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BASIC CONCEPT OF THE TECHNICAL STUDY OF THE TRAFFIC CONTROL SYSTEM IN PREŠOV

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The project „Support Programme for the development of intelligent transport systems – National Traffic Information System for Slovakia“ also includes implementation of ITS of 11 chosen Slovak urban agglomerations. For the purposes of this project Technical study document for each town was elaborated in the first phase. The Technical study analyses existing and expected situation, defines critical localities on the basis of this analysis, which is necessary to solve and defines a framework for solution and its technical characteristics, respectively different alternatives of solutions. The article describes the current state of the ITS in the Slovak Republic, the scope of the Technical study of urban ITS and an ideological proposal of the Traffic Control System (TCS) in Prešov town, which has been elaborated at the author's' workplace. The urban ITS with respect to main goal – capacity increasing of existing urban road network and traffic congestion reducing – has been designed. In the article, functions and connections of all subsystems of TCS Prešov, their location within the town and connection to the NTIC (National Traffic Information Centre) master system are described in more details.

Keywords*:* intelligent transport system, ITS, traffic control system, detection system, traffic control centre

1. Introduction

The mobility of inhabitants and degree of motorization was increased not only in other developed countries but also in Slovakia. This has resulted in increased traffic loading and overloading of existing urban road networks. Problems are most evident in towns where there is a growth in traffic congestions, traffic accidents and negative impacts on the environment. Intelligent Transport Systems (ITS) implementation is one of the ways to effectively use the existing road network in the towns and increase its capacity and safety [1].

ITS is inevitable within the state, thus in towns, to be built in coordination and consistently on basis of interoperable systems based on open and public standards. Design of urban ITS in Slovakia must be in accordance with the „Support Programme for the development of intelligent transport systems – National Traffic Information System for Slovakia“ in accordance with the resolution of the Government of Slovakia No. 22/2009 dated 14.01.2009. The framework for implementation of the National Traffic Information System (NaTIS) was established within this Program.

The part of the proposed system environment NaTIS is implementation of ITS in 11 chosen towns in Slovakia. For the purposes of this project Technical study document for each town was elaborated in the first phase. The Technical study analyses existing and expected situation, defines critical localities on the basis of this analysis, which is necessary to solve and defines a framework for solution and its technical characteristics, respectively different alternatives of solutions.

The article describes the current state of the ITS in the Slovak Republic, the scope of the Technical study of urban ITS and an ideological proposal of the Traffic Control System (TCS) in Prešov town, which has been elaborated at the author's' workplace. In the article, functions and connections of all subsystems, their location within the town and connection to the NTIC (National Traffic Information Centre) master system are described in more details.

2. Design of Urban ITS as a Part of NaTIS Project

Compared to the Slovak Republic some advanced EU countries have already had for several years operational systems enabling reception and distribution of relevant information related to road transport not only on domestic roads, but also on interstate roads. Although Slovakia is for a relatively long time a part of the EU, in the field of creation and mainly exchange of traffic information with foreign countries it is significantly behind. The situation should by improved by creating a National Traffic Information System, which should be a complex system environment for acquisition, processing, sharing and distribution of traffic data from information and communication systems and technologies on the road network in Slovakia.

To ensure the basic functionality of NaTIS Slovakia, four realisation domains presented in the figure 1 were allocated. Moreover, they could be built separately and in future connected to each other:

- **Implementation domain of NTIC** – central system for securing the acquisition of traffic data from various agent based information and telematic applications, processing, exchange, publication and distribution of traffic data,
- **Implementation domain of Production and acquisition of information** – central evidence system of closed roads, system of planned road servicing, agenda system of oversize and dangerous cargo, etc.,
- **Implementation domain of ITS of main roads** – extension of technological equipment and improvement of telematic applications on main roads (mainly, the I. class roads) which secure the detection of traffic flow characteristics, automatic traffic counting, queue detection, acquisition of the meteorological data and state of road surface.
- **Implementation domain of ITS of agglomerations**.

From the viewpoint of ITS implementation in towns, the essential part of NaTIS project creates the 4-th realisation domain which represents solution of integrated ITSs systems for 11 chosen agglomerations in the Slovak Republic. The third biggest town Prešov has been chosen, too. Currently, in the Slovak Republic no integrated urban ITS has been completed and made functional yet.

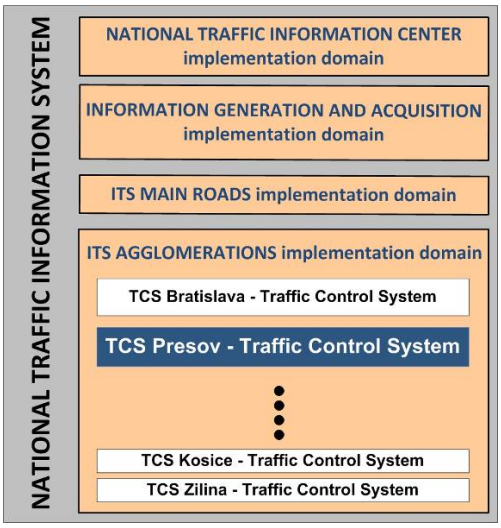

Figure 1. Realisation domains of NaTIS project

3. Basic Steps of ITS Agglomerations Implementation – Technical Study

In ITS systems design the process shown on Figure 2 was generally accepted in accordance with the technical regulation TP 09/2008 [2], where the phased process of ITS systems creation (a necessary design documentation process) is described. These stages are closely related to each other and result in an integrated implementation of transport systems that are solving the transport service for a defined territory.

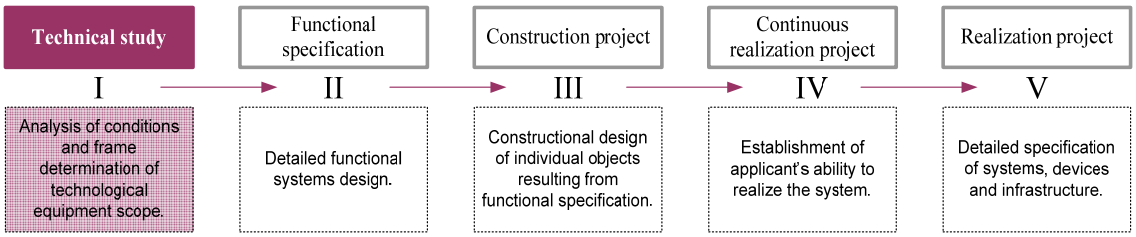

Figure 2. Phases of ITS implementation

For realisation purposes of the NaTIS project it is necessary in the first phase of implementation domain of ITS agglomerations to elaborate the Technical study (TS) for each town agglomeration, i.e. a document which:

- analyses the existing and expected situation,
- defines problems on the basis of this analysis, which is necessary to be solved,
- defines a framework for solution and its technical characteristics, or different alternatives of solutions.

The aim of TS is an analysis of external conditions in particular solving urban area of agglomeration (Table 1) and framework for determination of the extent of technological equipment (Table 2) in terms of the technical regulation TP 09/2008 [2] and instructions of the Slovak Road Administration (SRA). The SRA is actively taking part in the NaTIS project. A prognostic period of TS is 10 years.

The minimal range of external conditions analysis is as follows:

- classification of individual road sections,
- constructional properties of roads,
- identification of road sections in which capacity is reduced (according to TP 10/2010) because of objective or subjective reasons,
- identification of critical locations from traffic point of view,
- identification of critical locations from meteorological point of view,
- determination of sections from which traffic has to be instantly excluded in case of need,
- determination of network control need,
- constructional properties analysis of tunnels (for each tunnel separately),
- analysis of other important factors.

The range of a basic framework design infrastructure is as follows:

- power supply infrastructure,
- communication infrastructure and
- operator workplaces equipment.

In an analysis of external conditions, the following primary inputs have been considered: analysis of construction conditions and traffic volume of the road network, capacity analysis of roads and intersections, possibilities of diversion routes, as well as analysis of traffic accidents, weather conditions and the existing state of technology systems. Based on these inputs and analysis is then possible to identify critical points and to consider the merits of ITS implementation with determination of a basic framework and concept of technological equipment realisation.

Minimally the first stages of ITS project documentation, i.e. the Technical study and the Functional specification, for all 11 urban agglomerations have to be ready according to the NaTIS project by the end of 2011. In some urban agglomerations works on the Construction project have already started.

Table 1. The minimal range of external conditions analysis

ANALYSIS OF EXTERNAL CONDITIONS
Classification of individual road sections
Constructional properties of roads
Identification of road sections in which capacity is reduced (according to TP 10/2010) because of objective or subjective reasons
Identification of critical locations from traffic point of view
Identification of critical locations from meteorological point of view
Determination of sections from which traffic has to be instantly excluded in case of need
Determination of network control need
Constructional properties analysis of tunnels (for each tunnel separately)
Analysis of other important factors

Table 2. The range of a basic framework design infrastructure

RANGE OF TECHNOLOGICAL EQUIPMENT
Power supply infrastructure
Communication infrastructure
Operator workplaces equipment

4. The Traffic Control System in Prešov

In this part of the article the ideological design of Traffic Control System (TCS) in agglomeration Prešov is described in general terms [3]. In compliance with the NaTIS project a Technical study of ITS for the Prešov agglomeration has been elaborated at authors' workplace. There are described in more details the functions and links of each system, their localization within agglomeration town and connection with the NaTIC (National Traffic Information Center) master system. The TCS Prešov itself is designed as an open system which enables integration of other systems, such as navigation system for local parking, urban mass transportation etc.

The TCS Prešov has been designed on the basis of detailed analysis of external conditions. An urban road network of Prešov is presented on Figure 3, where examples of external analysis outputs – critical location from traffic point of view and critical location of traffic accidents are drawn. Urban road sections and intersections, not complying with terms of capacity are drawn in red. Based on the results of external analysis in terms of the Slovak Technical Regulation TP 09/2008 [2] (table 1) it was determined a range of technological equipment to enable centralized complex control and influence of traffic flows in agglomeration.

These are the fundamental functions of designed TCS Prešov:

- acquisition of traffic information and data,
- traffic control and navigation,
- operator monitoring,
- providing of information,
- supervision and repression,
- technological revision of operation.

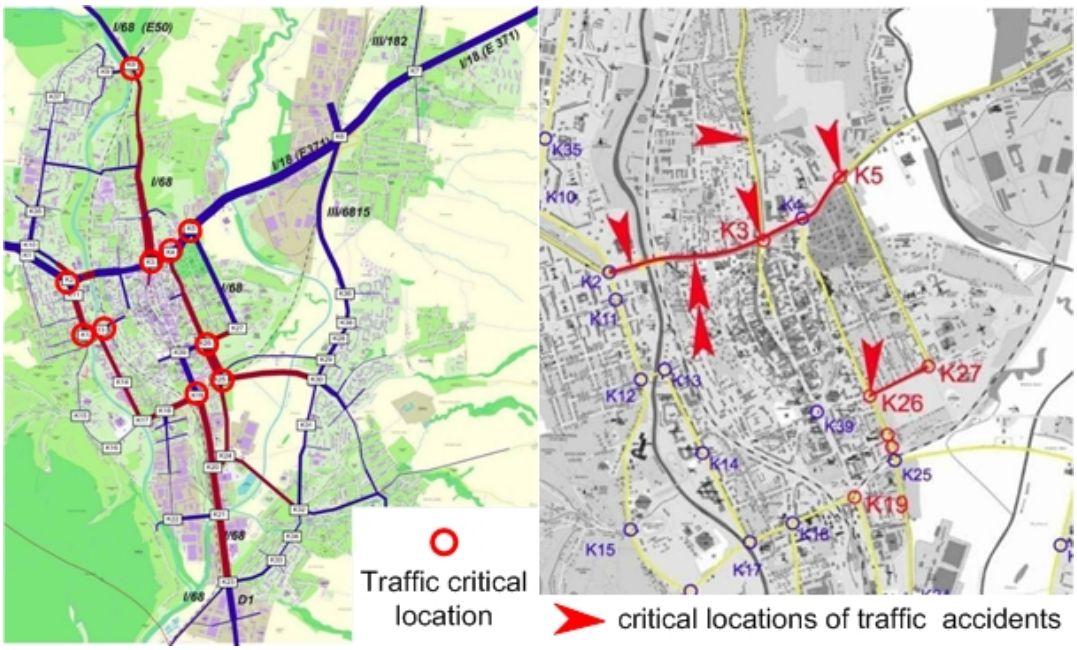

Figure 3. Urban road network of Prešov – critical locations from traffic point of view and critical locations of traffic accidents

4.1. Fundamental subsystems of the TCS Prešov

The main goal of designed TCS Prešov has been to increase capacity of existing road network and to reduce traffic congestions by [3]:

- timely and accurate monitoring of the current traffic situation in a controlled area with optimizing of traffic management,
- increasing the capacity of existing urban roads and intersections for more vehicles,
- reducing the impact and duration of congestion in the controlled area.
- improving of performance and timely problem solving of capacity in emergencies or other emergency states,

- increasing the average speed of vehicles on the roads and reducing the time passing through the city,
- increasing operational efficiency and safety of the travelling public,
- providing sufficient information for road users with a choice of routes,
- cooperating with other transportation management systems (e.g, highway management systems).

To achieve this goal, a complex traffic control system was designed within the frame of Technical Study of ITS Prešov which consists of three basic layers [3]:

- **technological layer**, which consists of technological devices which monitor, inform and control the traffic situation according to directives of the traffic control centre (traffic signal controllers, detectors, variable message signs, monitoring cameras etc.),
- **transmission layer** formed by active transmission and network elements serves for data transmission mediation between the technological and control layer (communication system for data transmission and control from traffic control centre),
- **superior control layer** consisting of the control and visualisation system (components of these systems are concentrated in traffic control centre).

The mentioned three layers – technological, transmission and superior – are for TCS Prešov analytically divided into the following subsystems [3]:

A. Local Traffic Control System – LTCS,
B. Vehicle Detection System (on strategy level) – VDS,
C. Monitoring camera system (Closed Circuit TV) – CCTV,
D. Variable Message Sign System – VMSS,
E. Data Communication Network – DCN,
F. Traffic Control Centre – TCC.

In addition to these systems an Electrical Power Infrastructure (EPI) of all technological devices and meteorological stations were designed in the study.

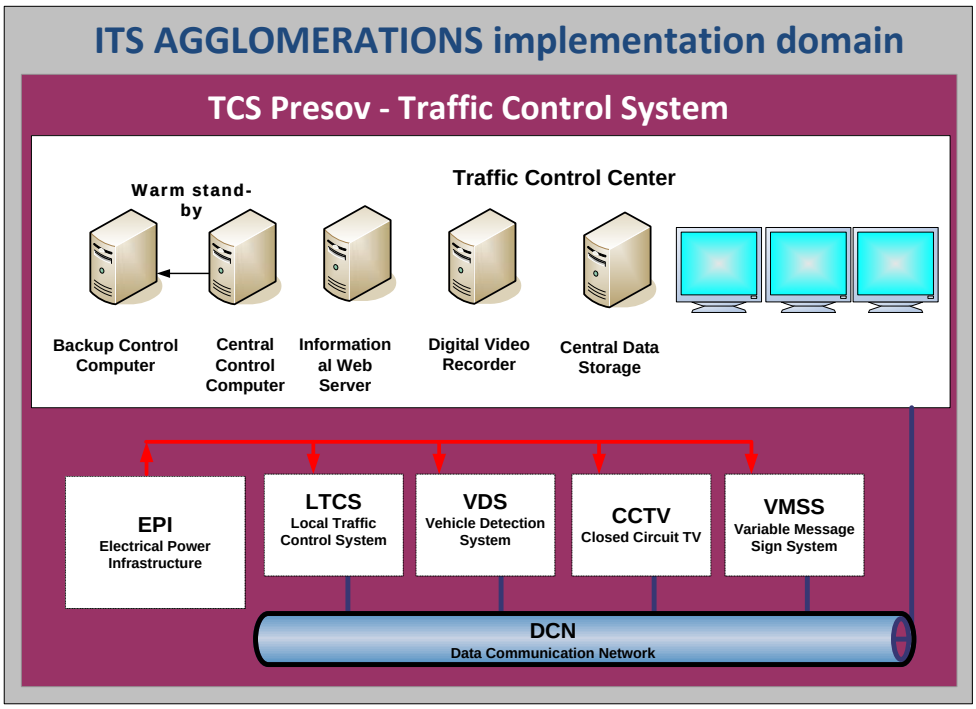

Figure 4. Schematic description of TCS Prešov

The TCS Prešov is schematically shown on Figure 4. Individual components of TCS will be interconnected into a fully functional unit. The TCS Prešov will work on two levels:

- **the operated level** – controlling of traffic flows on local level of traffic node (intersections), eventually several intersections in coordination. The controlling will be optimized on the basis traffic requirements determined by a detection system of intersection traffic controller (Local Traffic Control System – LTCS),

- **the strategic level** – the TCS system will automatically evaluate the current traffic situation on-line detected on detection zones of designed controlled area (Vehicle Detection System on strategy level – VDS). If necessary, a superior system will realize a proper action based on new traffic conditions to optimize control of traffic flows in area. Detection of traffic conditions on this level is realized by a standalone vehicle detection system (independent from the detection system of a traffic light controller) and traffic flows are controlled by traffic light controllers or using variable message signs to redirect traffic flows to alternative routes of urban road network.

Intersections that will be implemented by local traffic control system (LTCS) and also positions where the strategic detectors of traffic detection system (VDS) will be placed within Prešov area are shown on Figure 10.

4.2. Local Traffic Control System – LTCS

The main component of the Local Traffic Control System (LTCS) is a traffic signal controller with its own detection system. Detection system in many cases consists of loop detectors. Detectors are separated from VDS and traffic data are collected in controller for efficiently control signals. LTCS operates traffic signals by optimizing signal display and signal time according to the traffic data in each direction on the road – dynamic (on-line) traffic controlling on the basis traffic demands in real time. Fundamental function LTCS will be to control traffic flow on the road and mitigate traffic congestion by properly controlling signals. There are traffic signal controllers designed on 17 intersections in Prešov – 2 existing traffic lights, 8 reconstructed traffic lights and 7 new traffic lights.

All local traffic signal controllers installed in town will be checked and operated from Traffic Control Centre automatically.

4.3. Vehicle Detection System – VDS

A necessary foundation for traffic control is traffic data acquired from traffic detectors which mediates an image of traffic behaviour in a location requiring traffic-flow control. Primarily the input data for evaluation are the traffic volume, speed and traffic-flow composition. Detected data are evaluated in such a way that they do not only provide information about the actual traffic volume but also predict formation of impulse waves of vehicles or identify traffic accidents.

VDS (Vehicle Detection System) Prešov is a system to collect traffic data on strategy level and consists of traffic survey detectors. These devices are divided according to function:

- Traffic Flow Analyzer (TFA) – traffic survey detector, which function is detecting of immediate characteristics of traffic flow to monitoring and traffic controlling in real time (such as traffic volume, speed, share, time gap, etc.),
- Traffic Incident Detection Device (TIDD) – traffic survey detector, which function is in real time to identify of specified incidents in traffic flow.

The traffic data collected via VDS from traffic detectors TFA or TIDD are provided to the Traffic Control Centre for the purpose of traffic strategy management. There are video detectors designed on 32 locations in Prešov (Figure 10) and this type of detectors cover both functions – traffic flow analysis and traffic incident detection, too.

In addition to TFA and TIDD traffic detectors a Railway Crossing Occupancy Detection (RCOD) has also been proposed within VDS system in Prešov on strategic level.

4.3.1 Railway Level Crossing Occupancy Detection

Within the Prešov town two problematic level crossings of railway and primary road have been identified whose traffic has a direct impact on adjacent road nodes (intersections) and significantly influence the performance of urban road network. The first railway level crossing is located on major road line belonging to the most loaded roads of urban road network not only by internal traffic but also by external traffic (origin, destination and transit traffic). Already in recent times the road sections and intersections on this road are overloaded. The railway level crossing is located between traffic lights controlled intersections and during barriers activation intersects the coordinated set line of controllers. Considering the high frequency of barriers activation mainly during the traffic peak hours long queues of vehicles are formed before railway level crossing with long waiting time. The second railway level crossing is located on an important alternate route to major road line, on which vehicle queue over 1 km long is formed during traffic peak hours. The Figure 5 shows schematic localisation of these railway level crossings.

In both cases from the view of effective traffic control it is desirable on TCS level to provide acquisition, processing and evaluation of data related to occupancy of these railway level crossings. Based on the information from detectors it will be possible using LTCS (Local Traffic Control System) to modify the control on neighbouring intersections and on the intersections of coordinated traffic line. By changing the signal programs with direction preference on intersections directing apart from the railway crossing the queue formation will be avoided and the secondary intersections directions will be depleted. Moreover the VMSS (Variable Message Signs System) enables information of drivers together with the option to redirect the traffic onto alternate routes.

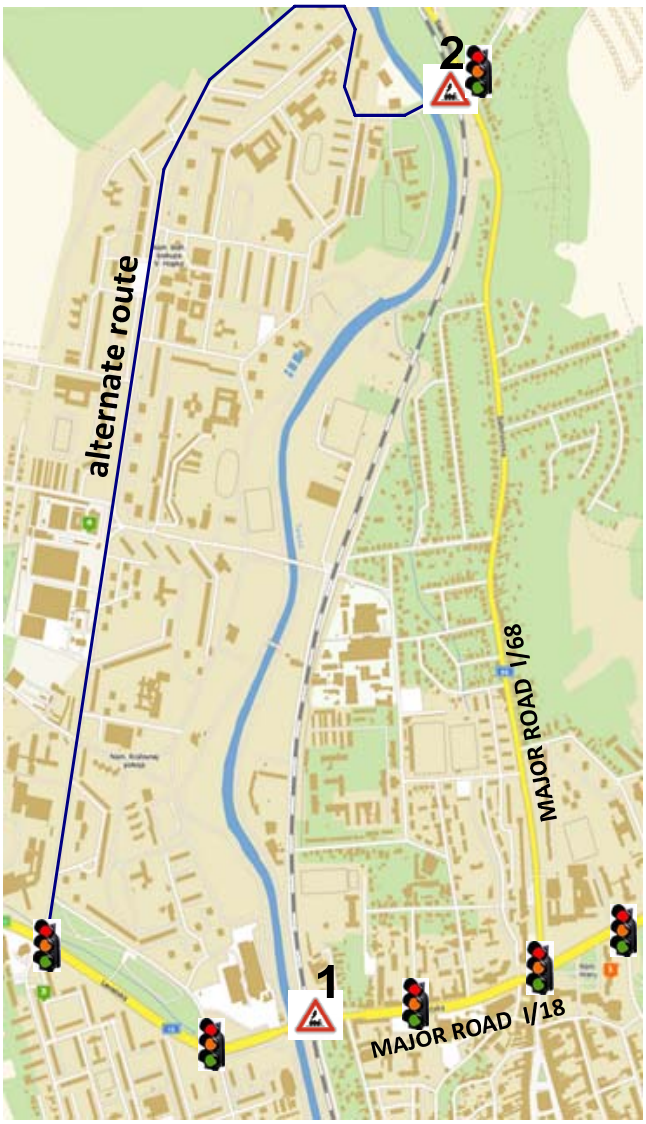

Figure 5. Schematic localisation of railway level crossings in Prešov

During the Technical Study elaboration three possible concepts of railway level crossing occupancy by a railway vehicle have been proposed. In principle two alternatives have been considered: detection of actual barriers activation and indirect detection of road sections in front of the railway level crossing (steady vehicle, queue formation).

Concept 1

The first concept assumes detection of barriers activation using direct linkage to the Railway Level Crossing Device – RCD (Figure 6). The advantage of this solution is high reliability not only from the point of view of safety RCD operation but also from the point of view of information provided. However such a configuration emerged as problematic on the score of direct linkage to the RCD because of valid technical regulations of the Slovak Railways.

Concept 2

The second concept is based on detection of barriers activation, too. However in this case some of the non-invasive detectors are used (Figure 7). This way of detection based on video-detection of actual barriers position (lowered – raised) without affecting the railway crossing device has been evaluated as unsuitable for the given environment because of reduced reliability.

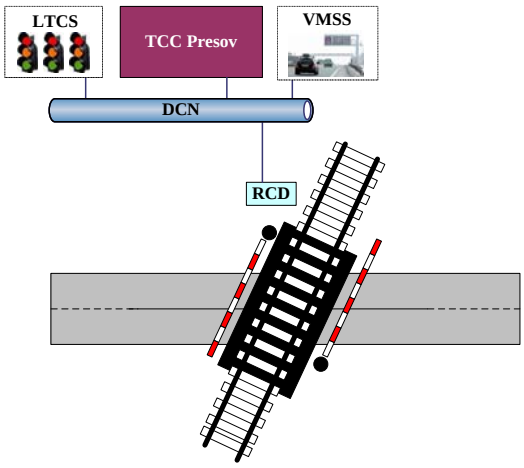

Figure 6. Concept1 – detection using direct linkage to the RCD

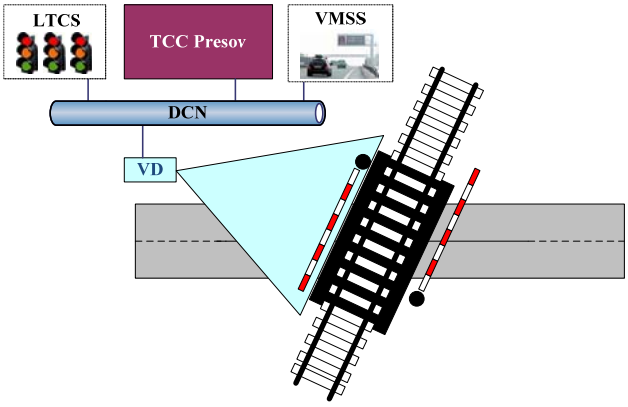

Figure 7. Concept 2 – barrier activation video-detection

TCC Presov – Traffic Control Center, DCN – Data Communication Network, LTCS - Local Traffic Control System, VMSS – Variable Message Sign System, RCD – Railway Crossing Device, VD – Videodetector

Concept 3

The third concept is based on monitoring of traffic situation on the road sections in front of the railway level crossing by an indirect detection using. Non-invasive traffic detectors have been proposed to detecting steady vehicle, vehicle speed, queue formation, etc. (Figure 8). A steady vehicle in coincidence with other fulfilled assumptions means lowered barriers. The advantage of this solution is besides detection of railway crossing occupancy also the possibility of additional utilisation of measured traffic data in the TCS Prešov system. At the same time such a detector becomes a push-forward element of neighbouring intersections.

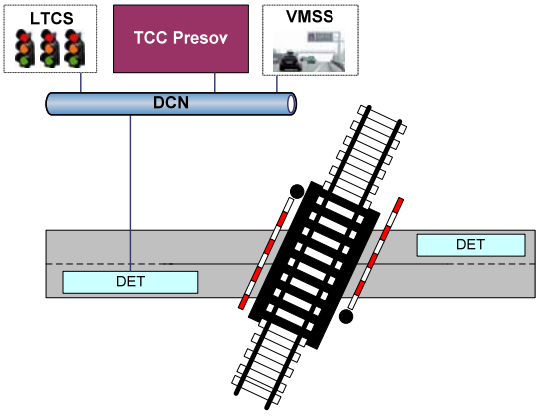

Figure 8. Concept 3 – indirect detection by non-invasive traffic detectors using

TCC Presov – Traffic Control Center, DCN – Data Communication Network, LTCS – Local Traffic Control System, VMSS – Variable Message Sign System, DET – Non-invasive Traffic Detector

In principle all concepts include the Railway Crossing Occupancy Detector (RCOD) from which data is sent by the proposed Data Communication Network (DCN) to Traffic Control Centre Prešov. After processing and evaluation data the control commands are automatically sent to the controllers of adjacent intersections. Moreover information about permanent crossing occupancy can be sent to the system of Variable Message Signs in order to increase the awareness of drivers about the traffic situation in town or to redirect them to the alternate routes.

Regarding the timeliness of the provided information the detection of actual barriers activation is preferable. Of course, a mutual combination of the proposed solutions is possible, which would include the information about lowered barriers complemented by traffic information on the road sections in front of the railway crossing.

4.4. Monitoring camera system – CCTV

Monitoring camera system is created by Closed Circuit TV (CCTV). CCTV is a system for monitoring traffic situation of selected roads and intersections, for visually and simultaneously checking it at traffic information centres when incident or emergency happens, for helping road-users and for performing a road safety function. Considering this, CCTV is designed on 17 locations and there are rotary DOME cameras designed (Figure 10).

4.5. Variable Message Sign System – VMSS

Variable Message Sign System (VMSS) is a system to inform road users about road and traffic states, car accidents, closed roads or road construction information in real time. Variable message signs are applied for reroute traffic flow to alternative routes from overloaded roads, too. VMSS is designed for three purposes in Prešov:

- to regulate traffic flow – reroute traffic to alternative routes,
- to control traffic flow and
- to inform road users.

The informing drivers, the warning about existing congestions and diverting traffic on alternative routes is possible by change of certain symbols or messages on VMSS. There are VMSS (prismatic or LED) designed at 5 locations in Prešov (Figure 10).

4.6. Data Communication Network – DCN

The created communication network infrastructure formed by optical network (Figure 9) will serve for network transmission of data between traffic (operator) centre and technological devices (TD) combined into technological nodes [4, 5]. The technological node is according to configuration able to support several TDs like vehicle detector, variable traffic sign, traffic controller, surveillance CCTV camera, etc.

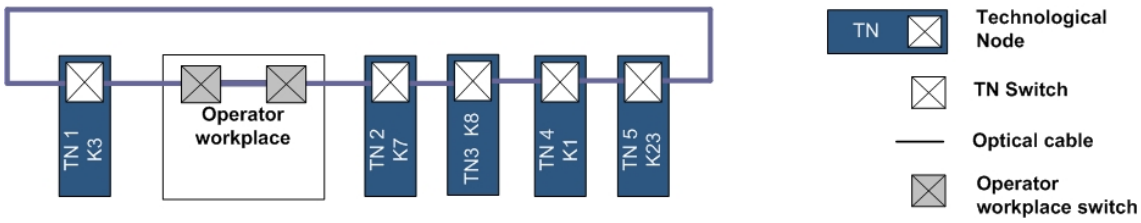

Figure 9. Private backbone network (L1 type) TCS Prešov

4.7. Traffic Control Centre – TCC

The Traffic Control Centre is a place concentrating the initial care of traffic controlled area. It is intended for application domains for traffic data processing, traffic control and monitoring of the entire traffic control system. It operates all technological devices and ensures archiving of all events by a record system. In this location the momentary technical conditions of all devices in traffic controlled area are monitored and where necessary an intervention is decided. The central control system inputs within its competitions actively into traffic control in the controlled area in full-automatic mode. The competent dispatching worker – operator can perform, based on supporting systems results, an adequate intervention to traffic control by either inputting the necessary data (for example about a traffic accident) into the automatic control system, or by a direct manual action. A direct manual intervention into control has to be limited by access rights so that it could be performed only by operators disposed of the corresponding legislative authority (Slovak Police Forces members).

From practical perspective within traffic control in a town a main function is examined – optimisation of traffic flows in controlled area together with control of critical or emergency states. For on-line control it is necessary to ensure that the Traffic Control Centre in Prešov has actual information not only from TCS subsystems (LTCS, VDS, eventually CCTV), but also from the superior National Traffic Information Centre. Traffic data and information from TCS subsystems will directly form the picture of traffic situation in town or send information about critical or emergency state (occurrence of congestions, traffic accident or other emergency situation). The superior NTIC will provide to TCS information primarily about traffic situation on main roads entering town and also on the adjacent superior road network (D1 highway and R4 motor way), on which the town communication system is connected. This way the TCS Prešov will be able to react on time on traffic problems on these roads and optimise the traffic control in town with respect on traffic situation or traffic problems outside town. It also holds in the opposite case when based on traffic data from TCS Prešov enables the superior NaTIS to effectively control and regulate traffic on adjacent and superior road network outside town with respect to current traffic situation in town. Besides traffic control and regulation itself it is necessary to ensure informing of drivers either from position of TCS Prešov or NaTIS by the available ways (VMSS, RDS-TMS, radio, cell-phone, internet).

4.8. Localization of Technological Devices within Prešov Agglomeration

Based on TCS Prešov proposal on the controlled road network of town Prešov it is possible to generate a final location plan of designed technological devices (Figure 10). This way deployed technological devices after completion by another ITS devices (like meteorological-stations of RWIS system, etc.) complexly cover the controlled area and accomplish the goals summarised in the conclusion of this paper.

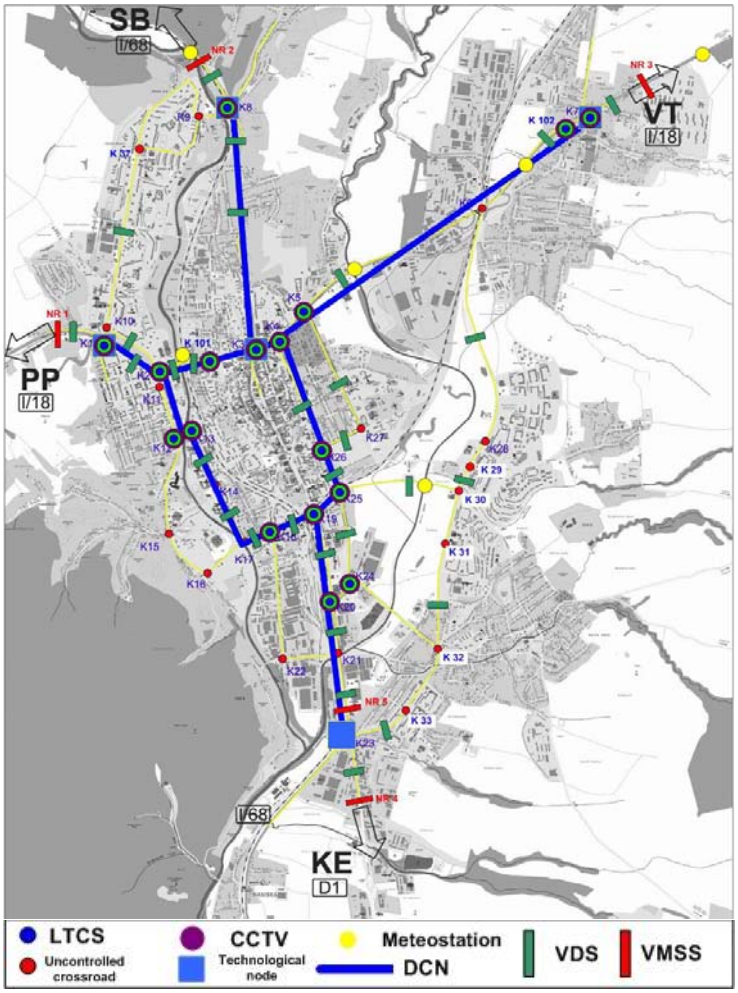

Figure 10. The proposed deployment of technological devices in Prešov

5. Conclusions

The urban ITS proposal of TCS Prešov significantly contributes to reduction of congestions formation and high traffic volumes on by overloaded urban roads within the town Prešov. At the same time it creates a background for a significant operational effectiveness increase of authorities, organisations and institutions in the area of administration and maintenance of roads, their components and accessories, in the area of economy of pavements and other property, in the area of traffic supervision on roads. The real output of the TCS Prešov project is implementation of procedures within the area of traffic control and optimisation and within the area of analytical operation targeting towards permanent removal of traffic problems which impair safety or traffic continuity within the Prešov town territory. Collected data from TCC can then be used for planning long-term outages, for the creation of urban plan or developing new or existing urban road network.

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