Functional Configuration of ITS for Urban Agglomeration

Grzegorz Karoń[1(✉)] and Jerzy Mikulski[2]

[1] Silesian University of Technology, Akademicka 2A, 44-100 Gliwice, Poland
grzegorz.karon@polsl.pl
[2] Katowice School of Technology, Rolna 43, 40-001 Katowice, Poland
mikulski.jurek@gmail.com

Abstract. This article presents selected problems design of intelligent transportation systems (ITS) in aspect of functional and technical configuration of ITS. The configuration of ITS system may includes several subsystems described taking into account following aspects and components: main objectives, specific objectives, functionalities, integration with external systems, main installations and technical components, technical components location. The structure of an example ITS configuration based on ITS for urban agglomeration – case study for ITS KZK GOP (in Poland) – has been presented.

Keywords: Intelligent transportation systems (ITS) · Configuration of ITS · Urban agglomeration · ITS stakeholders aspirations · Aspirations-implementations matrix of ITS

1 Introduction

The variety of technical and functional solutions of ITS systems can include taking in the description of the system the functional and operational configuration of ITS which constitute a properly designed and cooperating structures [1, 2, 4, 6, 9, 14–16, 20]: logical architecture (functional) and physical architecture. The configuration of ITS system, in high-level design of systems engineering [18, 19], can be described taking into account the following aspects and components [2]:

- stakeholders aspirations,
- user needs,
- included transport modes,
- ITS architecture, taking into account:
  - ITS users,
  - ITS services,
  - ITS data storages,
  - ITS functions, taking into account: allocation of functions, decomposition of functions, synthesis of functions,
  - ITS data flows diagrams, taking into account following processes: functional processes, physical processes, communication processes, organizational processes,

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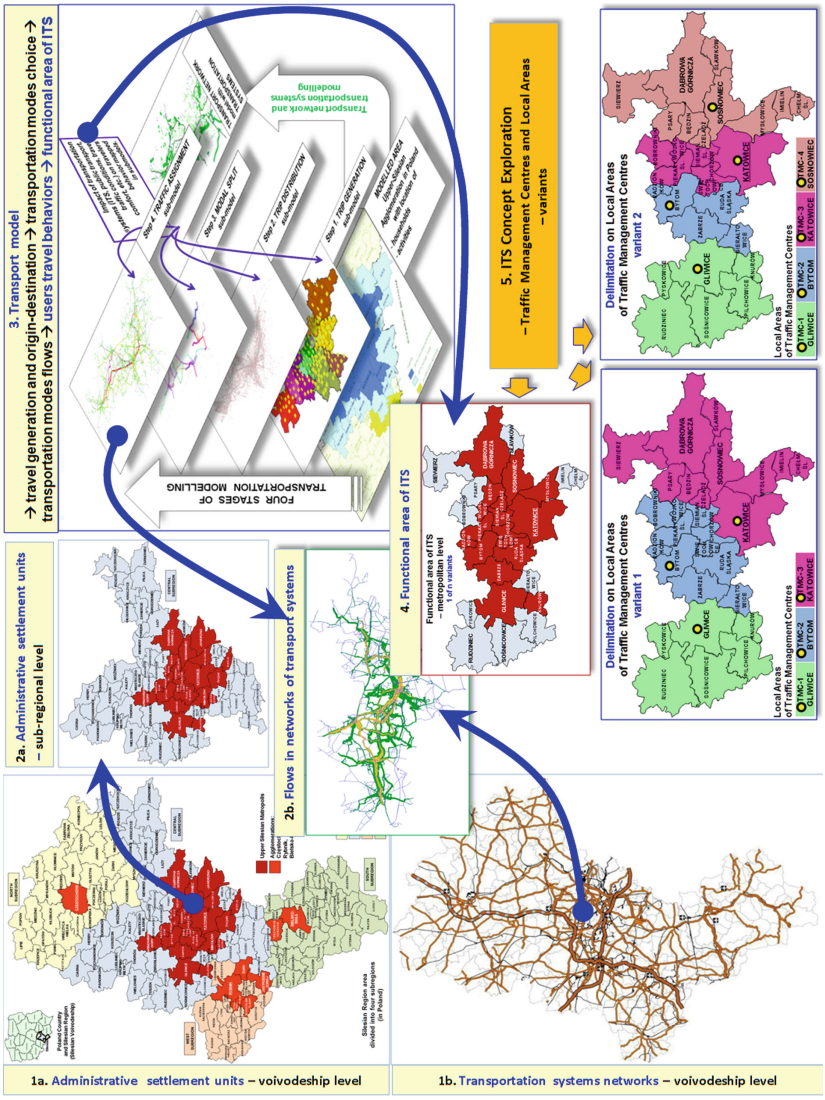

Fig. 1. Traffic Management Centres TMCs– concept exploration with use of transport model; result is in two variants of delimitation on local area: variant 1 – three TMCs, variant 2 – four TMCs. (own study based on [7, 12, 13, 17]).

- ITS viewpoints, taking into account the following views: functional, physical, communication, organizational,
- component specifications,
- ITS standards,
- communication requirements,
- organizational issues.

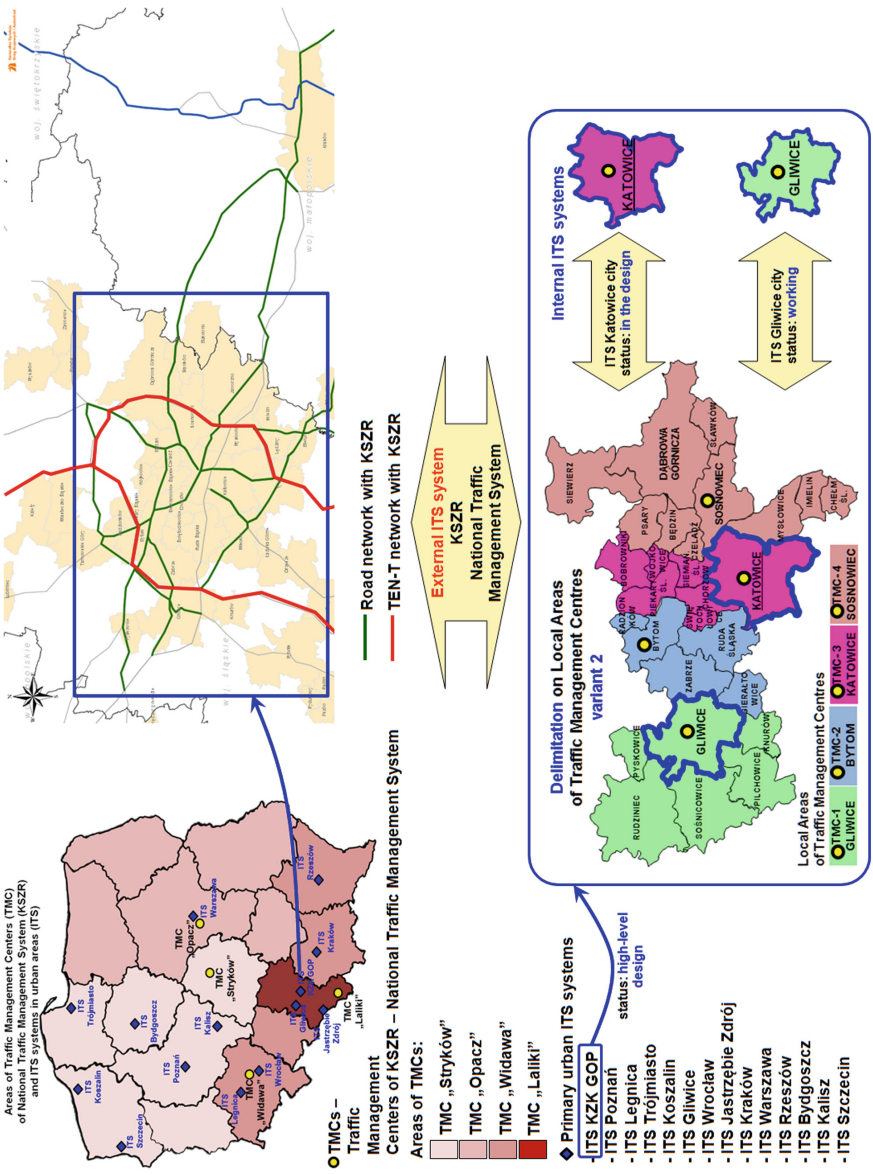

Fig. 2. External and internal ITS systems for urban agglomeration – ITS KZK GOP (own study based on [7, 10, 11, 17]).

In this paper, the system configuration has been presented, taking into account the following aspects and components of ITS system (see Sect. 2):

– main objectives,
– specific objectives,

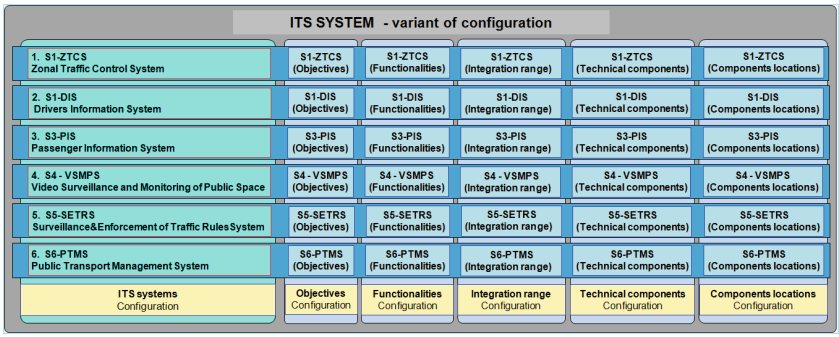

Fig. 3. ITS system configuration – fields of configurations – example for urban agglomeration ITS KZK GOP (own study based on [8]).

- functionalities,
- integration with external systems,
- main installations and technical components,
- technical components location.

Detailed description of above aspects has been presented in following part of article. Decsription is based on case study "ITS KZK GOP" for Upper Silesian agglomeration i Poland (see Fig. 1 for variants of Traffic Management Centers (TMCs), and Fig. 2 for external and internal ITS systems for ITS KZK GOP) [3, 5, 7, 8]. The result of the concept for this case are following ITS subsystems [7, 8, 17]:

- Zonal Traffic Control System (S1-ZTCS),
- Drivers Information System (S2-DIS),
- Passenger Information System (S3-PIS),
- Video Surveillance and Monitoring of Public Space System (S4-VSMPS),
- Surveillance and Enforcement of Traffic Rules System (S5-SETRS),
- Public Transport Management System (S6-PTMS).

Structure of ITS configuration taking into account aspects and components of ITS system has been shown on Fig. 3.

2 Functional and Technical Configuration of ITS – Examples for Urban Agglomeration

2.1 Zonal Traffic Control System (S1-ZTCS)

Main objectives:

- Reducing congestion in the transport network,
- Increasing smoothness traffic flows,
- Increasing level of service.

Specific objectives:

- Two-level optimization of traffic control – the central level (parent) to the local level,
- Delimitation of the transport network into several zones of traffic control,
- Grouping of signal-controlled intersections in three sets:
  - set I – includes the most important signal-controlled intersections – intersections into the main transport corridors with highest traffic flows between the cities of agglomeration; especially intersections on public transport lines (tram lines and bus lines) to apply priority.
  - set B – includes signal-controlled intersections into transport corridors with traffic flows less then set A,
  - set C – least important signal-controlled intersections.
- Grouping of signal-controlled intersections from sets I nad II **into coordinated control zones**.

Functionalities:

- Increasing the traffic handling capacity of roads,
- Reducing collisions and waiting time for both vehicles and pedestrians,
- Encouraging travel within the speed limit to meet green lights,
- Increasing smothness of traffic flows,
- Reducing unnecessary stopping and starting of traffic - this in turn reduces fuel consumption, air and noise pollution, and vehicle wear,
- Reducing travel time especially by public transport vehicles priority,
- Reducing driver frustration and road rage

Integration with external systems:

- ITS in Gliwice City – transmission of information about traffic conditions and road accidents, and data transfer enables coordination of signaling and priority for public transport vehicles.
- National ITS (KSZR) – transmission of information about traffic conditions and road accidents,
- traffic surveillance system in the tunnel under the roundabout in Katowicach city – transmission of information about traffic conditions and road accidents,
- urban information service with SMS in Katowice city – transmission of information about traffic conditions and road accidents,

Main installations and technical components:

- development of technical documentation,
- exchange or adaptation of existing signal controllers and signaling devices,
- installation of induction loops,
- installation of systems software for: area traffic control, management software of signal controllers, design solutions in the field of traffic engineering, macro and micro traffic simulation, PLC programming,
- providing workstations,

– adaptation of premises for the operators of traffic control center,
– construction of the adaptation intersections signaling,
– installation of fiber optics.

Technical components location:

– Traffic Management Centers,
– signal controllers and signaling devices on the intersections.

2.2 Drivers Information System (S2-DIS)

Main objectives:

– Information for drivers about traffic conditions in transportation systems of urban agglomeration.
– Information for drivers about recommended actions while driving due to difficulties – e.g. recommended routes.
– Information for drivers about vacant parking spaces and recommended routes.

Specific objectives:

- Information for drivers about traffic conditions (level of service) on main roads of agglomeration and about recommended alternative routes,
- Information for drivers about difficulties related to:
  – traffic incidents such as accidents, road works, detours etc.,
  – mass event (demonstration),
  – dangerous weather phenomena and weather conditions on the road (air temperature, surface temperature, information on rainfall, snow and the possible emergence of dangerous weather phenomena like black ice, fog, gale, hail, etc.),
- Information about the availability of parking spaces in parking lots, indicating the type of car park facilities, payment system, and recommended routes – to reduce search time of vacant parking spaces, which in turn reduces congestion on the surrounding roads for other traffic.

Functionalities:

- Information about traffic incidents – options:
  – full information about traffic incidents with identification of their type – dedicated equipment for the detection incidents,
  – traffic incidents detected as congestion by the traffic lights controllers,
  – level of service estimation – traffic measurements (volume, density and speed of traffic flows) and recognition of the structure of vehicles carried out by a dedicated devices and the traffic lights controllers,
- Weather information system – options:
  – information from the dedicated measuring devices of weather stations,
  – information from the external servers or a weather station,

- Parking guidance and information system – options:
  - detection of each individual parking space in the parking lot and on the street (the system supports the areas of paid and free parking lots), with software to manage the car parks and VMS (variable message signs) with information about the vacancies at several car parks,
  - the system counts the vehicles at the entrance and exit of the parking lots (the system does not support zones of paid parking); there is no communication between the VMS and the server system, so VMS inform about vacancies at the parking lot only; there is no exact information about the number of parking vacancies in parking on the streets; the system is not equipped with software for parking management.

Integration with external systems:

- ITS in Gliwice City,
- National ITS (KSZR),
- traffic surveillance system in the tunnel under the roundabout in Katowicach city,
- urban information service with SMS in Katowice city,
- transmission of information.

Main installations and technical components:

- installations with equipment (hardware and software) for:
  - measurement of traffic flows and structure of vehicles,
  - detection of traffic incidents and their recognition,
  - detection of vacant parking spaces,
  - weather conditions,
- VMS (variable message signs) for information about:
  - traffic condition (level of service) and recommended routes,
  - traffic incidents and recommended routes,
  - vacant parking spaces and recommended routes,
  - weather.

Technical components location:

- Software in Traffic Control Centres (TCC),
- VMS (variable message signs):
  - main roads and selected urban streets of urban agglomeration,
  - intersections of main roads and intersections of selected urban streets,
  - at the entrances to the car parks and park zones.

2.3 Passenger Information System (S3-PIS)

Main objectives:

- better able to conduct journey by travelers, including taking any necessary steps in the event of delays, by providing real time information; this helps to encourage greater use of public transport,

Specific objectives:

- provide real-time passenger information: arrival and departure times, nature and causes of disruptions,
- personalised channels (web service, mobile application, SMS service) will be set up to mimic the view from a station or stop and may in addition be linked to journey planners.

Functionalities:

- include both predictions about arrival and departure times, as well as information about the nature and causes of disruptions,
- use both physically within a transportation nodes and remotely using a web browser and mobile device,
- information at a **stations and stops** – provide up to date predictions of:
  - arrival times, lines/routes and destinations of the following few arrivals of public transport vehicles,
  - how closely vehicles are running to timetable,
  - general advice on current travel disruptions that may be useful to the passenger in understanding the implications for their travel plans,
- information on **vehicles** – provide up to date predictions of:
  - the next station or stop,
  - arrival time,
  - how closely it is running to timetable,
  - advice on connecting services,
- apart from **visual** information also **voice** information,
- information on **web service** and **mobile application**:
  - public transport network diagram,
  - location of public transport vehicles on the network diagram in real-time,
  - location of currently registered traffic incidents (accidents, road works, closures etc.),
  - timetables all lines with up to date departure times for the following few arrivals for each line serving a specific stop or station,
  - actual information about all transport modes in urban agglomeration,
  - travel multimodal planner,
  - information about the nearest destinations: park&ride, multimodal nodes, POIs etc.
  - location of parking lots with the number of free parking spaces,
  - traffic conditions on road network,
  - scanning the QR-code placed at bus stops, which allow the identification of the bus stop,
  - information provided via SMS,

Integration with external systems:

- integration with a similar system functioning at selected main stops,
- adaptation of public service vehicles to work with the system in the field of on-board computer, GPS, GSM, LCD or LED displays,

– integration with other urban information systems and web portals – exchange the information between systems about traffic incidents, mass events and traffic disruptions.

Main installations and technical components:

– software and hardware with management information system,
– LCD monitors and/or VMS on stops, stations and on-board in vehicles,
– on-board audio system for voice information in vehicels,
– web application and mobile application,
– main software with management information system.

Technical components location:

– software and hardware in public transport management center,
– LCD monitors and/or VMS on stops and stations,
– LCD monitors and audio system with voice information on-board in vehicels,
– mobile application installed on mobile devices (smartphones, tablets etc.).

2.4 Video Surveillance and Monitoring of Public Space System (S4-VSMPS)

Main objectives:

– increase security based on the possibility of rapid detection of road accidents and incidents with armed robbery, theft etc.,
– support the activities of the Voivodeships Crisis Management Centre in Katowice.

Specific objectives:

– automatic notifications and alerts (via email, SMS, by phone) appropriate authorities and services about incidents.

Functionalities:

– monitoring of roads, streets, public buildings and other public spaces,
– monitoring of public transport vehicles and stops, stations and multimodal transport nodes,
– provide video information for: police, city guards, regional and local rescue and crisis centers.

Integration with external systems:

– extension of existing systems with new camera points; maximum use of existing cameras and equipment or replacement of old devices that do not provide sufficient image quality.

Main installations and technical components:

– IP cameras and CCTV cameras
– video recorders, videoservers, storage devices – in centres and vehicles,
– workstations with software and joysticks/manipulators,
– video walls.

Technical components location:

- traffic management centres, public transport operator centre,
- terminals in the following institutions: police, city guards, regional and local rescue and crisis centers.

2.5 Surveillance and Enforcement of Traffic Rules System (S5-SETRS)

Main objectives:

- traffic monitoring and recording of road accidents,
- enforcement of traffic rules: speed and red light violation enforcement, stop sign and bus lane violation enforcement,
- commercial vehicles weight enforcement,
- hazardous materials management.

Specific objectives:

- video vehicle detection
- vehicle identification based on automatic number plate recognition (ANPR) cameras,

Functionalities:

- identification of speed violation vehicles – speed violation at fixed points and average speed violation between two fixed points,
- identification of stolen or wanted vehicles,
- identification of red light violation vehicles,
- identification of commercial vehicles weight violation – weight-in-motion system.

Integration with external systems:

- functioning speed cameras and radars,
- functioning red light violation cameras,
- functioning weight violation system.

Main installations and technical components:

- automatic number plate recognition (ANPR) cameras,
- speed and red light violation devices,
- stop sign and bus lane violation devices,
- weight-in-motion devices.

Technical components location:

- ANPR cameras and devices on selected points of transport Network,
- Hardware and software in Traffic Control Centers.

2.6 Public Transport Management System (S6-PTMS)

Main objectives:

- planning organization and management of public transport in urban agglomeration,
- management of transport infrastructure and vehicles,
- monitoring and evaluation of drivers.

Specific objectives:

- implementation of specialized software supporting the management of public urban transport and rail transport,
- integration of public transport services by introducing correlated timetables and common tariffs.

Functionalities:

- support for the development of strategic document – transport plan,
- analysis and settlement of transport work between municipalities and operators on the basis of information about the number of passengers,
- timetabling fir public transport services,
- management of companies and operators database,
- maintaining a register of stops and vehicles,
- monitoring and evaluation of service work.

Integration with external systems:

- integration with actual software used by operators of public urban transport and rail transport,
- data flows from other subsystems.

Main installations and technical components:

- hardware and specialized software for transport management.

Technical components location:

- hardware and specialized software in headquarter of urban public transport operator,
- hardware and specialized software in headquarter of rail transport.

3 The Configuration Matrix of Aspirations-Implementations – Examples for Urban Agglomeration

The most important and functional-utility aspirations A1÷A56 of The ITS KZK GOP case study are as follows. The implementation of following aspirations by the sub-systems of ITS configuration – aspirations-implementations matrix of ITS – has been show in Table 1.

Table 1. The aspirations-implementations matrix of ITS [7, 17]

Implementation of aspirations by the subsystems of ITS configuration													
No aspiration	S1-ZTC	S2-DIS	S3-PIS	S4-VSMPS	S5-SETRS	S6-PTMS	No aspiration	S1-ZTC	S2-DIS	S3-PIS	S4-VSMPS	S5-SETRS	S6-PTMS
A1	+	+	+	+	+	+	A29			+			
A2	+	+	+	+	+	+	A30			+			+
A3	+	+	+	+	+	+	A31		+	+			
A4	+	+	+	+	+	+	A32		+	+			
A5	+	+	+	+	+	+	A33		+	+			
A6	+	+					A34		+	+			
A7	+	+					A35		+	+			
A8	+						A36	+	+	+	+	+	+
A9	+						A37	+	+				
A10	+						A38	+	+				
A11	+						A39			+			+
A12	+						A40		+	+			
A13	+	+					A41		+	+			
A14		+	+				A42		+				
A15			+				A43	+					
A16		+	+				A44					+	
A17	+	+	+	+	+	+	A45					+	
A18			+			+	A46	+	+	+	+	+	+
A19				+			A47				+		
A20				+			A48		+				
A21	+						A49			+			+
A22	+						A50	+	+				
A23	+						A51	+		+			+
A24		+	+				A52						+
A25		+	+				A53						+
A26		+	+				A54	+					
A27		+	+				A55			+			
A28		+	+				A56	+	+	+	+	+	+

List of takeholders aspirations – example for ITS KZK GOP case study [7, 17]

A1. Technical documentation of the system should include a precise description of the data types and protocols for their transmission,
A2. System should be technologically open and flexible to allow for its continuous expansion,
A3. System should operate according to the principle "collect data once, use it many times,"
A4. System should have mechanisms to ensure the security of the collected and transmitted data,
A5. System should use open protocols for communication between devices, so that when the expansion was not necessary to rebuy/expansion license, a new device can be supplied by different manufacturers,
A6. System should collect data on traffic flows in the road network,
A7. System should recognize the different types of vehicles,
A8. System should calculate signal timing for traffic lights based on traffic data,
A9. System should allow the simulation of new solutions and strategies for road traffic control,
A10. System should include transport models both in macrosimulation and microsimulation,

A11. System should measure the traffic flows parameters and evaluate the effectiveness of control strategies,
A12. System should store sequence control (values of stages, phases, signal timing and detectors) for all intersections,
A13. System should detect traffic incidents,
A14. System should inform users about traffic incidents,
A15. System should support people with disabilities,
A16. System should inform users about the traffic situation in the network,
A17. System should diagnose own functioning and automatically report faults to operators (self-diagnosis),
A18. System should carry out electronic payments for transport services,
A19. System should detect stolen cars,
A20. System should detect vehicles properly labeled,
A21. System should support the priorities for public transportnej,
A22. System should handle the priorities for privileged vehicles,
A23. System should coordinate the work of signal controllers to create a 'green wave' for vehicles,
A24. System should provide free of charge traffic data for users,
A25. System should support users in the travel planning,
A26. System should support users in the plan a trip using various means of transport (multimodality),
A27. System should provide information about cultural events, sports, etc.,
A28. System should allow the location of the POI on the map,
A29. System should provide a road map for users,
A30. System should provide a map of public transport network,
A31. System should collect and provide information on available parking spaces,
A32. System should provide information using variable message signs (VMS),
A33. System should provide the information using the Internet,
A34. System should provide information using applications on smartphones,
A35. System should provide the information in a graphical, textual, audio,
A36. System should provide software tools for management and diagnostics of system,
A37. System should be able to exchange information about events with other telematics systems,
A38. System should be able to exchange information about the traffic on the roads with other telematic systems,
A39. System should provide information about the actual departure times of public transport vehicles,
A40. System should provide information on the traffic conditions in the network traffic both before and during the trip,
A41. System should indicate an alternative route,
A42. System should provide information about current weather conditions and related dangers,
A43. System should manage traffic to ensure travelers shorten travel time,
A44. System should monitor the situation on the roads, intersections, neighborhoods, parks, etc., to increase the security of citizens,

A45. System should monitor situations in public transport vehicles and in their vicinity,
A46. System should allow operators to remotely control and service equipment,
A47. System should detect vehicles exceeding the speed at a given point or on a given road section,
A48. System should allow the speed limit using variable message signs,
A49. System should record the routes, which passengers are traveling by public transport,
A50. System should collect data on events and make them available in the form of statistics,
A51. System should increase the efficiency and attractiveness of public transport,
A52. System should support the transport organizer in the development of timetables and manage transport services,
A53. System should allow the assessment of the quality of the operators of public transport,
A54. System should allow management of priorities for public service vehicles and privilaged vehicles,
A55. System should locate public transport vehicles on the map,
A56. System should use the data collected by other telematics systems.

4 Conclusion

The ITS configuration for urban agglomeration may be evaluated [17] using SWOT analysis. The results of this assessment for ITS KZK GOP case study are as follows. **Strengths:** open system architecture, technological neutrality, support for public transport, increase the safety of citizens, especially road users, support integration between urban public transport and rail. **Opportunities:** integration with other telematics systems, ability to finance this system with use of European funds. **Weaknesses:** high cost of building and maintenance of this system. **Threats:** large area of the system, need to agree of the architecture and functionality of the system with many institutions, long time to build the system, problems of interaction this system with other external systems, e.g. ITS system in Gliwice city.

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