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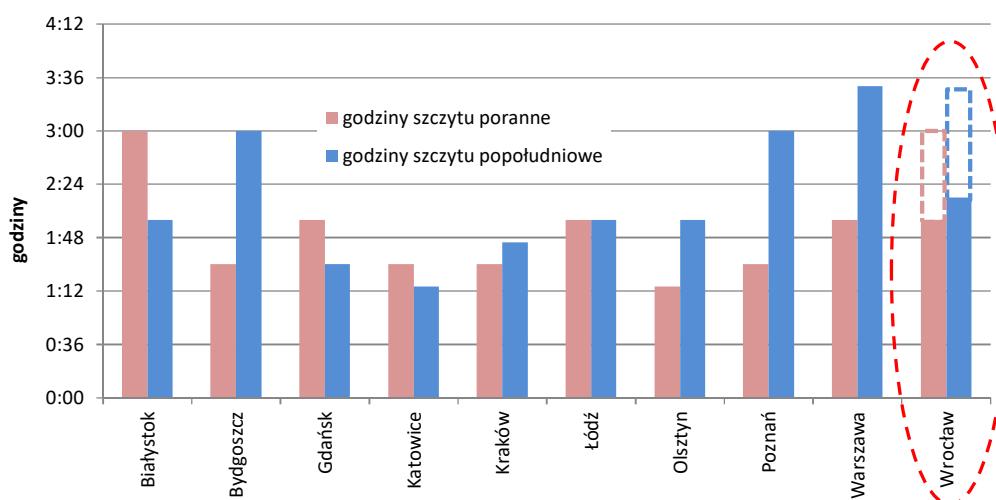
The effectiveness of cableways in solving traffic problems on the example of ropeway functioning in Wroclaw University of Science and Technology

Abstract: In the article, on the example of ropeway functioning for three years at the Wroclaw University of Science and Technology, we describe possibilities of improving traffic conditions in the city centre. The article presents the history of the ropeway and variability of traffic at the stage of its operation. Communication service for two stations was shown. Based on measurements of the traffic intensity for different users, we showed changes in the traffic in the area of campus. Further development of the cableways in connection with the expansion of the university was discussed.

Keywords: Cable railway; Public transport; traffic

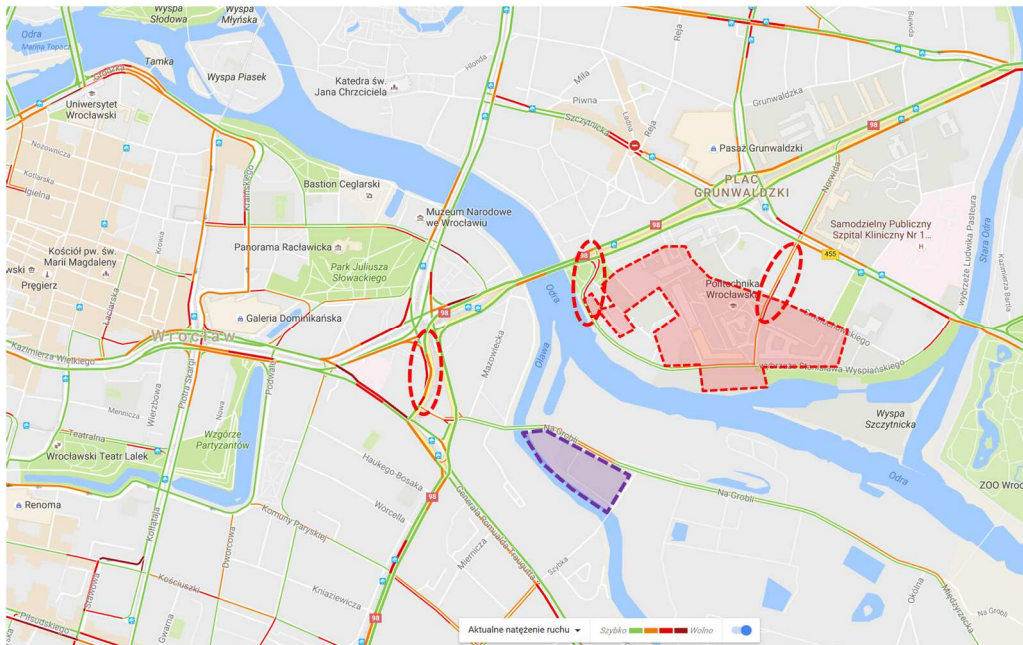
Introduction

Wroclaw is a city where many places in the city are experiencing increasing traffic problems. As in other large cities, morning clearings (7:30 - 9.30) and afternoon (15.30-18: 00) are observed in Wroclaw. Although the average values are similar to other cities in Poland, they may be locally larger (fig. 1) and reach a few hours. The area of specific motion conditions is the area of the Wroclaw University of Science and Technology campus. Nearby is a number of other universities, institutions, and, crucial for the city, transport hub - Rondo Regana. Undoubtedly, students and staff would expect the required speed of travel, efficient parking, adequate transport accessibility and comfort, and attractiveness. Wroclaw University of Science and Technology is a large movement center in Wroclaw. There are about 35,000 students and about 4,500 employees.



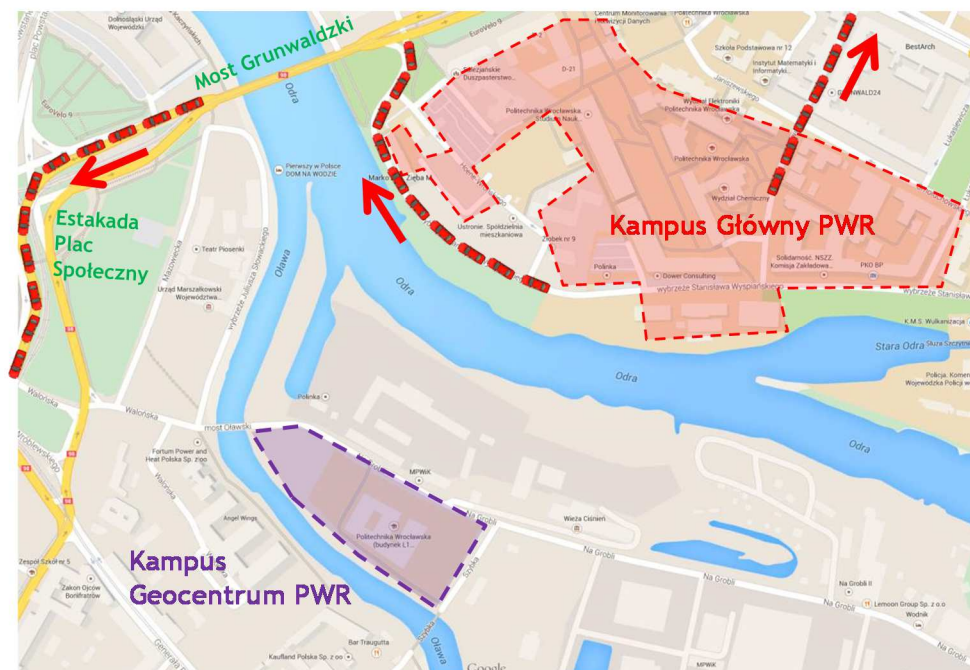
1. Rush hours in selected cities (source: motofakty.pl+own research)

Unfortunately, in this area during rush hours there is a significant accumulation of traffic. The situation was heightened by the change of the traffic organization on some streets of the city to reduce the number of public lanes and to allocate them to buses and taxis. Figure 2 shows the location of the two areas of the Wrocław University of Science and Technology on the background of traffic conditions at the peak.



2. Distribution of traffic in peak hours in the area of the Wrocław University of Science and Technology campus (source: google.pl/maps)

Due to this situation, the average speed of travel at the departure from the university falls to a dozen or so kilometers per hour. These mobility conditions limit the comfort for students and staff who use the two campus areas separated by the Oder River. The Main Campus of PWR is situated on the Wyspiński Coast, while the recently opened Geographical Center of PWR is located on the other side of the river at Na Grobli Street. Departure from the Main Campus PWR is possible from two streets, and its connection to the Geodetic Center PWR runs through the often overcrowded flyover on the Plac Społeczny (fig. 3).



3. Location of Wrocław University of Science and Technology campus and exit conditions

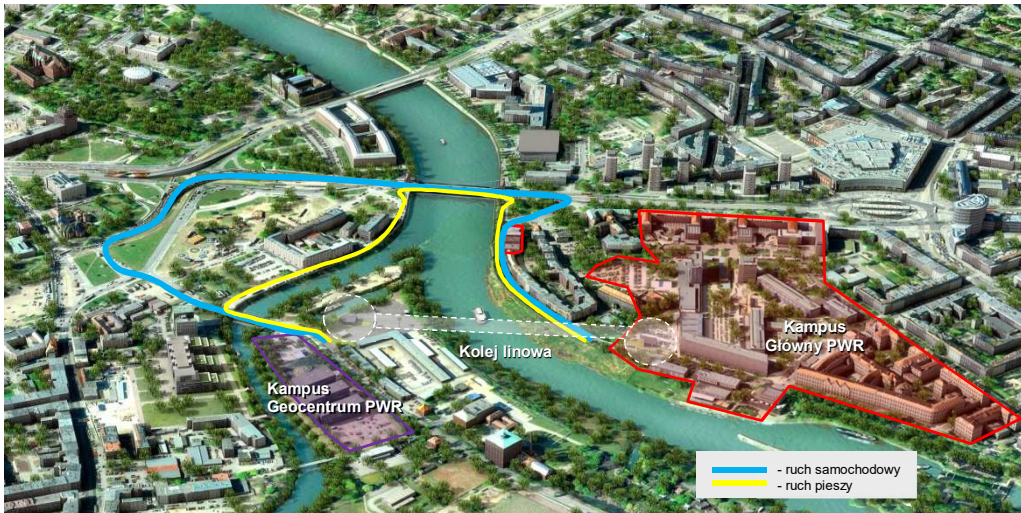
The new terrains located at Na Grobli Street has developed research and didactic purposes. In 2010-2012, Geocentrum-Phase I was completed, where three faculties were located. Authorities of the Wrocław University of Science and Technology before the construction Geocentrum decided on an unconventional solution in the form of cable railway, developing its first concepts. The tender for the "design and build" system was announced in 2012 and opened on 1 October 2013.

Many agglomerations in the world are trying to make urban transport more efficient and attractive. In 2011, the European Commission published a White Paper on Transport [1], which pointed to trends in European transport, including urban transport. An unconventional and innovative transport solution in the form of a cableway in the agglomeration of Wrocław quickly found support from the academic community that uses it. A competition for the name of the railroad ("Polinka") was created. The fees for people from the "outside" were introduced only after half a year of operation. The employees, students and PhD students of the Wrocław University of Science and Technology benefit from the presentation of a valid electronic student card, student ID card or doctoral student ID card. Those who do not have the abovementioned documents for a one-time passage by cableway of the Technical University of Wrocław pay: 3 zł (normal ticket) or 1.5 zł (reduced-fare). Tickets can be purchased on all MPK ticket machines in the city (also available at both stations). Bicycles and dogs were also transported. The train operates on weekdays (Monday - Friday - 7am - 9pm) and on weekends (Saturday - Sunday - 11am - 6pm).

Traffic research

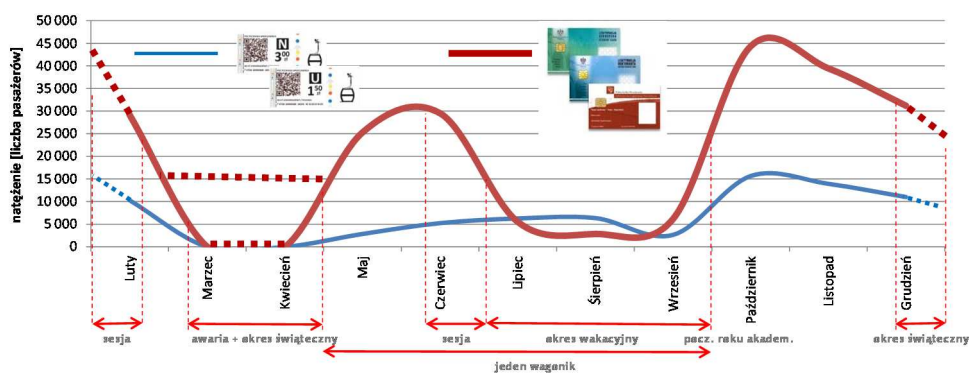
In the Department of Roads and Airports of Wrocław University of Science and Technology, which cooperated with railway concepts and with the functional-utility program, works are carried out in the field of collective transport and influences of a cableway on the conditions of the movement in the field of the university. The main analysis was the influence of the cableway on the traffic conditions in the area of the Wyspiański Coast and at Na Grobli Street. The parking conditions at Na Grobli Street and passenger traffic taking place by rail. Figure 4 shows the location of railways and didactic campuses as well as road and pedestrian routes. Three junctions, two bridges, and a flyover should be crossed to reach the Campus Geocentrum. In comfortable driving conditions, the car takes about 7 minutes, while in the rush hours 25 minutes. The time of day is about 15 minutes. Student classes are organized in such a way as to limit the movement

between the two areas, but due to the extensive teaching infrastructure and schedule, it is sometimes necessary to cross the Odra River three times a day. The length of the railway is 373 meters and the journey takes 2.5 - 3 minutes. The speed of the cab is 5 m / s, each of the cabs can carry 15 people. This means that the capacity is 366 people per hour. Other technical details related to railways are included in the publication [4], [2].



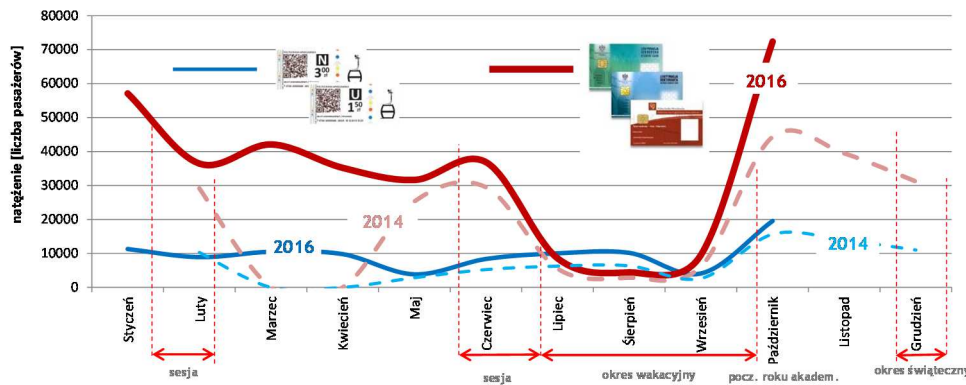
4. Location of Wrocław University of Science and Technology campus and cableway (own elaboration)

Passenger traffic measures have been monitored since 2014. Figure 5 shows the distribution of passenger traffic paid for tickets and academic traffic. During the winter session, there is a significant traffic up to 35 thousand passengers per month. During the holiday season, the academic movement is decreasing. In 2014, a collision occurred in March-April (a collision with a river crane) and the cableway did not function. Another increase in student and academic traffic occurs in June (before and during the session), decreases during the holiday season, and again increases at the beginning of the academic year (October). The "outside" movement shows fewer fluctuations, and its growth was observed during the holiday season and in October.



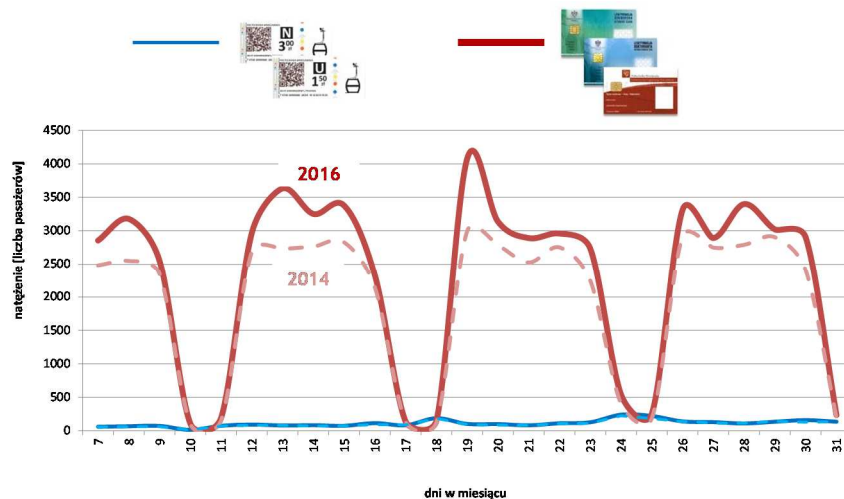
5. Passenger transport by cableway in 2014

The year 2014 was the first year after the cableway was commissioned and it was treated as an indicator of movement analysis. Nevertheless, 2016 was considered a more representative period (Figure 6). Still, during intensive learning periods, students are seeing increased interest in cableway and reduced traffic during holiday and holiday periods. Compared to the year 2014, there was an increase in both academic traffic of around 25% and "ticket" traffic by about 35%. This is particularly noticeable during the holiday season and most likely related to the surrounding attractions: Hydroopolis and Africarium.



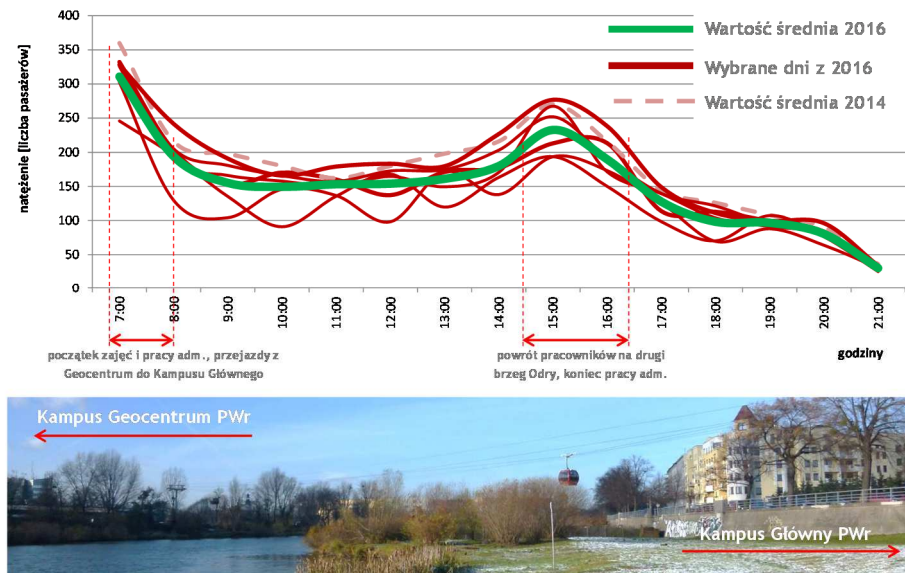
6. Comparison of cableway passenger transport in 2014 and 2016

Figure 7 shows passenger traffic fluctuations over the selected January period in 2014 and 2016. Winter is not conducive to walking and is the month in which students work intensively while preparing for the upcoming winter session. The increase in traffic is visible in the middle of the month and at the beginning of some weeks. Interest in the academic community is decreasing at weekends, while interest in tourism is growing. Compared to the year 2014 there is an increase in traffic, which in some months (January, October) reaches even 57,000 passengers a month.



7. Comparison of monthly passenger transport by cableway in 2014 and 2016

During the day, the highest traffic occurs in the morning and is observed at both cableway stations (Figure 7). Passenger traffic in the direction of the Main Campus is related to the people leaving the vehicles at the public parking lot at the Geocentrum, while the opposite direction moves employees and students to the classes. It should be noted that on the basis of the preliminary surveys, a significant proportion of administrative staff and staff from other institutions and institutions located near the Wyspiański Coast have been registered. During detailed measurements in 2016, it was found that there were significant fluctuations in daytime traffic and some hours significantly deviated from the mean. The analyses indicate that this is related to the distribution of classes, which varies considerably depending on the day of the week and the semester. Compared to the year 2014 there is a tendency of increased interest in the cableway in the morning and afternoons related to the end of the occupations and work of the administration of the Technical University, and the daily traffic reaches 2,500 passengers. This is currently half the capacity of the cableway.



7. Comparison of daily passenger transport by cableway in 2014 and 2016

Nevertheless, some travel restrictions are observed at certain times. In rush hours (example, November 2016, 3:00 pm), 43 people were waiting at the station at Na Grobli Street (fig. 8). It has been noted that some people resigned and went on foot to the second campus, stating that waiting for 3 queue courses (i.e. about 10 minutes) is not attractive. At the same time, a similar length of queues was registered at the station at the Wyspiański Coast (Fig.9).

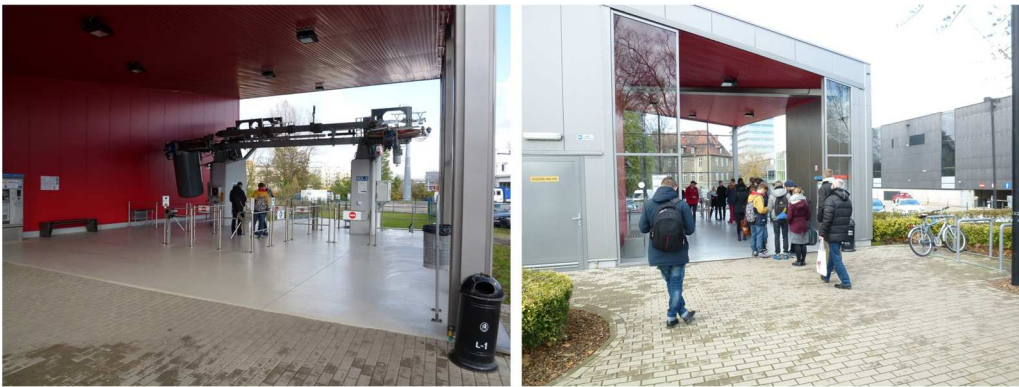


8. The queue at the station at Na Grobli Street (November 2016, 3 pm)



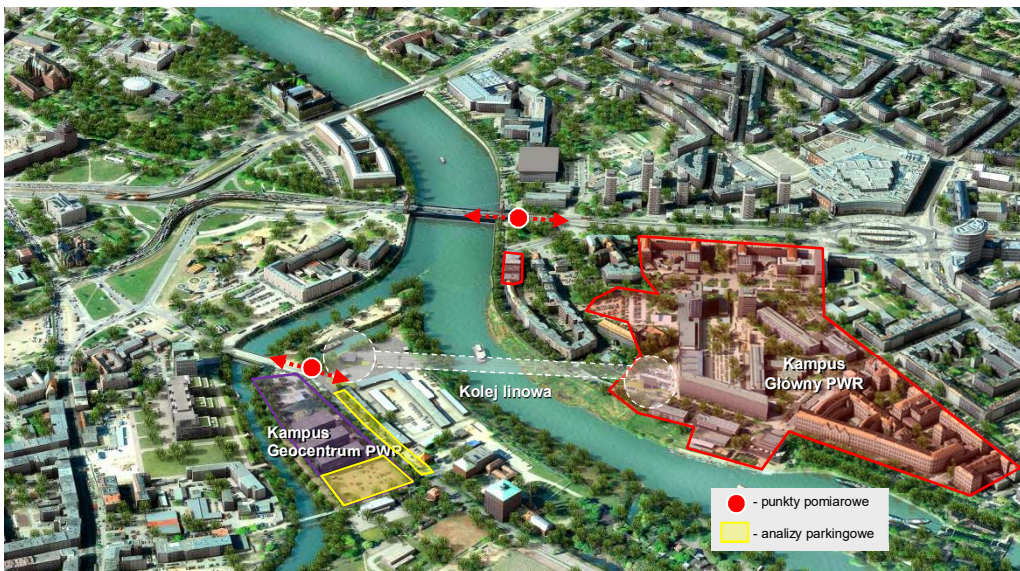
9. The queue at the station at the Wyspiański Coast (November 2016, 3 pm)

As mentioned earlier in the day, there are significant fluctuations in traffic related to the distribution of occupations, and the distribution of movement between the two directions is strongly differentiated (Figure 10). This situation often requires longer waiting for passengers due to the need to fully use the cab.



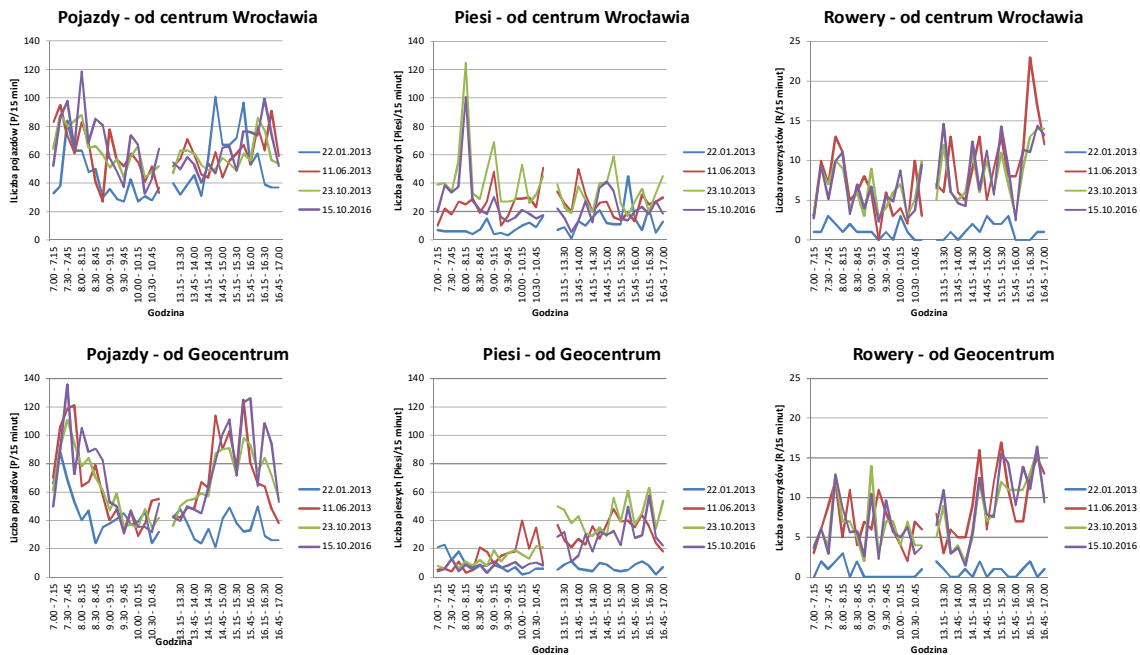
10. Uneven distribution of traffic at the station at Na Grobla Street - 3 people waiting (on the left) and on the Wyspiański Coast - 17 people waiting (right), November 2016, 1.30 pm

In terms of movement analyzes were also carried out to observe the traffic in the area surrounding the Polytechnic. The first traffic measurements were made before the cableway was put into service (in January 2013). The pedestrians, cyclists, and vehicles in the area of the Grunwaldzki Bridge (at the Main Campus) and the Oława Bridge (at the Geocentrum) were analyzed (Figure 11). The changes in parking at Na Grobla Street and in the Geocentrum parking lot.

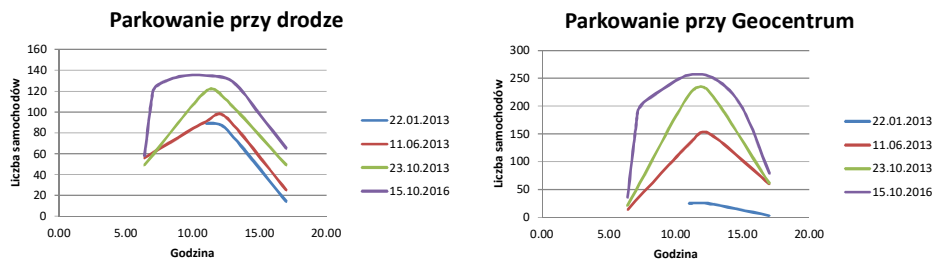


11. Localization of measurement points in the area of the Wrocław University of Science and Technology campus connected with the measurement of traffic and parking

Comparing the period prior to commissioning (2013) and during operation (2014-2016), there was a tendency towards a slight decrease in the intensity of vehicles towards the city center and a noticeable decrease in pedestrian traffic in the area of the Grunwaldzki Bridge. For example, compared to October 2013 and 2016, pedestrian traffic has decreased by about 45%. At Oława Bridge (Fig. 12), pedestrian traffic was reduced by about 35% and the traffic intensity increased by about 10%. However, compared to the period when the traffic was not functioning, traffic increased by about 50%. This explains the fact that there is considerable interest in parking at the Geocentrum parking lot and in the area at Na Grobla Street. Geocentrum parking surveys show that increased parking needs are still occurring before the start of the didactic classes (before 7.30) and have been increasing steadily since 2013 (Figure 13). Around 2 pm, the maximum level of saturation is observed, and vehicles already park on maneuvering roads and other irregular places (fig. 14). It should be noted that in the area of the Main Campus at 7.00 no parking is allowed.



12. Results of traffic measurements in Geocentrum area



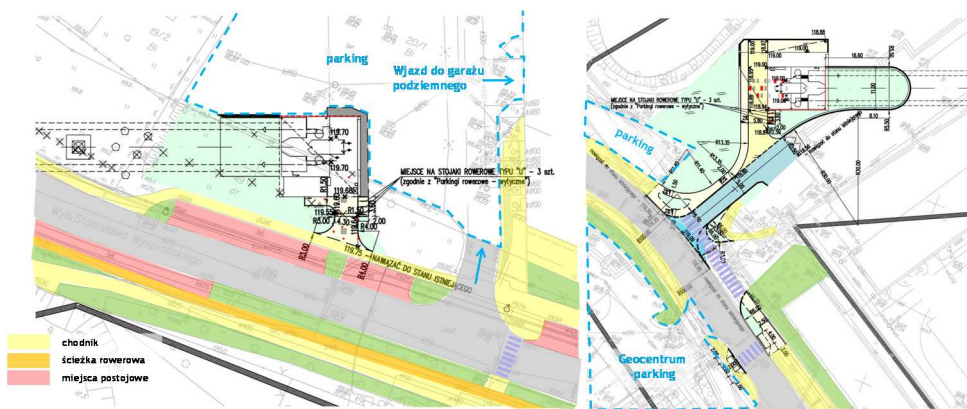
13. Results of parking measurements in Geocentrum area



14. Parking in the Geocentrum area - November 2 pm

The railway station at Wrocław University of Science and Technology has a good location in terms of communication service. They are located directly in the parking lots and available public transport infrastructure (car parks, bicycle lanes) (fig. 15). Slightly worse location is the railway station at Na Grobla Street as students and staff have to cross the street to reach the

building. Such a location was, however, conditioned by the availability of areas under construction.



15. Transport service of the cableway station in the Wyspiański Coast (left) and Geocentrum (right)

In the future plans near the Na Grobli cableway station, a new research center of the Wrocław University of Science and Technology GEO-3EM will be established. It will focus on four faculties and will undoubtedly contribute to the growth of passenger traffic and will change the structure of the traffic in this area. Although the cableway is currently halfway up to capacity, due to significant fluctuations in traffic during the day, the waiting time may be extended to 7 courses, which will be equivalent to the time needed to move from one area to another.

Summary

On the basis of the three-year measurements of passenger and road traffic, it is stated that there are significant changes in the area of the Wrocław University of Science and Technology campus which is operated by the cableway.

There has been an increase in the annual (academic) traffic in 2016 compared to 2014 by approximately 25%. Also, the growth of the annual traffic (ticket) in 2016 compared to 2014 by about 35% indicates significant interest also to other users. This concerns both commuters and people using nearby tourist attractions (Hydroopolis, Africarium). Preliminary surveys indicate the participation of employees of the University of Life Sciences and other people who follow the Grunwaldzki Square.

Holiday travel in 2016 increased by 40% compared to 2014. The most burdened months are October and January. It is reported that increased daily fluctuations are related to the distribution of occupations, and the waiting time in some seasons reaches 5-6 cycles.

Among the users is the tendency of morning parking in the Geocentrum area and mixing to the other shore to the Main Campus, then back around 15.00. This is confirmed by parking studies showing an annual increase in parking interest by approximately 10%. The saturation level of the park is maintained in the early hours from 7.00 to 15.00.

There are no significant changes in the intensity of vehicles, cyclists. The intensity of pedestrians has been reduced. This demonstrates the growing interest in cableway passenger traffic with increasing traffic in the city and the need for parking.

The presented solution, which combines the two Wrocław University of Science and Technology campuses located on both sides of the Odra River, is considered to be a very appropriate solution to solve the traffic problems of pedestrian traffic and to make the travel conditions more attractive. It represents an unconventional and alternative solution for other typical applications such as pedestrian bridges.

Wrocław University of Science and Technology as an innovative university is a good example of the development of this kind of public transport in cities, as well as other foreign universities presented in the publication [3]. "Polinka" perfectly maintains its function as a means of transportation within the university. It not only serves students and employees but also tourists,

people working nearby and people visiting Wrocław. At a later stage of motor research, the authors will focus on the study of passenger structure.

Source materials

- [1] KOMISJA EUROPEJSKA. BIAŁA KSIĘGA. Plan utworzenia jednolitego europejskiego obszaru transportu – dążenie do osiągnięcia konkurencyjnego i zasobooszczędnego systemu transportu. Bruksela, 28.03.2011
- [2] Mackiewicz Piotr, Szydło Antoni, Wardęga Robert: 2013, „Kolej linowa - alternatywna przeprawa przez Odrę”. Obiekty mostowe w infrastrukturze miejskiej: Wrocławskie Dni Mostowe: seminarium, Wrocław, 21 - 22 listopada 2013. Wrocław: Dolnośląskie Wydawnictwo Edukacyjne, s. 131 – 139.
- [3] Mackiewicz Piotr: 2014, „Kolej linowa jako skuteczny napowietrzny system transportu”. Przegląd Komunikacyjny, R. 69, nr 8, s. 5 – 11
- [4] Szydło Antoni, Wardęga Robert, Mackiewicz Piotr: 2011, „Nowa przeprawa przez Odrę we Wrocławiu”. Przegląd Komunikacyjny. R. 66, nr 9/10, s. 150 – 151.