Implementation of Intelligent Transport Systems in an Urban Agglomeration: A Case Study

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Abstract. The development of road transport requires cities to have a multi-faceted traffic management system. It is particularly true in city centers, where public transport modes (buses and trams) are also being added in addition to individual vehicles. The article is based on field research carried out, for which the case study was the city center of Szczecin. The article proposes a three-stage research methodology, consisting of an inventory of the current state of the selected infrastructure section, surveys of traffic density and travel time, and analysis of the data obtained (field research), which are the key to selecting locally appropriate ITS-class devices. The actions taken resulted in selecting ITS systems according to criteria such as improvement of traffic safety and fluidity, improvement of the overall traffic management and information system, and improvement in the functioning of public transport. As part of the work, many devices and systems were identified that can significantly improve the collective and individual mobility of the studied street section. These include intersection monitoring, accommodating signaling, a tram priority system, and passenger and parking information boards. This article aims to present the possibilities of implementing ITS systems in city centers, taking into account the specific individual road conditions and the need to improve vehicle flow management, using the example of a ready-made proposal for the city of Szczecin, using the minimum necessary equipment.

Keywords: ITS · Traffic Studies · Cities Mobility · Public Transport · Sustainable Transportation

1 Introduction

With the increasing number of vehicles, transport within city limits, especially in city centers, is becoming increasingly difficult. One of the solutions used to increase traffic safety, improve mobility in city centers and increase the efficiency of urban traffic management is the implementation of solutions and devices belonging to the group of intelligent transport systems. The concept of ITS implementation proposed in the article was developed based on an analysis of the current state of a selected road section in the

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very center of Szczecin, which, due to the significant volume of car traffic and means of public transport and the lack of possibilities to expand the infrastructure, requires a proper, holistic approach to traffic management. The street section chosen for the study does not meet many contemporary transport standards, e.g., very few devices are responsible for assisting and directing traffic, and the traffic organization that has remained unchanged for many years only exacerbates the problem. The main aim of the article is to prepare a concept for the application of ITS, which can be directly implemented on the road section selected for the study.

2 Literature Review

Transport systems, consisting of, i.e. road infrastructure and means of transport, are an indispensable part of any country's economy. Hence, they are of interest to many researchers. Research related to transport systems addresses their problems on numerous levels.

One of the problems is the reliability of system operation. It can be considered both in the context of the reliability of means of transport, including the application of innovative solutions [1], reliability of road infrastructure [2], management decision-making [3], processes related to cargo manipulation in freight transport [4] or location of vehicle diagnostic and repair centers [5]. An equally important research area related to transport systems [6] is safety analysis.

The development of telematics, including telecommunications, information technology, and automation, has made it possible to make a qualitative leap in the approach to developing transport systems [7]. Such solutions are used at all levels of different systems [8, 9], ranging from issues related to the development of the automotive industry [10], communication between individual traffic participants [11], through the collection of data on the current state of the road infrastructure [12], to advanced technologies for controlling individual elements [13], as well as entire systems [14].

Urban agglomerations, due to their large population centers and the associated high number of road users, are very sensitive areas regarding traffic management [15]. Consequently, all kinds of technical solutions to support decision-making in matters of organization [16] and infrastructure management [17] are increasingly being implemented [18].

In practice, a major challenge for those deciding on road infrastructure development is the appropriate construction of an ITS structure [19] based on which a comprehensive traffic control system would operate in a selected area. This is due to the multitude of ITS solutions currently operating on the market [20], the lack of clearly formulated implementation schemes, and the definition of rational selection criteria. Based on the literature analysis, it was concluded that there is a need to develop a methodology facilitating the implementation of ITS solutions in urban agglomerations.

3 Research Methodology

The wide range of subsystems, the need to define selection criteria, and the considerable differences in road infrastructure make it necessary to carry out a detailed study to

determine the level of relevance of the various solutions that can be introduced into the transport system.

The proposed research methodology is divided into three stages. The first comprises a series of preparatory activities aimed at developing a concept for ITS implementation, which thus constitutes the second stage of the research. The last, third stage is open-ended and consists of proposed solutions that can be introduced within the ITS system. A simplified diagram of the research methodology is presented in Fig. 1.

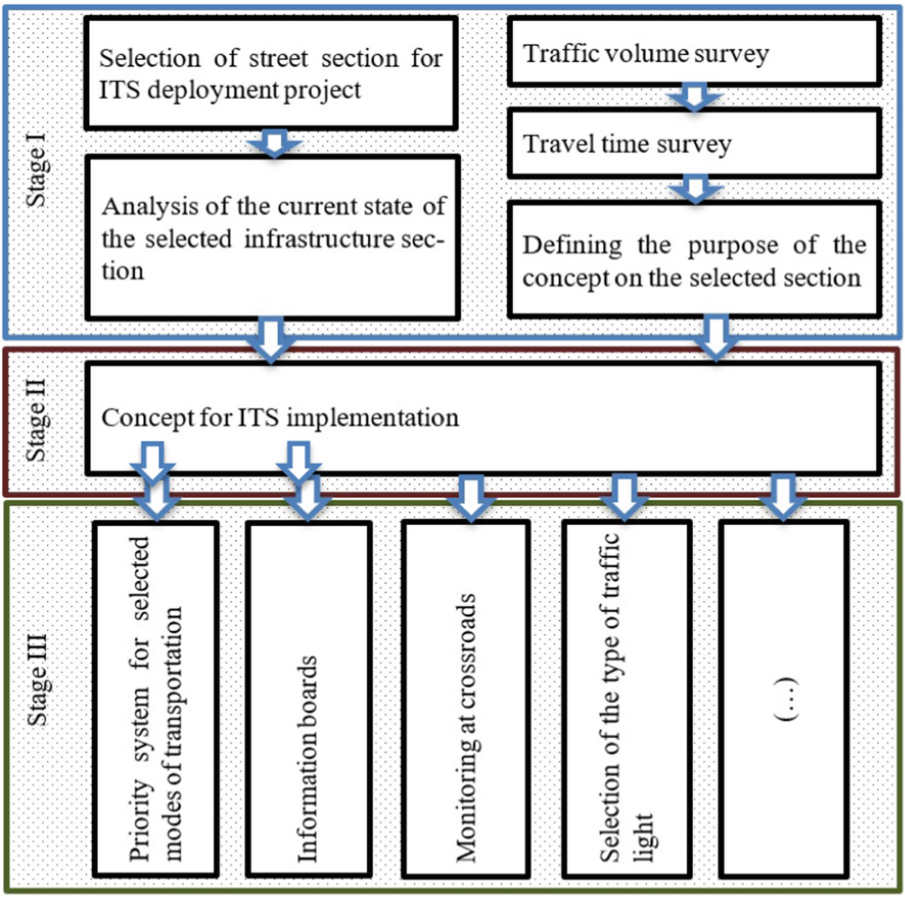

Fig. 1. Simplified scheme of the research methodology.

3.1 Stage I - Creation of the Database

The selection of the section for the ITS project is carried out according to the following criteria:

– transit importance for the city - both of local and all-city importance, enabling the passage of passenger vehicles, heavy goods vehicles, and public transport,
– paid parking zone - the selection of a section close to the paid parking zone allows the implementation of devices supporting the parking system,
– high intensity of public transport – many public transport lines are in the selected section.

The selected infrastructure section's current condition, i.e., an infrastructure inventory, is analyzed after prior fragmentation into sections of no more than 300 m. The analysis includes information on the layout and division of streets, the location of intersections, traffic lights, public transport stops, the division of traffic lanes, paid parking zones, the layout of tracks, and the general urban context. The traffic volume survey was carried out based on a modified method by the General Directorate of National Roads and Motorways. Modifications concern the following areas:

– exclusion of vehicles such as agricultural tractors and motorbikes - due to their marginal contribution to traffic,
– the inclusion of rail public transport vehicles,
– the combination of truck tractors with and without semi-trailers in one group.

Travel time study - field studies. Split between passenger vehicles and public transport vehicles. Selection of frequency and hours of measurement following the traffic characteristics of the section, i.e., including both peak and off-peak times.

The definition of the concept's objective for the selected section can only occur after a preliminary analysis of the results obtained in the previous steps of stage one. The identification of the problems of the section in question, including the identification of weak points, forms the basis for the creation of the ITS implementation concept.

3.2 Stage II - Creating a Concept for Its Implementation

The main idea behind the concept is to implement ITS systems in such a way that it is possible to improve the transport system in a given section. These primary concerns:

– general improvement of safety,
– increase in the scope of operation and improvement of the information system for passengers and drivers,
– improving traffic flow,
– improving the functioning of public transport.

3.3 Stage III - Definition of Its Elements

At this stage, the ITS structure possible to implement in the analyzed road infrastructure area is defined. The results of previous research and analyses determine the selection of individual elements. The purpose of the third stage is to propose specific solutions, the implementation of which will contribute to the realization of the assumptions presented in the earlier stages of the research methodology.

4 Results and Discussion

For a long time now, various processes and studies have been conducted on a large scale to improve urban mobility. However, there are still places where traffic flow needs to be improved or where modern ITS solutions have already been introduced, but where they do not fully meet the intended purpose. This study aimed to assess the feasibility of implementing ITS to improve urban traffic flow in the example of Szczecin. It should be noted that ITS is of particular importance in city centers, where there is no possibility of significant interference with the road system, in areas that are characterized by increased traffic volumes at certain times of the day, etc. ITS can be used to improve traffic flow. Since the current road infrastructure in towns and cities is not adapted to the level of traffic, the separation and implementation of the relevant elements belonging to ITS is a necessary solution for improving the safety of all traffic users.

According to the proposed research methodology, the first stage concerns the creation of a database necessary to develop the concept of ITS implementation in the surveyed city. In addition to the basic criteria influencing the selection of the street section to be surveyed, issues of previously introduced ITS solutions in the given area of the city were also taken into account, as well as the possible inclusion of the given section in Szczecin's road infrastructure development plans. The road section between the junction of Bohaterów Warszawy Avenue, 26 Kwietnia Street and Bolesława Krzywoustego Street and Zwycięstwa Square was selected for conceptual studies and divided into four sections (200–300 m length each) for further detailed analysis. It should be noted that this street section is very important for the city as it is one of the main road arteries in the city center.

The next step was to analyze the current state of the selected infrastructure section, which provided information on the layout and division of streets, the location of intersections, traffic lights, as well as the course of tracks, and the location of public transport stops. An additional source of information was the traffic volume survey of the selected section, which was carried out on 7th January 2022. Two observers in two rounds carried out the measurements – the first during the traffic peak (13:00–15:00) and the second during the off-peak period (16:00–18:00). One of four measurement forms is presented in Table 1.

Based on the analysis of the measurements obtained, the following conclusions were reached:

- about 80% of all passing vehicles were passenger cars, while vans and lorries made up a small proportion (about 11%),
- the frequency of buses was lower than that of trams, with buses passing on average every second phase of the traffic light cycle change, and trams passing on average in each phase of the traffic light cycle, also two per phase,
- in the first phase of measurements, traffic was more intense in the direction towards the city center, while in the second phase of measurements (traffic rush hour), there was a decrease in traffic towards the city center and an increase in traffic towards the city center,
- the number of running buses and trams was similar in both measurement phases.

Table 1. Traffic measurement form - section 4 - corner of Wojska Polskiego Avenue and Bolesława Krzywoustego Street (north side).

Location of research:		4) Corner of Wojska Polskiego Avenue and Bolesława Krzywoustego Street (north side)				
Direction of vehicle movement:		West - Bolesława Krzywoustego Street				
Observer:		Łukasz Gilewicz		Date: 07.01.2022		
Measurement phase:	Measurement time	Passengers vehicle	Delivery vehicles	Heavy goods vehicles	Buses	Trams
I	14:40 – 14:45	40	0	1	0	1
		17	1	0	0	1
		28	4	0	1	1
		17	1	1	0	1
		10	0	0	1	0
	Total	112	6	2	2	4
II	17:10 – 17:15	20	0	0	1	1
		28	2	1	0	0
		38	1	1	1	2
		35	0	0	0	1
		18	3	1	1	1
	Total	139	6	3	3	5

The second study measured the time required to travel along a selected section using a car and a means of public transport - the tramway. The results of the individual measurements are presented in Table 2.

Analysis of the measurement data allows the following conclusions to be drawn:

– average arrival times by car and tram are similar, as the tram travels on a shared route with road vehicles for about half of its route,
– the average travel speed of the tram is slightly higher.

The final element of the first stage of the work was to define the conceptual goal of the selected section. As a result of the traffic volume and travel time surveys, a fairly high number of unsafe situations and driver errors were also observed, which had a negative impact on traffic safety and fluidity. The analysis of the results of the infrastructure inventory of the selected road section also revealed equipment deficiencies, i.e., support facilities for the information system for drivers and passengers. On this basis, the aim of the project was to implement intelligent transport systems devices to improve road safety and traffic flow and the information system for public transport passengers and individual drivers.

Table 2. Average travel times for the selected modes of transport on the surveyed street section.

No.	Number of journey phase	Type of vehicle	Average travel time [min]	The length of surveyed street section [m]	Average driving speed [km/h]
1	I	Passenger car	4:21	980	13.52
2	II (traffic peak)	Passenger car	4:38	980	12.69
3	I	Tram	4:29	980	13.12
4	II (traffic peak)	Tram	4:25	980	13.31

Because the selected section is of great traffic importance for road users, stage II of the research methodology proposed the implementation of a number of ITS devices according to the functions performed, i.e.:

– improving traffic safety (monitoring at junctions, accommodating signaling, tram priority system),
– improvement of the information system for passengers and drivers (passenger and parking information boards),
– improving traffic flow and the quality of tram transport operation (accommodating signaling, tram priority system).

The third stage involves introducing and justifying the selection of locally appropriate ITS devices proposed at stage two. The first solution proposed to improve traffic safety is to monitor sensitive areas (junctions) using eleven CCTV cameras. It will enable real-time observation and recording of all dangerous events in the area of intersections - including vehicles driving contrary to traffic regulations. The camera subsystem will be supplemented by a dedicated accommodative signaling subsystem, which will manage the traffic lights in the area of Plac Kosciuszki. This system is designed to adapt the phases of individual traffic lights to changing traffic conditions, e.g., to regulate the phases of traffic signal changes during and after the traffic rush hour and to increase the capacity of this section as much as possible. The third element in this group is the tram priority subsystem - the receiving equipment must be connected and synchronized with the traffic light control system. In this case, it is planned to reduce the travel time of trams on a selected section. An appropriate interplay between the accommodating signaling subsystem and tram priority should enable a smoother passage for all users.

The second group of ITS devices aims to improve the transmission of information to passengers and other road users. To this end, it is planned to complete the missing passenger information boards for public transport users and to install 9 new parking information boards. The boards will display information on the number of available parking spaces in selected car parks, which should contribute to a better turnover of parking vehicles in the city center.

5 Conclusions

The conducted field studies allowed determining the basic parameters of road traffic. The share of motor vehicles and trucks was determined, respectively 80% and 11%, concerning all road users. The general traffic volume was also analyzed concerning their direction (to and from the city center) and the detailed intensity, including averaged travel times for passenger cars and trams. It allowed concluding that the average travel times by the indicated means of transport are similar.

Safe and efficient travel in city centers is currently one of the most important transport problems. A study carried out in January 2022 in Szczecin showed that it is still possible to identify strategic road sections that are not adapted to the prevailing individual and collective vehicle traffic (including trams).

As a result of the study, it was proposed to implement solutions such as:

- the deployment of an additional eleven CCTV cameras,
- an installation of a dedicated accommodative signaling subsystem, which will manage the traffic lights in the area of Plac Kosciuszki,
- include the tram priority subsystem - the receiving equipment must be connected and synchronized with the traffic light control system,
- complete the missing passenger information boards for public transport users,
- an installation of nine new parking information boards.

The ITS devices proposed in the study, layout, and location are intended to fulfill the expected tasks with a minimum of additional equipment. The main idea is to improve traffic flow in the city center for passenger vehicles, delivery vehicles, and others, but also for public transport vehicles (buses and trams).

Future research directions will focus on continuing research into urban traffic safety and optimizing the use of ITS.

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