AdTrans project, 2023-1-PL01-KA220-HED-000158917

ADTRANS
ADVANCED DATA ANALYSIS FOR TRANSPORTATION AND MOBILITY ACADEMIC TEACHERS

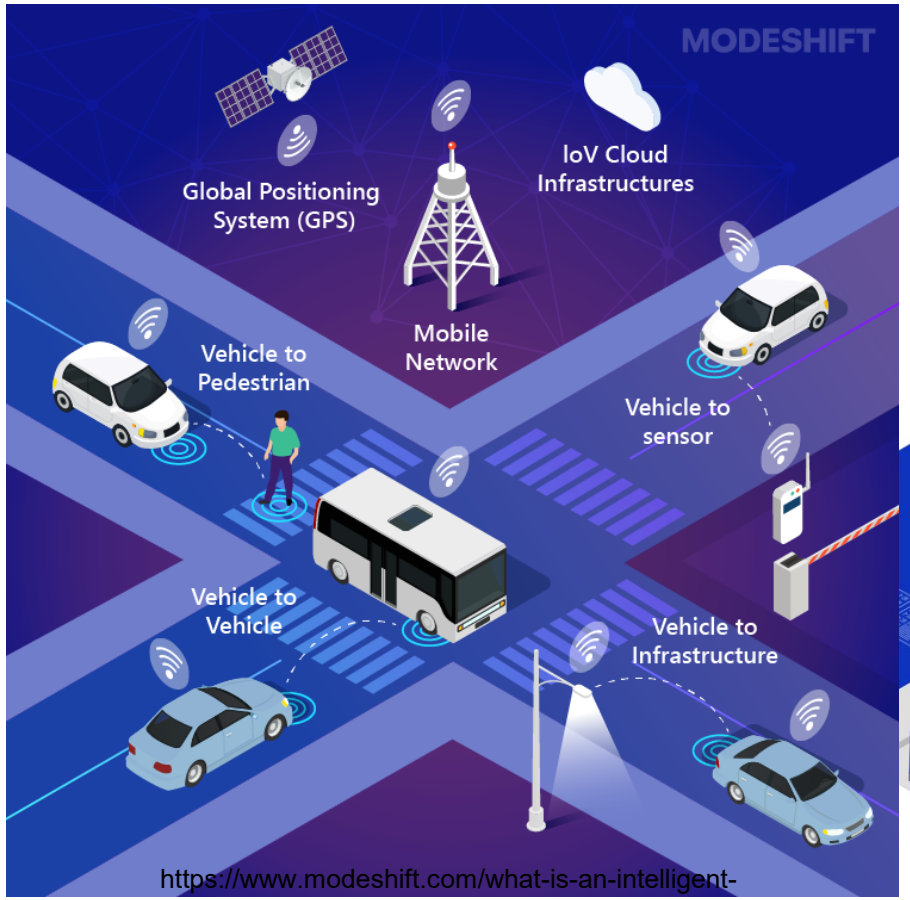
Road Traffic Control: Intelligent Transportation System - Components and Traffic Control Applications

Jacek Oskarbski

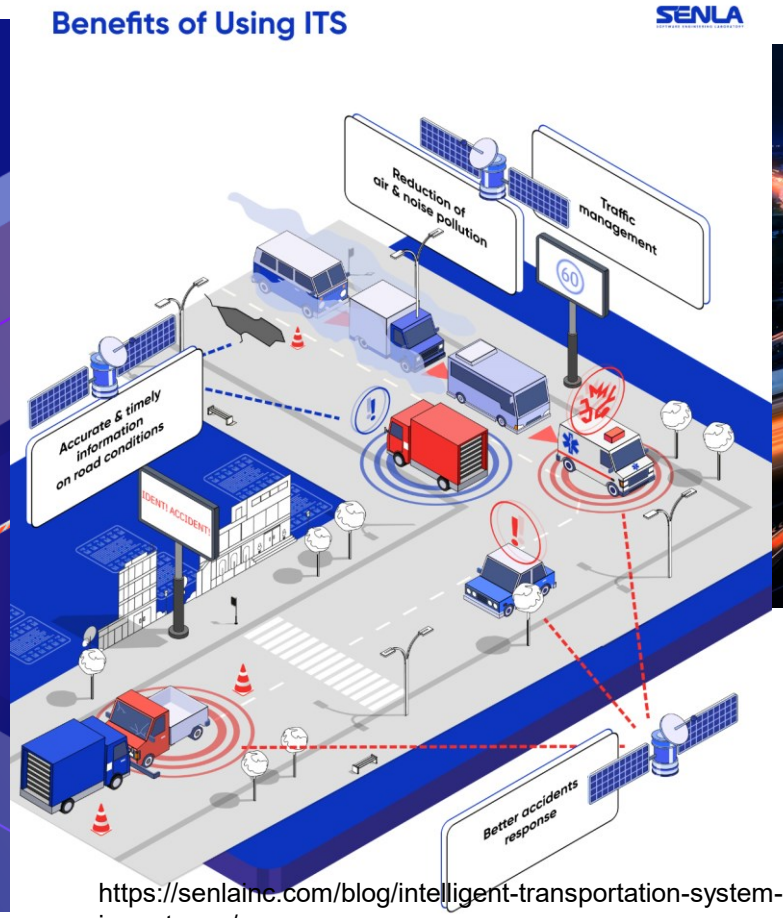
Co-funded by the European Union

Intelligent Transportation System (ITS)

- Intelligent Transportation System (ITS) – tools help to manage transport infrastructure and travellers service effectively.
  - Intelligent infrastructure – transportation infrastructure equiped with telematics devices
  - Intelligent vehicles – vehicles equiped with telematics devices



https://www.modeshift.com/what-is-an-intelligent-transport-system-and-how-does-it-work

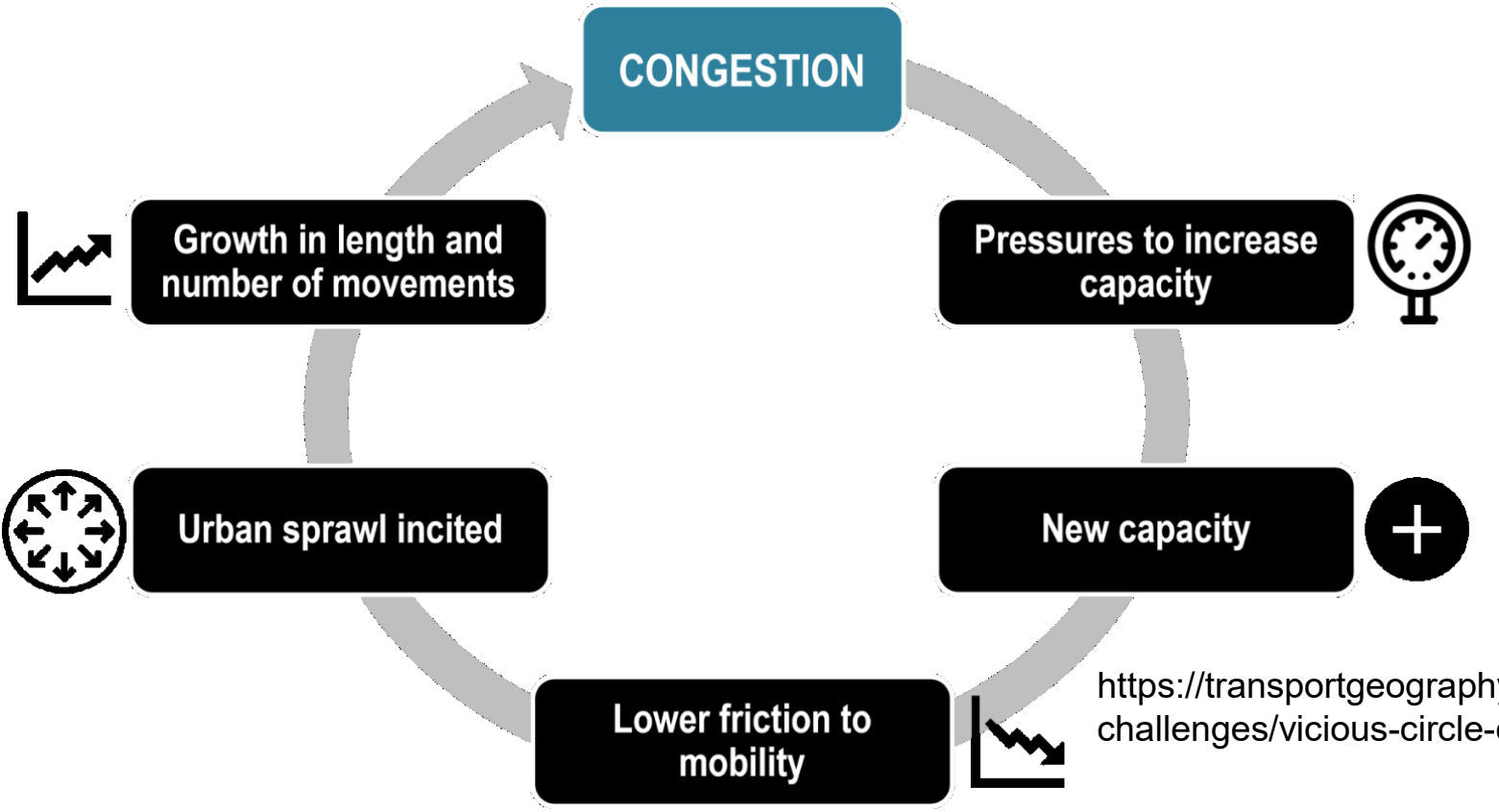


https://senlainc.com/blog/intelligent-transportation-system-importance/

https://intelligent0system.blogspot.com/2023/01/intelligent-transportation-system-its.

Transport system – problems

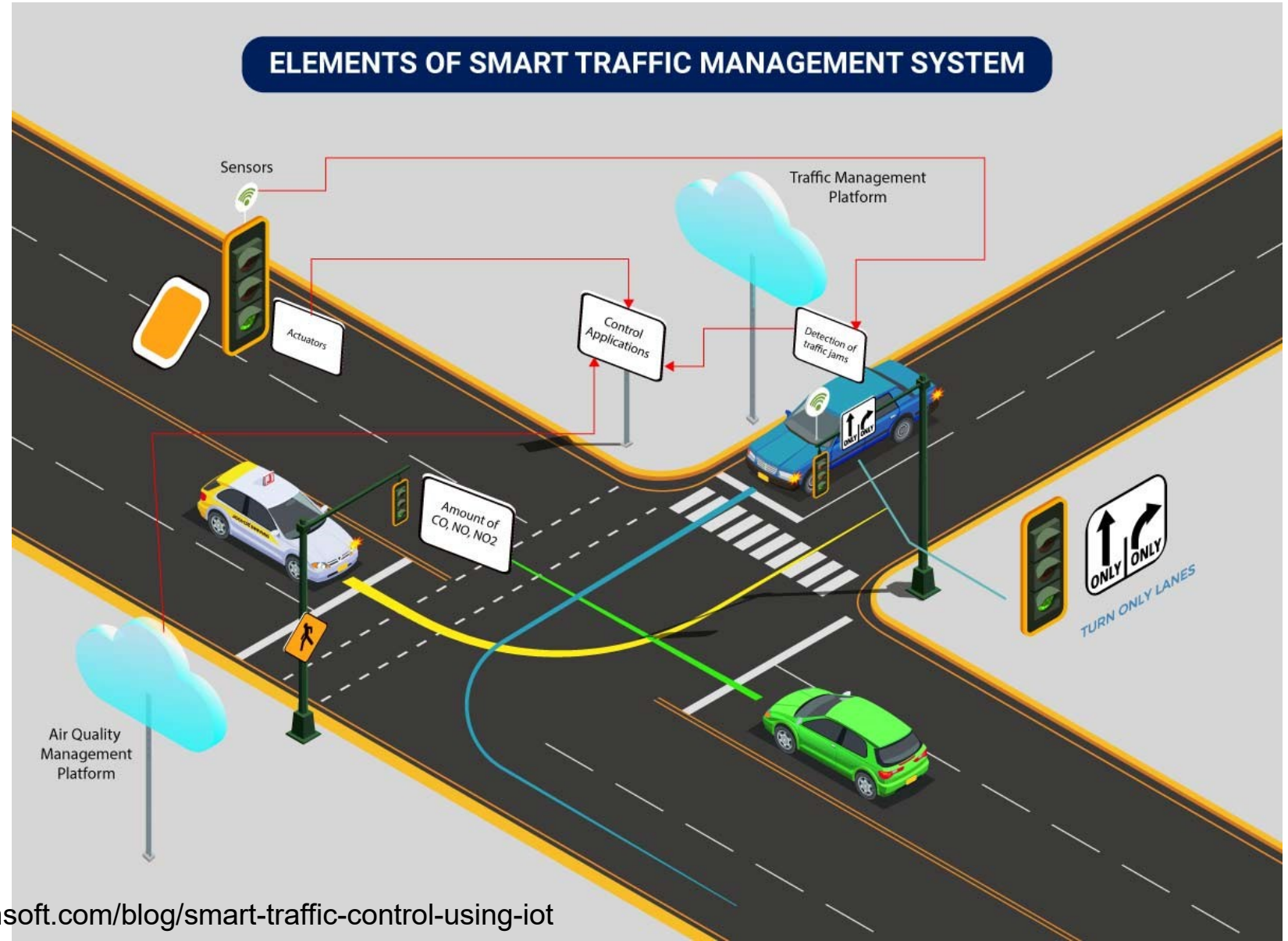
- Why ITS, mobility management, autonomous vehicles?
- Increase in mobility and congestion
- Passenger and freight transport varying over time (variable demand)
- Limited network capacity, frequent capacity reductions (variable supply)
- Safety issues, time and money losses, and negative impacts on the environment, social threats



https://transportgeography.org/contents/chapter8/urban-transport-challenges/vicious-circle-congestion/

Examples of Low-Cost ITS Solutions

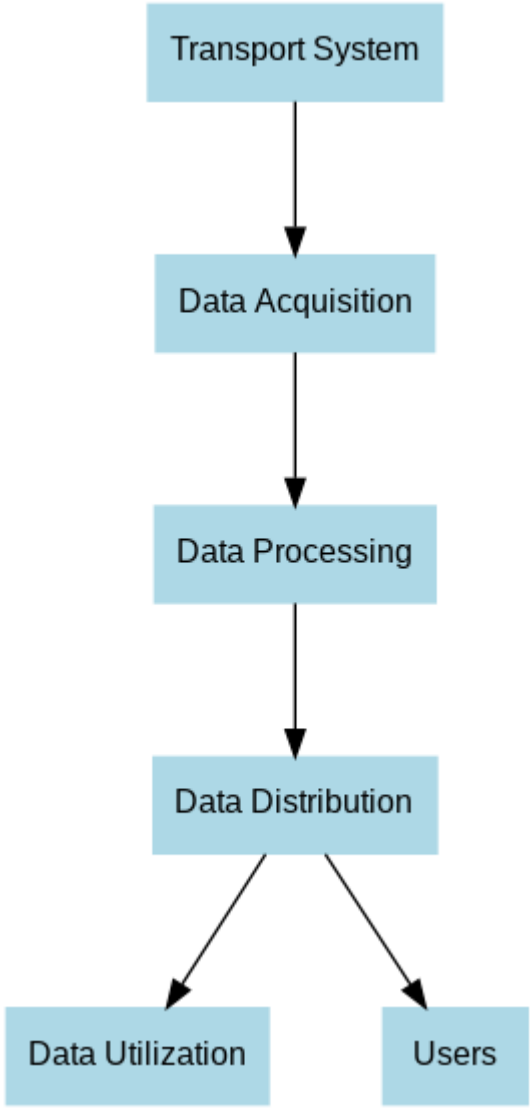
- Traffic signal control (urban traffic control)
- Dynamic speed limits
- Lane-use control
- Public transport priority
- Variable Message Signs (VMS)



https://www.rishabhsoft.com/blog/smart-traffic-control-using-iot

How an Intelligent Transportation System (ITS) operates

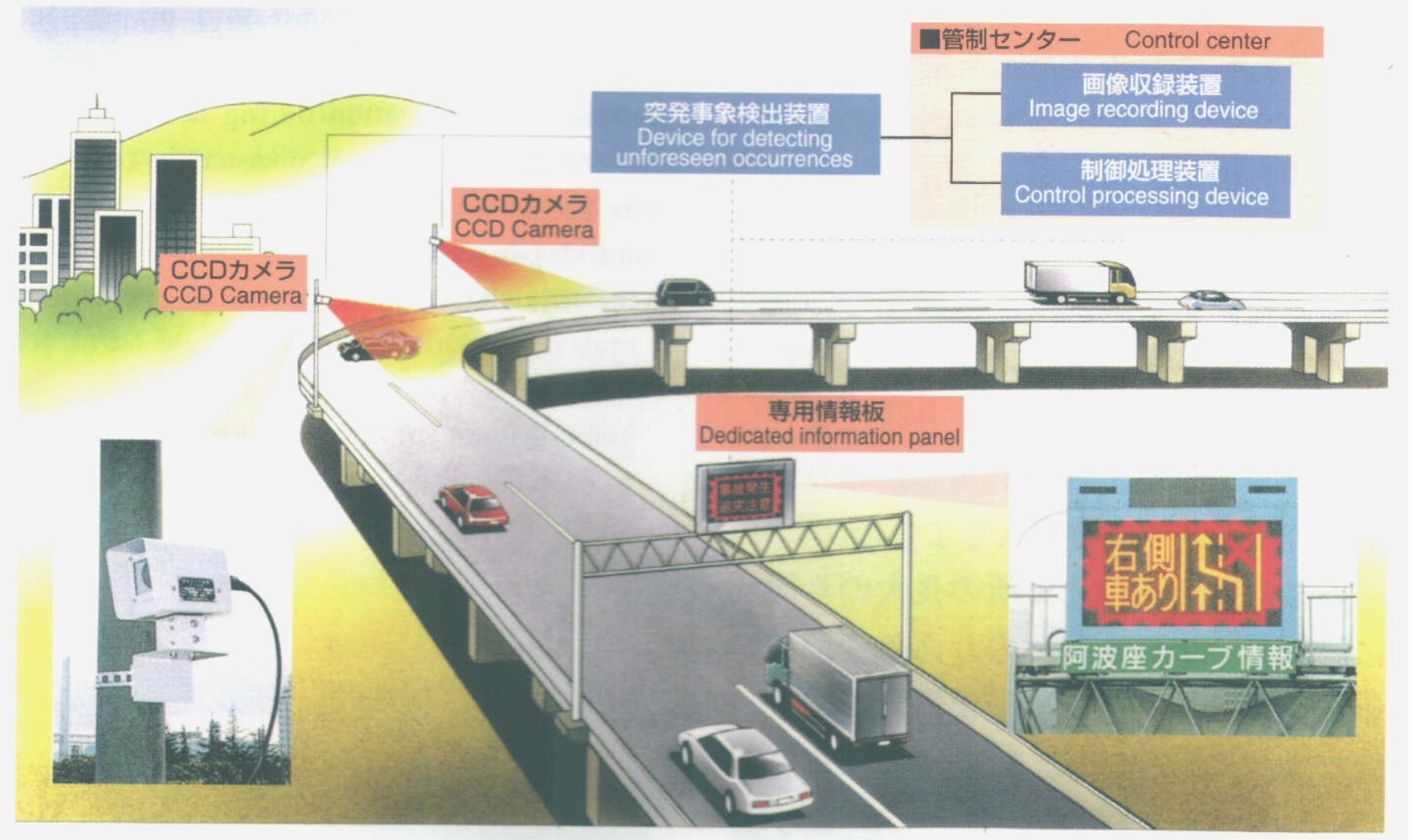
- 👉 This cycle illustrates how an Intelligent Transportation System (ITS) operates: from data collection, through analysis, to providing information for improved efficiency and safety of transport.
- Transport System – the source of data (vehicles, infrastructure, traffic signals, passengers).
- Data Acquisition – collecting data from sensors, cameras, traffic detectors, GPS, etc.
- Data Processing – analysing and processing data in traffic management centres.
- Data Distribution – delivering processed information to various recipients (e.g., VMS boards, mobile apps, control systems).
- Data Utilization – practical use of data for traffic management, route planning, and transport optimization.
- Users – final recipients of the information: drivers, passengers, transport operators, and authorities.



Traffic management on motorways and expressways

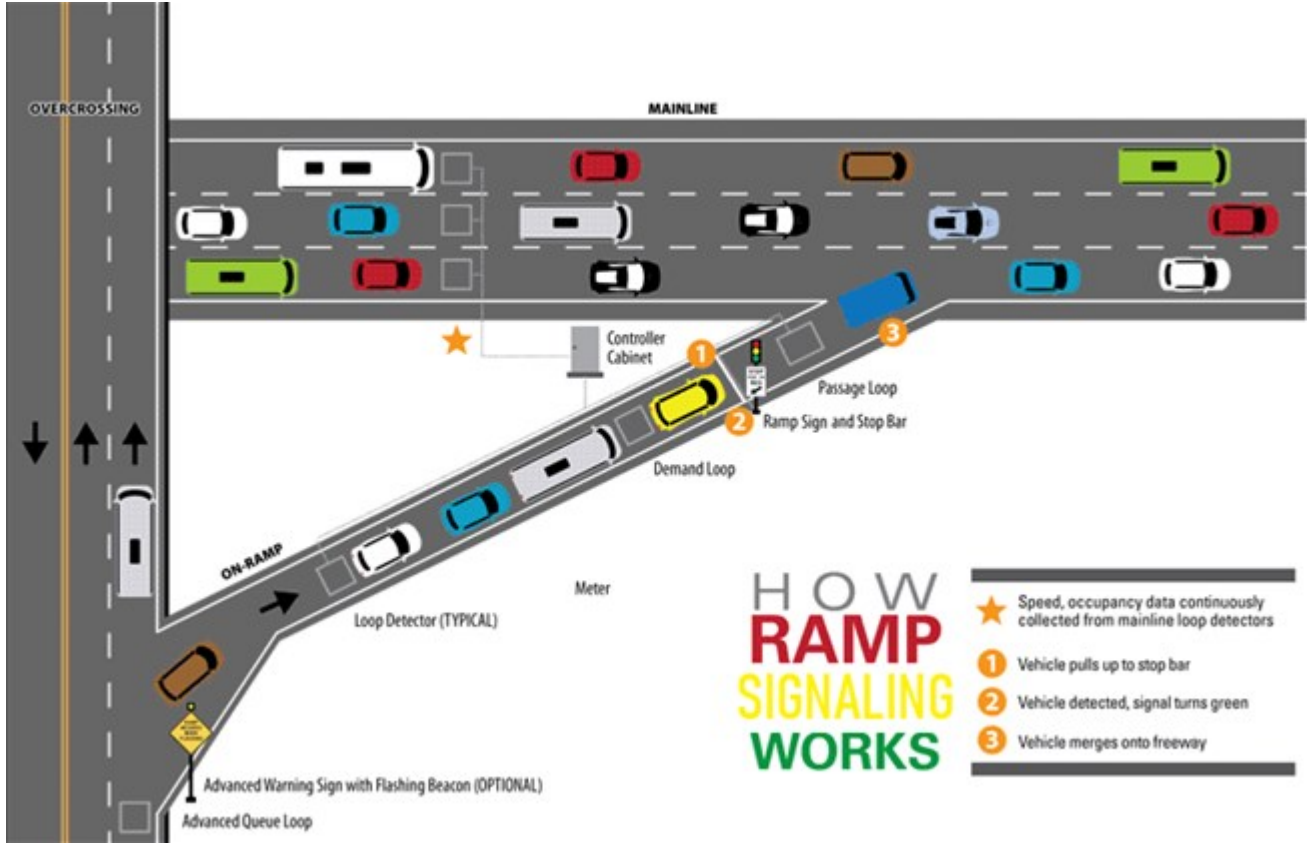
SYSTEMS	SUBSYSTEMS
Traffic control system at interchanges	• Vehicle traffic control system on main road entrances • Priority system for emergency vehicles • Vehicle and pedestrian traffic control system at intersections
Traffic control system on inter-node sections	• Traffic surveillance (CCTV cameras) • Traffic safety management system • Speed control system • Lane control • System for directing to alternative routes
Traffic information system	• Weather condition information system • Traffic condition information system • Information system about P+R (Park and Ride) strategic parking services

Example Accident Detection System



Ramp Metering

https://www.youtube.com/watch?v=SYbceSqk_Mk



GOAL: closing the entrance ramps to these carriageways so that traffic on the main carriageway operates within the optimal range of speed and density (maintaining safe distances between vehicles, which reduces the number of rear-end collisions).

EFFECT: ramp metering enables a reduction of accidents by more than 20%.

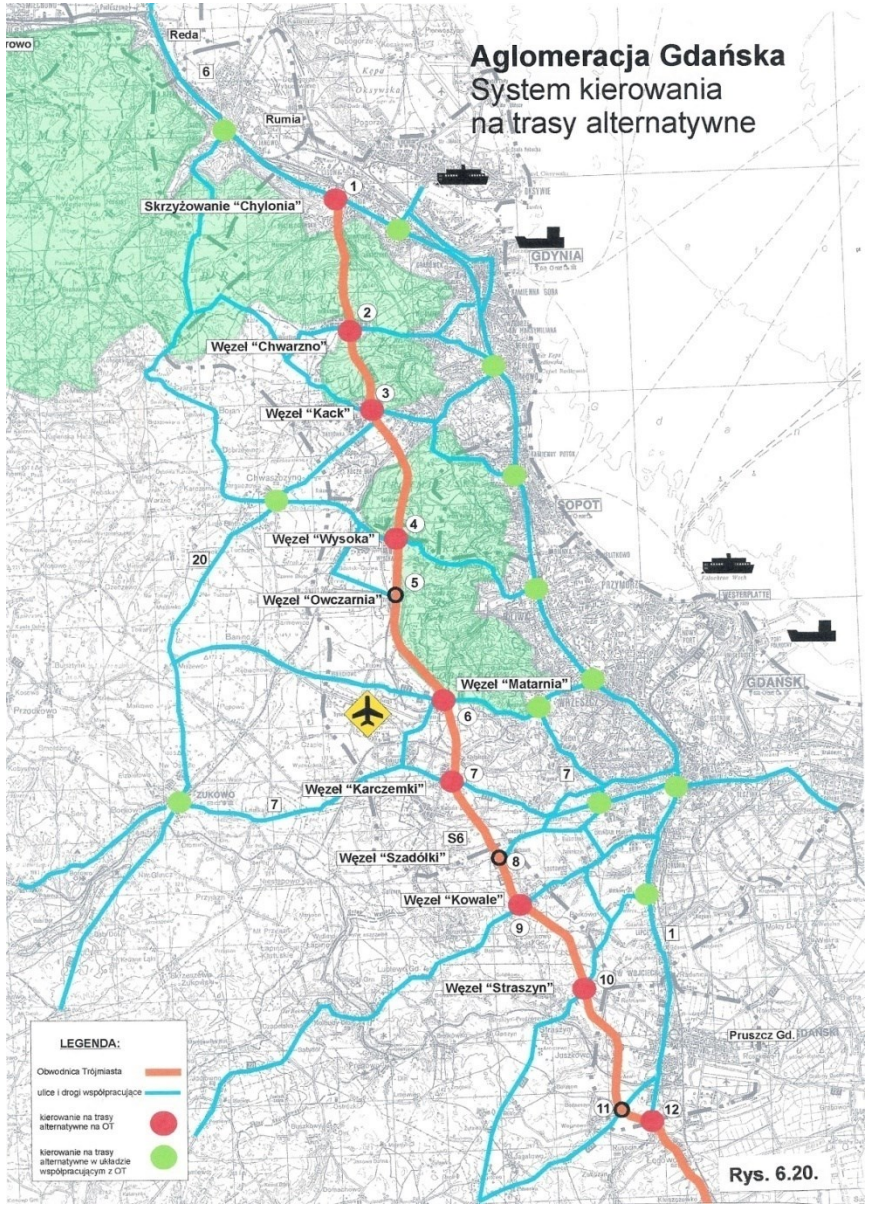
https://www.fdot.gov/traffic/Ramp-Signaling

Traffic management on motorway sections between interchanges

- Accidents and incidents
- Roadworks
- Lane management

Diversion route management system

- The objective of the system is to ensure balanced and full utilization of the entire infrastructure of the area under various traffic conditions (peak hours, weekend departures, emergency situations) – with the necessity of integration with the urban traffic management system.



Speed Control

- Homogenization of traffic flowInfluence on the density–flow relationship: traffic flow is maintained at higher densitiesImproved safety under adverse weather conditions or when approaching an incident

Rys. 3 Znaki zmiennej treści na autostradzie Monachium – Salzburg (Niemcy)

Information System for Drivers

Information on Traffic Conditions

* RDS–TMC – Radio Data System – Traffic Message Channel
** VMS – Variable Message Signs

Congestion
Traffic incidents
Adverse weather conditions
Roadworks
(DETECTION)

Traffic Management Centre

Regional/National Traffic Management Centre

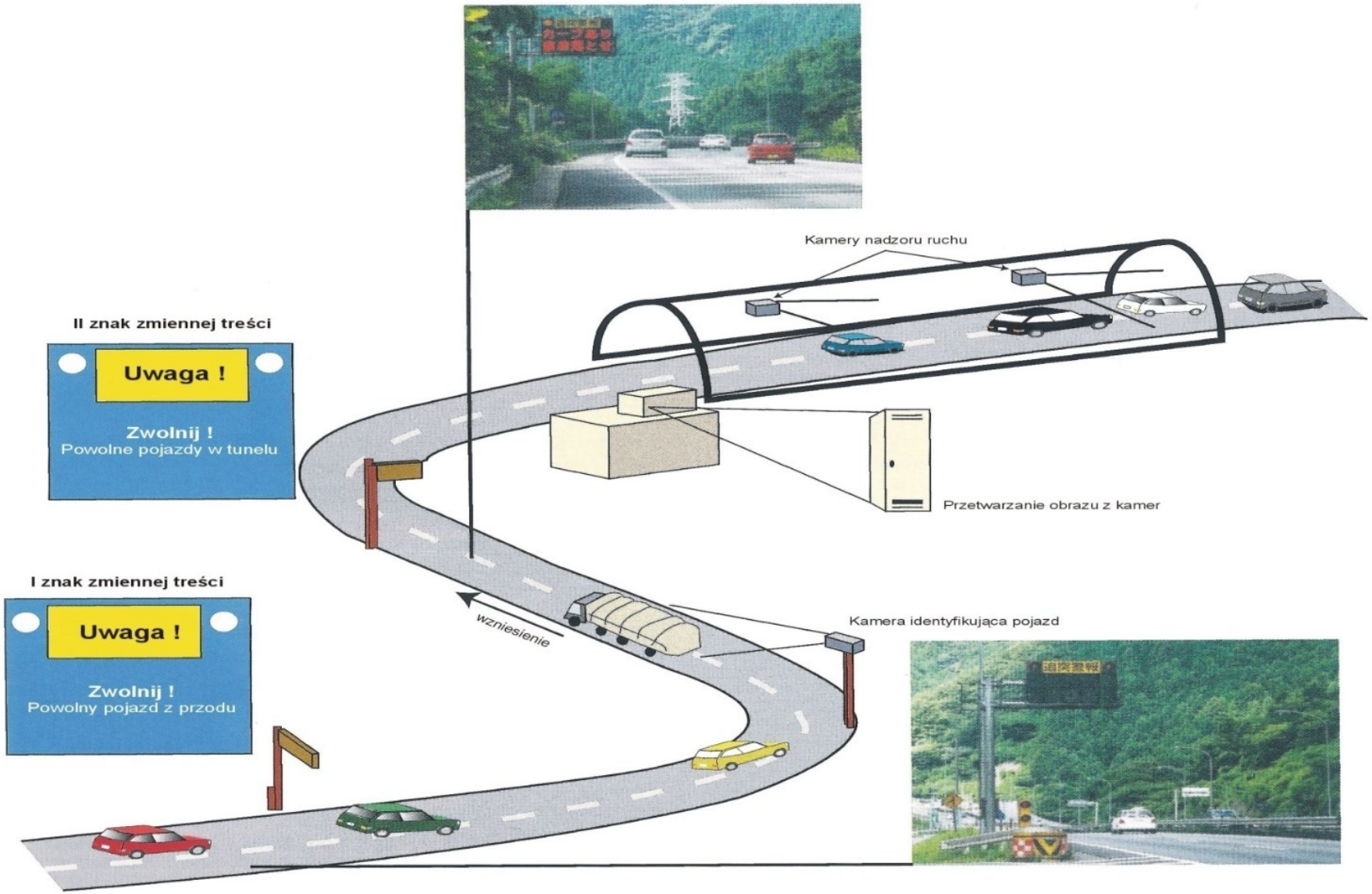
Travel Information (En-route)

Pre-trip information:
- Telephone
- Radio
- Internet

To the vehicle:
- RDS–TMC*
- GSM – mobile phone
- Short-range roadside radio
- Satellite communication

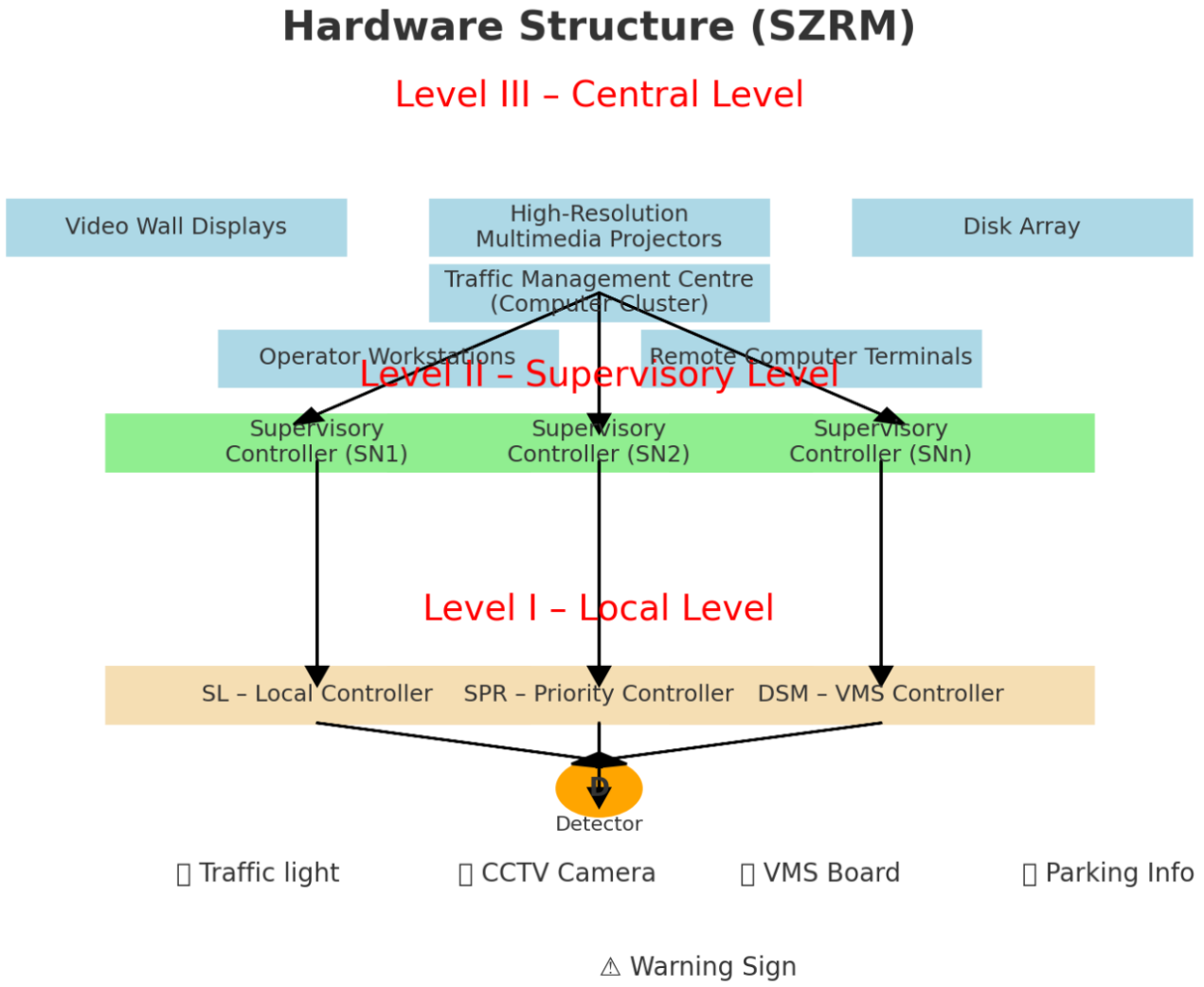
From the road:
- Variable Message Signs (VMS**)

Freight Traffic Control Systems - example



Traffic Management Center

Hardware structure of Traffic Management System



ITS Services – Interurban Systems (Traffic Efficiency)

- Ramp metering – reduction of travel time losses by 36%, traffic volume increase by 6–20% (but in other studies a decrease in traffic volume by 9–14%).
- Variable speed limits – speed reduction achieved for 76% of drivers, traffic volume increase by 3–5%.
- Road surface condition information – reduction of accidents by 39% (under conditions of information being provided).
- Incident management – reduction of incident duration (from emergency response to restoration of normal traffic conditions) by 29–300%.
- Electronic toll collection – reduction of travel time losses by 50–55%, average speed increase by 57%.Intelligent vehicles – reduction of travel time losses by 8%.
- Traveller information systems – increase of average speed by 81% (modelling studies).

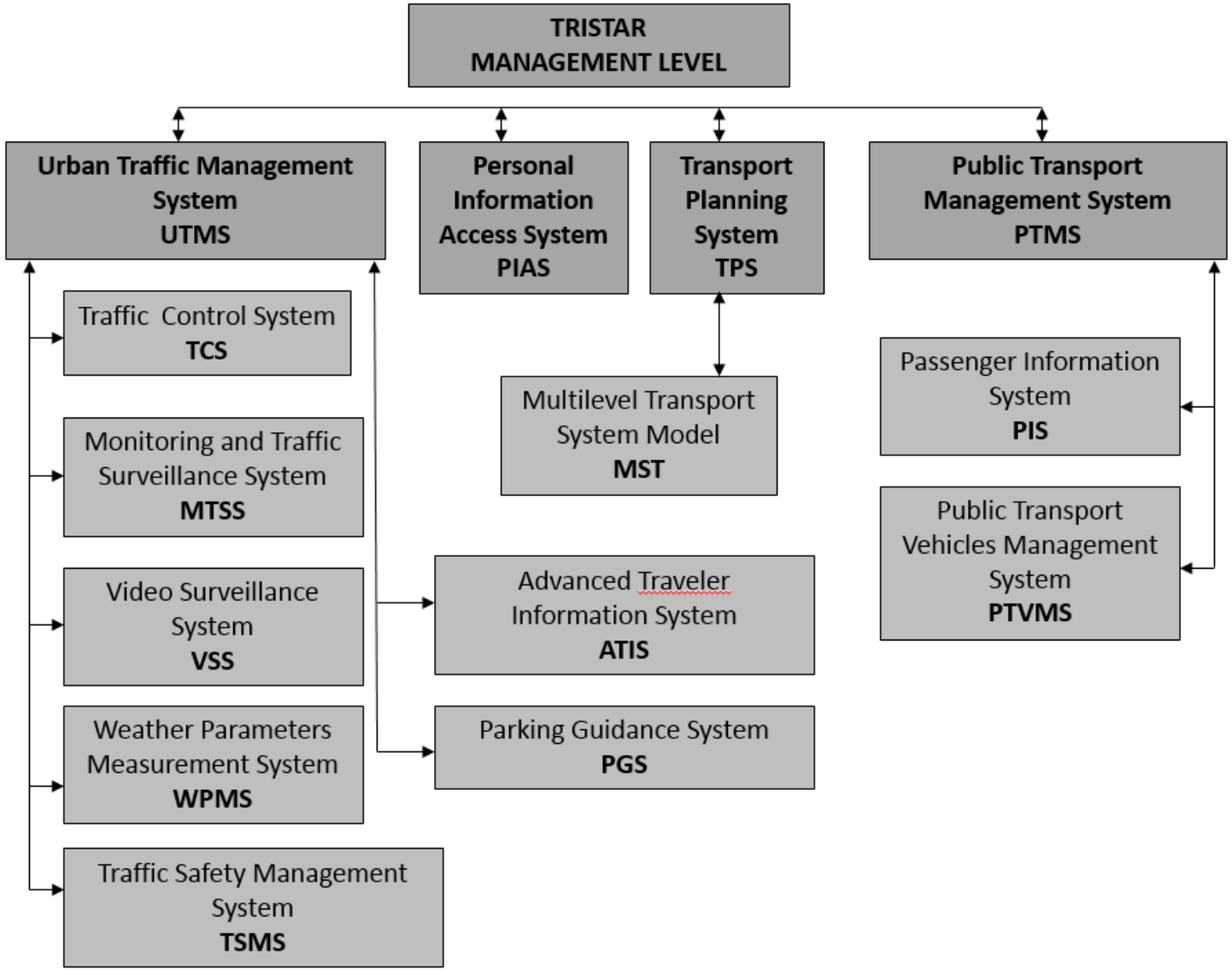
Centralized Priority – Advantages

- Possibility of dispatcher/operator intervention in real time: In a centralized system, the dispatcher or operator can monitor the situation in real time and manually intervene in granting priorities, allowing flexible responses to unusual situations, e.g., significant delays of PT vehicles.
- Automatic route planning for emergency and special vehicles: The centralized system can automatically plan routes for emergency vehicles (e.g., ambulances) or special vehicles (e.g., buses on key lines), granting them priority along the entire route, which increases travel efficiency.
- Ability to prioritize multiple priority requests: In the case of many PT vehicles, the centralized system makes it possible to establish a hierarchy of priorities, e.g., giving precedence to more delayed vehicles or to routes of greater importance, optimizing traffic across the entire area.
- Adaptability – automatic adjustment of priority to current traffic conditions: The centralized system can dynamically adjust priorities based on current traffic data (e.g., volumes, delays), enabling more effective traffic management in real time.
- Possibility of advance priority implementation at subsequent intersections: Thanks to centralized management, the system can prepare priorities in advance at consecutive intersections along the PT vehicle route, ensuring smoother travel and minimizing delays.

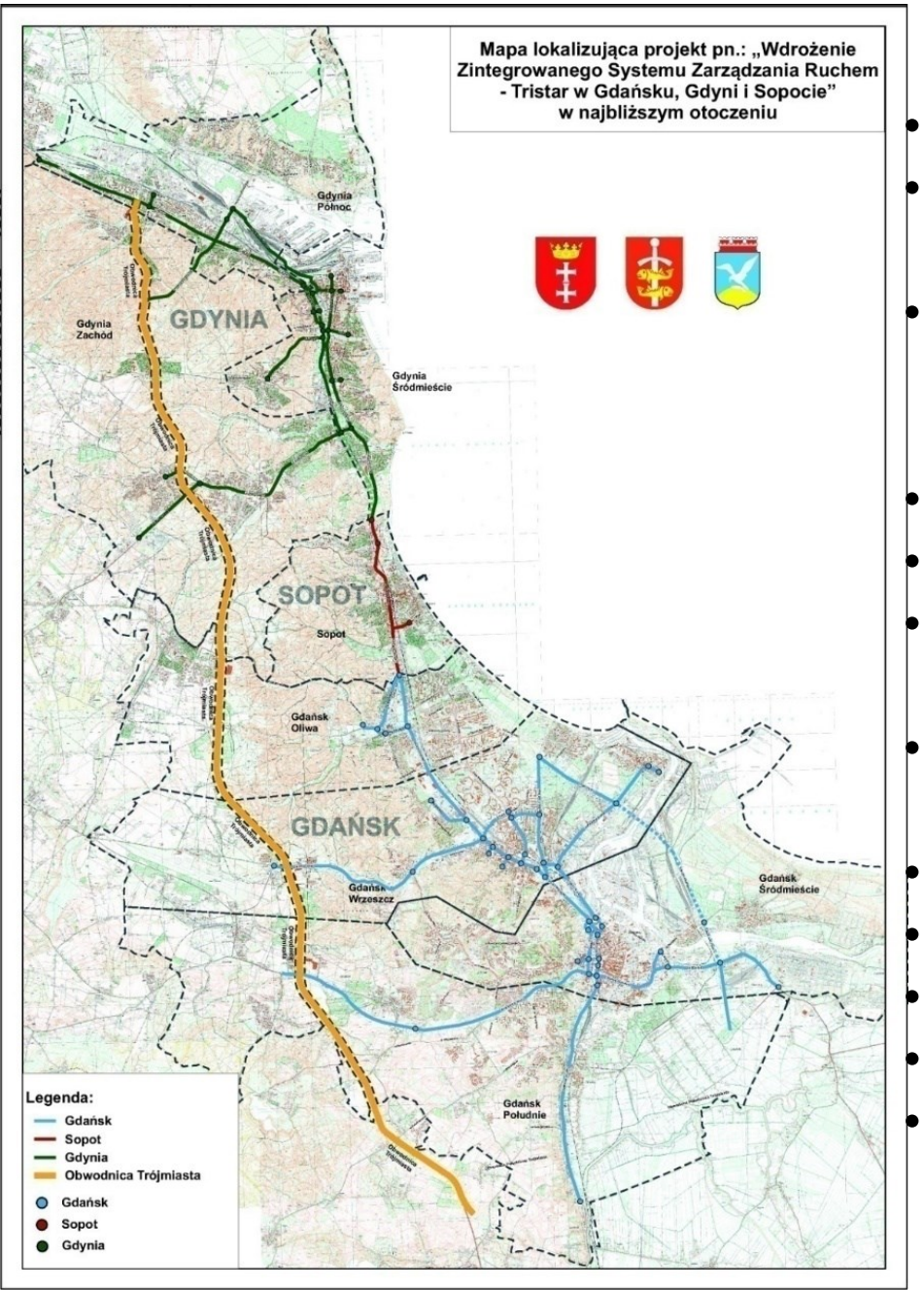
Rural/Interurban Systems (Traffic Safety)

- Ramp metering – reduction of accidents by 24–50%.
- Variable speed limits – speed reduction achieved for 76% of drivers, reduction of hazardous events by 10–30%, reduction of accident severity by 30%.
- Road surface condition information – reduction of accidents by 39% (under conditions of information being provided).
- Incident management – reduction of incident duration by 29–300%, reduction of secondary incidents (bundle of services).
- Electronic toll collection – reduction of hazardous events by 22–26%.
- Intelligent vehicles – reduction of accident involvement risk by 41%; automatic incident detection increases survival probability by 15%.
- Traveller information systems – reduction of fatalities by 3% (modelling studies).Automatic speed enforcement – reduction of accidents by 9–60%.

Urban ITS – example: TRISTAR system Architecture

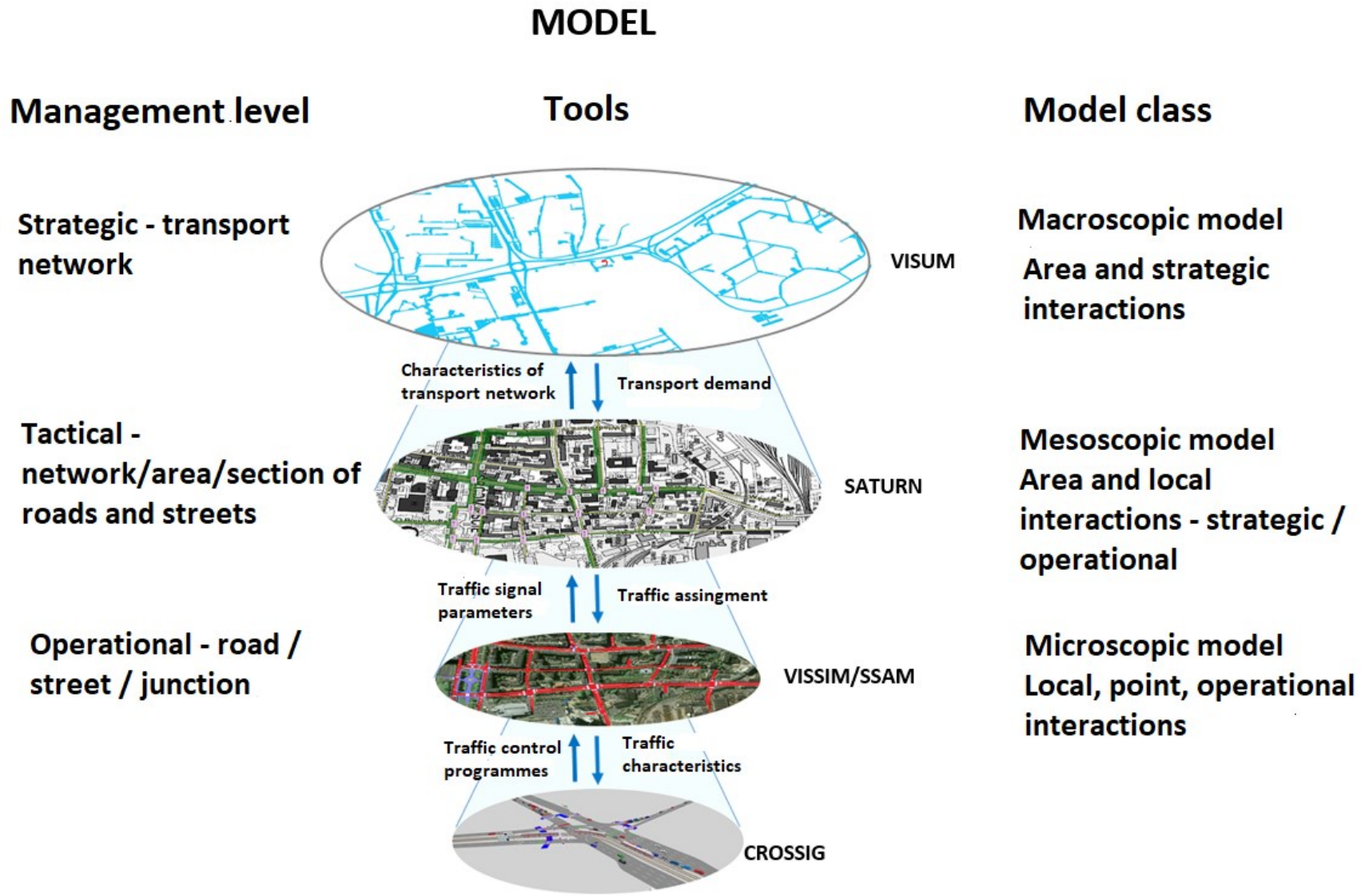


TRISTAR SYSTEM IN TRI-CITY (Gdańsk-Sopot-Gdynia)



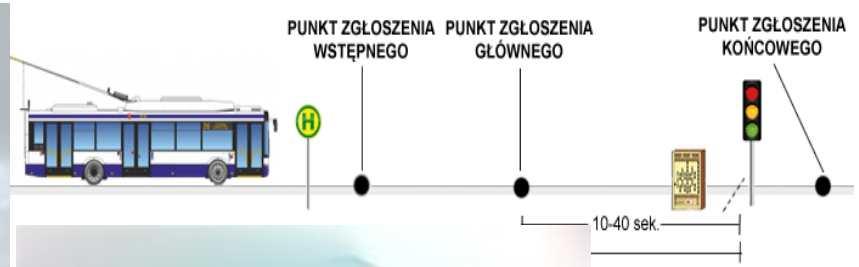
- 2 Traffic Management Centres
- 148 km of fiber optic connections
- 161 intersections with traffic signals (BALANCE/EPICS system)
- 73 video surveillance cameras
- 61 points with ANPR cameras
- 36 guidance parking information signs
- 34 PT passenger Information boards
- 22 Bluetooth/WiFi scanners
- 19 Variable Message Boards
- 16 Tripplanners
- 14 Weather stations
- 7 Variable Message Signs

Multi-level Model of Transportation Systems supports ITS Management



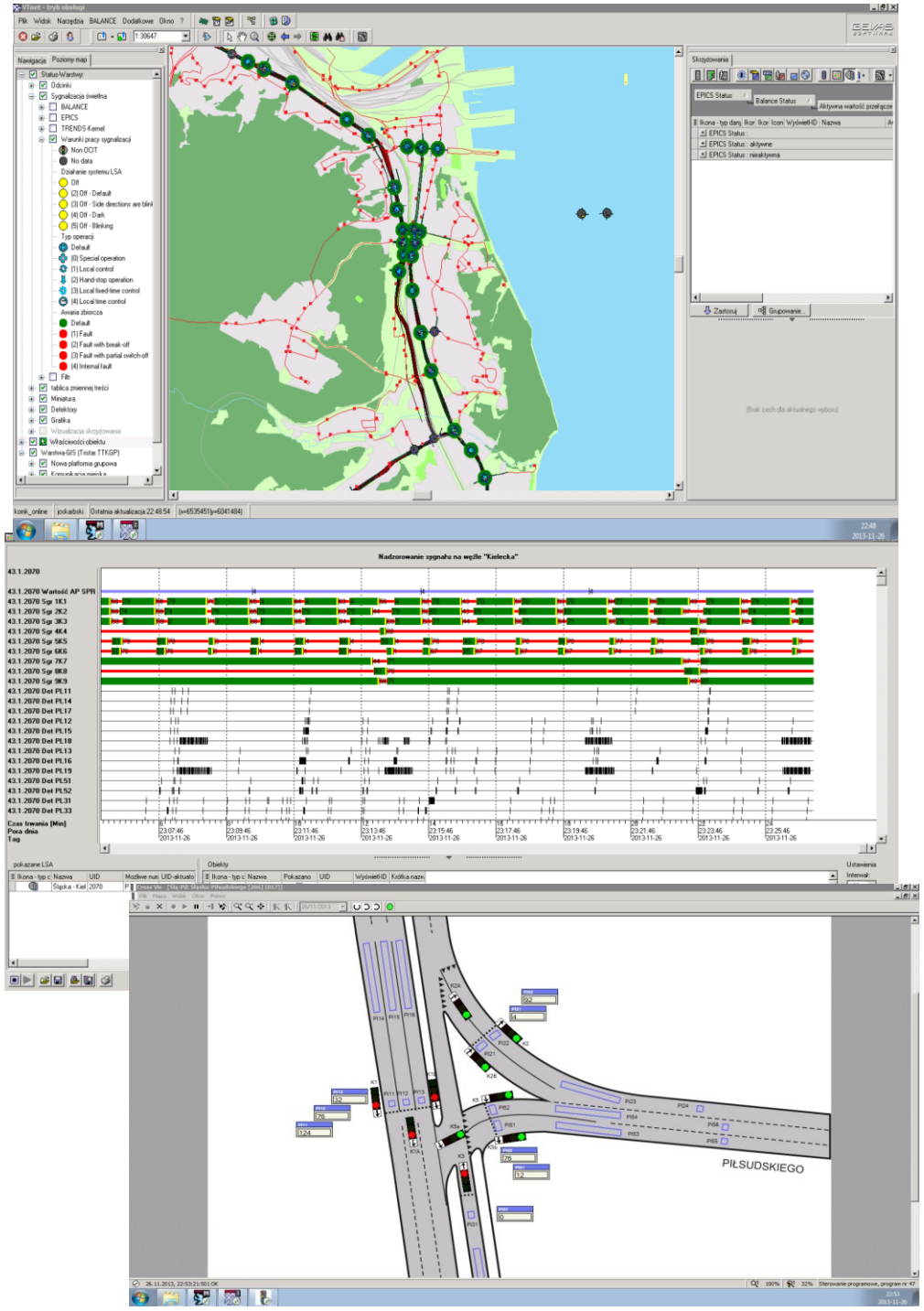
Monitoring and Traffic Surveillance System

- Road Traffic Data Collection
- Example detection modules in the TRISTAR system:
- Traffic measurement stations – 161 intersections – inductive loops
- Inductive loops and video detection – Traffic Control System
- Bluetooth/Wi-Fi scanners and ANPR cameras – Incident Detection Module (Traffic Safety Management System) and Driver Information System
- Public transport vehicles (on-board computers) – Public Transport Vehicle Management System
- Meteorological parameters – Weather stations



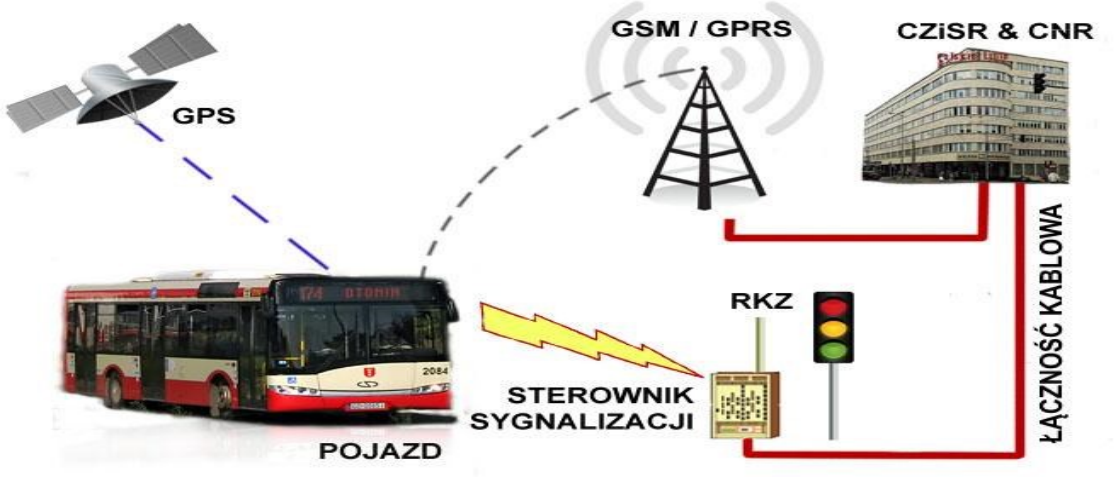
Traffic Control System

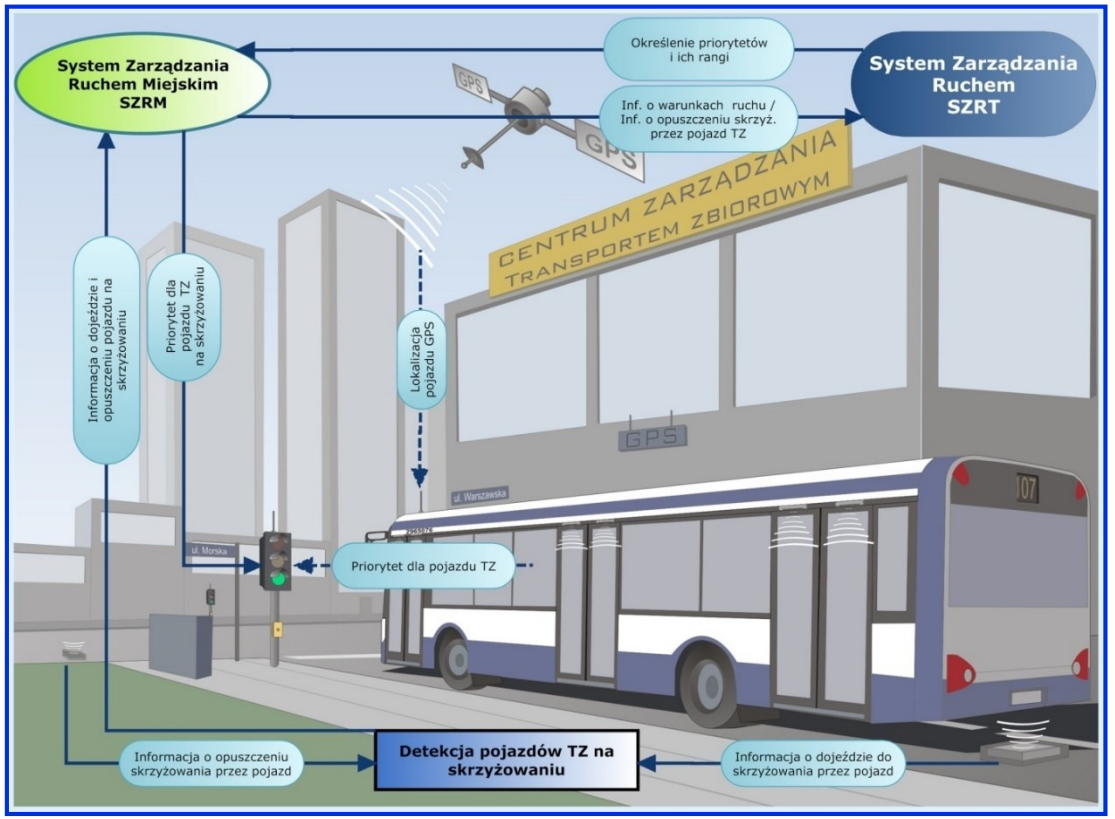
- Over 160 intersections covered by the system
- Replacement of outdated traffic signal equipment (LED upgrade)
- BALANCE-EPICS Traffic Control System (GEVAS) – local control with public transport priority and area-wide control.
- EPICS – microscopic optimization (1-minute forecasts – possibility to extend a phase during the current cycle).
- BALANCE – macroscopic optimization (objective function) – short-term forecasts of 5–15 minutes.

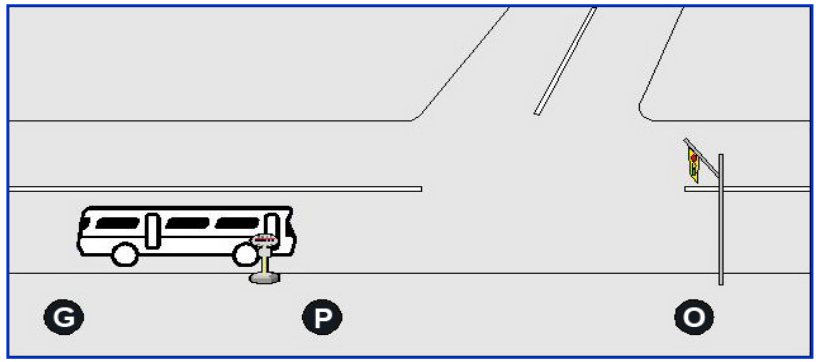


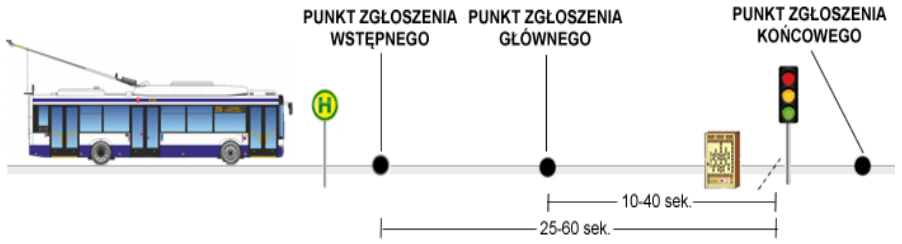
Public Transport Signal Priority (TSP)

- Relative Priority:
- Public transport vehicles delayed in relation to the timetable
- Absolute Priority:
- Ambulances, fire brigades, police (in the future)

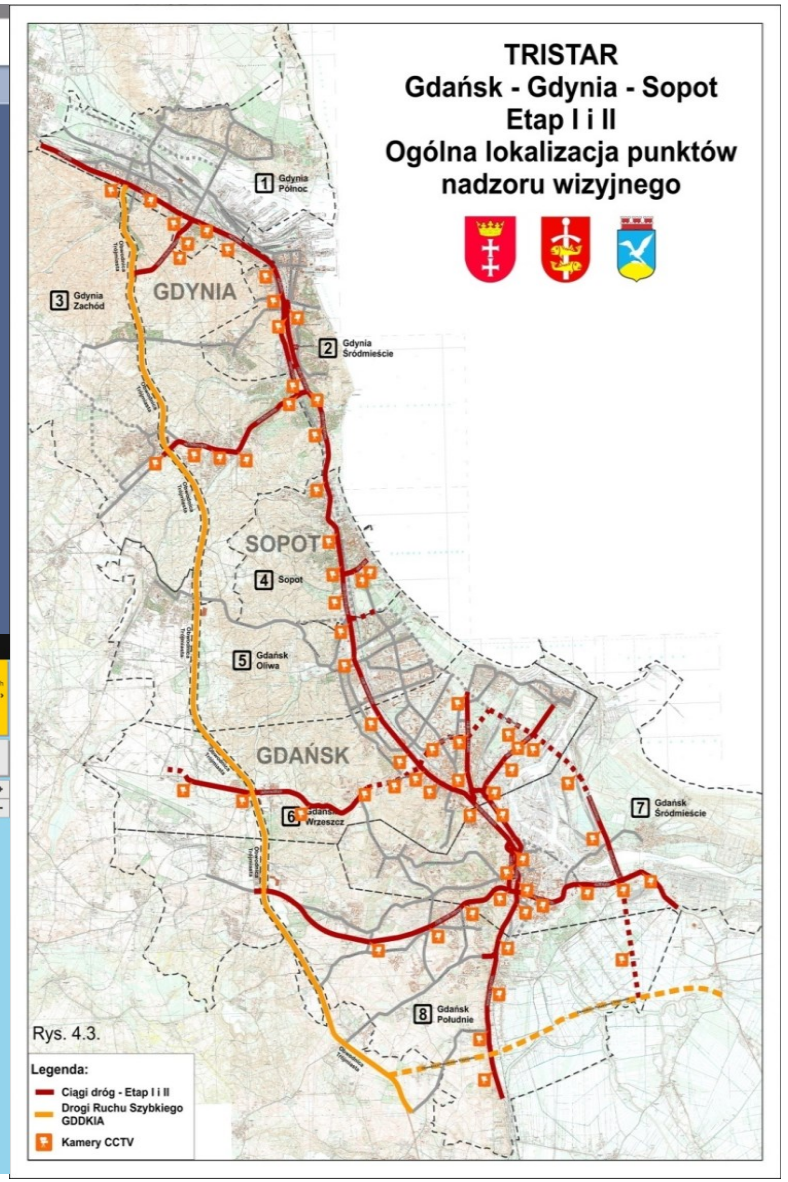




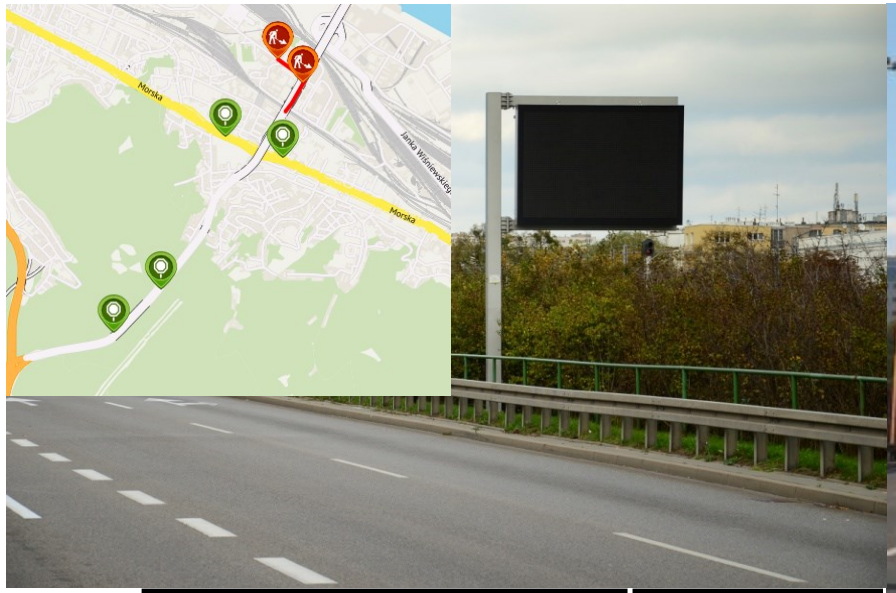


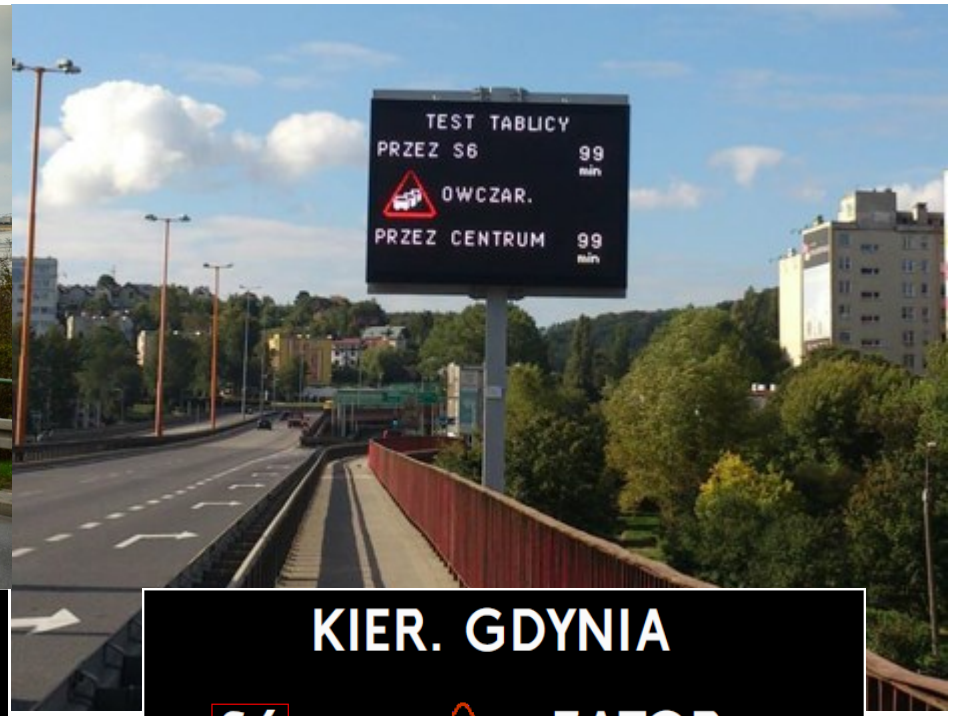


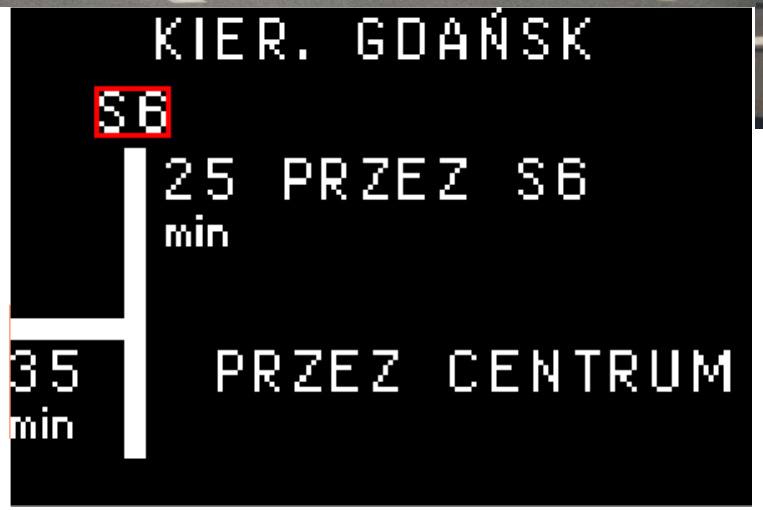
Video Surveillance System



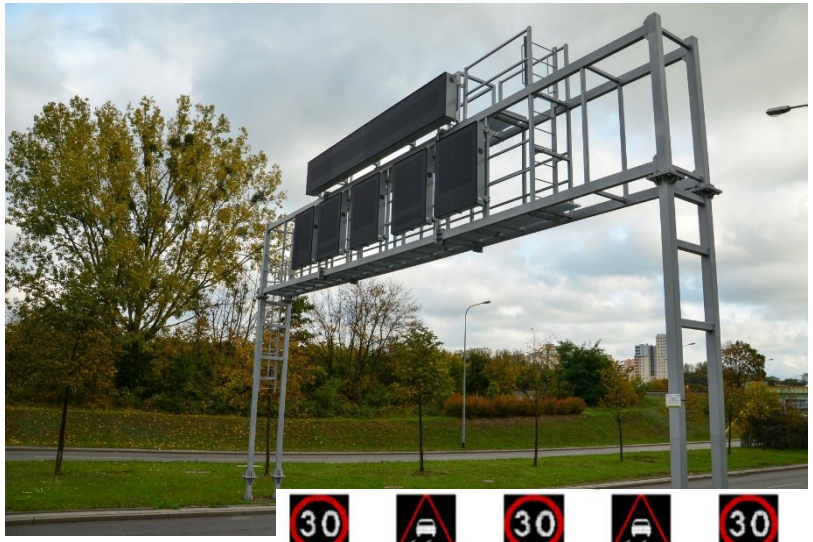
Advanced Traveller Information System

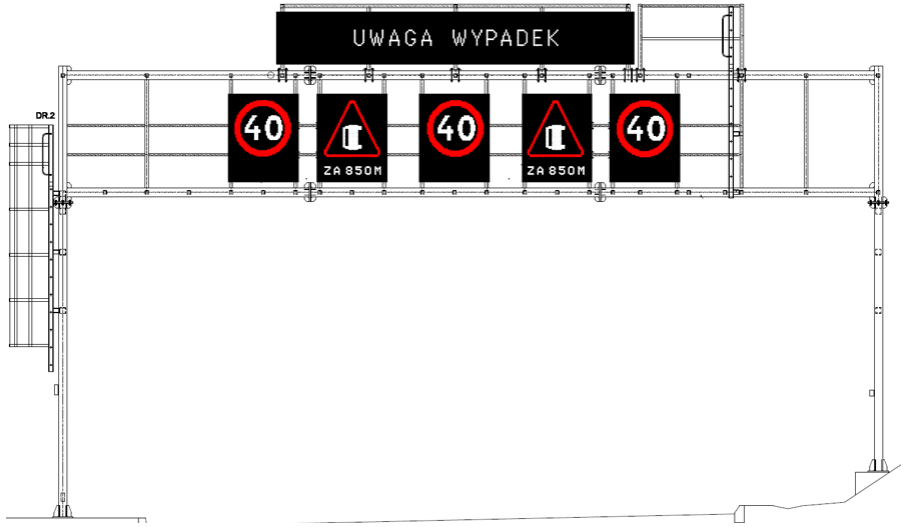


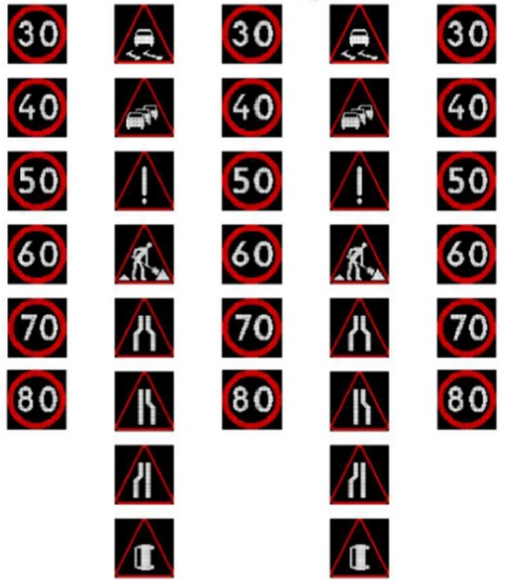




Advanced Traveller Information System

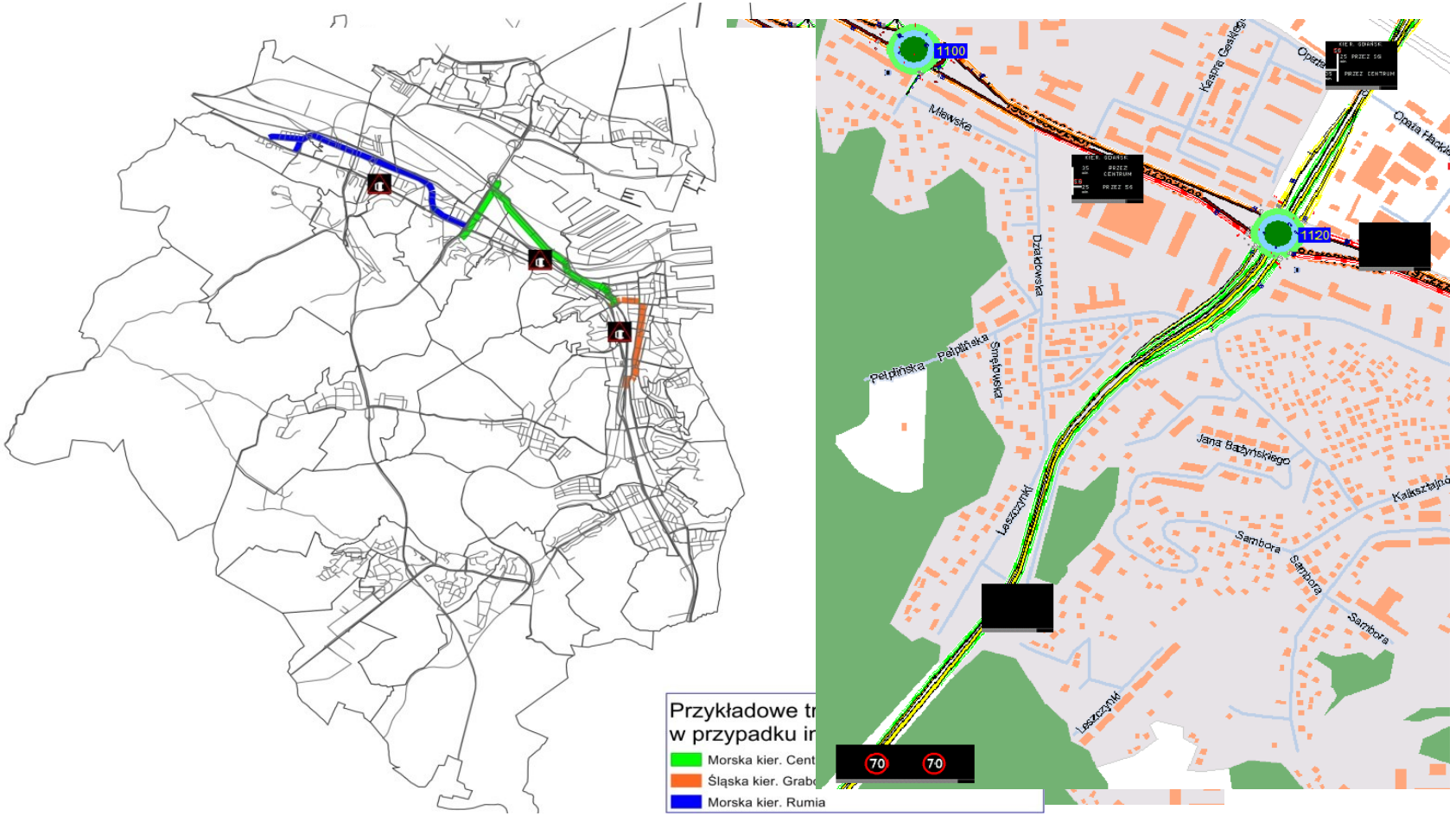






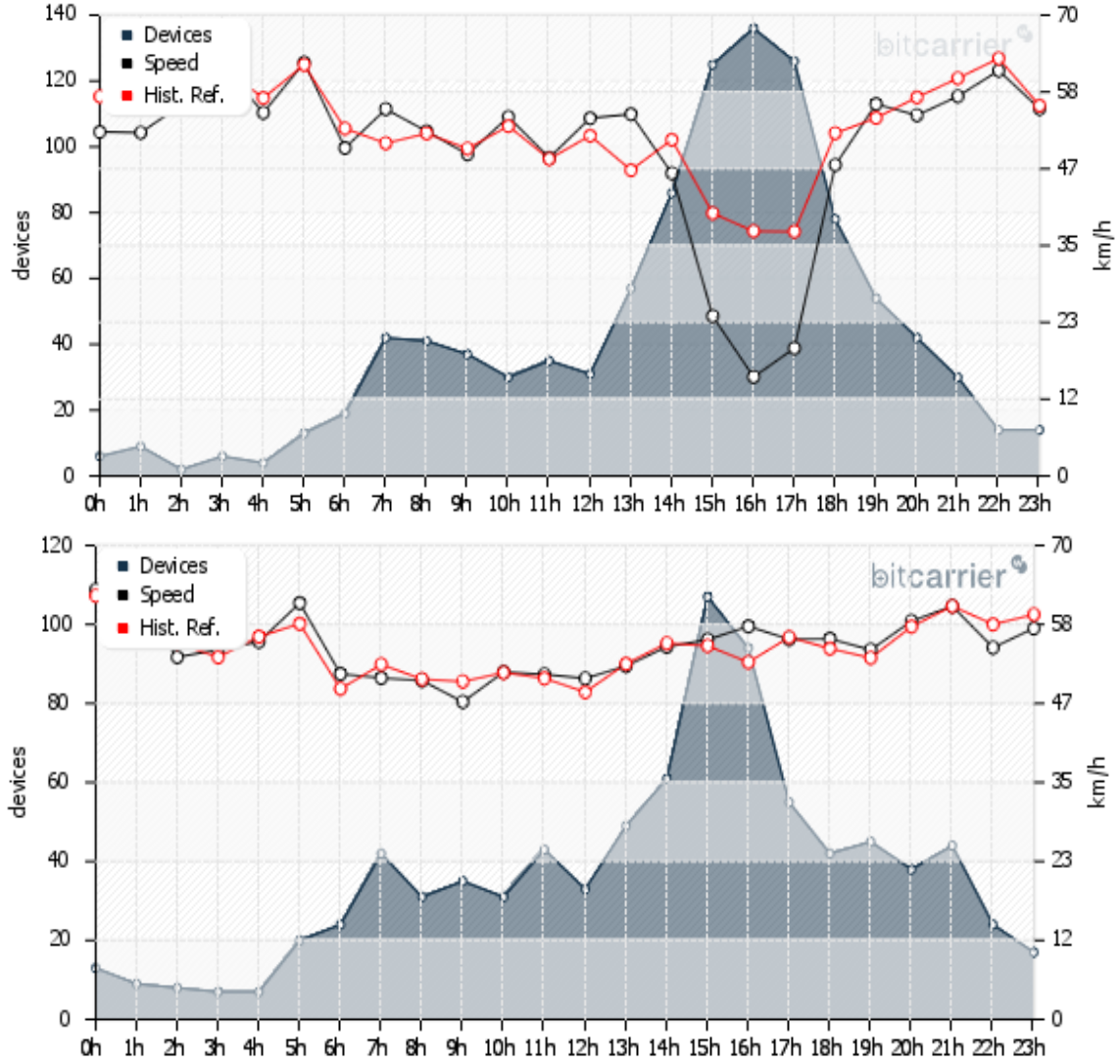
Advanced Traveller Information System

- Alternative routes
- Traffic diversion in case of an incident
- Traffic dispersion in case of congestion

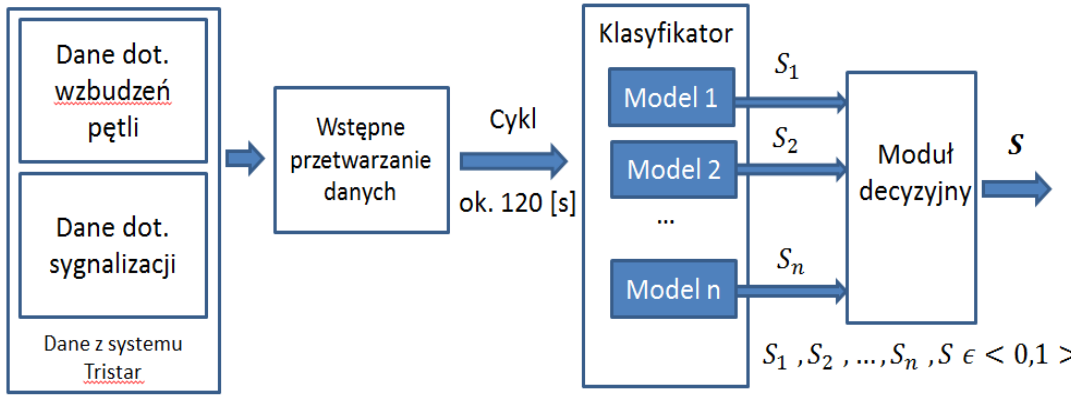


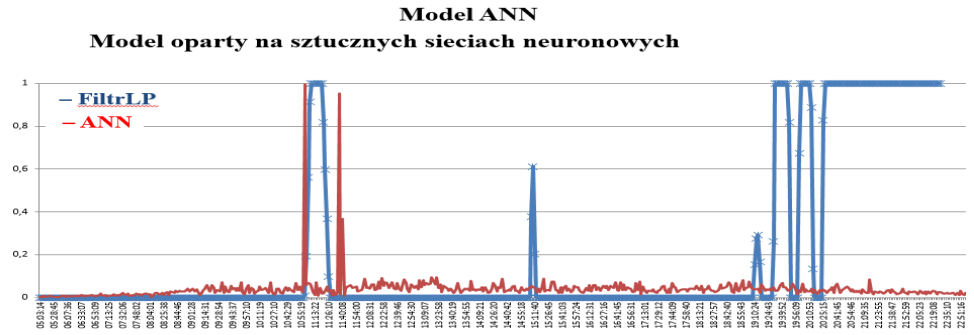
Advanced Traveller Information System

- Example of accident detection – incident detection module – pilot
- Real-time data – historical data
- Kwiatkowski Route – Gdynia
- Algorithm based on Kalman filter



Incident Detection at Intersections

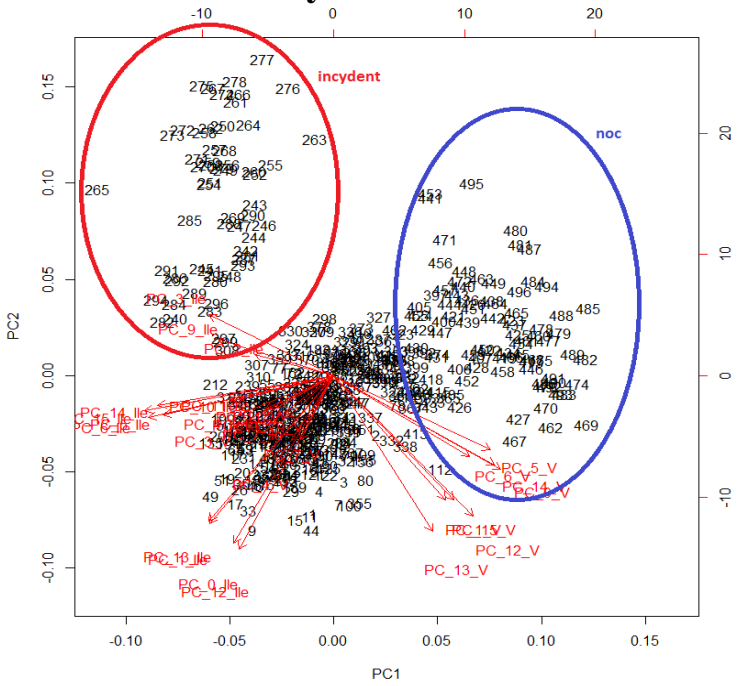




Progi przyjęte w zbiorze uczącym

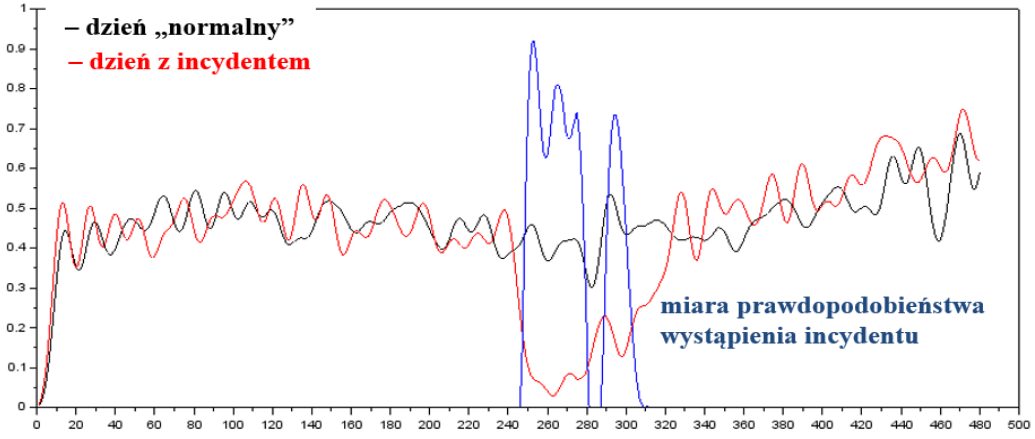
$$Y = \begin{cases} 0 & ruch\ normalny \\ 0.3 & kolejka \\ 0.5 & blokowanie \\ 1 & incydent \end{cases}$$

Multidimensional Cycles – PCA-based Analysis



Model FiltrLP

Szereg czasowy PK_0_V (trend)

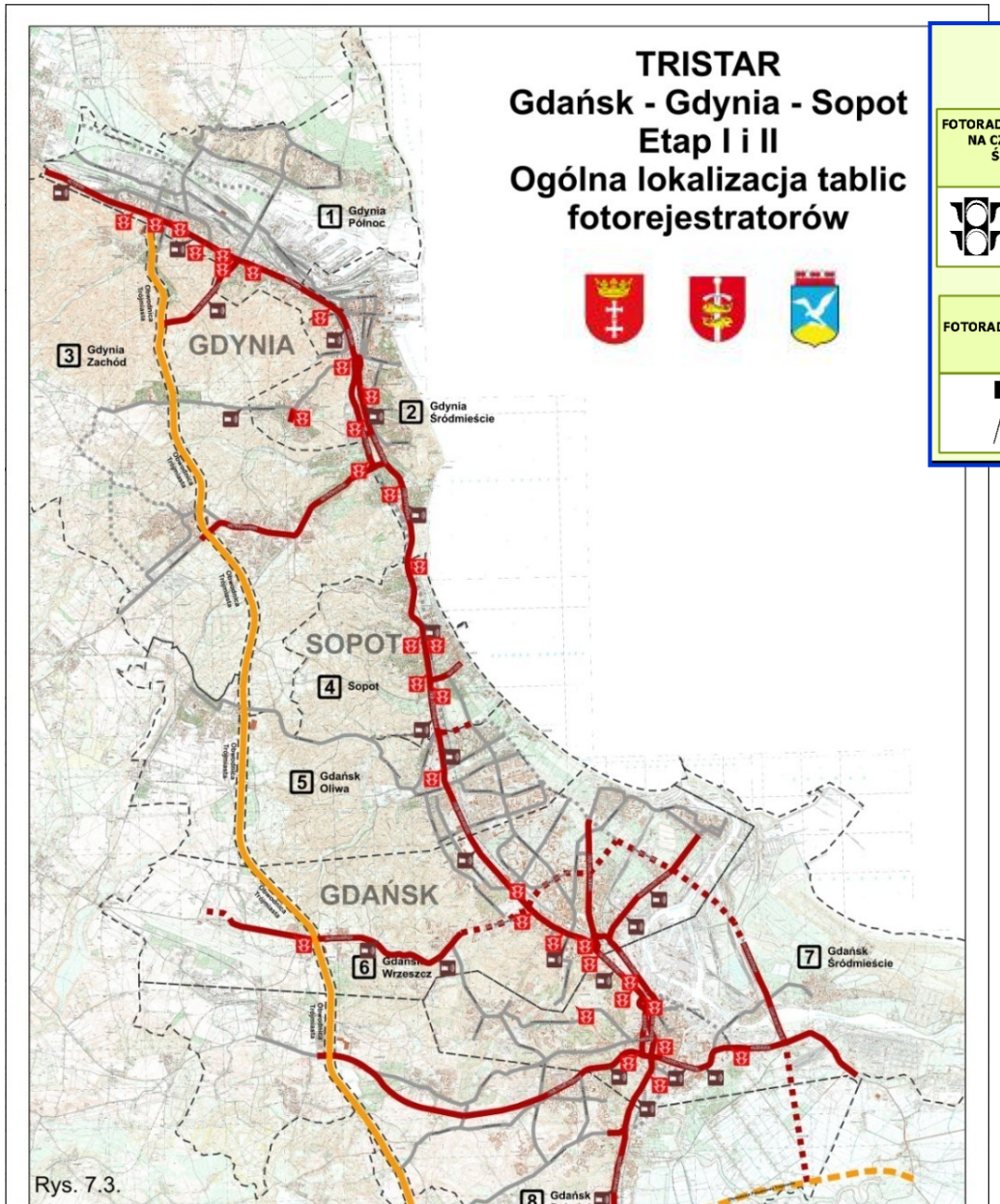


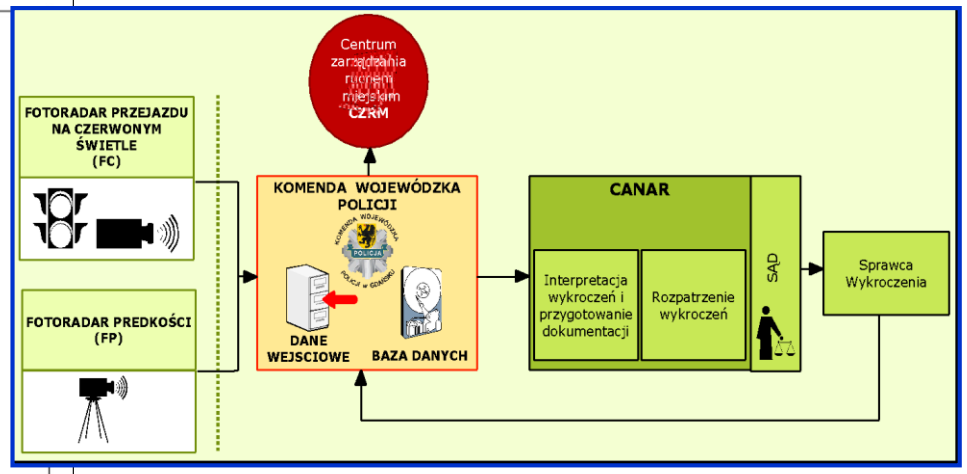
$$S = \begin{cases} 0 & jeżeli\ T_n - T_b \le \Delta_1 \\ \dfrac{T_n - T_b - \Delta_1}{\Delta_2 - \Delta_1} & jeżeli\ \Delta_2 > T_n - T_b > \Delta_1 \\ 1 & jeżeli\ T_n - T_b \ge \Delta_2 \end{cases}$$

CiViTAS
Cleaner and better transport in cities
DYN@MO

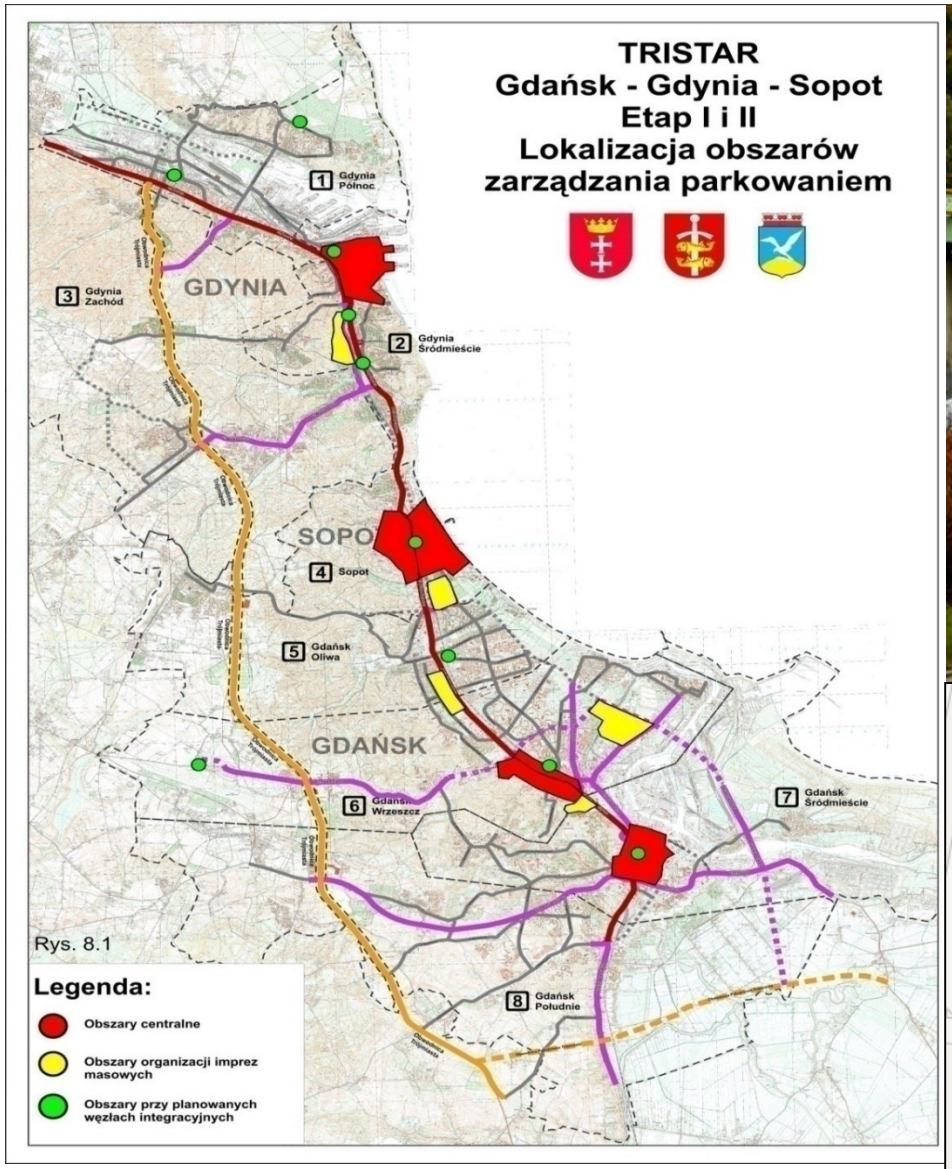
Traffic Violation Enforcement System

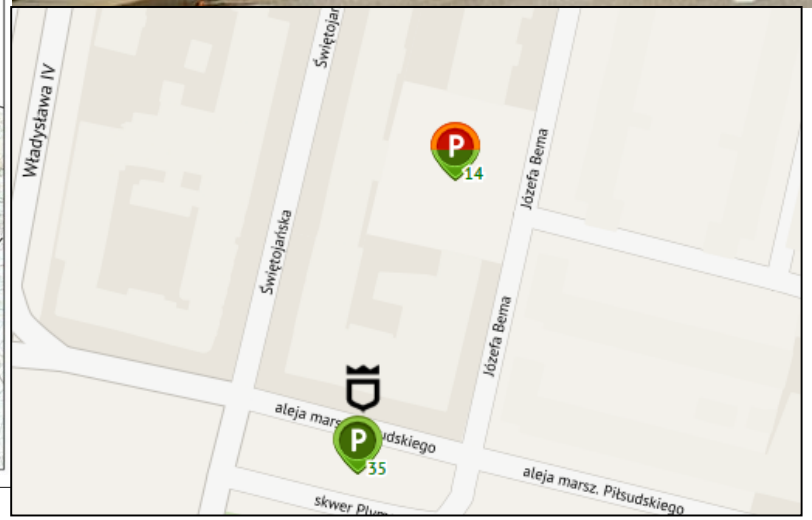
- ANPR Cameras
- “Black list”, “white list”
- Travel time information (short-term forecasts in the future)
- Violation registration (in the future)

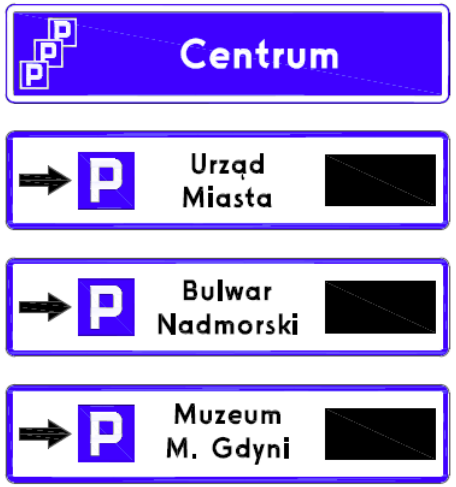




Parking Guidance System

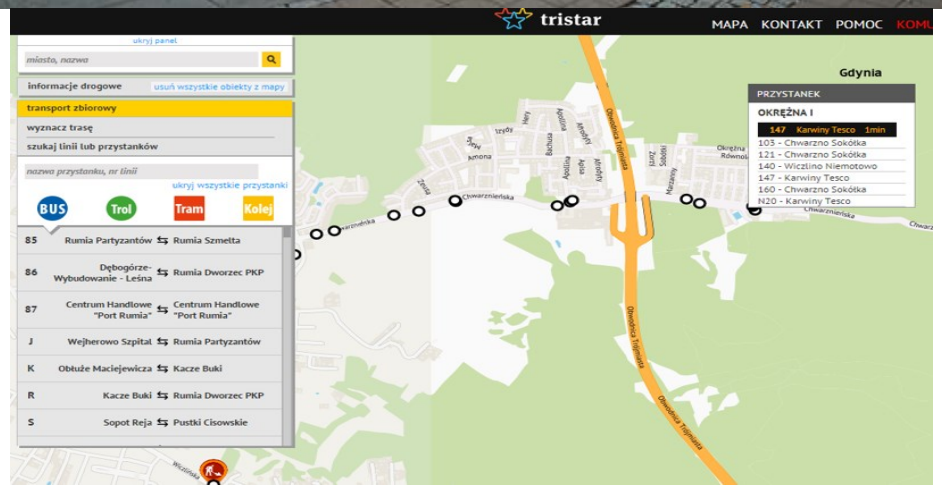






Passenger Information System

- Online information
- Online trip planning (web, trip planners)
- 745 public transport vehicles equipped with on-board computers with GPS, GPRS, and short-range radio.
- Passenger information displays (73 units)
- Website
- Passenger information terminals (22 units at integration hubs and other facilities)

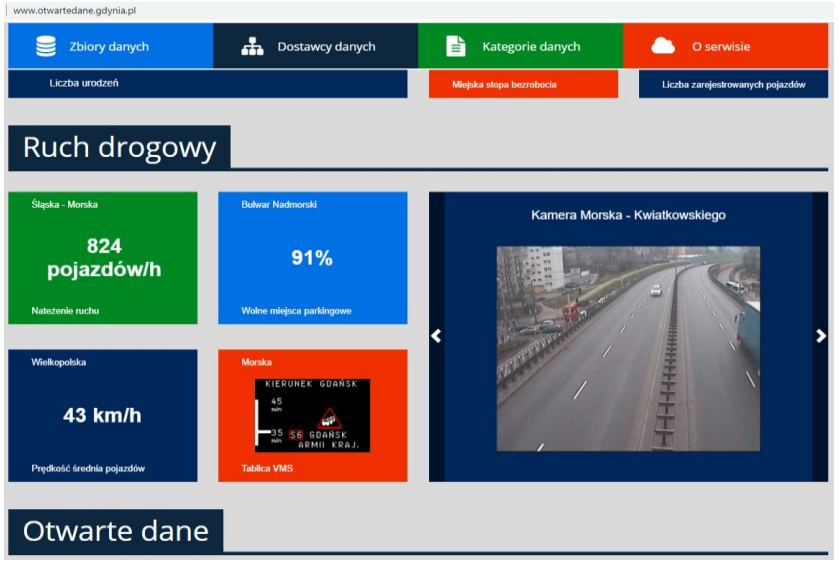


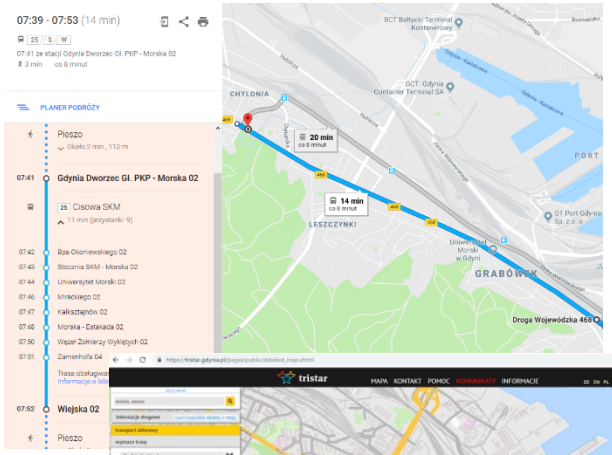
PT vehicles Management System

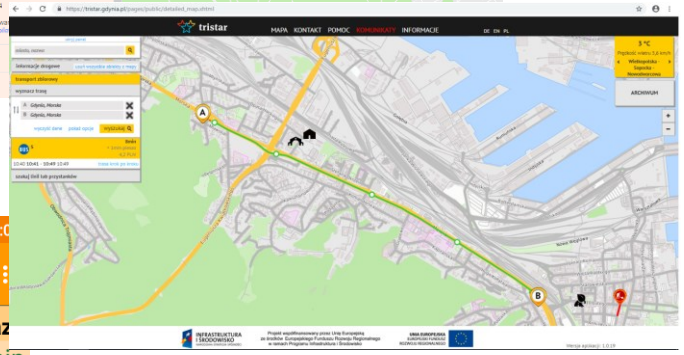
- Dispatch traffic management
- Schedule control
- Detour planning
- Online visualization on the metropolitan map
- Communication with drivers

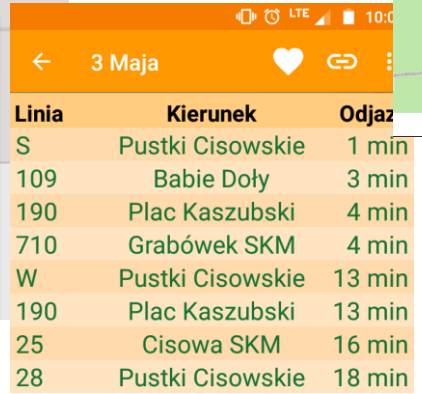
Source: QUMAK, GMV

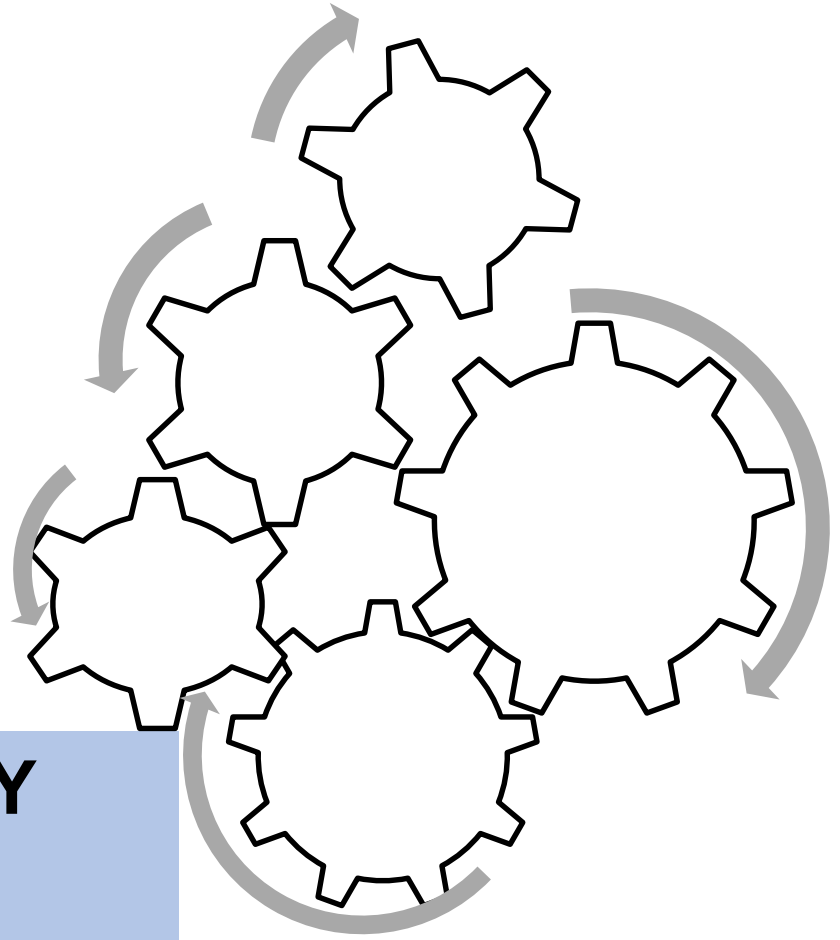
Open Data











SMART CITY
MaaS
TMaaS

Benefits Of System Implementation

- Possibility of real-time traffic management
- Reduction of travel time for both private vehicles and public transport – decrease in travel time along individual corridors by several to more than ten percent
- Improved traffic flow, reduction in the number of stops, reduction in exhaust emissions (thanks to the Traffic Control System and the Driver Information System)
- Reduction in the number of road incidents and faster clearance of congestion after an incident (thanks to warning systems, red-light enforcement, speed control, and the Driver Information System)
- Enhancement of the passenger information system for public transport users (real-time trip planning)Increased reliability of passenger waiting times
- Lower costs and shorter time required for reprogramming traffic signals

Benefits Of System Implementation

- Increased punctuality and reliability of public transport, improved attractiveness – higher competitiveness of public transport (greater number of passengers)
- Increased scheduled speed (data for timetable planning) – more efficient use of rolling stock – reduced costs
- Real-time monitoring of equipment operation and condition