Emilia Skupień
Dr inż.
Politechnika Wrocławska, Wydział Mechaniczny
emilia.skupien@pwr.edu.pl

Mateusz Rydlewski
Inż.
Student Politechniki Wrocławskiej
mateusz.rydlewski@gmail.com

DOI: 10.35117/A_ENG_18_04_01

Analysis of the influence of traffic lights on the functioning of public transport within Kosciuszko square in Wroclaw

Abstract: Traffic management in a city, even assisted by intelligent transport systems, is a very complex process. Analyzing a single intersection may not produce the intended effect or even contribute to a deterioration from the initial state. The most important element of introducing changes should be traffic monitoring. The article presents the influence of traffic lights on the functioning of public transport, on the example of Kosciuszko Square in Wroclaw. Presented proposals were preceded by several hours of traffic observations, some of the results were presented at this paper. The article proposes changes to streamline public transport within the square.

Keywords: Traffic control; traffic engineering; traffic lights

Introduction

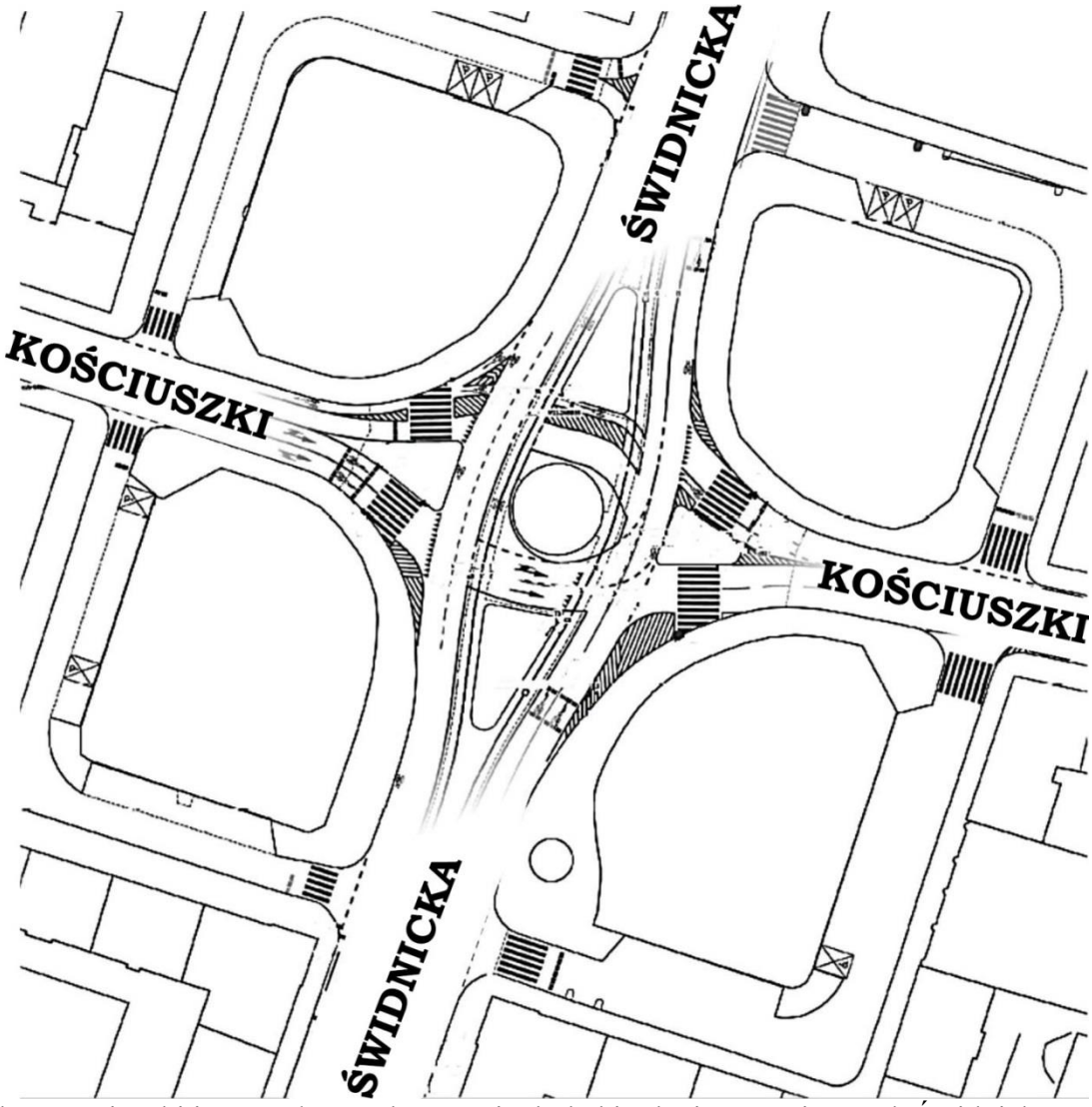
In large cities, traffic lights play a significant role in traffic control. The influence of traffic lights on the functioning of municipal public transport is particularly noticeable in the hours of communication peaks when the traffic intensity increases.

Many cities, in their planning documents, record the priority of collective transport, including Wrocław [5]. However, this assumption is difficult to implement, because passenger cars are much more than public transport vehicles and taking away their priority or shortening the green signal display, it can quickly turn into traffic jams, which will also make traffic more difficult for public transport vehicles. Among other things, for this reason, the management of the city's transport system is a complex problem.

The article presents the influence of traffic lights on the functioning of public transport, on the example of Kościuszko Square in Wrocław. As a result of the analysis, changes were also proposed to improve the movement of public transport within the square.

The range of tests

Kosciuszko Square is an example of an intersection with the central island. Across the island, along with the concentration of traffic, there is a tram track. It is one of the most important intersections of Wroclaw. 5 tram lines and three normal and two fast bus routes run along the square on regular routes [3]. This gives traffic at the level of 30 pairs of trams and 25 buses per peak hour [6]. The layout of Kosciuszko Square with the streets entering the intersection area is shown in Fig. 1.



1. Plac Kościuszki in Wrocław and streets included in the intersection, red: Świdnicka Street, blue: Kościuszki Street, own study

The highest traffic volume is observed along Świdnicka Street, which is also the direction with the priority of crossing the intersection. In both directions they drive two lanes for individual vehicles, a tram track marked out by horizontal lines and horizontal signage informing about the presence of cyclists on the road. Trams pass through the arch crossing (surrounding the central island).

Subordinate directions run perpendicular to Świdnicka Street along Kościuszki Street, which is 30 meters from the discussed intersection, towards Kołłątaja Street, is one-way (in the direction from the square), where counter-traffic is allowed only for cyclists. After the refurbishment of the intersection completed in 2015, traffic lights were installed, which was covered by the ITS system [4]. In addition to the signaling within the square, there were also facilities for cyclists, such as belts or bicycle locks, but also traffic lights intended only for this group of users. Freedom of pedestrian traffic was significantly reduced and strictly dependent on the operation of traffic lights.

According to the design documents, the aim of introducing traffic lights at Kosciuszko Square was to *improve the traffic safety at the intersection and to improve the capacity and liquidity of rail public transport vehicles* [9].

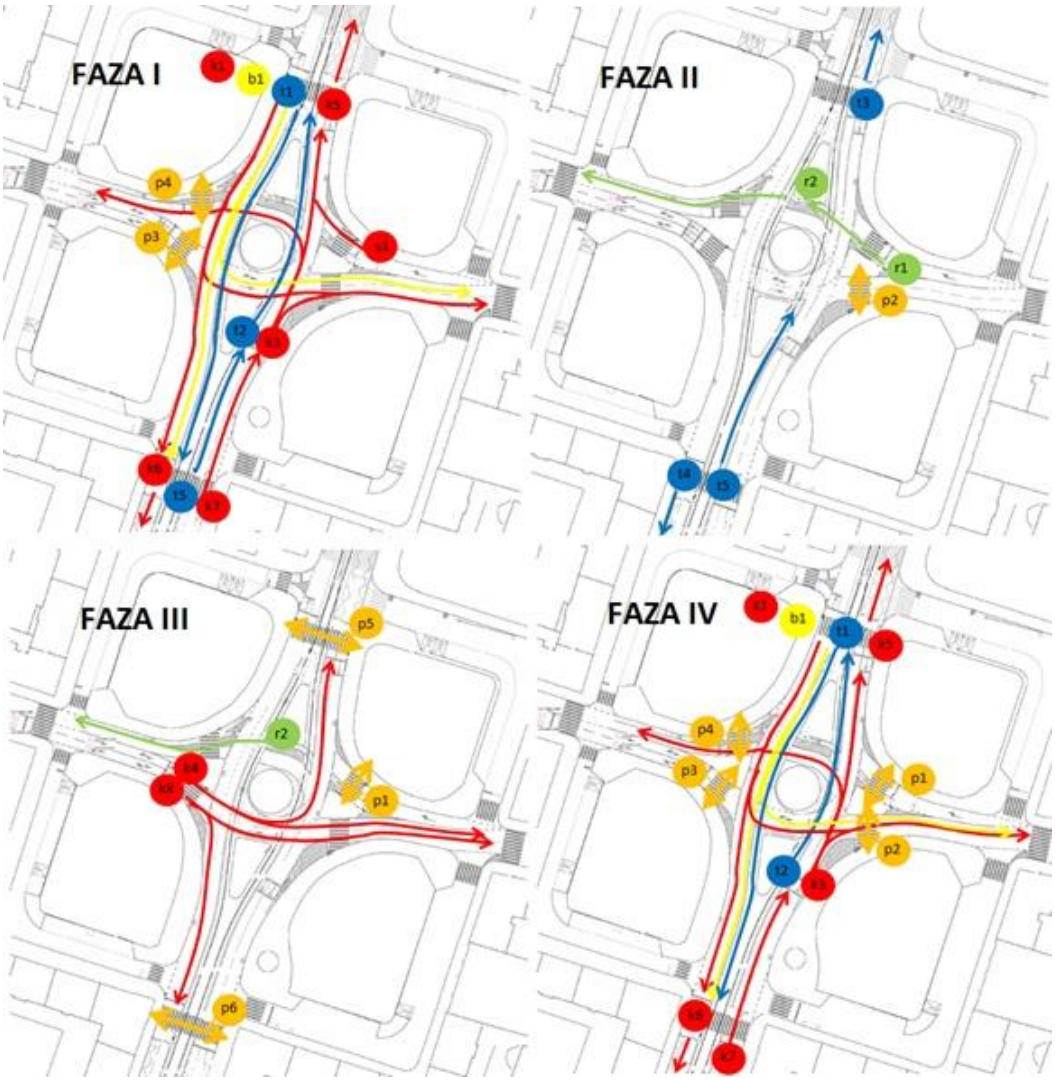
Opinion obtained on the basis of direct interviews with employees of Wrocław MPK indicates that the installation of traffic lights generally affects the disadvantage of passing trams and buses. In the case of the additional square discussed, the problem is the final admission of the left-hand relationship from the direction with the right of way. In the initial phase of designing changes at this intersection, the possibility of introducing left-handers was not taken into account, however, due to social opposition from the drivers, the project was corrected, in which the possibility of turning was allowed. Enabling this maneuver significantly affects the movement of trams, which can be limited by a vehicle standing on the track. The most frequent consequence of this phenomenon is the loss of several dozen seconds resulting not only from stopping before the vehicle blocking the track but also before the next signaling device, which stopped displaying the signal enabling the passage.

Traffic lights within the intersection

The signaling is covered by the Intelligent Transport System (ITS), which thanks to numerous detectors located at the intersection, receives information in real time and analyzes it in an algorithm that decides whether and where to activate a special program. This solution is aimed at favoring public transport and allowing them to cross the intersection in the shortest possible time. It should be noted, however, that the traffic lights at the intersection only give priority to trams [2].

The basic length of the traffic light cycle, operating within the square, is 100s [8]. The program structure consists of 4 phases of movement, which are shown in Fig. 2 in the communication diagram of the intersection. The phases for individual signal groups are represented by the colors that correspond to the given traffic users in the following way:

- Yellow - buses (marking b);
- Blue - trams (marking t);
- Orange - pedestrians (marking p);
- Green - cyclists (marking r);
- Red - individual drivers (marking k).



2. Phases of traffic lights at Kościuszki square in Wrocław, own elaboration

Movement of municipal public transport vehicles within the square

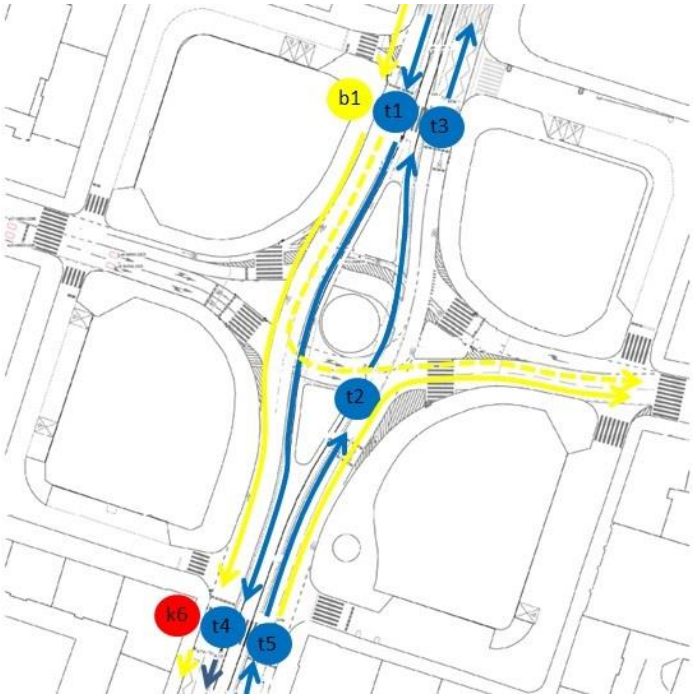
The movement of trams and fast buses takes place along Świdnicka street and leads from the intersection with Podwale street to the intersection with Piłsudskiego. The remaining three bus lines pass through Kosciuszko Square only one way, turning towards Kościuszki Street. A total of 6 signalers for public transport are installed within the square, including one exclusively for buses. Fig. 3 presents the locations of signaling devices intended for mass transport means and given signaling groups describing them. The blue line indicates tram routes and yellow lines of buses, with the continuous line referring to the express bus route, and the dotted line to the normal line route (these lines run in the opposite direction along Podwale street, bypassing Kosciuszko Square).

Tram traffic on the square is characterized by high intensity. For this reason, in order to enable a faster possibility of passing trams through the intersection in both directions behind the discussed square, double stops are used [7]. In order to verify what part of the vehicles (trams and buses were considered separately) passing through Kościuszki Square was forced to stop other than caused by the passenger service at the bus stop, study of the traffic of public transport vehicles was carried out. During the tests, the number of trams and buses crossing the square was counted and the number of them, as a result of various factors such as the operation of traffic lights or traffic of other users, was forced to stop.

It was observed that depending on the situation, the detention lasted from several to several dozen seconds (sometimes the need to stop for the entire light cycle). The results showing the number of trams and buses as well as the resulting detentions are presented in Table 1.

Tab. 1. The number of detentions of collective transport at Kościuszko Square, together with the percentage of reasons for detention. Based on research carried out between 12:00 and 13:15 and 16:00 and 17:00, own study

The means of communication	Number of transit:			Detention resulting from:		
	altogether	without stop	with stop	car presence	signaling activities	other reason
TRAM	102	38 (37%)	64 (63%)	19%	67%	14%
BUS	57	23 (40%)	34 (60%)	68%	21%	12%



3. Location of signaling devices for public transport within Kościuszki Square, own elaboration

Based on the above tests, it can be noticed that the most frequent reason for stopping the trams, 67%, was the succession of transmitting a signal that would not allow transit. Such a high result indicates that the basic assumption made during the design of traffic lights at this intersection is not met - increasing the flow of traffic.

In the case of buses, taking into account the predominant number of torsional relations, the largest part of detentions (68%) results from the presence of a vehicle in the driving area, i.e. the blockage, which most often arises during left turns. The stops as a result of the traffic lights mainly concern the passage of fast lines, the stops of which were observed before the k6 signaling device.

During the next test, the data was collected in real time during a tram ride through Kościuszko Square. The ride took place between the Arkady (Capitol) stops and Renoma in both directions. The test consisted, among others, in measuring the time of passenger service at the bus stop, checking the punctuality of arrival, recording the length of possible detention and the factor that influenced the detention and analyzing whether the journey between the stops through Kosciuszko Square was longer than scheduled 2 minutes. The test results are presented in Table 2.

Tab. 2. Results of dynamic motion studies showing the number of events causing stopping, average stopping time, standard deviation and analysis of the average time of travel, source: own study

Initial stop	**Final stop**	**Value**	**Time of travel**	**Detention resulting from:**			
				Departure from the stop	**Light in front of the central island**	**Car blocking the track**	**Light behind the central island**
ARKADY	**RENOMA**	Number of events:	23	15	2	3	18
		Average [s]:	2:05	13	34	9	24
		Standard deviation [s]:	0:25	5,44	21,92	5,86	25,93
RENOMA	**ARKADY**	Number of events:	22	20	1	3	5
		Average [s]:	2:21	48	39	6	40
		Standard deviation [s]:	0:30	24,14	-	4,73	34,04
BOTH DIRECTIONS		Number of events:	45	35	3	6	23
		Average [s]:	2:13	33	35	8	27
		Standard deviation [s]:	0:29	25,39	15,82	5,17	27,92

By the phrase "departure from a stop" is meant the waiting time for a signal that allows crossing through the intersection counted from the moment the door at the bus stop is closed. The term "lights in front of the central island" is for the Arkady direction →Renoma before the signaling device from the signal group t5 (fig. 3) in the opposite direction is the signal group t1. Stopping "behind the central island" means stopping in front of the signaling devices from the signal groups: t3 or t4.

Based on the analysis of measurement data, it can be concluded that:

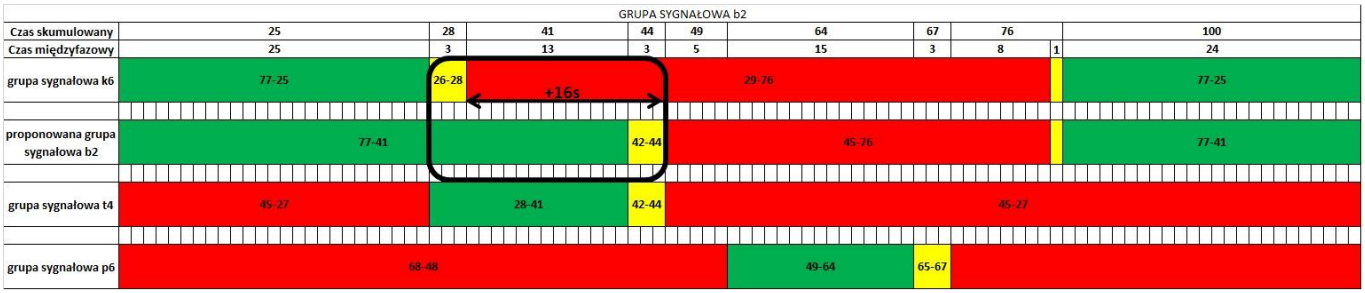
- 90% of trams going to Kościuszko Square from Podwale street, as a result of poorly coordinated traffic lights, after closing the door at the stop, it loses an average of 48s waiting for the possibility of crossing the intersection. This problem is not so great in the case of streetcar rides from Powstańców Śląskich street. The average travel time from the stop to the bus stop (counted from closing to door opening) is 2 minutes 13s;
- The cars blocking the track were just a little over 10% of all detentions and the detention time was relatively short compared to other reasons. This may indicate a high level of awareness among individual drivers who pay attention to collective communication;
- Trams stopping in front of the central island were only isolated cases in which one should not find problems with the functioning of traffic lights, but only those resulting from the traffic situation (random events difficult to predict);
- A big problem is the time of displaying the green signal by the t3 group siren, which allows the tram to enter the Renoma stop. Traffic lights in this case give a definite priority to individual vehicles causing an average waiting time of around 24s.

Suggestions for changes

Improvement of the traffic of a given group of users usually takes place at the expense of another group. Therefore, the most important element of planning changes is to anticipate their consequences.The traffic of fast buses towards the Arkady (Capitol) stop takes place along Świdnicka Street along the entire length of the square (Figure 3). Before the square, traffic orders the siren from signal group b1. Next, buses are forced to adhere to the indication of a siren from group k6 intended for individual vehicles.

During observations on the square, a frequent problem was found resulting from the stop of fast buses directly in front of the k6 signaling device. The bus stop is located directly behind the pedestrian crossing in front of which the k6 siren is placed. In the further part there is also a tram stop. The sequence in the signaling program is as follows: stopping the signal group k6 (including buses), enabling the t4 group (trams), closing the signal group t4 (the tram handles passengers at the stop from the roadway), opening the signal group p6 (pedestrians). After 52 seconds of displaying the red signal on the siren from group k6, the green signal is restarted. Therefore, the loss of time resulting from the bus stop before the pedestrian crossing is almost a minute. In addition, entering a bus stop in the initial phase of the green signal display carries negative effects. In addition to blocking the lane for individual vehicles by a bus that supports passengers (no bus bay), it is possible that in the case of extended time of passenger service, the vehicle will not be able to reach the next intersection with the green light.

It is worth noting that the blocking of the lane in question significantly affects the movement of all other traffic users on the square. The solution to this problem, due to the inability to transfer the stop before the pedestrian crossing (presence of the transverse road inlet), is to install an additional signaling device. It would be intended only for buses. A fragment of the signaling program including the discussed signaling groups (along with the proposed b2) and the whole described situation is shown in Fig. 4. As a result of this change, buses are given the opportunity to cross the 63s through the whole cycle, ie for almost 2/3 of the cycle.

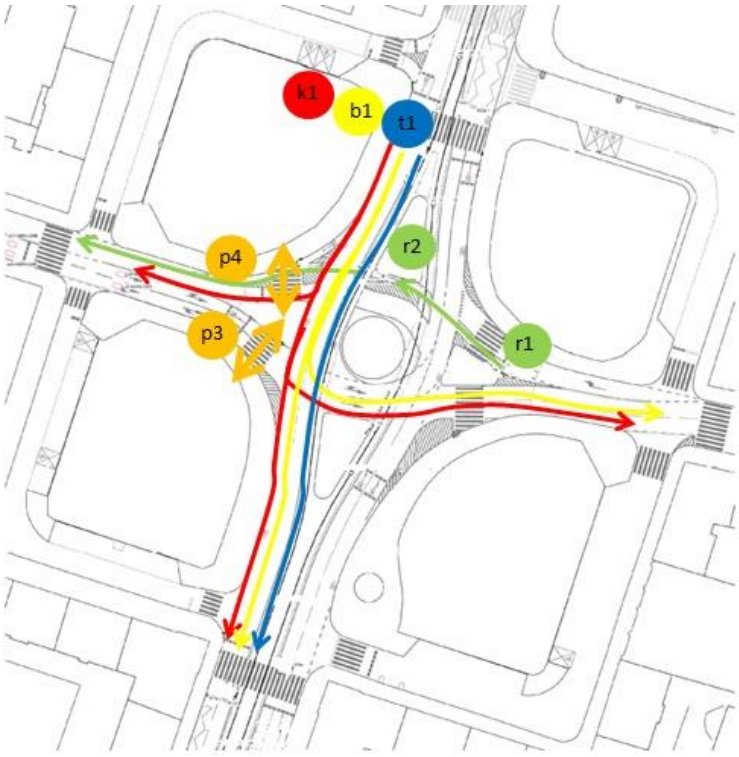


4. Fragment of the program of traffic lights within Kosciuszko Square including the proposal to introduce the signal group b2 (the colors correspond to the indications of the signaling device and the numbers of durations in the cycle printed on them), own elaboration

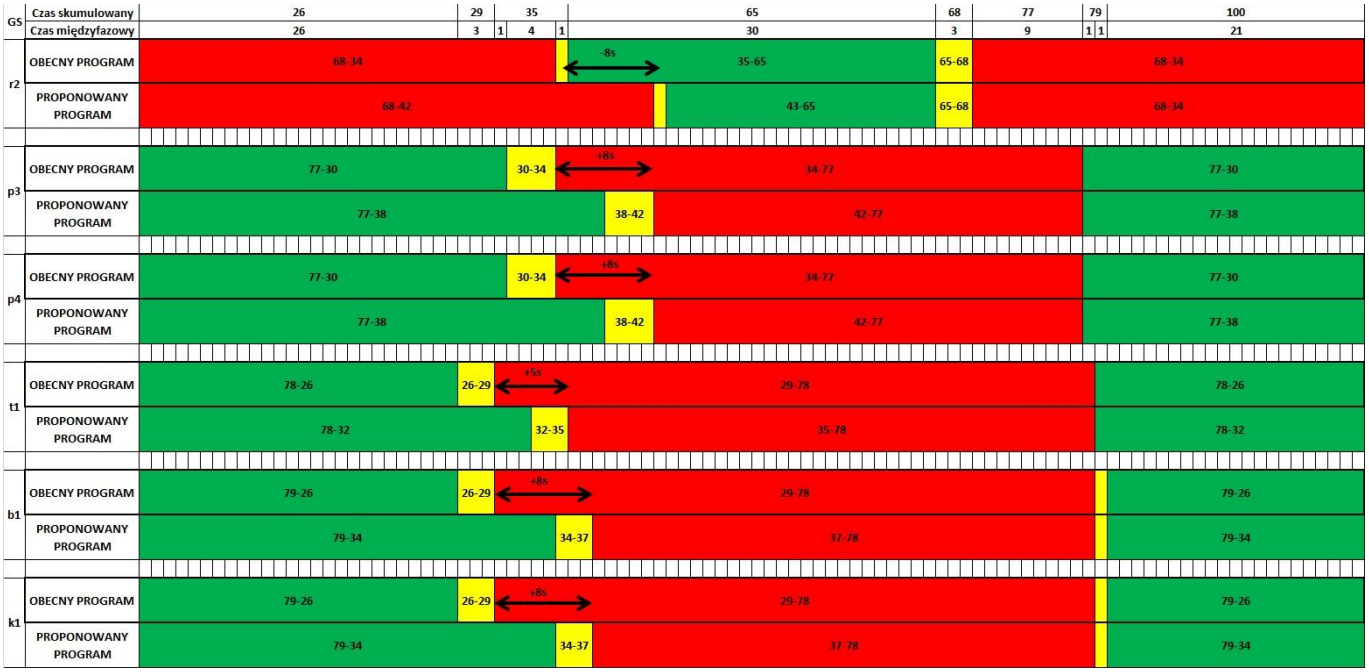
In this case, there was no impact on other traffic users. However, it should be remembered that this traffic signal is 24-hour. This solution could also have a positive impact on the time of traveling by night bus lines using the crossing through this intersection

Another change proposal applies to the bicycle signaling device from the r2 group. In Fig. 5, all signal groups that are discussed in this example are presented. The green signal for the group r2 is displayed in the second phase of signaling. It is a collision crossing with signaling groups located in front of the square and regulating traffic towards the south, i.e. b1, k1 and t1, and pedestrians on the crosswalk.

The current length of the green signal display for r2 is equal to 30 seconds [8] which gives almost 1/3 the length of the whole cycle. Due to the fact that most cyclists going to the west continue their journey from the group r1, you can allow to start sending the signal r2 with a lag in relation to r1. Currently, the green signal starts in the same second of the program for both the r1 and r2 groups. Taking into account the time of arrival of cyclists from the siren r1 to r2, it was proposed to shift the beginning of the signal transmission by 8 seconds. The results of such a change in relation to the current program are presented in Fig. 6. As a result of this shift, a total of 37 seconds of green signal was obtained for various traffic users..



5. signal group r2 together with collision groups and groups p3 and r1, own elaboration



6. Fragment of the current traffic light program at Kościuszko Square, including signal groups r2, p3, p4, t1, b1 and k1 along with the proposal to change the program, own study

Fig. 6 shows that starting to display the green signal from the r2 group by 8 seconds later, gives the possibility of extending the green signal display time for the following groups:

- p3, 8s;
- p4, 8s;
- t1, 5s;
- b1, 8s;
- k1, 8s.

The prolongation of the green signal transmission of the above-mentioned groups does not affect collisionally on any other signal groups.

When analyzing this case, it is necessary to consider the validity of the signaling device from the group r2. Vehicles with torsional relations, whose direction of travel is analogous to cyclists, do not apply to any siren in this case. Their journey takes place with the principle of giving way to all other traffic users. In the case of cyclists, a similar possibility could be applied provided that the evacuation times from the siren r1 were checked.

Summary

The discussed intersection is a very important communication node and a showcase of the city. Świdnicka Street is one of the largest shopping streets in Wrocław and is a direct connection to the Wrocław market. For this reason, the efficiently run traffic through Kosciuszko Square should be used to properly unload it and, above all, give it a proper priority for pedestrians and collective transport. Along with the initial stage of designing the reconstruction of streetcar stops along Świnicka Street, social consultations were carried out, in addition to the changes resulting from the modernization of the stops, the issue of the Kosciuszko square, which is an integral part of this street, was addressed. Therefore, the proposed changes presented in the publication were sent directly to the head of the Department of Engineering at the City Hall. The change regarding the shortening of the green signal has already been permanently entered into the signaling program. The proposal

regarding the installation of new traffic lights for buses is to be implemented as part of the renovation of Świnicka Street.

Traffic management in the city, even assisted by intelligent transport systems, is a very complex process. Analyzing a single intersection in an entire harmonizing set may not bring the intended results, or even contribute to the deterioration of the initial state of the entire system. One change, usually involves the next. In connection with the above, large adjustments of signaling programs should be undertaken comprehensively with additional analysis of the impact on other intersections. In the case of corrections exclusively in the program at the selected intersection, the program changes introduced can contribute to the improvement of traffic as well as improve the comfort of movement of various traffic users. The most important element of introducing such changes should be traffic observation. On its basis you can notice the problems of various traffic users as well as identify places in the cycle where you can search for improvements. The above proposed changes to the program were preceded by several-hour traffic observations and surveys, some of which were presented at the work.

Source materials

[1] Kaczmarek M., Rychlewski J., *Zmiennoczasowa sygnalizacja świetlna na skrzyżowaniach w miastach*. Zeszyty Naukowe Politechniki Śląskiej nr 1621, Gliwice 2004, str. 221-232

[2] Rychlewski J, *Doświadczenia ze stosowania priorytetu tramwajowego w Poznaniu,* Przegląd Komunikacyjny nr 4-6, Wrocław 2010, str. 42-47

[3] Strona Miasta Wrocław, http://www.wroclaw.pl/rozmawia/przystanek-swidnicka-stan-obecny (dostęp 21.11.2016r.)

[4] Trzcinowicz B., *Rozwiązania dla transportu publicznego planowane w Projekcie ITS Wrocław*, Przegląd Komunikacyjny nr 1-2, Wrocław 2011, str. 54-57

[5] Uchwała nr XLVIII/1169/13 Rady Miejskiej Wrocławia z dnia 19 września 2013 r. w sprawie Wrocławskiej polityki mobilności

[6] Urząd Miejski Wrocławia, Biuro Rozwoju Wrocławia, Wydział Inżynierii Miejskiej, prezentacja *PRZYSTANEK ŚWIDNICKA spotkanie konsultacyjne 24 listopada 2016*, dokument dostępny online, http://www.wroclaw.pl/rozmawia/przystanek-swidnicka-do-pobrania (dostęp 28.11.2016r.)

[7] Wolek C., Kowerski S., *Wpływ sygnalizacji świetlnej na starty czasu tramwaju w obszarze przystanku*, Przegląd Komunikacyjny nr 9, Wrocław 2016, str 29-33

[8] ZDiUM Wrocław, *Dokumentacja programu sygnalizacji: Sterownik sygnalizacji ulicznej MPS-RP nr 40*, dokument opracowany przez firmę WASKO S.A.

[9] ZDiUM Wrocław, Dokumentacja techniczna, *Budowa Sygnalizacji świetlnej na Pl. Kościuszki we Wrocławiu wraz z aktualizacją dokumentacji projektowej, Branża: Inżynieria Ruchu, Organizacja Ruchu Docelowego*, 2014