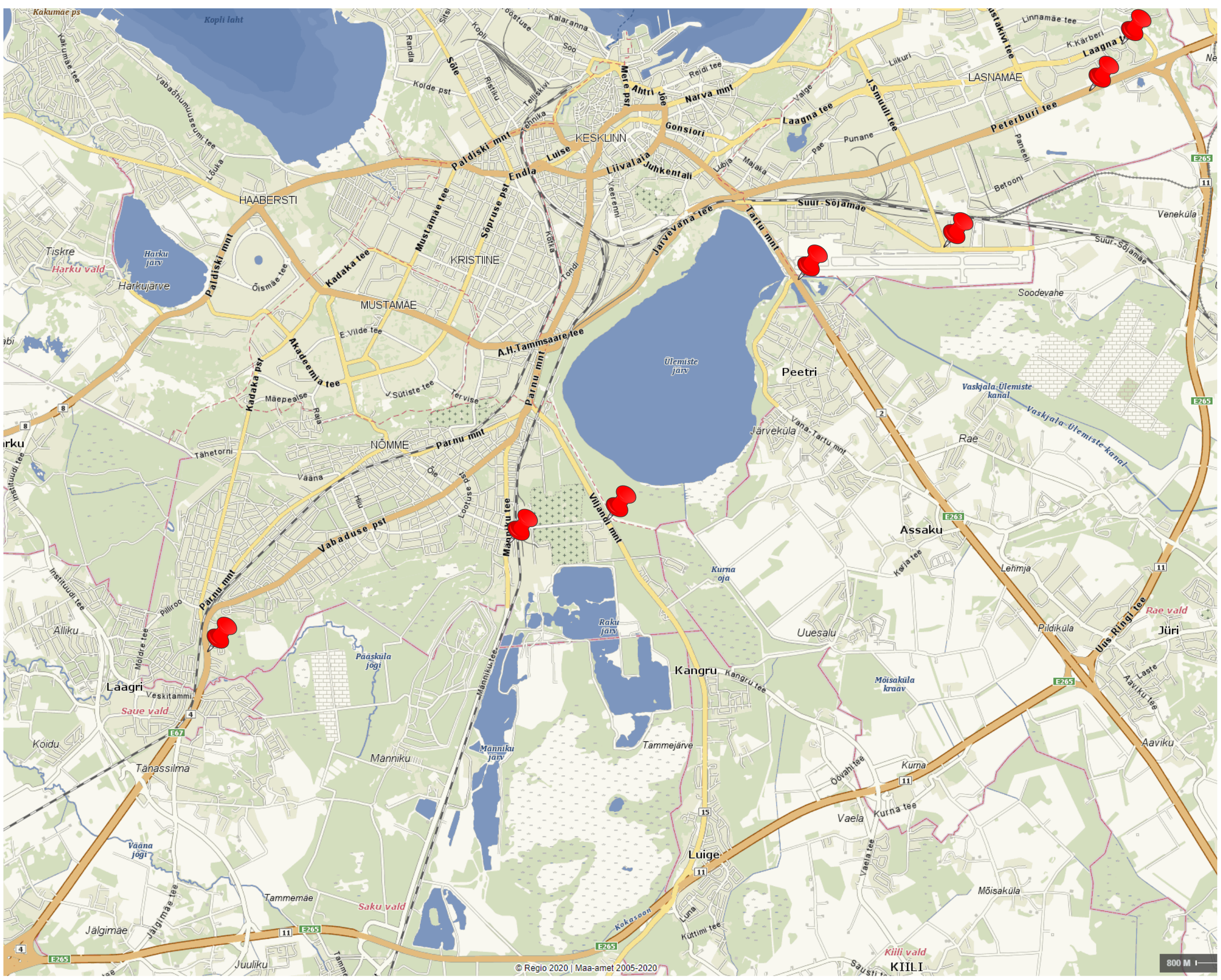


Figure 6.1 The monitoring points on the border of Tallinn

As the current monitoring system is only used for preparing analyses and summaries at a later date, the capability of the system of processing the data from the monitoring points in real time and sending the data to the traffic management centre of the Road Administration should be analysed first. The main obstacle to using the monitoring data of Tallinn through the central server may arise from the fact that even though Tallinn has fully paid for the development, operating, and maintenance of the central monitoring data solution, the city has no ownership rights to the solution. Thus, it is not known whether and under which conditions the owner of the central server solution would be prepared to enable information exchange. One alternative would be to make the monitoring points send data directly to the traffic control centre of the Road Administration.

From the perspective of the Tallinn traffic light control centre, it is above all important to obtain information about incidents and temporary changes in traffic management, as well as traffic restrictions. A conversation with a representative of the Tallinn Transport Department revealed that the city of Tallinn is prepared to develop the capability for cross-usage of the data in the form of co-financing.

In a longer perspective, though, the Tallinn traffic light control centre and the traffic management centre of the Road Administration could become one integrated unit. This would above all require a unified system and the same principles of handling of data; however, the authorities could remain situated in two different geographical locations. Creation of a full Frame-based ITS architecture with the involvement of the city of Tallinn would provide a strong and steady ground for creating a common system.

7. ITS architecture

Purpose

The purpose of the architecture is to ensure perfect interoperability and smooth integration of all current and future systems. The ITS architecture is also technology-neutral and primarily focused on a functional view.

7.1 Description and purpose of the E265 ITSs

Data storage of the Road Administration – central storage of basic data and serving of the data for preparing analyses, plans, forecasts, etc.

Tark Tee – a public traffic information application which provides road users information about traffic restrictions, road works, and road conditions.

VMS control (TMC) – a traffic management centre of the Road Administration which controls and monitors variable message signs.

Milestone Smart Client – the client solution of the Milestone server of the police which displays to the operators video feed from road and traffic cameras. An external system which is not connected to the systems of the Road Administration.

TMS – traffic monitoring system. Collects basic, aggregated, and event data from the sensors on the roads. Aggregates the data, if necessary, and transfers the data to higher level systems.

RWS – road weather station system. Collects basic and event data from road weather stations and transfers the data to higher level systems.

I2V/V2I – short-range, direct communication-based infrastructure-to-vehicle/vehicle-to-infrastructure communication network which sends warnings and information to vehicles and collects vehicle data.

ABGS – automatic barrier gate system for re-routing traffic. A separate system.

Parklad – a car park management system which provides information about the level of occupancy of car parks.

CAM – a set of road and traffic cameras which is managed through the Milestone server.

Numeric data portal – the gate through which numeric data is made available to the public.

External parties – e.g. the police, rescue board, and other bodies which receive information from the systems of the Road Administration.

Traffic management functionality – a superior functionality which aggregates all traffic management sub-functionalities which are related to the ITS of E265.

7.2 Overview of the E265 ITS

The overview is a symbiotic scheme of the current systems, new systems, and the traffic management functionality which includes the data flows between them. The principles of the Frame reference architecture were adjusted in preparing the scheme. The traffic management functionality is the collection of all user requirements and sub-functionalities which meet the requirements.

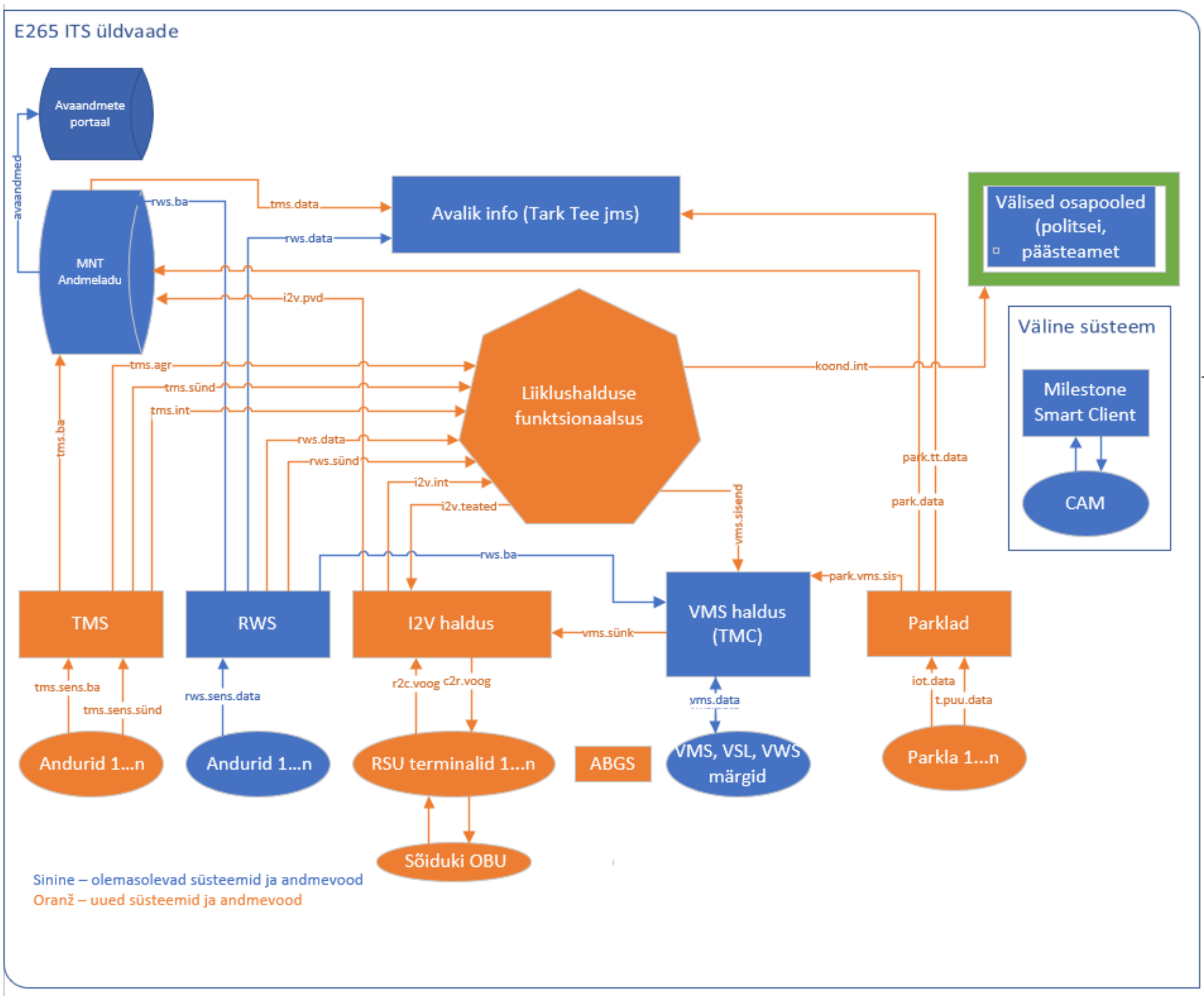


Figure 7.1 General view of the E265 ITS

/joonise tekst/

E265 ITS ülevaade – Overview of the E265 ITS; Avaandmete portaal – Open data portal; avaandmed – open data; MNT Andmeladu – Data storage of the Road Administration; Avalik info (Tark Tee jms) – Public information (Tark Tee, etc.); Välised osapooled (politsei, päästeamet) – External parties (police, Rescue Board); Liiklushalduse funktsionaalsus – Traffic management functionality; Väline süsteem – External system; I2V haldus – I2V control; VMS haldus – VMS control; Parklad – Car parks; Andurid – Sensors; RSU terminalid – Roadside units; VMS, VSL, VWS märgid – VMSs, VSL signs, VWSs; Parkla – Car park; Sõiduki OBU – Vehicle OBU; Sinine… – Blue – existing systems and data flows; Oranž… – Orange – new systems and data flows

7.3 E265 ITS data flows

TMS data flows

a) tms.sens.ba – basic data flow from the sensors of the traffic monitoring system
b) tms.sens.sünd – event data flow of the sensors of the traffic monitoring system
c) tms.ba – basic data of the traffic monitoring system to data storage
d) tms.sünd – event data of the traffic monitoring system to the TMC
e) tms.agr – aggregated data of the traffic monitoring system to the TMC
f) tms.int – incident data of the traffic monitoring system to the TMC

RWS data flows

a) rws.sens.data – data flow from the sensors of the road weather stations
b) rws.ba – basic data from the road weather stations to data storage
c) rws.data – data flow from the road weather stations
d) rws.sünd – event data flow from the road weather stations (black ice, severe precipitation, etc.)

I2V data flows

a) r2c.voog – the data flow between the roadside units and the centre
b) c2r.voog – the data flow between the centre and the roadside units
c) v2i.pvd – probe vehicle data
d) v2i.int – probe vehicle incident data flow
e) i2v.vms.sünk – synchronisation of the parameters of the IVS messages from vehicles

Truck park data flows

a) iot.data – the data flow from the IoT sensors
b) t.puu.data – the data flow from the barrier solution
c) park.vms.sis – truck park occupancy input data to the VMSs
d) park.data – truck park usage data flow
e) park.tt.data – publicly available truck park data

Traffic management functionality data flows

a) i2v.teated – messages sent to vehicles via I2V

b) vms.sisend – VMS control data

c) koond.int – accumulated incident flow to external parties

7.4 User requirements of the E265 ITS

1.Transport Planning		
1.1 Objectives		
	1.1.1	The system shall be able to exchange traffic and travel information between adjacent TCC's to improve strategic planning.
1.2 Information Management		
	1.2.1	The system shall be able to produce information for travelers on the traffic and travel conditions of all relevant transport modes.
	1.2.2	The system shall be able to collect traffic data for road network use analysis and prediction calculations.
1.3 Planning		
	1.3.1	The system shall be able to model the road network for strategic planning calculations, e.g. to make best use of the existing road infrastructure.
	1.3.2	The system shall be able to develop and implement traffic environmental management strategies based on current and predicted traffic conditions.
	1.3.3	The system shall be able to assist in the planning of (inter-modal) routes.
1.4 Evaluation		
	1.4.1	The system shall be able to measure the effect of a strategy, and to modify it when necessary.
1.5 Reporting		
	1.5.1	The system shall collect and report data as required by legally appointed authorities.
2.Infrastructure Maintenance Managememt		
2.1 Basic Services		
	2.2.1	The system shall provide support for road maintenance and infrastructure management.
	2.2.2	The system shall be able to maintain statistics on road usage to evaluate the need for possible maintenance.
2.2 Activation		

	2.2.1	The system shall be able to initiate activities to mitigate the effects of ice and/or snow on the road infrastructure.
2.3 Monitoring		
	2.3.1	The system shall be able to receive infrastructure equipment status data remotely.
	2.3.2	The system shall be able to support a database of the road network, infrastructure and road-side equipment.
2.4 Maintenance Units		
	2.4.1	The system shall be able to transfer information to, and between, road maintenance units.
2.5 Contracts		
	2.5.1	The system shall be able to support the management and control of maintenance contracts.
3.Pre-trip Information		
3.1 Modal Choice		
	3.1.1	The system shall be able to provide extensive multi-modal trip information, e.g. prices, fares, routes, forecast & current traffic situations, traffic control, demand mgt measures, local warnings, special events, weather conditions, hotels etc.
3.2 Information Handling		
	3.2.1	The system shall be able to provide information to travelers so as to influence their choice of destination and/or mode of travel, e.g. to protect the environment of a "Point of Interest", or geographic area.
	3.2.2	The system shall be able to support a database of events with links between events that occur concurrently and at the same or adjacent locations.
	3.2.3	The system shall be able to provide road and traffic information adapted to different classes of users, e.g. travelers, radio broadcasters, service operators.
4.On-trip Information		
4.1 Information Handling		
	4.1.1	The system shall be able to adapt the information to different classes of users, e.g. travelers, radio broadcasters, service operators.
5.Traffic Control		
5.1 Objective		
	5.1.1	The system shall support the existing and new traffic management needs of authorities by providing a flexible yet comprehensive approach to determine traffic management strategies (including bridge and tunnel control).

	5.1.2	The system shall be able to manage traffic in all or part of the road network using a methodology that is appropriate for motorways, e.g. no junctions and pedestrian facilities, but with lane use management.
	5.1.3	The system shall be able to use different methodologies to control separate areas of the road network.
	5.1.4	The system shall be able to implement identified control strategies that conform with specified policy.
	5.1.5	The system shall not do anything to reduce road safety.
	5.1.6	The system shall manage road traffic in such a way that levels of environmental (i.e. atmospheric and noise) pollution may be reduced.
	5.1.7	The system shall manage road traffic in such a way that congestion (travel time) may be reduced.
	5.1.8	The system shall be able to help co-ordinate the activities of TICs and TCCs.
	5.1.9	The system shall be able to exchange information between TICs and TCCs, including across national boundaries.
	5.1.10	The system shall ensure that traveler information service providers are aware of the traffic management strategy, so that they can provide information that conforms to it.
5.2 Monitoring		
	5.2.1	The system shall be able to monitor sections of the road network to provide the current traffic conditions (e.g. flows, occupancies, speed and travel times etc.) as real time data.
	5.2.2	The system shall be able to monitor and record weather conditions (wind, fog, rain level, ice, etc.).
	5.2.3	The system shall be able to measure the range of visibility and detect reductions caused by adverse weather and pollution conditions (but not darkness).
5.3 Planning		
	5.3.1	The system shall be able to use consistent historical data to complement real-time data, when necessary.
	5.3.2	The system shall be able to use historical data to complement predicted data, when necessary.
	5.3.3	The system shall be able to analyze road and traffic data to predict possible critical situations.
	5.3.4	The system shall be able to predict weather conditions, in particular the formation of fog and/or ice.
	5.3.5	The system shall be able to provide historical and predicted data.

	5.3.6	The system shall be able to produce new traffic management strategies from one or more of historic, current, or predicted road traffic data.
5.4 Traffic Control Center		
	5.4.1	The system shall enable a TCC operator to control, possibly remotely, infrastructure elements (e.g. traffic lights, VMS).
	5.4.2	The system shall enable a TCC operator to log all significant incidents and to record free text messages prior to their output to travelers.
	5.4.3	The system shall be able to provide a graphical representation of the road network (including equipment, incidents, traffic condition etc....) to TCC operators.
	5.4.4	The system shall be able to activate control devices (e.g. traffic lights, VMS), either individually or in groups.
	5.4.5	The system shall enable TCC operators to make temporary changes to the normal control strategy in real-time.
	5.4.6	The system shall be able to implement planned control strategies for planned events (e.g. sport, cultural, etc.).
	5.4.7	The system shall be able to support a database of all known (future) events.
	5.4.8	The system shall provide TCC/TIC operators with controlled access to all relevant systems.
5.5 Traffic Flow Control		
	5.5.1	The system shall be able to control the entries and exits to motorways.
	5.5.2	The system shall be able to provide advice to drivers as they approach car parks (on-street and off-street, as well as motorway service area parking).
	5.5.3	The system shall be able to provide specific traffic management for exceptional vehicles (e.g. very dangerous cargo, wide loads, etc.).
5.6 Exceptions Management		
	5.6.1	The system shall be able to provide control measures to protect road maintenance work and workers.
	5.6.2	The system shall be able to command drivers to change lanes on multi-lane roads.
	5.6.3	The system shall be able to change the direction of traffic flow on a some or all of the lanes on a carriageway in an orderly manner so that it does not create a safety hazard to any road user.
	5.6.4	The system shall be able to recommend re-routing strategies to reduce congestion.

	5.6.5	The system shall request confirmation of all exceptional measures before they are executed.
5.7 O/D Computations		
	5.7.1	The system shall be able to provide Origin/Destination computations, and route assignment estimations, for the road network.
5.8 Speed Management		
	5.8.1	The system shall be able to show the maximum authorized speed of vehicles on selected carriageways to be shown to drivers.
	5.8.2	The system shall be able to set variable speed limits on parts of the road network.
	5.8.3	The system shall be able to calculate recommended speed limits for given traffic and weather conditions, and road network characteristics.
	5.8.4	The system shall transmit recommended speed limits to equipped vehicles.
5.9 Roadside-Vehicle Communications		
	5.9.1	The system shall be able to transmit information to a vehicle to update its on-board database.
6.Incident Management		
6.1 Objective		
	6.1.1	The system shall detect and respond to various incidents on the road network.
	6.1.2	The system shall not do anything that might aggravate, or cause, an incident.
	6.1.3	The system shall assist the emergency services to provide an effective response to road traffic incidents.
	6.1.4	The system shall minimize the time between the occurrence of an incident and its detection.
	6.1.5	The system shall be able to validate that an incident has occurred in order to minimize false alarms.
	6.1.6	The system shall be able to suggest one or more responses for dealing with an incident.
	6.1.7	The system shall be able to run (pre-)defined incident mitigation strategies automatically.
6.2 Information Management		
	6.2.1	The system shall be able to collect and store data on each incident, e.g. location, type, severity, number & type of vehicles involved, the emergency/rescue vehicles needed etc.
	6.2.2	The system shall be able to identify and classify all incidents on the road network.

	6.2.3	The system shall be able to provide information on each incident to TICs for onward transmission to travelers.
	6.2.4	The system shall be able to provide information to travelers about the reason why a particular incident management strategy is being implemented.
6.3 Reporting		
	6.3.1	The system shall be able to produce incident data statistics, e.g. frequencies of occurrence, by time, type and location; identification of "high risk" locations on the road network; performance of the incident detection system.
6.4 Post-Incident Management		
	6.4.1	The system shall be able to minimize the consequences of an incident on the road network for those travelers who are not involved.
	6.4.2	The system shall be able to monitor the aftermath of an incident.
6.5 Pre-Incident Management		
	6.5.1	The system shall be able to detect "non-vehicle" incidents before they can escalate into traffic accidents, e.g. bad weather conditions, objects on the road, ghost drivers, etc.
	6.5.2	The system shall be able to provide local warnings on dangerous sections of the road network.
7.Cooperative Systems		
		(X)FCD - extended floating car data.
7.1 Road Hazard Warning		
	7.1.1	(X)FCD - The system shall be able to maintain a database of the road network.
	7.1.2	(X)FCD - The system shall enable data received from vehicles by a road-side device to be integrated, analyzed and fused.
	7.1.3	(X)FCD - The system shall enable a road-side device to send fused traffic data to the TCC.
	7.1.4	(X)FCD - The system shall enable a road-side device to send weather and environmental conditions to the TCC road-side device.
	7.1.5	(X)FCD - The system shall be able to fuse the XFCD data from a number of vehicles with the host vehicle data to create a more accurate view of the road and traffic conditions in that area.
	7.1.6	(X)FCD - The system shall be able to add traffic data from the infrastructure (e.g. induction loops, radar) to the fused XFCD data of the road-side device.
	7.1.7	Hazard Detection - The system shall enable the TCC to determine whether an incident has occurred.

	7.1.8	Traffic Condition Warning - The system shall be able to warn drivers in a timely manner of moving incidents (e.g. road/winter maintenance vehicles, long/wide loads) via an in-vehicle display.
	7.1.9	Hazardous Location Notification - The system shall be able to warn drivers in a timely manner of incidents ahead (e.g. road works, accident, traffic queue) via an in-vehicle display. Where available and relevant this information shall include lane(s)/road section(s) affected and expected delay.
	7.1.10	Hazardous Location Notification - The system shall be able to warn the driver in a timely manner, via an in-vehicle display, of adverse road surfaces and weather conditions along the planned route.
	7.1.11	Hazardous Location Notification - The system shall be able to inform drivers, via road-side devices, of obstacles in the carriageway and advise on the appropriate action (e.g. speed and lane).
	7.1.12	Hazardous Location Notification - The system shall enable a road-side device to select and activate a traffic management strategy in the event of an incident (including poor driving conditions).
	7.1.13	Hazardous Location Notification - The system shall provide "copies" of the traffic signs that are relevant to the current section of the road (e.g. speed limit, road hazards, junctions) to the driver at all times via an in-vehicle display.
7.2 Ghost Driver Management		
	7.2.1	The system shall be able to detect that a (non-self-reporting) vehicle is travelling in the wrong direction along a “one-way” road (i.e. a ghost driver), and warn other vehicles “ahead” of that vehicle.
7.3 Lane Utilization		
	7.3.1	The system shall be able to provide lane usage information to the driver via an in-vehicle display.
	7.3.2	The system shall be able to provide lane restriction information (e.g. HGV, HOV) from outside the vehicle and to confirm that it is consistent with the information that has been sent directly to that vehicle.
	7.3.3	The system shall be able to provide instructions not to change lanes to the driver via an in-vehicle device in order to stabilize the total traffic flow. These instructions may either apply to all types of vehicle, or to sub-sets.

	7.3.4	The system shall be able to provide lane usage information to the driver via an in-vehicle display when there are temporary restrictions to lane usage (e.g. at road works).
	7.3.5	The system shall be able to advise a driver, via an in-vehicle device, which lane to use when passing an incident/accident.
7.4 Speed Management		
	7.4.1	The system shall be able to recommend a safe speed limit according to the prevailing traffic, weather and road conditions based on the current legal speed limit.
	7.4.2	The system shall enable the TCC to display safety-related information (e.g. legal speed limit, recommended speed limit) to drivers via a road-side device.
	7.4.3	The system shall enable the driver of the host vehicle, via an in-vehicle device, to receive safety-related information (e.g. legal speed limit, recommended speed limit) from the TCC.
7.5 Headway Management		
	7.5.1	The system shall enable the TCC to calculate recommended headways for the current traffic and environment conditions.
7.6 Vulnerable Road User (VRU) Warning		
	7.6.1	The system shall be able to warn the driver, via an in-vehicle device, that a VRU has been detected in a dangerous location by a system at the road side.
7.7 Emergency Vehicle Warning		
	7.7.1	The system shall be able to advise the driver, via an in-vehicle device, of an appropriate lane to use to create a “blue corridor”.
8.Cooperative Systems - Efficiency		
8.1 Traffic Flow Optimization		
	8.1.1	The system shall enable the service provided to the traveler to be passed from one TCC to another as the traveler moves from one area of coverage to another.
	8.1.2	The system shall enable the TCC to instruct drivers, via an in-vehicle device, of an alternative route that should be followed (to avoid an incident).
	8.1.3	The system shall be able to analyze traffic data using an off-line simulation tool.

	8.1.4	The system shall be able to monitor the current inter-urban traffic and weather/environmental conditions, identify incidents, assess their impact, make short term predictions, and select and initiate an appropriate mitigation strategy.
	8.1.5	The system shall be able to use a simulation model for predicting the effects of implementing a given cooperative traffic management scenario.
	8.1.6	The system shall be able to monitor the current inter-urban traffic and weather/environmental conditions for the road network and recommend and/or set an appropriate traffic management strategy.
	8.1.7	The system shall be able to manage the traffic in an area using a number of local semi-autonomous traffic management units, whose rules can be modified when required.
	8.1.8	The system shall enable the TCC to receive information about emergencies, e.g. eCall, ghost drivers.
9.Freight Management		
9.1 Hazardous Goods Vehicle Management		
	9.1.1	The system shall enable the relevant authority to detect incidents within its area and to re-route any vehicle carrying hazardous goods that will be affected by the consequences of that incident.
9.2 Driver Rest Areas		
	9.2.1	The system shall be able to receive a message that a vehicle is leaving the rest area.
	9.2.2	The system shall enable the freight vehicle driver, to request a reservation for a rest area parking place. The request will include the planned route, estimated time, required duration, potential flexibility, possible hazardous goods and vehicle type.
	9.2.3	The system shall enable a rest area parking reservation to be made based on the request that has been received, or to state that one is not available and/or propose and alternative booking, and to send the details to the freight vehicle driver and the fleet operator.
	9.2.4	The system shall be able to identify the vehicle that arrives at a rest area, and to inform the driver which parking slot to use and how to get there.

Summary

Tallinn ring road E265 ITS is a project for establishing dynamic traffic management and a smart truck park. In the course of the project, intelligent transport systems (ITS) for traffic management, monitoring, and notification of road users will be installed on kilometres 0–30 of the Tallinn ring road which is included in the TEN-T network, and a smart (intelligent and secure) truck park will be built. The Tallinn ring road will be equipped with information boards as well as variable speed limit and warning signs which are already familiar to road users. There will also be traffic counters, an accident detection system, road weather stations, and traffic cameras. Novel solutions used will include a system for re-routing traffic and V2I/I2V (vehicle to infrastructure/infrastructure to vehicle) devices which will be used for communication between the vehicle and the infrastructure. The V2I/I2V communication systems will increase the driver's awareness of potential hazards and will help to reduce the likelihood of traffic accidents, resulting in a safer traffic environment. This technology will also increase the efficiency of traffic, providing warnings about traffic jams ahead, allowing to choose alternative routes, thereby ensuring environmentally friendlier journeys. Although there are similar tools in the form of Waze, Google, and other applications available today, this technology will cut out the human link and the vehicle will independently obtain information for decision-making. A smart truck parking area for 100 trucks will also be built by the Tallinn ring road between the city of Tallinn and Veneküla (km 1.5).

Within the framework of this study, a detailed overview of the equipment/solutions required for the dynamic traffic management of kilometres 0–30 of the Tallinn ring road and for the parking system of the truck park was prepared. For each type of equipment, the most optimal solution which could be integrated to the traffic management centre of the Road Administration was suggested.

The study is divided into seven sections by the ITSs:

1. the traffic monitoring system;
2. the V2I/I2V (vehicle to infrastructure/infrastructure to vehicle) communication equipment;
3. the automatic barrier gate system for re-routing (ABGS);
4. the barrier control system and parking sensors for the truck park;

5. the re-routing scenarios;
6. information exchange between the traffic management centre of the Road Administration and the Tallinn traffic light control centre;

   the architecture and interoperability of the ITS solution.