

Park&Ride; transport hub; modal split; computer simulation; traffic flow

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## ESTIMATION OF EFFECTS CAUSED BY THE IMPLEMENTATION OF PARK&RIDE SYSTEM IN THE TRANSPORT HUB

**Summary.** Local authorities of Katowice have proposed to localize a transport hub of the Park&Ride system at Brynowska junction. The paper reviews the impact of this proposition on road traffic at the hub. The analysis of transport modal split was performed. In order to estimate the effects of such a system, an analysis of traffic distribution was done with a questionnaire survey. Based on the results, two traffic simulation models have been developed: first, simulating the current state of Brynowska junction and, second, presenting the junction with the transport hub of the Park&Ride system.

A comparison of the two models made it possible to estimate the effects of the implementation of the Park&Ride system. Obtained results prove that this solution could improve the current state of the transportation system.

## OSZACOWANIE EFEKTÓW SPOWODOWANYCH WDROŻENIEM SYSTEMU PARK&RIDE W WĘŻLE PRZESIADKOWYM

**Streszczenie.** Władze miasta Katowice zaproponowały utworzenie systemu Park&Ride w węźle przesiadkowym „Brynowska”. W artykule przedstawiono wpływ wybudowania systemu Park&Ride na pętlę oraz na ruch drogowy. Wykonano analizę podziału modalnego środków transportu. W celu oceny efektów wdrożenia systemu wykonano analizę rozkładu ruchu drogowego oraz przeprowadzono badania ankietowe. Na podstawie otrzymanych wyników sporządzono symulację modelu ruchu, stanu obecnego oraz proponowanego po wdrożeniu systemu Park&Ride.

Porównanie dwóch modeli pozwoliło na oszacowanie efektów wdrożenia systemu Park&Ride. Otrzymane rezultaty dowodzą, że takie rozwiązanie może poprawić aktualny stan ruchu drogowego w analizowanym miejscu.

### 1. INTRODUCTION

Local authorities of Katowice have proposed to localize the transport hub of the Park&Ride system at Brynowska junction. This transport hub is one of the major hubs distributing traffic between the southern districts and the centre of Katowice. Brynowska is a junction that merges two modes of public transport systems: bus and tram. In the current state, commuters from the southern districts may use one of the following transport means: bus, tram or car. Commuters combine the transport means to get to the city centre. Many of them go by car because changing to public transport brings about many problems. One of them is congestion (in the junction analysed), which occurs in the morning rush hour on the junction roads. This causes significant delays when passengers change the means of transport.

Currently, transfer from bus to tram is poorly planned. Passengers who want to change to a tram have no information about tram departure times. Another disadvantage of changing at Brynowska junction is the exposed path between the bus stop and the tram, especially when changing during bad weather.

Park&Ride systems function in many European cities, including Vienna, Prague, Amsterdam and Berlin. The major reasons for the creation of such systems are the efficiency of public transport, high level of motorization, and a large number of people employed in the city centre. The introduction of Park&Ride systems may reduce the congestion and create a new way to travel to the centre of the city. This solution also makes it easier for commuters to reach bus stops. Local authorities of Katowice are planning to build a hub of Park&Ride system at Brynowska junction (50 parking spaces at the transfer hub and another 400 parking spaces nearby).

Paper [1] describes Park & Ride facilities localization. Park & Ride should offer the ability to access the centre of city, which normally is the most congested area. Planning of the Park& Ride system is done in three steps: passengers drive from their home to the facility, park there and switch to the public transportation to reach their final destination. The author in [12] categorises Park&Ride systems' users into three: everyday users, holiday users (users, who do not want to worry about parking space availability), users who prefer, for example, to read a book while travelling, something they cannot do if driving a car. The common characteristic of the users is that they plan to use the Park&Ride system, which is not a spontaneous decision. Features of well-planned Park&Ride systems, such as safe parking, are presented in [14]. The paper describes the situation where Park&Ride is used with dedicated buses transferring passengers from the parking lot to the airport. Authors in [2] present the close relation between parking availability and accessibility in an urban area, which is connected by a unified framework of parking plan. Paper [13] describes the effectiveness of a bus-based Park&Ride system. Authors examine such characteristics as factors that can encourage or discourage motorists to use Park&Ride, the frequency of using the Park&Ride, and the level of congestion reduction in the town centre.

Mode choice models are an important factor during Park & Ride system development. One of the major problems of the Park&Ride system is how to persuade car drivers to use it. Authors in [3] describe mode choice models based on schedule, which include all the mode alternatives available for the specific OD pair and the time and cost variables. This model allows the prediction of actual passenger flow on individual service trips. Another approach is shown in the paper [7]. The mode choice model using individual grouping is based on cluster analysis based on the stated preference and revealed preference survey data. The authors' results show that this analysis is an effective mathematical method to divide individuals into groups.

The aim of the study is to evaluate the proposition of using the transport hub Park&Ride system at Brynowska junction. This paper is organized as follows. Section 2 describes the current state of the transport hub, public transportation and traffic flow on the junction Kościuszki-Rzepakowa-Kolejowa, which has a direct impact on the Brynowska junction. This is followed by a section describing the results of conducted questionnaire on passengers' opinions about the Park&Ride system. The next section presents the estimated impact of the Park&Ride system on the transport hub and traffic, with the use of two simulations. Section 5 of the paper contains conclusions and a proposition for future work.

## **2. CURRENT STATE OF THE “BRYNOWSKA” JUNCTION**

The aim of the analysis is the estimation of the effects of the Park&Ride system implementation into “Brynowska” junction. For this purpose, the current state of the junction was analysed using a video camera. The video stream was registered during the morning rush hour on a working day. The current state analysis can be divided into two parts. One of them describes the public transport characteristic: number of buses and trams, number of passengers travelling by bus and the number of people changing from bus to tram. The second part describes the traffic flow at the hub (which is necessary to build a simulation model) on the Kościuszki-Rzepakowa-Kolejowa junction, where congestion occurs in the morning rush hour, affecting the efficiency of transport mode change. Additionally, the number of passengers driving by car was noted.

Figure one presents the split between the numbers of the passengers who are changing to tram and those who are continuing the trip by bus. Twenty-nine percent of the passengers change from bus to tram. While comparing the measuring intervals, it has been noticed that the number of passengers changing to tram decreases proportionally to the traffic flow during the rush hour.

Table 1

Number of public transport vehicles using transport hub  
“Brynowska” during the rush hour

Time [min]	Trams	Buses	
		Buses	Articulated buses
(0-15>	3	2	2
(15-30>	3	3	2
(30-45>	2	2	4
(45-60>	3	1	2

Table one reports the number of public transport vehicles that run through to the transport hub “Brynowska”. During the morning rush hour buses arrive at the transport hub on average every  $3\frac{1}{3}$  minutes and trams depart on average every 5 minutes.

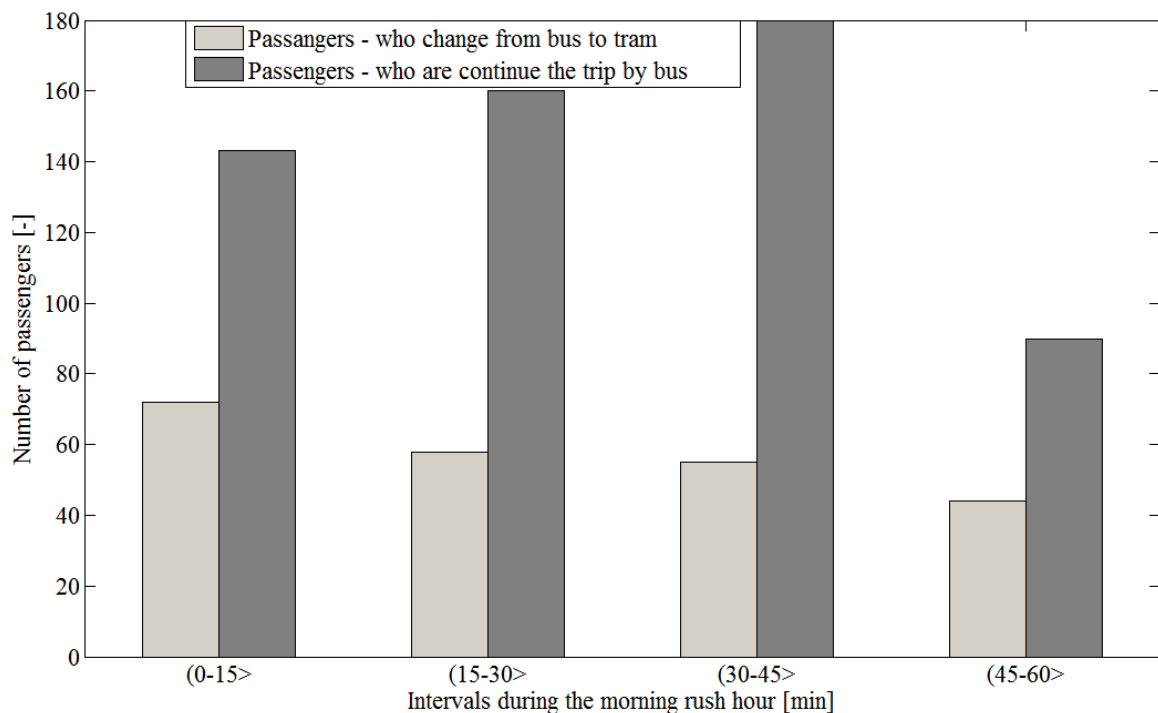


Fig. 1. Split between number of passengers changing to tram and those who continue their trip by bus  
Rys. 1. Podział liczby pasażerów korzystających z przesiadek w stosunku do osób kontynuujących podróż autobusem

Table and figure one contain detailed information about public transport related to the number of changing passengers and the number of vehicles. In order to define the distribution of traffic modes, it was also necessary to examine the traffic flow on Kościuszki road. Table 2 contains individual transport data.

Based on the data presented in figure 1 and in table 2, the difference between the number of passengers using public and individual transportation has been calculated. Individual transportation is used by 153 passengers more than public transport. In the morning rush hour, there was statistically 18

buses with 573 passengers and 974 cars with 1517 passengers in the cars on the analyzed section of the road. This data is used in the computer simulations.

Table 2

Time [min]	Number of the passengers in one car				
	1	2	3	4	5+
(0-15>	170	65	28	17	10
(15-30>	121	55	21	15	6
(30-45>	198	39	15	10	3
(45-60>	167	19	10	5	0

The results presented in table 2 show that most of the people drive alone by car. Based on the analysis of the number of passenger cars, it has been calculated that 67% of motorists are travelling individually. This way of travelling is disadvantageous from the viewpoint of traffic engineering and the environment. In addition, passengers who are using public transport occupy a much smaller part of the road than passengers using individual transport. The main goal is to limit the number of people using individual transport.

### 3. QUESTIONNAIRE SURVEY

The questionnaire survey was conducted in order to discern the public opinion about Park&Ride. On the Brynowska junction two hundred people from the southern district of Katowice were questioned. The questionnaire survey contained fourteen questions which were designed to assess the effects of introducing the transport hub of the Park&Ride system in that place and to identify the preferred mode of transport, trip destination and the willingness to use the Park&Ride system. All interviewees were informed that the questionnaire survey relates to the Brynowska junction.

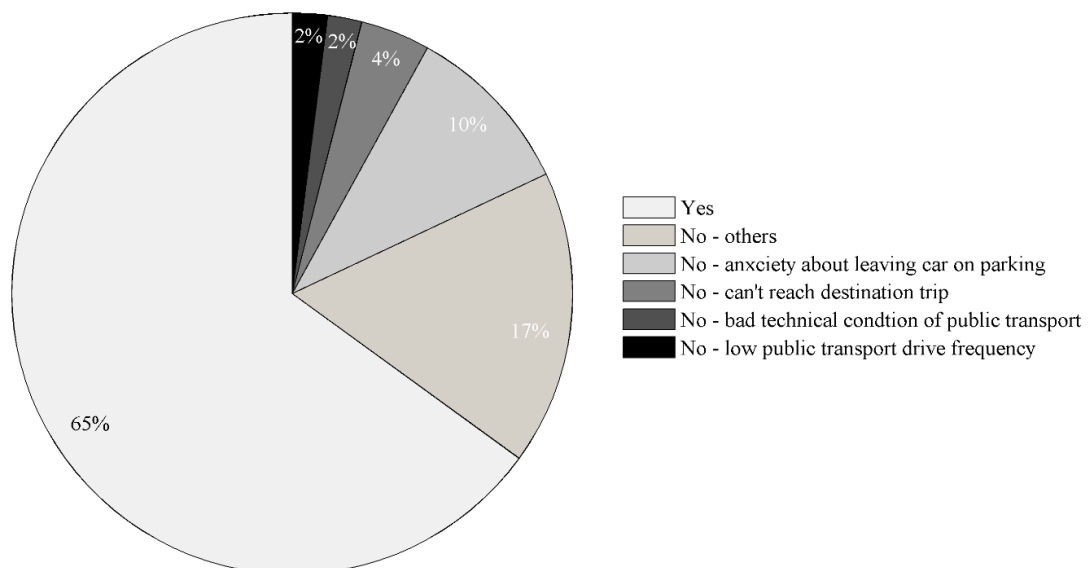


Fig. 2. Graph representing the distribution of answers to the questionnaire survey questions "Would you use the new Park&Ride system?" and "Why don't you want to use Park&Ride system?"

Rys. 2. Wykres dotyczący odpowiedzi na pytania ankietowe: „Czy używałbyś nowego systemu Park&Ride?” oraz „Dlaczego nie chcesz korzystać z systemu Park&Ride?”

Figure two presents the distribution of answers to the questions “Would you use the new Park&Ride system?” and “Why don’t you want to use the Park&Ride system?”. More than half of interviewees declared that they would use the Park&Ride system. A questionnaire survey was conducted for six different age groups. The biggest interest about the new idea was registered in the age group from 30 to 50. During the survey, interviewees who declared their will to use the described solution were also asked for additional information about the Park&Ride system. It is important to notice that this kind of solution is not very popular. Therefore, the implementation of such a system should be followed by a promotional campaign addressed to the future users. Young and old people do not need the Park&Ride system. The young do not have cars and people advanced in years travel rarely. The question on trip destination shows that most of the people travelling in the morning rush hour are going to work.

Figure two shows that 35 percent of interviewees do not want to use the Park&Ride system. These people were asked an additional question: “Why don’t you want to use the Park&Ride system?”. Concerns about leaving the car in the Park&Ride parking lot is one of the most often chosen answers. People do not have knowledge about that system; therefore, they are worried about the safety of their cars. In modern Park&Ride systems, parking lots are monitored, so they have a high level of safety. People, who have chosen the answer “Others” mostly claimed that changing to tram would not be comfortable for them. Another answer (in the category “Others”) was the fear that additional fees will be charged for the parking lot usage in the Park&Ride system. A popular solution to this is making parking space free for passengers with a public transport ticket.

#### 4. COMPUTER SIMULATIONS

Simulations were performed in CUBE Dynasim 4 program. The modelled area covers the Brynowska junction (Rzepakowa, Kościuszki, Kłodnicka - crossroads). The first model represents the current state of the Brynowska junction during the morning rush hour. The second model shows the state which is expected after the implementation of the transport hub of the Park&Ride system at Brynowska. Based on the questionnaire survey, 65 percent of interviewees want to use the new system. However, this study does not reflect the entire population; so the traffic flow in the model was reduced on the roads Kościuszki and Rzepakowa by 20 percent during the morning rush hour. The simulations were configured using the real traffic light programs.

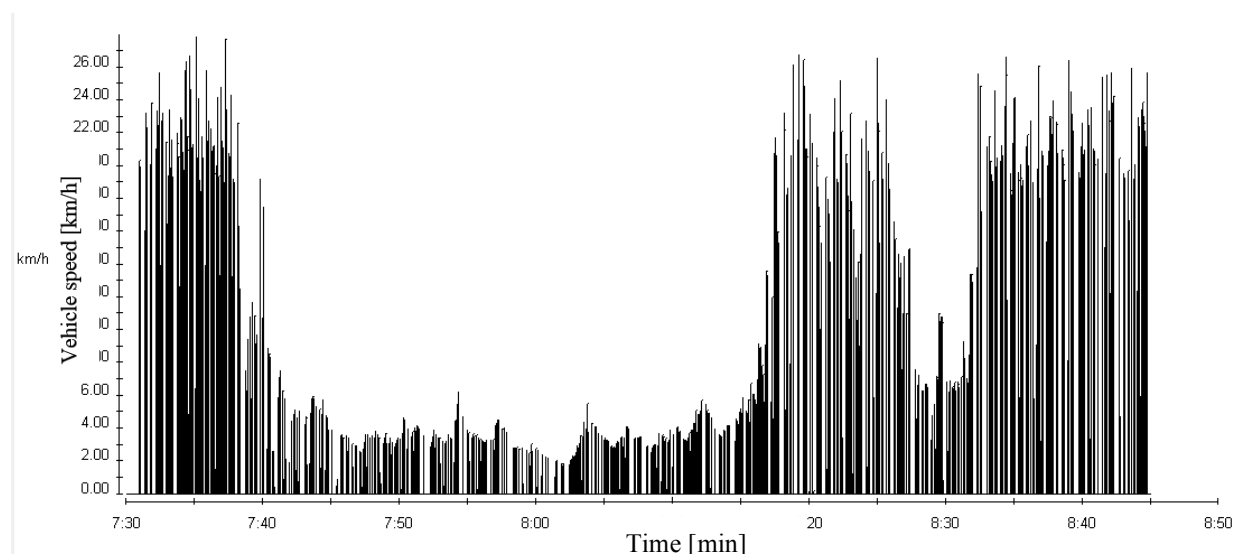


Fig. 3. Graph of vehicles: mean speed to time. Graph presenting current state of outflow Kościuszki  
Rys. 3. Zależność prędkości pojazdów od czasu. Wykres stanu obecnego wylotu, ul. Kościuszki

In order to estimate the effects of the Park&Ride system implementation, a data collector tool was added into both models. This tool enables collection of traffic data on a defined road section (70 m). In the model, this section was located on Kościuszki road, where the bus stop is located and congestion occurs in the current state.

Figures 3 and 4 show results obtained during the computer simulation of transport hub „Brynowska”. Presented data describes traffic was registered in the time interval from 7:30 to 8:45. Segments represent vehicles passing through the analyzed section of the road. The height segment reflects the mean speed of a single vehicle. Charts present the dependency between mean speed values of vehicles at points in time. The comparison of these charts representing the current and expected state reflects the effects of the Park&Ride system implementation.

Table 3

Time and speed analysis of current state: Data from computer model					
Time [sec]			Speed		
Min	Mean	Max	Mean [km/h]	Standard deviation [km/h]	
17.8	117.8	140.9	9.33	7.86	

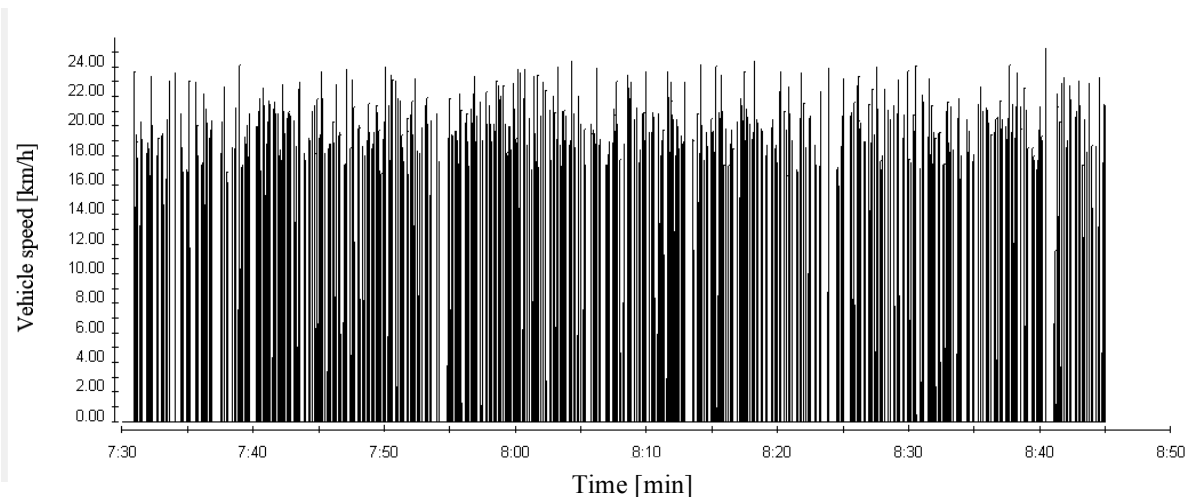


Fig. 4. Graph of vehicles speed to time. Graph presenting expected state of outflow Kościuszki  
Rys. 4. Zależność prędkości pojazdów od czasu. Wykres prognozowanego stanu wylotu, ul. Kościuszki

Table 4

Time and speed analysis of expected state: Data from computer model					
Time [sec]			Speed		
Min	Mean	Max	Mean [km/h]	Standard deviation [km/h]	
14.1	16.2	18.5	20.11	1.96	

Figures 3 and 4 illustrate the difference between the current and the expected state of traffic. On chart 3 we can observe that congestion starts around 7:40 and ends at 8:15. Vehicles, including public transport, lose much time on the stops. Chart 3 shows that the mean speed value of vehicles increases when the rush hour ends. Chart 4 presents the estimated effects of the transport hub Park&Ride system implementation at the Brynowska junction, which proves that the traffic flow during the rush hour will be greatly improved.

Tables 3 and 4 contain data computed using the models. Simulations were based on real traffic flow data measured on the roads during the morning rush hour. Analyzed data presents time and vehicle speed. The biggest difference between both models is the value of the mean time needed to drive through the selected section. The value of such difference is over 124 seconds. The average speed difference is about 11 kilometres per hour. The standard deviation in those models shows a dispersion of vehicle

mean speed results. The low value of standard deviation in the feature model shows that the Park&Ride system implementation will have an advantageous impact on traffic flow on hub Brynowska.

## 5. CONCLUSION

Based on the questionnaire survey results, an observation can be made that the current state during the morning rush hour is disadvantageous for commuters. Commuters have problems with changing the mode of transport. Analysis of traffic modal split shows that more passengers are using individual transportation than public transport. This situation has a negative impact on road traffic and the environment. In addition, passengers using individual transport mostly travel alone. The analysis of the questionnaire results shows that most of the interviewees would like to use the Park&Ride system. The generated computer simulations allow us to compare the current state of the Brynowska junction and estimate the effects of implementation of the transport hub of the Park&Ride system at this junction. The obtained results prove that this solution could improve the current state of the transportation system.

Further research may include a detailed comparison (using GPS tracker) of three different modes of transport (by bus, changing from bus to tram and by car). This research could prove that implementation of the Park&Ride system could make travel time to the city centre much shorter.

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