

THE ANALYSIS OF ANPR CAMERA LOCATION POINTS IN BUS LANES MONITORING SYSTEM IN THE CITY OF WARSAW

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Abstract

Warsaw has the most developed public transportation system in Poland and, therefore, the longest network of bus only lanes. The studies show a significant number of their violations made by individual vehicles, mostly because of complex traffic conditions and lack of physical separation from the other road lanes. This situation leads not only to road traffic law violations, but also mainly to disturbance in regularity and efficiency of bus connections. According to similar solutions implemented in other cities, Motor Transport Institute designed a concept bus lane enforcement system for Warsaw, which comprises the analysis of state-of-the-art law regulations on using monitoring systems in Poland, as well as operational and technical conditions for implementing the designed system and the concept of the system and system architecture itself. During the research, Motor Transport Institute conducted a complex audit of the bus lanes, in result of which the desired locations for ANPR camera points were identified. The article thoroughly describes the Polish law regulations on ANPR cameras location and confronts it with the actual needs regarding specific urban road sections. It also presents the methodology adopted for localizing the camera points. As a result, several examples of proposed locations are presented and discussed in terms of their compliance with the regulations, necessity for changing the traffic system on the specific road section and efficiency in bus lane enforcement.

Keywords: *transport, public transport, ANPR, monitoring, bus lane, bus-only lanes*

1. Introduction

A significant growth of travels made using individual means of transport, as well as the overall increase of motoring level in Poland, caused a number of considerable difficulties in functioning of the urban transportation systems. Additional effect of this phenomenon can be seen in gradual decrease of overall travels made using means of public transport system, which are not in position to compete with individual vehicles in terms of comfort and the directness of travel.

The aforementioned conditions resulting in the overload of road transport system in Warsaw cause frequent traffic problems, which are represented by a significant congestion. The Congestion Index 2012, presented by the TomTom Company, reveals that the average delay of the vehicles travelling around Warsaw during rush hours is 55 minutes compared to a normative one-hour drive in free traffic flow conditions. This results in Warsaw being the second most congested city in Europe [2].

The congestion problems also cause a substantial effect on reliability and efficiency of the bus transportation system as the bus routes are mainly being led on the roads available for all types of the vehicles. Unfortunately, traffic generated by the individual means of transport on the main and distributor roads significantly impedes providing the punctual public transport services. However, Warsaw authorities provide attempts to improve the performance of public transport system, not only by introducing the prioritization for the vehicles, but also by using different planning, technical, organizational and financial means. Nevertheless, the bus and tram priorities are the most popular and most frequently seen methods to do so.

The most popular, yet quite controversial, implementation of the priorities for public transport vehicles are the bus-only lanes. Warsaw's transport policy implies introducing them on main roads of the city, as well as on the road sections, where the free flow of public transport vehicles was severely handicapped by a massive traffic caused by individual vehicles. Unfortunately, these solutions are only local, while an integrated network of bus-only lanes seems to be inevitable in the further perspective, mostly due to increasing amount of individual vehicles and a need to improve the quality of public transportation services. Therefore, a strong need to control the existing bus priority lanes is addressed by the public transport and road management authorities of Warsaw. This happens according to the fact revealed by the conducted traffic measurement studies, which clearly show a frequent violation of the bus lanes by the individual vehicles. A lack of integrated preventing solutions seems to be biggest obstacle in changing this trend and causes further decrease in quality of the public transport services. Also, casual controls from Police and Metropolitan Police cannot be treated as the efficient and long-term solution, because despite their frequent use, all they cause is only a slight and temporary benefit, which and be observed mostly during the controlling period.

To answer the aforementioned need for a bus lane violation control system, Motor Transport Institute conducted a project in order to design a solution that could be fitted exactly to the needs of the transportation system of the city of Warsaw. The aim was to design a conceptual model of telematic system based on use of ANPR cameras and being able to transfer the data gathered from the camera points to the external entities, not only to issue the penalties, but also to provide thorough traffic analysis. The research and development in scope of the project included the following topics:

- analysis of the law regulations regarding the control and violations on the separated road lanes, powers of different authorities to monitor and penalize such offences, law limitations for building bus-only lanes monitoring system,
- description of technical and functional requirements for the registered data and data security in the telematics system,
- provision of data processing model suited to the Polish law regulations and competence of different authorities,
- analysis of the optimal location for the ANPR camera points.

All of the aforementioned areas of the project led to the final provision of a conceptual bus-only lanes monitoring system, which included the proposed logical architecture, technical conditions for the proper functioning of the violation registration centre and the analysis of the influence that could be caused by the system for both the behaviour of the individual vehicles' drivers and the effectiveness of the bus-only lane with the system implemented.

The following article thoroughly covers the topic of the optimal ANPR camera point locations in the proposed bus lane monitoring system in Warsaw. In the first part, the authors describe law and organizational conditions, which need to be met in order to properly, locate the camera point. The second part of the article highlights the proposal of the camera point locations on the chosen bus-only lane in Warsaw and provides the detailed comments for each of them.

2. Organizational and law conditions for the bus-only lane monitoring system

The proper location of the camera points on road sections covered with bus-only lanes is a crucial aspect for the effectiveness of the system. Yet, the system designers have a very limited latitude in providing the optimal locations, taking into account both law regulations and road traffic organization on the road sections. This brings a certain need for these two aspects to be carefully examined.

The Regulation on conditions for the location, method of marking and measuring by the recording devices of the Minister of Infrastructure poses the biggest practical obstacle in implementing the system efficiently [3]. It addresses the problem of arbitrary positioning of the registration devices. Unfortunately, the main disadvantage is the determination by the legislature of particular conditions, taking into account only the requirements necessary for the recording devices which are currently

the most common on Polish roads, thus recording an infringement of the speed limit at a given point or along the road and drive through the intersection on a prohibit signal. In Chapter 2, §2, paragraph 2 of the regulation, the conditions for stationary location of recording devices were set out:

“Stationary recording equipment may be located:

- in urban area at a distance of not less than 500 m from any other stationary recording device in this direction,
- outside the urban area at a distance of not less than 2000 m from any other stationary recording device on this direction – with the exception that these devices cannot be located on roads under the supervision using recording devices, which reveal the violation of traffic rules in a particular section of road.”

Unfortunately, the definition of the distance between the recording devices has been designated taking into account only the characteristics of the speed limit exceeding measurements. Regarding the other uses of ANPR devices, this recording becomes irrelevant. Unfortunately, the notation, which prohibits placing other recording devices within the road sections of segmental speed measurement, excludes locating ANPR devices which have different functionalities than the speed limit violations. This situation is unfavourable for both the localization of these devices, especially the inability to monitor violations of bus lane on the road covered by segmental measurement of vehicle speed, and economics – the device could be placed on the same poles and powered by single supply system, and sending recorded data by single transmission link, with a correspondingly high rate.

When the legitimacy of camera point locations is being analysed, the key aspects, which have to be specified at the very beginning, are the main factors causing the tendency to violate the bus-only lane. Such lane is frequently crossed on its course with the sections where the traffic of other vehicles is allowed. Therefore, the endings of these sections are mostly exposed to a potential violation of the regulations.

Aforementioned sections occur mainly due to the necessity for:

- turning or turning back,
- joining the traffic flow,
- entering or leave the property or non-public roads,
- park the vehicle.

The sections enabling to turn (exclusion sections) are mainly implemented before the crossings and highway-class road exits. Their length is not regulated and is mainly determined according to the speed limit on the road section. As seen on the following pictures, the exclusion sections interfere the bus-only lane from both left and right – they let the individual vehicles to turn or turn back as well as to turn on them.



Fig. 1. Types of exclusion sections on bus lanes – from left: the section made before a non-collision turn, section before the four-inlet crossing, section designed for a road with increased speed limit

The analysis reveals that two main types of the bus-only lane violations may occur there:

- changing the lane to the bus-only lane before its ending and the beginning of the exclusion section,
- changing the lane to the bus-only lane after the ending of the exclusion section.

Both of them may take place more frequently when the traffic in the individual transport lanes does not represent a free flow of the vehicles. This is why the camera point location is both reasonable and allowed to be provided for both the endings and beginnings of such exclusion sections, as the law regulation defines each of the aforementioned section as the crossings. It was found especially important to provide the camera points at the beginnings of the exclusion sections, as the analysis reveals that the violation made in this part of the lane is especially favorable for the drivers following the same route as the prioritized buses.

The inclusion sections allow the drivers to join the traffic flow on the nominal lane after e.g. turning at the crossing or leaving the trestle. They are implemented mainly right after the ending of the crossings which allow to turn to the road where a bus-only lane is located. The following figure shows the examples of the inclusion sections:

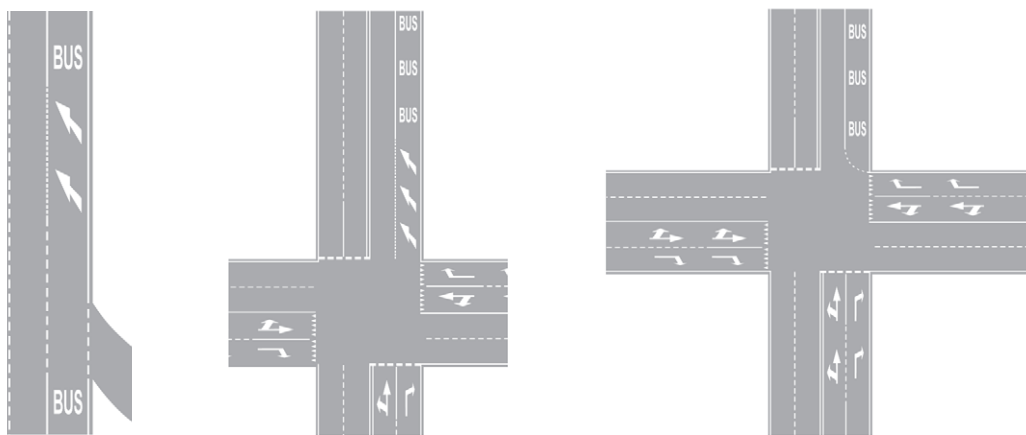


Fig. 2. Examples of inlet sections on the bus-only lanes. From left: inclusion section behind the trestle inlet, inclusion section on a crossing enabling to turn into inlet with bus-only lane, crossing not enabling to turn on a bus-only lane

Unlike the exclusion sections, these ones can only be violated by riding a vehicle on a bus-only lane after the end of the section. Therefore, the camera points should be located in some distance from the section ending. The detection zone of the ANPR camera should be able to provide the ‘clear’ violations and excluding the accidental ones, which could be caused by the difficulties in joining the traffic on the lanes used by the individual vehicles or a slightly late leaving the bus-only lane according to the insufficient attention of the driver or a high vehicle speed.

It is common that bus-only lane leads next to exits from private properties, parking lots and other non-public roads. Therefore, the lane can be interrupted with the exclusion and inclusion sections providing the exit or enter to these road. However, according to the Act of Road Traffic Law [4], such exits cannot be treated as the crossings, what, according to the Regulation of the Minister of the Infrastructure, brings the necessity of maintaining the minimal distances between the camera points. In reality, these limitations hardly allow to provide the cameras in such locations.

According to the regulations, camera points must be situated in the distance of at least 500 m from each other. This rule is yet not applicable if at least one crossing, exclusion or inclusion section is situated at this road section. This means that it is possible to mount at least one camera point between the following crossings. The analysis of the functional system of the existing and planned bus-only lanes in Warsaw points out that the distances between the beginnings and endings of the particular bus-only lane sections hardly reach 500 metres. Taking into the account only the existing sections, this situation occurs only once in whole network of bus lanes. The aforementioned limitation forces to point out which of their elements need to be monitored. Although no decision problem needs to be discussed when the lane includes two following inclusion sections, other cases

need to be thoroughly discussed and the priority for each solution needs to be addressed. Diversity of road network configurations in real-life systems causes a reasoned necessity for providing an individual analysis of each camera point's influence to the traffic in a certain location.

3. Analysis of camera point locations for chosen bus-lane

During the project, Motor Transport Institute thoroughly inventoried all of the existing bus-only lanes as well as the road sections which are appointed to introduce a bus lane in the nearest future. The research included gathering the information about:

- physical and organizational characteristics of the bus lane as well as the traffic organization in scope of the road it is provided on,
- key information about the surrounding of the road section, e.g. parking places, parking organization,
- types of exclusion/inclusion sections on the road crossings.

In order to highlight the way of appointing the proposed ANPR camera point locations, following chapter thoroughly shows the analysis made in scope of one of the bus-only lanes in Warsaw.

The bus-only lane in Kasprzaka street has a total length of 1377 m and was delineated on the southern roadway of the street. Four regular bus lines provide public transport services at this road section. The street itself collects a major traffic coming from the western districts of Warsaw, as well as its western outskirts, to the newly developed business district and the very city center. The 'main road' class given by Warsaw Road Management Authorities also proves its key role in the public roads network.

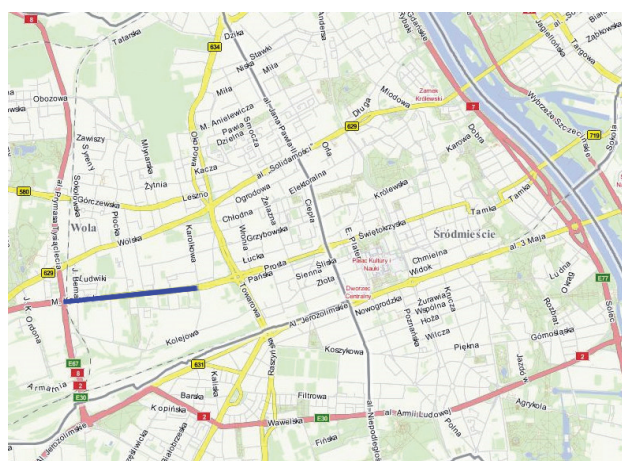


Fig. 3. The bus-only lane on Kasprzaka street (marked with blue color) in relation to the centre of Warsaw

The bus-only lane was delineated from the crossing with Prymasa Tysiąclecia Alley to the crossing with Karolkowa Street. The following table reveals characteristics of each road section in scope of it. The bus lane was divided into sections, divided by the crossings with other streets (Tab. 1).

As a result of conducted bus lane inventory two proposals for the camera point locations were introduced. The first one is compatible with the binding, yet unfavourable, law regulations for the ANPR monitoring systems. The second proposal was based on implied law regulation, which would change the minimal distance between the camera points to 200 m. The result in their number can be clearly seen not only according to this example, but also to the majority of other bus-only lanes examined.

Both the first and the last sections of the described bus lane cannot be discussed in case of locating the camera points. Both of them provide both inclusion and exclusion sections, what causes it to be the zones of mixed – both public transport and individual vehicles – traffic.

Tab. 1. Characteristics of a bus-only lane on Kasprzaka Street in Warsaw

No.	Distance	Number of lanes	Road class	Parking allowance	Bus lane hours
Al. Prymasa Tysiąclecia					
1.	110 m	3	main	none	7 AM – 9 AM 2 PM – 6 PM
Bema					
2.	550 m	3	main	parallel (allowed in proximity to Krzyżanowskiego Street)	7 AM – 9 AM 2 PM – 6 PM
Krzyżanowskiego					
3.	77 m	3	main	none	7 AM – 9 AM 2 PM – 6 PM
Brylowska					
4.	220 m	3	main	oblique	7 AM – 9 AM 2 PM – 6 PM
Zegadłowicza					
5.	300 m	3 => 2	main	none	7 AM – 9 AM 2 PM – 6 PM
Korczaka					
6.	120 m	3 (Bus lane on the left lane)	main	none	7 AM – 9 AM 2 PM – 6 PM
Karolkowa					
Total: 1377 m					Number of camera points:

The second section between the crossings with Bema and Krzyżanowskiego provide favourable conditions for introducing a camera point. The inclusion section ends at the distance of around 120 m from the crossing and the lane continues for more than 400 m. Therefore, it was assumed to propose a camera point location in a point 150 m distant from the crossing with Bema Street – the 30 additional metres tolerance was agreed to be well enough for a driver to change the lane, even during the heavy traffic. The same location was implied for both hypothetical proposals.

The sequential section between Krzyżanowskiego and Brylowska Streets, because of its short distance, does not represent the potential for mounting the camera points in terms of present regulations. In contrast, the second proposal implies introducing the ANPR monitoring 350 m behind the Bema street, as the area provides the beginning of parallel parking space.

It was found reasonable in terms of both proposals to implement the camera point in scope of road section between Brylowska and Zegadłowicza Streets. The inclusion section runs for almost 180 m from the inlet of Brylowska Street and ends with a regular bus-only lane. Cameras mounted in front of the inlet of Zegadłowicza Street would allow to monitor the end of a bus lane, which is then interrupted by the exit of this Street.

The section of Kasprzaka Street running from Zegadłowicza to Korczaka Streets includes narrowing the road to two lanes in the further part of the course. The bus lane is not only interrupted by exclusion/inclusion sections, but also by two exits from a parking lot. Therefore, a strong need for monitoring this section was addressed. Both proposals included providing the camera point 150 m behind Zegadłowicza Street, which is also a 20 distance behind the end of the inclusion section, yet still before the exit from the parking lot.

References

- [1] Project Deliverable, Projekt system monitorowania pasów autobusowych dla miasta stołecznego Warszawy, Instytut Transportu Samochodowego, Warszawa 2012.

Tab. 1. Characteristics of a bus-only lane on Kasprzaka Street in Warsaw

500 m version	Reason	200 m version	Reason
Al. Prymasa Tysiąclecia			
common lane for the buses and other vehicles turning right – camera point is non-adequate			
Bema			
150 m behind Bema Street	30 m behind the ending of inclusion section	150 m behind Bema Street	30 m behind the ending of inclusion section
Krzyżanowskiego			
no bus lane on this section		350 m behind Bema Street	the beginning of parallel parking space
Bryłowska			
in front of Zegadłowicza Street	monitoring the end of the bus lane	in front of Zegadłowicza Street	monitoring the end of the bus lane
Zegadłowicza			
150 m behind Zegadłowicza Street	20 m behind the end of the inclusion section, before the exit from a parking lot	150 m behind Zegadłowicza Street	20 m behind the end of the inclusion section, before the exit from a parking lot
Korczańska			
common lane for the buses and other vehicles turning left – camera point is non-adequate			
Karolkowa			
3		4	

- [2] Report, *TomTom Congestion Index 2012*, available online: <http://www.tomtom.com/lib/doc/congestionindex/2012-1003-TomTom-Congestion-Index-2012-Q2-europe-mi.pdf>.
- [3] The Regulation of Minister of Infrastructure on conditions for the location, method of marking and measuring by the recording devices of the Minister of Infrastructure (Dz. U. z 2013 r., poz. 366, rozdz. 2, §2.2).
- [4] The Act of Road Traffic Law (Dz.U. 1997 nr 98 poz. 602, Art. 2, ust. 10).

