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PERSONALIZED FUNCTIONAL VIEWPOINT OF THE ITS SYSTEMS ARCHITECTURE REGARDING INFORMATION FOR USERS OF URBAN TRANSPORT SYSTEMS – A CASE STUDY FOR THE CENTRAL CITY OF A METROPOLIS

Summary. *The article presents a personalized functional view of the ITS architecture concerning Information for users of urban transport systems using the example of ITS systems of the central city of a metropolis. A fundamental issue from the perspective of transport users is obtaining information about the full functional scope of transport systems. Based on such information, it is possible to plan trips in a way that is as efficient as possible for each user individually, and on the other hand, in a sustainable way from the point of view of transport systems and a specific transport policy of the urban/metropolitan area. The choice of such a view is related to the fact that the basic need of the so-called end users of ITS systems, i.e., people moving using transport systems, is to receive valuable and current information in an effective way – preferably in real time, i.e., during the movement of users. The title issue, i.e., personalized functional point of view of the ITS system architecture concerning Information for users of urban transport systems, was presented on the example of ITS systems operating in the central city of an urban agglomeration in Poland with the status of a metropolis. These ITS systems were implemented at the turn of 2023-2024 and were designed using the European ITS framework architecture. The objectives are to identify the current scope of information for users and the current scope of system functions of the examined ITS system to indicate further directions of development of the examined ITS system. Therefore, the characteristics of the connections between the needs of urban transport users and the functions of ITS systems related to Information for these users are presented. Based on such a view of ITS systems, the directions of their further expansion were identified in the functional scope covering the needs of users using urban micromobility and shared transport systems, i.e., car sharing, bike sharing, and electric scooters sharing in journeys planned in real time. The second development area is electromobility, including the development of services related to guiding to parking spaces with electric chargers and planning journeys taking into account the recharging of the traction battery of electric vehicles – passenger cars, delivery vehicles, and trucks.*

Key words: *intelligent transportation systems, ITS systems Framework Architecture FRAME, needs of transport users, ITS system services, information for transport system users.*

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1. INTRODUCTION

The aim of this article is to present a personalized functional viewpoint of the ITS architecture concerning information for users of urban transport systems using the example of ITS systems of the central city of a metropolis. The specific objectives are to identify the current scope of information for users and the current scope of system functions of the examined ITS system to indicate further directions of its development. This viewpoint is not a standard view adopted according to the FRAME methodology [1]. However, the perspective of this view shows the assignment of user needs in the scope of transport information to the appropriate functions of the ITS subsystems and then to the technical and organizational subsystems along with their location. A fundamental issue from the perspective of transport users is obtaining information about the full functional scope of transport systems. Based on such information, it is possible to plan trips in a way that is as efficient as possible for each user individually, and on the other hand, in a sustainable way from the point of view of transport systems and a specific transport policy of the urban/metropolitan area.

The structure of the article content includes the following components:

- problem characteristics based on a review of the literature on the architecture of ITS systems and selected issues related to the topic of this paper (chapter 2),
- presentation of the purpose and scope of the issues discussed in this paper (chapter 3),
- methodological assumptions for the presented research problem (chapter 4),
- characteristics of the connections between the needs of users and the functions of ITS systems related to information for users of transport systems – a case study for the ITS system of the central city of an urban agglomeration with the status of a metropolis (chapter 5),
- summary with conclusions and indication of further research (chapter 6).

2. PROBLEM STATEMENT AND LITERATURE REVIEW

To justify the topic of this paper, a literature review was conducted concerning the importance of transport information for users of transport systems in several aspects. The authors [2] indicate expectations regarding ITS systems in the scope of providing passenger-oriented public transport services. Therefore, they draw attention to the fact that there is a problem with the perception of information technologies concerning real-time information and display platforms by users, especially in specific socio-economic and demographic groups. The authors' research shows, among other things, that the most valued real-time information services are information on the arrival/departure time and trip planning type. There are also apparent differences in using this information, i.e., younger users prefer mobile applications, while older users prefer display platforms. In those studies, the following types were considered: vehicle location map, arrival/departure time, seating availability, trip planning, and bike sharing availability. In terms of display platforms, the following solutions were included in the research: panel, bus monitor, apps, journey planning software, SMS/Call, and operator website. The conclusions from the research presented in paper [3] point to the need to adapt information to the range of travel. The types of information needed for long journeys differ from those needed for short journeys. Current displays are not ideal because of several problems, such as ambiguity, poor readability, and unsightly layouts. Users like to have information quickly communicated at stops, on routes, and at transfers. Technical information and entertainment are of secondary importance. The two main issues are what to show (i.e., the organization of the information needed) and how to show it (i.e., the design of information that is easy to understand). A real-time mobility information system for managing unexpected events, delays, and service disruptions concerning public transport in the city is presented in the paper [4]. The authors emphasize that the use of information on traffic disruptions in travel planning contributes to improving the attractiveness of public transport services because if disruptions are easily and automatically handled, the perception of reliability and robustness increases significantly, and uncertainty decreases, which makes the option of traveling by public transport more attractive. The importance of information for drivers is presented in the results of research on the impact of factors such as the level of congestion and travel time reliability on truck drivers' decisions

regarding route selection – two groups of drivers had different levels of awareness of real and historical traffic conditions on available routes [5]. The results of the research indicate that in the case of truck drivers unfamiliar with historical traffic conditions and travel times on available routes, real-time congestion information is an important factor in the route selection decision process, while travel time reliability is not as important to them. On the other hand, for truck drivers familiar with historical traffic conditions and travel times on available routes, travel time reliability is an important factor in the route decision process, and congestion information is not as important to them. The impact of integrated information on improving road safety is the subject of the paper [6], which presents the results of a method of combining historical accident data with real-time data on road traffic and driver behaviour, including facial recognition to detect signs of fatigue and distraction, together with an assessment of overall driving competence. The results of the study [7] indicate that factors related to congestion and driving the bus during rush hours and the related concern for the safety of the car have a negative impact on the work of bus drivers. Large passenger flows affect emotionally the high responsibility for the safety of pedestrians and passengers. Delays from the timetable and lack of time to make responsible decisions are the determining factors of the quality of transport, which depends on the individual characteristics of the driver, causing high nervous and emotional tension.

The use of data in ITS systems based on vehicle ad hoc networks (VANETs) that also function as mobile ad hoc networks (MANETs) is presented in the paper [8]. Such networks use dedicated short-range communications (DSRC) to exchange information between vehicles and between vehicles and the infrastructure along the road. The paper presents a nonintrusive driver behavior detection system using a context-aware system in VANETs to detect abnormal behaviors exhibited by drivers and warn other vehicles on the road to prevent accidents. A model is presented that infers four types of driver behavior (normal, drunk, reckless, and tired) and combines contextual information about the driver, vehicle, and environment. A five-layer context-aware architecture is proposed, which is able to collect contextual information about the driving environment, to perform reasoning about certain and uncertain contextual information, and to react to that information.

3. PURPOSE AND SCOPE OF THE PRESENTED ISSUES

The general objective of the article is to practically present the possibilities offered by the application of the FRAME architecture in the analysis of the selected functional scope of the ITS system. The article assumes the functional scope concerning "information for users of urban transport systems" for the implemented and functioning urban intelligent transport system. The specific objectives are to identify the current scope of information for users and the current scope of system functions of the examined ITS system in order to indicate further directions of development of the examined ITS system in the scope of new user needs and corresponding new system functions – supporting sustainable urban mobility using new forms (modes) of individual transport such as micromobility, and electromobility.

The title issue, i.e., personalized functional point of view of ITS system architecture concerning Information for users of urban transport systems, was presented on the example of ITS systems operating in the central city of an urban agglomeration in Poland with the status of a metropolis. These ITS systems were implemented at the turn of 2023-2024 and were designed using the European ITS framework architecture. The architecture of the discussed ITS systems with sources [9, 10, 11] is based on the European Framework Architecture FRAME standard. Using FRAME, the structure of the ITS system can be defined in four basic predefined perspectives:

- Functional Viewpoint – involves assigning functions, databases, and data flows that reflect selected User Needs;
- Physical Viewpoint – involves dividing the functional architecture of the ITS system into subsystems and modules;
- Organizational Viewpoint – involves assigning responsibility for individual parts of the functional architecture of the system to specific entities;

– Communications Viewpoint – specifies the requirements for communication between individual system components.

The structure of the discussed ITS case study was built following the FRAME methodology. The FRAME architecture is not a ready-made model to be used in creating the architecture of a given system, but a reference point, the so-called framework architecture. Its task is to show "what" is to be done and not "how" it is to be done. This approach can be a reference point for creating architectures of ITS services and systems of any type, because it includes and precisely describes practically all possible functionalities for traffic management systems, payment collection systems, traveler information systems, and many others. The FRAME architecture, therefore, allows for the creation of one's perspectives and does not impose any restrictions on the way of designing ITS systems and services.

On this basis, the article presents an additional, individually created personalized view of this FRAME architecture, which allows for the analysis of the functionality of this case study for "information for users of urban transport systems" in terms of "user needs" and "ITS system functions of this case study". This approach allows for identifying individual system functions of the implemented ITS case study and the identification of the adopted user needs. In this way, it is possible to plan the further development of this system for new user needs related to developing new forms (modes) of transport, e.g. micromobility, checking which current functions can be used for "new user needs" and which "new user needs" require the design of additional "new ITS system functions".

Therefore, the remaining aspects (points of view) of the FRAME architecture of the discussed ITS case study have been omitted. The proposed approach concerns presenting the FRAME architecture of a specific implemented ITS system in such a formulated point of view. The intentional omission of presenting the entire FRAME architecture for this ITS system, the volume of which significantly exceeds the capacity of this article, is also since the content of the paper is legible and transparent for the adopted point of view, i.e. "information for users of urban transport systems". Examples of traffic information provided to drivers by the discussed ITS system are shown in Fig. 1 and Fig. 2.

Fig. 1. Variable message board of the discussed "ITS Katowice" system with the displayed information "TRAFFIC DISRUPTIONS, CLOSED VIADUCT ON MIKOŁOWSKA Street"

Fig. 2. Variable message board of the discussed "ITS Katowice" system displaying travel times to selected points of interest, i.e., the neighboring cities "TYCHY" and "CHORZÓW", and to the intersection with MIKOŁOWSKA Street.

The green color of the numbers (Fig. 2) "10 min", "8 min", "7 min" indicates short travel times, i.e., good traffic conditions – despite the visible heavy congestion, the speed of the traffic flow is approx. 20-30 km/h in this location.

According to the Centre for EU Transport Projects (ECUPT) – a state institution in Poland dealing with comprehensive support for beneficiaries in the process of preparing and implementing transport investments [12], the most important components of the FRAME architecture are:

- a set of user needs that formally describe the functional requirements of the designed ITS systems and services that can be met (User Needs), e.g.: "The system should be able to monitor the condition of infrastructure elements, e.g. roads, bridges, tunnels, gantries, etc.", "The system should be able to detect that a vehicle has been involved in an accident, determine its location and initiate an "eCall" connection automatically.", "The system should be able to charge a fee for using a section of road or facility (e.g., bridge, tunnel, etc.), based on specified parameters, e.g., travel time, distance, traffic congestion, etc.";
- a set of functions, data repositories, and data flows reflecting the mentioned user needs.

In this paper, it was assumed that a personalized functional view (ViewPoint) of the ITS system architecture concerning Information for users of urban transport systems will be prepared and presented. The choice of such a view is related to the fact that the basic need of the so-called end users of ITS systems, i.e., people moving using transport systems, is to receive valuable and current information effectively – preferably in real time, i.e., during the movement of users. Considering transport processes from the point of view of end users, this information can be assigned to its three basic stages:

- the journey planning stage, in which the route and transport system are selected, and the order can be arbitrary, e.g., first selecting the transport system and then the route in the transport network, or first selecting the route in the network and then the transport system;
- during the journey stage, in which the route may change, the transport system may change, or even the destination may change, e.g., selecting another retail and service location, with better transport accessibility at the time, more parking spaces available, etc.;
- the reaching the destination stage, in which there may be a need to leave a passenger car (one`s own or from a car-sharing system) at a parking space and the associated additional process of searching for a parking space ; it should be emphasized that the process of searching for a parking space may also occur during the journey with a change of transport system, e.g., using Park&Ride systems.

The above-mentioned issues constitute the main criteria for the personalized functional view of the architecture for the studied case of operating ITS systems presented in the following sections of the paper.

4. ASSUMPTIONS OF THE METHODOLOGY IN THE PRESENTED CASE STUDY

According to FRAME, the basis for creating an architecture for ITS systems are the aspirations of stakeholders, i.e., the requirements of people and institutions involved in the implementation and then in the use of the ITS system. These include decision-makers – city authorities, public transport operators, freight transport operators, suppliers, and end users – including people using transport daily. The collected aspirations of stakeholders are transformed into the so-called User Needs, the list of which is one of the elements of FRAME.

The collection and development of user (stakeholder) requirements and needs based on their aspirations was the subject of analysis by a separate team of experts appointed by the institution ordering this ITS system, and it is the internal documentation of this institution. In this regard, it is worth emphasizing that, to a large extent, the requirements and needs of users (stakeholders) are the result of consultations with experts, including from the following teams:

- the team of automation experts and experts in modeling transport systems and processes;
- the team of experts in the implementation of technical systems and devices that are components of this ITS system, who, in particular, know the current technical solutions and the possibilities

of their development; their requirements were reported at meetings of the team creating the ITS system concept and tender documentation, including the tender specification;

- the team of experts who previously, i.e. before the design and implementation of the discussed ITS system, implemented and then worked with existing in this city system components that were integrated within the discussed ITS system; these included, among others, people familiar with the functionality of the following previously operating subsystems: traffic lights at intersections, Dynamic Passenger Information System at bus and tram stops, traffic management system in the tunnel under the roundabout in this city;
- the team of experts from the city authorities and experts from the Institution responsible for the operation of public transport in the city and the urban agglomeration, whose requirements were related to the implementation of a specific transport policy of the city and the entire urban agglomeration, plans for the operation and development of transport systems, including in particular planning the sustainable development of public transport, traffic priority for public transport vehicles, and integration with the ITS systems of other cities in the entire urban agglomeration;
- the team of experts from municipal services, including the police, fire department, and the road transport inspection.

The process of creating an architecture consists of selecting the functions, databases, and data flows appropriate for a given case from a large number of available elements. FRAME is the separation of a subset of elements (subsystem), which is to reflect the functionalities of the designed system. Then, depending on the needs, these elements (subsystems) can be assigned to different subsystem groups, e.g., subsystems supporting public transport, subsystems supporting individual vehicle traffic, etc. It should be remembered that when we look at the system, for example, from a functional perspective (Functional Viewpoint), then we only analyze the functionalities of ITS systems needed to meet the requirements defined earlier. We are then aware that not all system elements will be in one place, for example, some of them may be located in the Traffic Management Center, and the rest in the roadside area, and still others in mobile devices as a dedicated application for travel planning and assistance during travel. However, at the moment, we are not interested in this because the division of the system and the assignment of specific locations are among the activities within the system analysis that result from a different perspective, i.e., from the physical perspective.

When preparing a personalized functional ViewPoint of the ITS system architecture concerning "Information for users of urban transport systems", the tender documentation [9] for the implementation of this system was used, including the Functional and Utility Program [10, 11]. In addition, the authors of this paper participated in the main conceptual and pre-design work for the ITS systems discussed in this paper – this work preceded the construction phase of this ITS system as the project implementation period is 2017-2023, including the construction period: 2021–2023. The results of the authors' work in that period include functional analyses for this system [13], analyses concerning the priority for public transport vehicles [14, 5], conceptual work on the architecture of this system [16] and on the preliminary tender documentation for the implementation of this system [17, 18].

Therefore, they have the appropriate expert knowledge for this case study, mainly since this work was carried out according to the principles of systems engineering, including the principle recommending work in multidisciplinary teams. In this case, the teams consisted of analysts (economic, legal, transport) from the city authorities as the beneficiary and the departments of the city authorities currently managing the system (municipal management of streets and bridges of the city). Scientific knowledge and experience were represented by, among others, the authors of this paper, who exchanged their current experience and expertise at industry scientific and technical conferences. Knowledge and practical experience were also brought to the team by designers of ITS systems from the industry, including integrators of individual subsystems and functional components, who participated in the construction and implementation works of ITS systems operating in other cities in the country and abroad. The results include publications in which selected key problems of creating an ITS system for this case were proposed and presented.

The paper [19] presents an analysis of stakeholder aspirations in the form of a matrix of their implementation by ITS subsystems in a specific configuration. The structure of the ITS project is also presented in the context of a high-level project in the V-model of systems engineering. The issues mentioned are linked to the problems of comprehensive traffic and transport studies for transport modeling to assess the ITS project using a transport model. Selected problems related to defining the configuration and architecture of ITS systems at the conceptual and design stage are presented in the article [20]. Problems and a structured method of solving them are presented on the example of the concept and feasibility study of ITS for a metropolitan area city. Selected issues related to the design of ITS systems in terms of functional and technical configuration are presented in the paper [21]. The issues are presented on the example of ITS for a polycentric agglomeration, distinguishing the following aspects: main goals, detailed goals, functionalities, integration with external systems, central installations, technical components, and their location . Scenarios for the development of the ITS system on the example of a medium-sized city in Poland and the results of their assessment by the inhabitants of this city are presented in the paper [22]. The issues related to macroscopic/strategic transport modeling during the conceptual design of the ITS system functionality are characterized in the paper [23]. In particular, the criterion for selecting transport modes using a utility function using the perceived travel time is discussed. A mathematical formal description of issues related to the design of ITS system services is presented in the paper [24]. A description of stakeholders and their aspirations regarding ITS system services and a description of these services in the context of technical variants of ITS configuration are included. The fundamental methodological aspects related to the process of designing ITS systems for the case study, i.e., pre-design documentation of the ITS system for an urban agglomeration, are presented in the paper [25]. Among other things, systems engineering in ITS design, as an essential part of the systems approach, the possibilities of using the V model in the design and development of ITS systems are presented [26].

5. PERSONALIZED FUNCTIONAL VIEWPOINT – TRAVELER INFORMATION AREA

The personalized functional ViewPoint of the Information for users of urban transport systems was obtained by reviewing all needs and selecting those from all other needs that concern valuable information for transport. As a result, the following groups of needs were selected – see Fig. 3 for the Management Activities group, Fig. 4 – for the Information for Travelers group, and Fig. 5 – for the Public Transport group. Note: the analysis results are presented in the tables indicated in the diagrams.

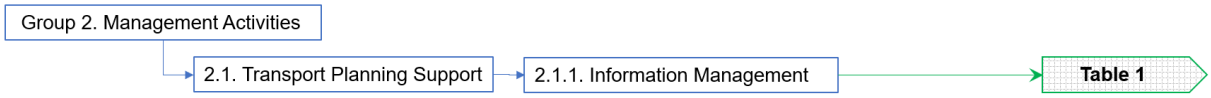

Fig. 3. The "Management Activities" group selected for analysis of the personalized functional ViewPoint of ITS (the analysis results are presented in the table indicated in the diagram). Source: own study based on the architecture of the ITS case study.

Then, the connections between selected user needs in the scope of transport information and the functions that implement the appropriate services of the implemented ITS system were selected and characterized – both for the city residents, as well as for users related to the city's surroundings (city residents and residents of directly neighboring cities) and users using the city's transport systems in transit. This city's road and rail transport network and public transport systems (buses and trams) constitute standard (organizationally and tariff-integrated) transport systems of the entire metropolis, including 41 member cities/communes.

The following tables present a personalized functional view (ViewPoint) of the ITS architecture concerning Information for users of urban transport systems. The structure of this view is a link between needs and the functions of the ITS system that support these needs.

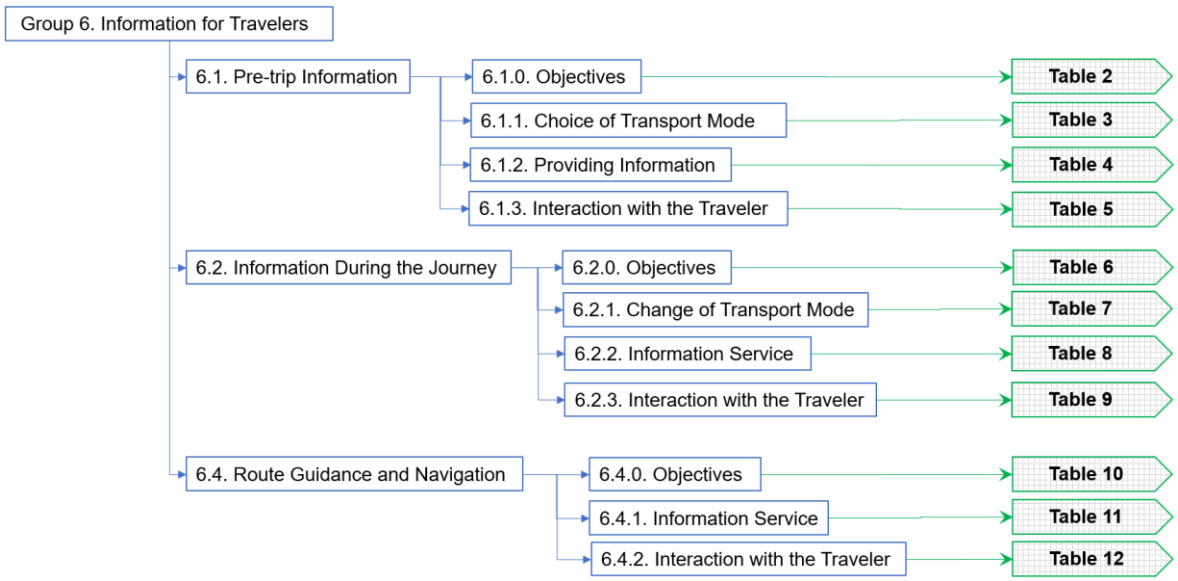

Fig. 4. The "Information for Travelers" group selected for analysis of the personalized functional ViewPoint of ITS (the analysis results are presented in the tables indicated in the diagram). Source: own study based on the architecture of the ITS case study.

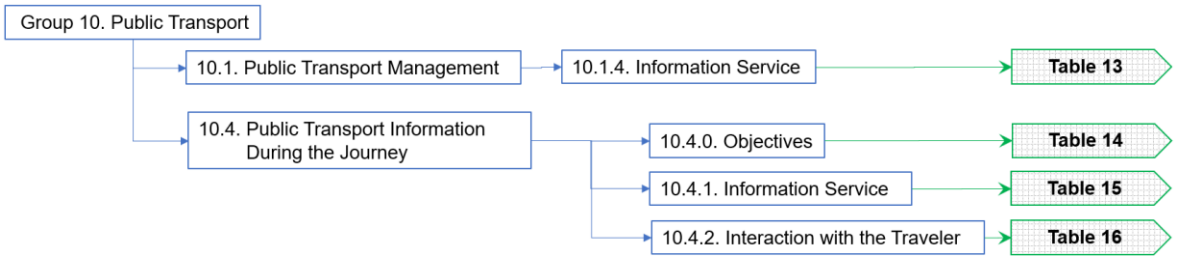

Fig. 5. The "Public Transport" group selected for analysis of the personalized functional ViewPoint of ITS (the analysis results are presented in the tables indicated in the diagram). Source: own study based on the architecture of the ITS case study.

5.1. Group 2. Management Activities

In the group of needs covering "*Management Activities*", assumptions were made regarding providing information to travelers on traffic conditions and travel for all significant modes of transport. In connection with this, the system should collect traffic data to conduct road network use analyses and perform traffic condition prediction calculations. ITS system functions were assigned to the listed needs presented in Table 1.

Table 1

User needs and functions fulfilled by the ITS system in Group 2. Management Activities → 2.1. Transport Planning Support → 2.1.1. Information Management

Description of user needs	Assigned ITS system functions
2.1.1.1. The system should be able to provide information to travelers on traffic and travel conditions for all relevant forms of transport.	3.1.1.14. Urban traffic data management. 3.1.2.9. Output data on intercity traffic.
2.1.1.3. The system should be able to collect traffic data for road network usage analysis and prediction calculations.	3.1.1.10. Collecting data on urban traffic. 3.1.1.14. City Traffic Data Management. 3.1.4.1. Monitoring the number of vehicles in parking lots. 3.1.4.2. Parking space occupancy detection. 3.1.5.1. Monitoring occupancy in parking areas.

Source: own study based on the architecture of the ITS case study

5.2. Group 6. Information for Travelers

In the group of needs covering "Pre-trip Information", assumptions were made regarding the provision of free information for all users, including, among others, information on emergencies or other urgent events, information on traffic and travel conditions, information on alternative routes. The system should enable users, among others, to plan their own journeys based on their own criteria, including, among others, preferences regarding transport modes, departure or arrival times, routes in the network, etc., including the needs resulting from users' disabilities. A detailed description of the "objectives" for needs and the functions of the ITS system assigned to them is provided in Table 2.

Table 2

User needs and functions fulfilled by the ITS system in the scope of Group 6. Information for Travelers → 6.1. Pre-trip Information → 6.1.0. Objectives

Description of user needs	Assigned ITS system functions
6.1.0.1. The system should provide all road users free information on emergencies or other urgent events.	6.5.10. Providing the traveler with a trip planning interface.
6.1.0.3. The system should be able to provide accurate, reliable, timely, and easy-to-understand traffic and travel information in places where it will benefit the user.	6.3.13. Providing the traveler with a travel interface. 6.6.1. Providing an information interface for the traveler.
6.1.0.4. The system should be able to provide information about alternative routes that may be faster, cheaper, shorter, more scenic, etc.	6.7.1. Defining a traveler's overall travel preferences.
6.1.0.5. The system should enable travelers to plan their journeys using their travel criteria (transport modes, departure and arrival times, route criteria selection, etc.)	6.5.10. Providing the traveler with a trip planning interface. 6.6.1. Providing an information interface for the traveler. 6.7.1. Defining a traveler's overall travel preferences. 6.7.2. Evaluate your trip after it's over.
6.1.0.6. The system should enable travelers to plan their trips based on the needs of their disability.	6.5.10. Providing the traveler with a trip planning interface. 6.6.1. Providing an information interface for the traveler. 6.7.1. Defining a traveler's overall travel preferences.

Source: own study based on the architecture of the ITS case study

In terms of the needs of "Pre-trip Information" concerning "Choice of Transport Mode", assumptions were made regarding the selection of the transport mode from among those available following the objectives of a specific transport policy. Therefore, the system should provide information on multimodal journeys, taking into account such factors influencing the choice of travel mode as, among others, prices and tariffs, availability of routes in the network depending on current and predicted road traffic conditions. The system should provide ongoing information on the occurrence of serious road incidents or difficult weather conditions, as well as other planned and accidental events that will cause difficulties for one of the means of transport. A detailed description of the needs and the functions of the ITS system assigned to them is provided in Table 3.

Table 3

User needs and functions fulfilled by the ITS system in the scope of Group 6. Information for Travelers → 6.1. Pre-trip Information → 6.1.1. Choice of Transport Mode

Description of user needs	Assigned ITS system functions
6.1.1.1. The system should be able to influence the modal split of transport use by a defined transport policy.	6.5.10, Providing the traveler with a trip planning interface.

Table continuation 3

Description of user needs	Assigned ITS system functions
6.1.1.2. The system should be able to provide information about travel by different modes of transport, for example, the distribution of transport demand in the event of serious incidents or when unfavorable weather conditions, public protests, cultural or sporting events cause difficulties for one of the modes of transport.	3.3.13. Demand management output information. 6.5.10. Providing the traveler with a trip planning interface. 6.5.3.9. Details of the travel plan.
6.1.1.4. The system should be able to provide extensive information about multimodal travel, such as prices, fares, routes, predicted and current traffic situations, traffic management, traffic measurements, local warnings, special events, weather conditions, hotels, etc.	3.1.1.14. Urban traffic data management. 3.1.2.16. Extra-urban traffic data management. 3.3.13. Demand management output information. 3.4.10. Output environmental information. 6.5.10. Providing the traveler with a trip planning interface. 6.3.11. Monitoring the implementation of travel planning for travelers.

Source: own study based on the architecture of the ITS case study.

Regarding the needs of "Pre-trip Information" concerning "Providing Information", it was assumed that the system should inform the user that there have been changes to the criteria based on which the pre-trip information was developed. In this regard, information on traffic restrictions and related delays will be necessary, as well as information on cancelled journeys from intermodal transport hubs (e.g., railway stations, airports, ports or bus stations) resulting from bad weather conditions, public protests or other reasons. The information provided by the system should include the nearest traveler service points and points of public interest (POI), including, among others, places of interest (their location, opening hours, prices for services). The information provided to travelers should shape their transport decisions, considering environmental conditions. Additionally, the system should consider the needs resulting from users' disabilities. A detailed description of the needs and functions of the ITS system assigned to them is provided in Table 4.

Table 4

User needs and functions fulfilled by the ITS system in the scope of Group 6. Information for Travelers → 6.1. Pre-trip Information → 6.1.2. Providing Information

Description of user needs	Assigned ITS system functions
6.1.2.1. The system should inform the user when there are changes to the criteria based on which pre-trip information was provided.	6.3.11 Monitoring the implementation of travel planning for travelers.
6.1.2.2. The system should be able to provide information on cancellations from intermodal transport hubs (for example, railway stations, airports, ports, or bus stations) due to weather, public protests, or other reasons.	6.3.11. Monitoring the implementation of travel planning for travelers. 6.5.10. Providing the traveler with a trip planning interface. 6.6.2. Travel information production.
6.1.2.3. The system should be able to provide information to all drivers, taking into account road restrictions, travel times, etc..	6.3.13. Providing the traveler with a travel interface.
6.1.2.4. The system should be able to support an event database with connections between events that co-occur in the same location, or adjacent locations.	3.2.11. Providing the operator with an incident management interface. 6.5.3.8. Road traffic data collection.
6.1.2.5. The system should be able to analyze, process, and acquire data from various combinations of sources (including a mobile observer).	5.13.7. Preparation of extended data on the mobile observer's vehicle. 6.5.3.13. Providing data and routes to fleet operators and drivers. 6.5.3.3. Public transport data collection. 6.5.3.8. Road traffic data collection. 6.5.3.9. Details of the travel plan.

Table continuation 4

Description of user needs	Assigned ITS system functions
6.1.2.6. The system should be able to provide road and traffic information tailored to different classes of users, for example, travelers, radio broadcasters, and service operators.	3.1.1.14. Urban traffic data management. 3.1.2.9. Output data on intercity traffic. 6.6.1. Providing an information interface for the traveler.
6.1.2.7. The system should provide information using text and graphical interfaces. The graphical form should include the use of maps and text.	6.5.10. Providing the traveler with a trip planning interface. 6.6.1. Providing the traveler with an information interface.
6.1.2.8. The system should provide information in the native language of the output location and/or based on the user's selection of a corresponding foreign language.	6.6.1. Providing the traveler with an information interface. 6.7.1. Defining a traveler's general travel preferences.
6.1.2.9. The system should provide a tool for the operator to manage information.	6.5.3.7. Providing the operator with access to travel planning data. 6.7.3. Providing the operator with data for route information. 6.8.2. Providing an operator interface for managing trip planning.
6.1.2.10. The system should be able to provide access to information for travelers with special needs (for example, physical access, lifts, escalators, parking, and toilets, changing rooms for children, access for guide dogs, etc.) in relevant areas, for example, transport areas.	6.5.10. Providing the traveler with a trip planning interface. 6.6.1. Providing the traveler with an information interface.
6.1.2.11. The system should be able to provide information about interesting places, such as location, opening hours, service prices, and the nearest transport service points.	6.5.10. Providing the traveler with a trip planning interface. 6.5.3.9. Details of the travel plan. 6.6.1. Providing the traveler with an information interface.
6.1.2.12. The system should be able to receive information about ‘public places’ from the suppliers/owners/managers of these places.	6.5.3.9. Details of the travel plan.
6.1.2.13. The system should be able to provide information to travelers to influence their decisions about the travel destination and means of transport, for example, to protect the environment of a ‘public place’ or a geographical area.	3.4.10. Output environmental information. 6.5.3.8. Road traffic data collection. 6.5.3.9. Details of the travel plan. 6.6.1. Providing the traveler with an information interface. 6.6.2. Travel information production. 6.6.3. Output information for travelers.

Source: own study based on the architecture of the ITS case study.

In terms of the “Pre-trip Information” needs regarding “Interaction with the Traveler”, it was assumed that the user could configure the information (Table 5).

Table 5

User needs and functions fulfilled by the ITS system in the scope of Group 6. Information for Travelers → 6.1. Pre-trip Information → 6.1.3. Interaction with the Traveler

Description of user needs	Assigned ITS system functions
6.1.3.8. The system should be able to provide configurable pre-trip information to mobile or vehicle devices.	6.5.10. Providing the traveler with a trip planning interface. 6.7.1. Defining a traveler's general travel preferences.

Source: own study based on the architecture of the ITS case study.

In terms of the needs of "Information During the Journey", it was assumed that the information provided to users during their journey should be up-to-date and take into account, among others, traffic conditions, road incidents (accidents and collisions), special events, and, in particular, the status of parking spaces. It may affect both the choice of parking in the vicinity of the destination and the change of means of transport during the trip (e.g., using the Park&Ride system or parking in any parking space near a public transport stop). The system should inform the user that there have been changes in the criteria based on which the information was developed before the journey. It was also assumed that the system should know the user's location in the transport network and provide the location of the vehicle or person using it. A detailed description of the needs and the functions of the ITS system assigned to them is provided in Table 6.

Table 6

User needs and functions fulfilled by the ITS system in the scope of Group 6. Information for Travelers → 6.2. Information During the Journey → 6.2.0. Objectives

Description of user needs	Assigned ITS system functions
6.2.0.1. The system should provide emergency or urgent information to all users free of charge.	6.5.10. Providing the traveler with a trip planning interface.
6.2.0.3. The system should be able to activate itself automatically by another system, e.g., traffic management.	6.5.3.11. Providing "green wave" routes, i.e., routes through intersections with coordinated traffic lights. 6.5.3.13. Providing data and routes to fleet operators and drivers. 6.5.3.3. Public transport data collection. 6.5.3.8. Road traffic data collection.
6.2.0.4. The system should provide up-to-date traffic information to travelers throughout their journey, taking into account traffic conditions, accidents, special events, parking space status, etc.	6.3.13. Providing the traveler with a travel interface. 6.5.3.8. Road traffic data collection. 6.5.3.9. Details of the travel plan.
6.2.0.6. The system should inform the user of any changes that may have occurred to the information provided before travel according to specified criteria.	6.3.11. Monitoring the implementation of travel planning for travelers. 6.3.13. Providing the traveler with a travel interface.
6.2.0.7. The system should know the user's position in the transport network and therefore provide the location of the vehicle or person using the system.	6.3.10. Implementation of travel planning and traveler navigation.

Source: own study based on the architecture of the ITS case study.

In terms of the needs for "Information During the Journey" regarding "Change of Transport Mode", the assumptions were made that the system should provide information covering alternative routes and alternative means of transport to those currently used during the journey – also in terms of the availability of Park&Ride systems and public transport timetables, with particular emphasis on intermodal nodes. A detailed description of the needs and the functions of the ITS system assigned to them is provided in Table 7.

Table 7

User needs and functions fulfilled by the ITS system in the scope of Group 6. Information for Travelers → 6.2. Information During the Journey → 6.2.1. Change of Transport Mode

Description of user needs	Assigned ITS system functions
6.2.1.1. The system should be able to provide alternative routes or recommend a change of mode of transport when it detects or is informed that there may be problems with a specific mode of transport.	6.3.11. Monitoring the implementation of travel planning for travelers. 6.5.10. Providing the traveler with a trip planning interface.
6.2.1.2. The system should be able to display alternative routes or modes of transport at intermodal hubs or where tourist information is available.	6.6.3. Output information for travelers.

Table continuation 7

Description of user needs	Assigned ITS system functions
6.2.1.3. The system should be able to provide information about other modes of transport, e.g., P+R parking locations, public transport timetables, etc.	6.5.10. Providing the traveler with a trip planning interface. 6.5.3.3. Public transport data collection. 6.5.3.9. Details of the travel plan.

Source: own study based on the architecture of the ITS case study.

In terms of the needs of "Information During the Journey" concerning "Information Service", it was assumed that the system should provide drivers (travelers), cyclists, and pedestrians with information on the current travel time between selected points, P&R parking lots, and public transport. The system should take into account restrictions related to weather conditions and road safety that affect the choice of route, travel time, etc. The information collected and made available by the system should indicate to user modifications to the travel plan in situations where the course of the journey deviates from its plan. The system should take into account various recipients of its information, including travelers, radio broadcasters, transport service operators, etc. A detailed description of the needs and functions of the ITS system assigned to them is provided in Table 8.

Table 8

User needs and functions fulfilled by the ITS system in the scope of Group 6. Information for Travelers → 6.2. Information During the Journey → 6.2.2. Information Service

Description of user needs	Assigned ITS system functions
6.2.2.1. The system should be able to inform travelers about the current average travel time between given points.	6.3.13. Providing the traveler with a travel interface.
6.2.2.2. The system should be able to provide real-time information about P&R parking or public transport to vehicle drivers.	6.3.13. Providing the traveler with a travel interface. 6.5.10. Providing the traveler with a trip planning interface.
6.2.2.3. The system should be able to provide cyclists and pedestrians with information about appropriate routes.	6.3.13. Providing the traveler with a travel interface. 6.5.10. Providing the traveler with a trip planning interface. 6.5.3.8. Road traffic data collection. 6.5.3.9. Details of the travel plan.
6.2.2.4. The system should provide traffic safety advice based on current weather and traffic conditions.	6.3.13. Providing the traveler with a travel interface. 6.5.10. Providing the traveler with a trip planning interface.
6.2.2.5. The system should be able to provide information to all drivers taking into account route constraints, travel times, etc.	6.3.13. Providing the traveler with a travel interface. 6.5.3.11. Providing "green wave" routes, i.e. routes through intersections with coordinated traffic lights. 6.5.3.8. Road traffic data collection. 6.5.3.9. Details of the travel plan.
6.2.2.9. The system should be able to adapt information to different classes of users, e.g. travelers, radio broadcasters, service operators.	3.1.1.14. Urban traffic data management. 3.1.2.9. Output data on intercity traffic. 6.5.10. Providing the traveler with a trip planning interface. 6.5.3.9. Details of the travel plan.
6.2.2.10. The system should be able to collect data from various sources, e.g. traffic management system, police, weather services, mobile observer, etc.	5.13.7. Preparation of extended data about the observer vehicle. 6.5.3.8. Road traffic data collection. 6.5.3.9. Details of the travel plan.
6.2.2.11. The system should be able to provide the operator with an overall view of all active events in a given area.	3.2.10. Incident data warehouse management. 6.5.3.7. Providing the operator with access to trip planning data.
6.2.2.12. The system should provide an information management tool for the operator.	6.5.3.7. Providing the operator with access to trip planning data.

Table continuation 8

Description of user needs	Assigned ITS system functions
6.2.2.14. The system should be able to modify the travel plan if the traveler does not follow it.	6.3.10. Implementation of travel planning and traveler navigation. 6.3.11. Monitoring the implementation of travel planning for travelers.

Source: own study based on the architecture of the ITS case study.

In terms of the needs of "Information During the Journey" concerning "Interaction with the Traveler", it was assumed that the system should support various forms of presenting data to users, along with the possibility of their configuration by users, both on mobile devices, as well as on on-board vehicle devices and on roadside devices, including VMS. In connection with this, a variant of providing data from a set of defined messages was also adopted. The default language is Polish, but it is also possible to change the language to another one. A detailed description of the needs and the functions of the ITS system assigned to them is provided in Table 9.

Table 9

User needs and functions fulfilled by the ITS system in the scope of Group 6. Information for passengers → 6.2. Information During the Journey → 6.2.3. Interaction with the Traveler

Description of user needs	Assigned ITS system functions
6.2.3.1. The system within a vehicle or service center should support various forms of presenting data to the user.	6.5.10. Providing the traveler with a trip planning interface. 6.5.3.11. Providing "green wave" routes, i.e., routes through intersections with coordinated traffic lights. 6.5.3.8. Road traffic data collection 6.5.3.13. Providing data and routes to fleet operators and drivers. 6.5.3.9. Details of the travel plan. 6.7.1. Defining a traveler's general travel preferences.
6.2.3.2. in its normal operating state, the system should deliver messages from a set of defined messages.	6.3.13. Providing the traveler with a travel interface. 6.5.10. Providing the traveler with a trip planning interface. 6.5.3.11. Providing "green wave" routes, i.e., routes through intersections with coordinated traffic lights. 6.5.3.8. Road traffic data collection. 6.5.3.13. Providing the traveler with a trip planning interface. 6.5.3.9. Details of the travel plan. 6.7.1. Defining a traveler's general travel preferences.
6.2.3.3. The system shall provide information in Polish for the output location and/or in another language based on the user's selection from the foreign language group.	6.3.13. Providing the traveler with a travel interface. 6.5.10. Providing the traveler with a trip planning interface. 6.5.3.11. Providing "green wave" routes, i.e., routes through intersections with coordinated traffic lights. 6.5.3.8. Road traffic data collection. 6.5.3.13. Providing data and routes to fleet operators and drivers. 6.5.3.3. Public transport data collection. 6.5.3.8. Road traffic data collection. 6.5.3.9. Details of the travel plan. 6.7.1. Defining a traveler's general travel preferences.
6.2.3.4. The system should deliver information using open communication protocols.	6.3.13. Providing the traveler with a travel interface. 6.5.10. Providing the traveler with a trip planning interface. 6.5.3.11. Providing "green wave" routes, i.e., routes through intersections with coordinated traffic lights. 6.5.3.8. Road traffic data collection. 6.5.3.13. Providing data and routes to fleet operators and drivers. 6.5.3.3. Public transport data collection. 6.5.3.8. Road traffic data collection. 6.5.3.9. Details of the travel plan. 6.7.1. Defining a traveler's general travel preferences.

Table continuation 9

Description of user needs	Assigned ITS system functions
6.2.3.5. The system should be able to deliver defined information while traveling to mobile or vehicle devices.	5.14.5. Providing a driver journey navigation interface. 6.3.13. Providing the traveler with a travel interface. 6.5.10. Providing the traveler with a trip planning interface. 6.5.3.11. Providing "green wave" routes, i.e., routes through intersections with coordinated traffic lights. 6.5.3.8. Road traffic data collection. 6.5.3.13. Providing data and routes to fleet operators and drivers. 6.5.3.3. Public transport data collection. 6.5.3.9. Details of the travel plan. 6.7.1. Defining a traveler's general travel preferences.
6.2.3.6. The system should allow drivers to configure the style and content of information received on mobile or in-vehicle devices.	6.7.1. Defining a traveler's general travel preferences.
6.2.3.8. The system should be able to provide road and traffic information using roadside devices such as VMS (Variable Message Signs).	3.1.1.5.2. Output communication and information for drivers using city roads.

Source: own study based on the architecture of the ITS case study.

Regarding the needs for "*Guidance on Routes and Navigation*", it was assumed that the system should provide users with recommended routes for given locations and update these routes on an ongoing basis. A detailed description of the needs and the ITS functions assigned to them is provided in Table 10.

Table 10

User needs and functions fulfilled by the ITS system in the scope of Group 6. Information for Travelers → 6.4. Guidance on Routes and Navigation → 6.4.0. Objectives

Description of user needs	Assigned ITS system functions
6.4.0.1. The system should provide travelers with recommended routes to specific locations.	6.5.10. Providing the traveler with a trip planning interface. 6.5.3.9. Details of the travel plan.
6.4.0.3. The system should know its position in the road network.	6.3.10. Implementation of trip planning and traveler navigation.
6.4.0.4. The system should be able to modify navigation instructions if an incorrect maneuver is performed.	6.3.10. Implementation of trip planning and traveler navigation. 6.3.11. Monitoring the implementation of travel planning for travelers. 6.3.13. Providing the traveler with a travel interface.
6.4.0.5. The system should be able to provide the driver with alternative routes when the originally planned route becomes unavailable.	5.14.4. Vehicle travel plan implementation and navigation. 5.14.6. Monitoring the implementation of the vehicle travel plan.

Source: own study based on the architecture of the ITS case study.

In terms of the needs of "Guidance on Routes and Navigation" concerning "Information Service", it was assumed that the system should process data in real time to provide the user with information guiding them to the selected destination, including free parking spaces and "public utility places" (POI). The system should calculate the estimated travel time on the indicated route and consider various criteria during guidance. A detailed description of the needs and the functions of the ITS system assigned to them is provided in Table 11.

Table 11

User needs and functions fulfilled by the ITS system in the scope of Group 6. Information for Travelers → 6.4. Guidance on Routes and Navigation → 6.4.1. Information Service

Description of user needs	Assigned ITS system functions
6.4.1.1. The system should be able to provide guidance to parking spaces.	3.1.4.9. Output information about parking spaces for drivers. 5.14.1. Providing a driver interface for trip planning. 5.14.2. Creating and revising a driver's travel plan. 5.14.4. Vehicle travel plan implementation and navigation. 5.14.5. Providing a driver journey navigation interface. 5.14.6. Monitoring the implementation of the vehicle travel plan. 6.3.10. Implementation of travel planning and traveler navigation. 6.3.11. Monitoring the implementation of travel planning for travelers. 6.3.13. Providing the traveler with a travel interface. 6.5.10. Providing the traveler with a trip planning interface. 6.5.3.8. Road traffic data collection. 6.5.3.9. Details of the travel plan.
6.4.1.2. The system should be able to use real-time information to calculate recommended routes.	6.3.10. Implementation of travel planning and traveler navigation.
6.4.1.3. The system should be able to calculate the total estimated travel time on the indicated route.	6.5.10. Providing the traveler with a trip planning interface. 6.5.3.11. Providing "green wave" routes, i.e., routes through intersections with coordinated traffic lights. 6.5.3.13. Providing data and routes to fleet operators and drivers. 6.5.3.3. Public transport data collection. 6.5.3.8. Road traffic data collection. 6.5.3.9. Details of the travel plan.
6.4.1.4. The system should be able to provide user-tailored information that guides the user to a specific goal using various criteria.	6.5.10. Providing the traveler with a trip planning interface. 6.5.3.8. Road traffic data collection. 6.5.3.9. Details of the travel plan. 6.7.1. Defining a traveler's general travel preferences.
6.4.1.5. The system should be able to provide guidance to public utility places.	5.14.4. Vehicle travel plan implementation and navigation. 5.14.5. Providing a driver journey navigation interface. 5.14.6. Monitoring the implementation of the vehicle travel plan. 6.3.10. Implementation of travel planning and traveler navigation. 6.3.11. Monitoring the implementation of travel planning for travelers. 6.3.13. Providing the traveler with a travel interface. 6.5.10. Providing the traveler with a trip planning interface. 6.5.3.9. Details of the travel plan.
6.4.1.6. The system should provide information consistent with other road information.	6.5.3.9. Details of the travel plan.
6.4.1.7. The system should be able to provide reports on the provided navigation performance.	6.7.3. Providing the operator with data for route information.

Source: own study based on the architecture of the ITS case study.

In the scope of the needs of *"Guidance on Routes and Navigation"* concerning *"Interaction with the Traveler"*, it was assumed that the system should use, among others, mobile devices, voice commands for navigation, and the system interface should be convenient and intuitive. A detailed description of the needs and the functions of the ITS system assigned to them is provided in Table 12.

Table 12

User needs and functions fulfilled by the ITS system in the scope of Group 6. Information for Travelers → 6.4. Guidance on Routes and Navigation → 6.4.2. Interaction with the Traveler

Description of user needs	Assigned ITS system functions
6.4.2.2. The system should include a menu that is structured logically and focused on driver requirements, e.g., the most frequently used functions should be selected most easily.	6.7.1. Defining a traveler's general travel preferences.
6.4.2.3. The system should enable two-way voice communication and data exchange with the vehicle.	6.3.10. Implementation of travel planning and traveler navigation. 6.3.11. Monitoring the implementation of travel planning for travelers. 6.3.13. Providing the traveler with a travel interface.
6.4.2.4. The system should enable the use of mobile devices for navigation.	6.5.3.13. Providing data and routes to fleet operators and drivers.

Source: own study based on the architecture of the ITS case study.

5.3. Group 10. Public Transport

Regarding the needs of "Public Transport Management" regarding "Information Service", it was assumed that the system should provide users with information about the services of public transport subsystems. Basic information includes departure time, travel time, delays, fares, etc. Information should be provided before and during the journey. A detailed description of the needs and the functions of the ITS system assigned to them is provided in Table 13.

Table 13

User needs and functions fulfilled by the ITS system in the scope of Group 10. Public Transport → 10.1. Public Transport Management → 10.1.4. Information Service

Description of user needs	Assigned ITS system functions
10.1.4.1. The system should be able to inform passengers about public transport services depending on the transport mode, for example, travel times, delays, fares, etc.	4.1.11. Management of public transport stops. 4.1.12. Output information about the service for travelers.
10.1.4.2. The system should be able to provide information about public transport services to travelers before and during their journey.	4.1.11. Management of public transport stops. 4.1.12. Output information about the service for travelers. 4.1.6. Predicting travel times of public transport vehicles. 4.1.9. Output arrival information for passengers.
10.1.4.3. The system should be able to provide real-time updates of arrival/departure times and present them to passengers of this mode of transport before and during their journey.	4.1.11. Management of public transport stops. 4.1.12. Output information about the service for travelers. 4.1.6. Predicting travel times of public transport vehicles. 4.1.8. Evaluation of the quality of public transport service.

Source: own study based on the architecture of the ITS case study.

In terms of the needs for "*Public Transport Information During the Journey*", it was assumed that the system should provide users with information on all transport subsystems of public transport, i.e., tram, bus, rail, air transport, taxi, carpooling, etc. A detailed description of the needs and the functions of the ITS system assigned to them is provided in Table 14.

Table 14

User needs and functions fulfilled by the ITS system in the scope of Group 10. Public Transport → 10.4. Public Transport Information During the Journey → 10.4.0. Objectives

Description of user needs	Assigned ITS system functions
10.4.0.1. The system should be able to inform passengers about all public transport modes (including buses, trams, trains, planes, taxis, car pools, etc.)	4.1.12. Output service information for travelers. 4.2.7. Public transport route data warehouse management.

Source: own study based on the architecture of the ITS case study.

In terms of the needs of "Public Transport Information During the Journey" concerning "Information Service", it was assumed that the system should provide dynamic passenger information in vehicles and at passenger service points, i.e., transfer hubs, bus and railway stops, stations, and stations, as well as transfer hubs. The basic scope of information includes travel time, the name of the next stop (in vehicles), departure times, delays, etc. (at passenger service points). The system should also provide information relevant to passengers with special needs, such as obstacles, manually opened doors, restrictions for guide dogs or strollers, etc. A detailed description of the needs and the functions of the ITS system assigned to them is provided in Table 15.

Table. 15

User needs and functions fulfilled by the ITS system in the scope of Group 10. Public Transport → 10.4. Public Transport Information During the Journey → 10.4.1. Information Service

Description of user needs	Assigned ITS system functions
10.4.1.1. The system shall be able to provide general dynamic public transport information in the vehicle, such as the arrival time and name of the next stop for that vehicle.	4.1.6. Predicting arrival times of public transport vehicles. 4.1.9. Output arrival information for passengers.
10.4.1.2. The system should be able to provide general dynamic public transport information, personal safety information, and departure times of following vehicles, delays, etc., at transfer hubs such as bus stops, train stations, and bus terminals.	4.1.11. Management of public transport stops. 4.1.6. Predicting arrival times of public transport vehicles.
4.1.3. The system should be able to provide information relevant to a traveler with special needs, for example, obstacles, manual doors, restrictions for guide dogs or wheelchairs.	4.1.12. Output information about the service for travelers.

Source: own study based on the architecture of the ITS case study.

In terms of the needs for "Public Transport Information During the Journey" concerning "Interaction with the Traveler", it was assumed that the system should provide information that is legible, understandable, and concise (quick to learn), provided in Polish and other foreign languages. A detailed description of the needs and the functions of the ITS system assigned to them is provided in Table 16.

Table. 16

User needs and functions fulfilled by the ITS system in the scope of Group 10. Public Transport → 10.4. Public Transport Information During the Journey → 10.4.2. Interaction with the Traveler

Description of user needs	Assigned ITS system functions
10.4.2.1. The system should be able to provide legible, understandable information and can be digested very quickly by all travelers.	4.1.11. Management of public transport stops. 4.1.12. Output information about the service for travelers. 4.1.9. Output arrival information for passengers. 4.2.7. Public transport route data warehouse management. 6.5.10. Providing the traveler with a trip planning interface.
10.4.2.2. The system should provide information in Polish for the output localization and/or another language based on the user's selection from other appropriate foreign languages.	4.1.11. Management of public transport stops. 4.1.12. Output information about the service for travelers. 4.1.9. Output arrival information for passengers. 6.5.10. Providing the traveler with a trip planning interface.

Source: own study based on the architecture of the ITS case study.

5.4. Scope of information and scope of functions

The prepared and tabulated view enables the assessment of the scope of information for users and the functions defined in the system. The system functions in the source data groups include urban traffic data, road traffic data, public transport data, and extended vehicle data of the mobile observer – floating car data (see Fig. 6).

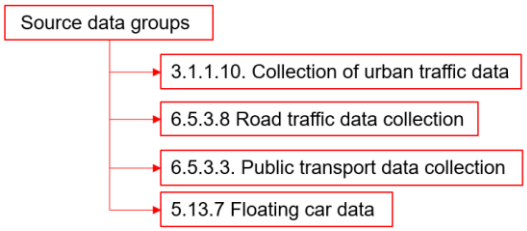

Fig. 6. The System functions in the "Source data groups".
Source: own study based on the architecture of the ITS case study.

The system functions relating to data processing for information production include, among other data management, provision of data and information, calculation of selected characteristics, e.g., estimation of arrival and departure times of public transport vehicles, implementation and possible corrections of travel and navigation plans, etc. (see Fig. 7).

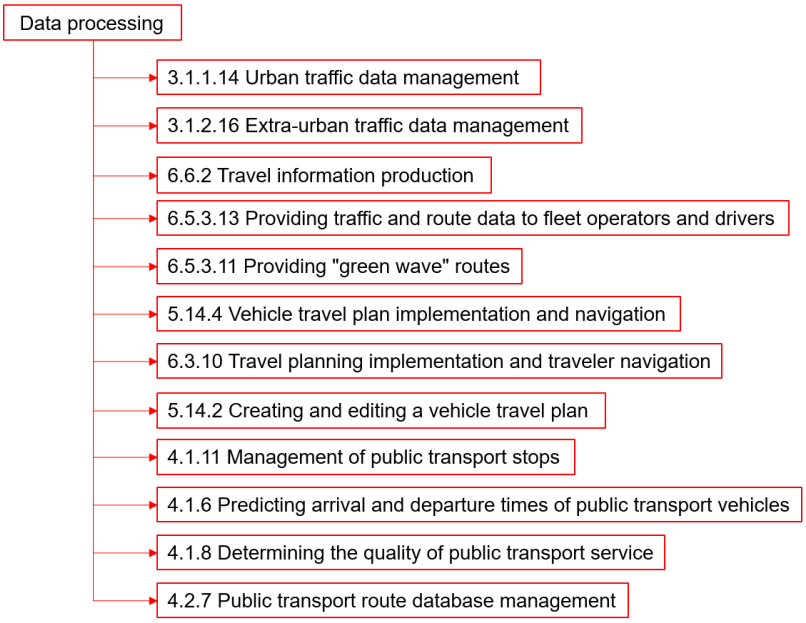

Fig. 7. The System functions in the "Data processing".
Source: own study based on the architecture of the ITS case study

The main results of these processes are outputs related to transport demand management, traffic information, travel information, parking space occupancy information, etc. (see Fig. 8).

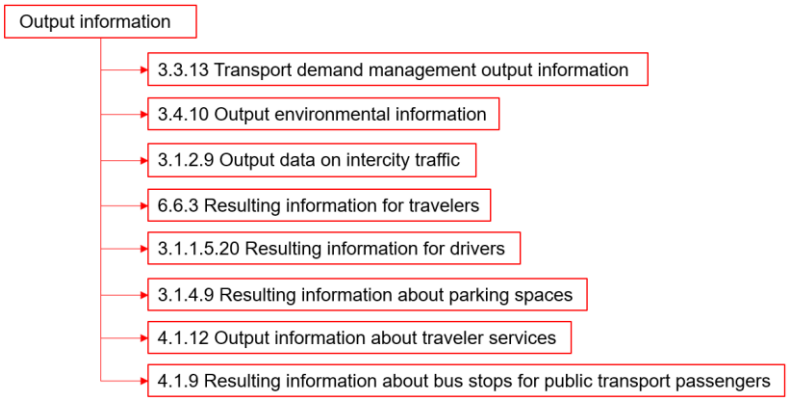

Fig. 8. The System functions in the "Output information". Source: own study based on the architecture of the ITS case study

Data processing and its results are supervised by monitoring and evaluation processes, including monitoring of travel planning by travelers and travel plan implementation, and the process of evaluating the trip after its completion (see Fig. 9).

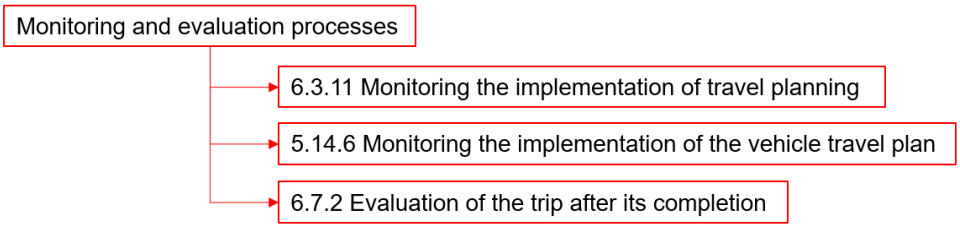

Fig. 9. The System functions in the "Monitoring and evaluation processes".
Source: own study based on the architecture of the ITS case study.

Providing and presenting information includes, among other things, providing the traveler and driver with a trip planning interface and a trip interface with an information presentation interface, together with the ability to define general travel preferences. For operators, additional interfaces are included for incident management, access to trip planning data, route information, and trip planning management (see Fig.10).

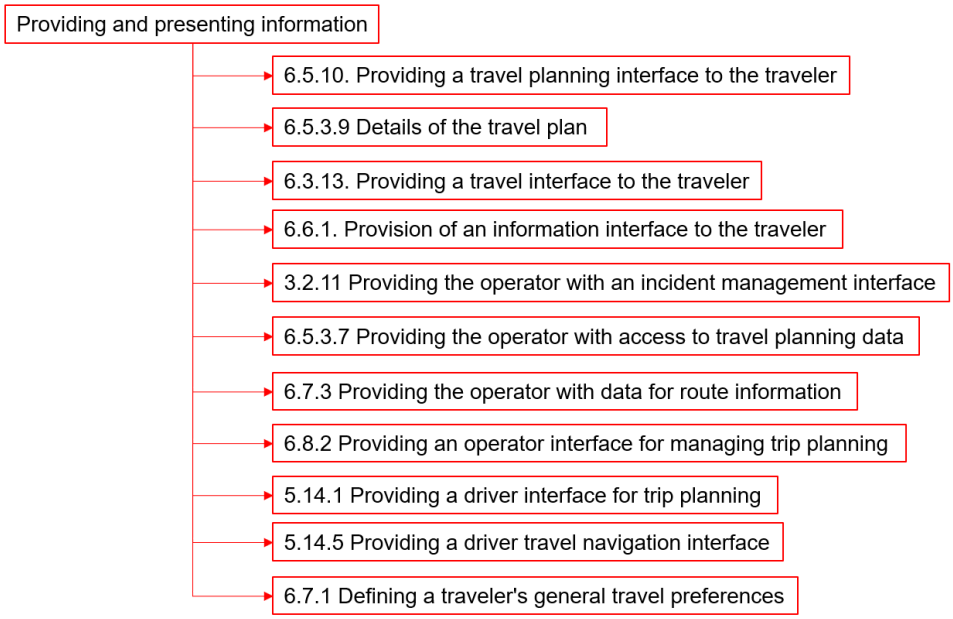

Fig.10. The System functions in the "Providing and presenting information".
Source: own study based on the architecture of the ITS case study.

6. CONCLUSIONS AND FUTURE RESEARCH PERSPECTIVES

In the paper, a personalized view of the architecture for the functioning urban ITS system was created. Creating this view was the general goal of the study, while the specific objectives were to analyze the current functions of this system regarding the appropriate needs of users and to find such functions that require further development of this ITS system.

Among the user needs and functions of the ITS case study, further directions of development of the discussed ITS system were identified, including the need to take into account transport modes using car sharing, bike sharing and scooter sharing as systems used in urban micromobility [27, 28, 29]. The second development area is related to electromobility, including services related to guiding to parking spaces with electric chargers and planning journeys [30], taking into account stopping to recharge the traction battery of electric vehicles [31] – passenger cars, delivery vans, and trucks. Considering the above, the needs in the

development of appropriate ITS services will contribute to reducing congestion in the urban street network, increasing the smoothness of traffic flows [32], and thus increasing road safety [33].

Creating a personalized view for a specific purpose/perspective was possible because the ITS system under study has a FRAME architecture. The method of analysis presented in the paper justifies the use of the ITS architecture during its design stage. Still, such an architecture is not always used at the design stage. The authors know of cases concerning the design of such an architecture after the ITS system has been built. This is an incorrect order of action, because the aspirations and needs of users that influenced the functionality of the ITS system without such an architecture are not known.

References

1. European Intelligent Transport Systems (ITS) Framework Architecture. Retrieved from: https://frame-online.eu/ (in English).

2. Macedo, E., Teixeira, J., Sampaio, C., Silva, N., Coelho, M. C., Glinos, M., & Bandeira, J. M. (2021). Real-time information systems for public transport: User perspective. *Transportation Research Procedia*, *52*, 732–739. DOI: 10.1016/j.trpro.2021.01.088 (in English).

3. Lin, T. S., & Chang, C. N. (2015). What Travelers Want: An Investigation into User Needs and User Wants on Display. In *Design, User Experience, and Usability: Interactive Experience Design: 4th International Conference, DUXU 2015, Held as Part of HCI International 2015, Los Angeles, CA, USA, August 2-7, 2015, Proceedings, Part III 4* (pp. 496–504). Springer International Publishing. DOI: 10.1007/978-3-319-20889-3_46 (in English).

4. Bruglieri, M., Bruschi, F., Colorni, A., Luè, A., Nocerino, R., & Rana, V. (2015). A real-time information system for public transport in case of delays and service disruptions. *Transportation Research Procedia*, *10*, 493–502. DOI: 10.1016/j.trpro.2015.09.003 (in English).

5. Kong, X., Eisele, W. L., Zhang, Y., & Cline, D. B. (2018). Evaluating the impact of real-time mobility and travel time reliability information on truck drivers' routing decisions. *Transportation Research Record*, *2672*(9), 164–172. DOI: 10.1177/0361198118797508 (in English).

6. Huang, Y., Jiang, S., Jafari, M., & Jin, P. J. (2024). Real-Time Driver and Traffic Data Integration for Enhanced Road Safety. *IEEE Transactions on Computational Social Systems*, (pp. 7711–7722). DOI: 10.1109/TCSS.2024.3448400 (in English).

7. Postranskyy, T., & Vovk, Y. (2020). Changing of the bus driver's functional state in city conditions. *Transport technologies*, *1*(1), 12–21. DOI: 10.23939/tt2020.01.012 (in English).

8. Al-Sultan, S., Al-Bayatti, A. H., & Zedan, H. (2013). Context-aware driver behavior detection system in intelligent transportation systems. *IEEE transactions on vehicular technology*, *62*(9), 4264–4275. DOI: 10.1109/TVT.2013.2263400 (in English).

9. Municipal Streets and Bridges Authority in Katowice. (2020). *Specification of essential terms of the order for Urban Intelligent Transport System* [Unpublished internal document]. Katowice, Poland (in Polish)

10. Municipal Streets and Bridges Authority in Katowice. (2020). *Functional and utility program of the Urban Intelligent Transport System* [Unpublished internal document]. Katowice, Poland (in Polish)

11. Municipal Streets and Bridges Authority in Katowice. (2020). *Annex to functional and utility program of the Urban Intelligent Transport System – FRAME architecture of the ITS system* [Unpublished internal document]. Katowice, Poland (in Polish)

12. ECUPT – The Centre for EU Transport Projects. Retrieved from: https://www.cupt.gov.pl/en/ceutp/about-us/ (in English).

13. Katowice City Authorities. (2011). *Content-related assessment (opinion, advice, consultations) of the investment project "Functional analysis for the Intelligent Transport Management System in Katowice, taking into account the metropolitan function of the city of Katowice"* [Unpublished internal study]. Katowice, Poland (in Polish)

14. Tramwaje Śląskie S.A. (2013). *Analysis of the possibilities of a systemic solution in the scope of priority for tram communication in the Upper Silesian Agglomeration* [Unpublished internal study]. Katowice, Poland (in Polish)

15. Tramwaje Śląskie S.A. (2013). *The need for a systemic solution regarding the priority of tram transport in the Upper Silesian Agglomeration* [Unpublished internal study]. Katowice, Poland (in Polish)

16. Katowice City Authorities. (2015). *Consulting, advising and issuing opinions for the "Concept and architecture of an intelligent traffic management system in the area of operation of the Municipal Transport Association of the Upper Silesian Industrial District"* [Unpublished internal study]. Katowice, Poland (in Polish)

17. Katowice City Authorities. (2016). *Analysis of the current status in terms of conditions for the development of pre-design documentation for the project "Katowice Intelligent Transport Management System"* [Unpublished internal study]. Katowice, Poland (in Polish)

18. Katowice City Authorities. (2016). *Guidelines for the tender specification for the selection of the contractor for the pre-design documentation for the project "Katowice Intelligent Transport Management System"* [Unpublished internal study]. Katowice, Poland (in Polish)

19. Karoń, G., & Mikulski, J. (2017). Selected problems of transport modelling with ITS services impact on travel behavior of users. In *2017 15th International Conference on ITS Telecommunications (ITST)* (pp. 1–7). IEEE. DOI: 10.1109/ITST.2017.7972231 (in English).

20. Karoń, G., & Mikulski, J. (2017). Selected problems of ITS project development–concept exploration and feasibility study. In *International Conference on Transport Systems Telematics* (pp. 1–15). Cham: Springer International Publishing. DOI: 10.1007/978-3-319-66251-0_1 (in English).

21. Karoń, G., & Mikulski, J. (2017). Functional configuration of ITS for urban agglomeration. In *Smart Solutions in Today's Transport: 17th International Conference on Transport Systems Telematics, TST 2017,* (pp. 55–69). Springer International Publishing. DOI: 10.1007/978-3-319-66251-0_5 (in English).

22. Karoń, G., & Janecki, R. (2017). Development of various scenarios of ITS systems for urban area. In *Intelligent Transport Systems and Travel Behaviour: 13th Scientific and Technical Conference "Transport Systems. Theory and Practice 2016" Katowice, Poland*, (pp. 3–12). Springer International Publishing. DOI: 10.1007/978-3-319-43991-4_1 (in English).

23. Karoń, G., & Mikulski, J. (2018). Problems of modelling of ITS services in transportation models. *Archives of Transport System Telematics*, *11*(3), 30–34. (in English).

24. Karoń, G., & Mikulski, J. (2018). Modelling of ITS service configuration and stakeholders' aspirations. *Archives of Transport System Telematics*, *11*(3), 24–29 (in English).

25. Karoń, G., & Mikulski, J. (2020). Its and systems engineering–methodical aspects. In *Research and the Future of Telematics: 20th International Conference on Transport Systems Telematics, TST 2020, Kraków, Poland,* (pp. 71–84). Springer International Publishing. DOI: 10.1007/978-3-030-59270-7_6 (in English).

26. Systems Engineering for Intelligent Transportation Systems: An Introduction for Transportation Professionals. Retrieved from: https://ops.fhwa.dot.gov/int_its_deployment/sys_eng.htm (in English).

27. Abduljabbar, R. L., Liyanage, S., & Dia, H. (2021). The role of micro-mobility in shaping sustainable cities: A systematic literature review. *Transportation research part D: transport and environment*, *92*, 102734. DOI: 10.1016/j.trd.2021.102734 (in English).

28. Reck, D. J., & Axhausen, K. W. (2021). Who uses shared micro-mobility services? Empirical evidence from Zurich, Switzerland. *Transportation Research Part D: Transport and Environment*, *94*, 102803. DOI: 10.1016/j.trd.2021.102803 (in English).

29. Ecer, F., Küçükönder, H., Kaya, S. K., & Görçün, Ö. F. (2023). Sustainability performance analysis of micro-mobility solutions in urban transportation with a novel IVFNN-Delphi-LOPCOW-CoCoSo framework. *Transportation research part a: policy and practice*, *172*, 103667. DOI: 10.1016/j.tra.2023.103667 (in English).

30. Schoenberg, S., & Dressler, F. (2019). Planning ahead for EV: Total travel time optimization for electric vehicles. In *2019 IEEE Intelligent Transportation Systems Conference (ITSC)*, (pp. 3068–3075). IEEE. DOI: 10.1109/ITSC.2019.8917335 (in English).

31. Xu, Y., Çolak, S., Kara, E. C., Moura, S. J., & González, M. C. (2018). Planning for electric vehicle needs by coupling charging profiles with urban mobility. *Nature Energy*, *3*(6), 484–493. DOI: 10.1038/s41560-018-0136-x (in English).

32. Żochowska, R., & Karoń, G. (2015). ITS services packages as a tool for managing traffic congestion in cities. In *Intelligent Transportation Systems–Problems and Perspectives*, (pp. 81–103). Cham: Springer International Publishing. DOI: 10.1007/978-3-319-19150-8_3 (in English).

33. Torbaghan, M. E., Sasidharan, M., Reardon, L., & Muchanga-Hvelplund, L. C. (2022). Understanding the potential of emerging digital technologies for improving road safety. *Accident Analysis & Prevention*, *166*, 106543. DOI: 10.1016/j.aap.2021.106543 (in English).

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ПЕРСОНАЛІЗОВАНЕ ФУНКЦІОНАЛЬНЕ БАЧЕННЯ АРХІТЕКТУРИ ІНТЕЛЕКТУАЛЬНИХ ТРАНСПОРТНИХ СИСТЕМ ЩОДО ІНФОРМАЦІЇ ДЛЯ КОРИСТУВАЧІВ МІСЬКИХ ТРАНСПОРТНИХ СИСТЕМ – ПРИКЛАД ДЛЯ ЦЕНТРАЛЬНОГО МІСТА МЕГАПОЛІСУ

Анотація. *У статті викладено персоналізоване функціональне бачення архітектури інтелектуальних транспортних систем (ІТС) щодо інформування користувачів міських транспортних систем на прикладі систем ІТС центрального міста мегаполісу. Фундаментальним питанням з погляду користувачів транспорту є отримання інформації про повний функціональний спектр транспортних систем. На основі такої інформації можна планувати поїздки так, щоб, з одного боку, вони були максимально ефективними для кожного користувача окремо, а з іншого – стійкими з погляду транспортних систем і конкретної транспортної політики міста / метрополії. Вибір такого бачення пов'язаний з тим, що основною потребою так званих кінцевих користувачів систем ІТС, тобто людей, які пересуваються за допомогою транспортних систем, є отримання цінної та актуальної інформації в ефективний спосіб – бажано в режимі реального часу, тобто під час пересування користувачів. Основне питання, тобто персоналізоване функціональне бачення архітектури системи ІТС щодо інформації для користувачів міських транспортних систем, висвітлено на прикладі систем ІТС, що працюють у центральному місті міської агломерації в Польщі, яке має статус мегаполісу. Ці системи ІТС були впроваджені на межі 2023–2024 років і розроблені з використанням європейської рамкової архітектури ІТС. Цілі полягають у визначенні поточного обсягу інформації для користувачів та поточного обсягу системних функцій досліджуваної системи ІТС, щоб вказати подальші напрями розвитку досліджуваної системи ІТС. Тому наведено характеристики зв'язків між потребами користувачів міського транспорту та функціями систем ІТС, пов'язаними з інформацією для цих користувачів. Відповідно до такого погляду на системи ІТС, визначено напрями їх подальшого розширення у функціональній сфері, що охоплює потреби людей, які користуються міською мікромобільністю та системами спільного користування транспортом, тобто спільного користування автомобілями, велосипедами та електросамокатами в поїздках, які планують у режимі реального часу. Другий напрям розвитку – електромобільність, що передбачає розвиток сервісів, пов'язаних із навігацією до паркувальних місць з електрозарядками та плануванням поїздок з урахуванням підзаряджання тягової батареї електромобілів – легкових автомобілів, автомобілів доставки та вантажівок.*

Ключові слова: *інтелектуальні транспортні системи, рамкова архітектура FRAME систем ІТС, потреби користувачів транспорту, послуги ІТС, інформація для користувачів транспортних систем.*