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ANALYSIS OF PUNCTUALITY COEFFICIENTS IN THE STATIC METHOD OF RESEARCH

Summary. Complex research of punctuality requires analysis of many coefficients. In the article the analysis and the example of application one of the basic methods of punctuality measurement – the static one – has been presented.

ANALIZA WSKAŹNIKÓW OCENIAJĄCYCH PUNKTUALNOŚĆ W METODZIE BADAŃ STATYCZNYCH

Streszczenie. Kompleksowe badanie punktualności wymaga analizy wielu wskaźników ją oceniających. W pracy przedstawiono taka analizę oraz przykład zastosowania jednej z podstawowych metod badania punktualności – metody badań statycznych.

1. INTRODUCTION

Punctuality is one of the most essential coefficients among synthetic criterions of reliability. It is a feature, which is very important for passengers, because it directly influences subjective passenger's estimate of organizer of transportation. It is an important factor of the quality of public transport. It has substantial meaning in the Silesian area, where system of public transport is extended, and it has played an important role in the field of organization of transport system for the whole region.

The method used in the article depends on research of departure time in definite section on the bus line. Estimation of several parameters at the same time for several bus lines simultaneously is an advantage of this method. It enables observation of phenomena on the entire communication route for all bus lines, which have been served. However it's impossible for this method to observe the phenomena during a journey.

2. MEASUREMENTS

The exact measurement is a key for complex analysis of punctuality. The period of measurements has been defined on the basis of applicable norms and literature [2]. It has been divided into four intervals of measurements:

- 6.00 – 8.00
- 8.00 – 13.00
- 13.00 – 18.00
- 18.00 – 23.00

The measurements have been conducted on Tuesdays, Wednesdays and Thursdays. These days are representative for this type of measurements.

During measurements two points (the bus stations) have been analysed. They were located in Zabrze on the route of the bus line 840, which connects Katowice and Gliwice:

- the bus station Zabrze Słowackiego in direction Katowice – Gliwice
- the bus station Zabrze Skargi in direction Gliwice – Katowice.

Decision about the choice of just these measurement points has been made on the basis of analysis of previous surveys carried out by the dynamic method on the bus line 840. It has been noticed, that analysed bus line after running across Zabrze big deviations had been generated from the bus schedule. However, from the point of view of passenger, these two bus stations were initial points, where the bad phenomena have appeared.

The route of the bus line 840 and location of two analysed bus stations have been presented in fig.1.

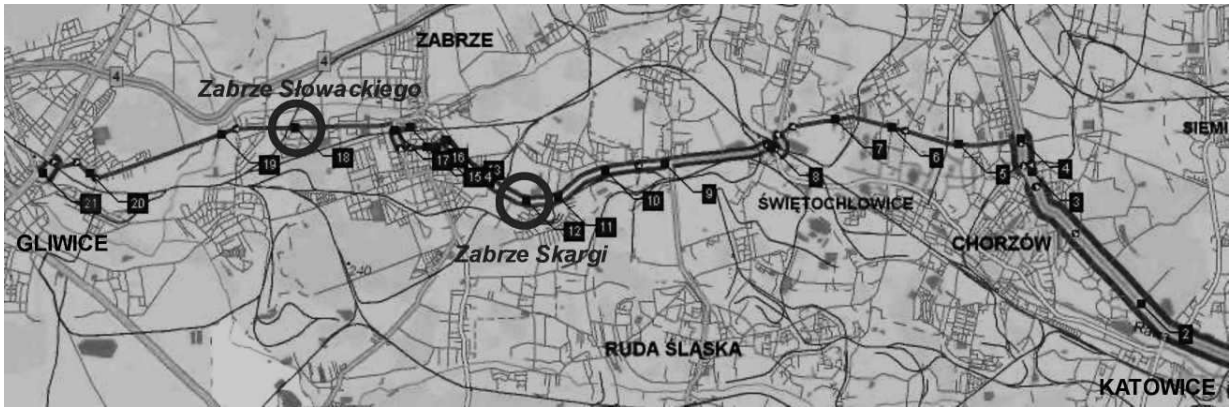

Fig.1. Location of analysed bus stations in Silesian area
Rys. 1. Umiejscowienie badanych przystanków na obszarze Aglomeracji Katowickiej

At the Zabrze Słowackiego bus station the following bus lines were stopped [4]:

- bus linie 6 from Katowice to Gliwice,
- bus linie 280 from Bytom to Gliwice,
- bus linie 617 from Zabrze to Gliwice,
- bus linie 840 from Katowice to Gliwice.

At the Zabrze Skargi bus station the following bus lines were stopped [4]:

- bus linie 6 from Gliwice to Katowice,
- bus linie 840 from Gliwice to Katowice.

3. ANALYSIS AND PRESENTATION OF MEASUREMENTS RESULTS

Punctuality is a compatibility with bus schedule. Estimation of several coefficients, which directly or indirectly influence punctuality, is necessary for conducting complex punctuality analysis [1].

3.1. Deviation

Deviation is a difference between schedule departure time t_r for every course and real departure time t_e for every course from definite point on the route of bus line [2].

$$d = t_r - t_e \tag{1}$$

Positive value of deviation represents acceleration and negative – delay.

Deviation value was indicated by the static method for every measurement, for every day of measurement, for every interval, for every bus line and for point of measurement. It is a lot of data, so in the article only average values for every interval, for every bus line and for point of measurement have been placed. The results of measurements have been presented in table 1.

Tab. 1

Average value of deviation

ZABRZE SKARGI				
Bus line	Interval	Average value of deviation for interval [min]	Average value of deviation for bus line [min]	Average value of deviation for point of measurement [min]
6	6.00-8.00	-1’33”	-2’41”	-3’28”
	8.00-13.00	-1’56”		
	13.00-18.00	-4’12”		
	18.00-23.00	-1’36”		
840	6.00-8.00	-4’13”	-4’13”	
	8.00-13.00	-3’15”		
	13.00-18.00	-5’26”		
	18.00-23.00	-2’44”		
ZABRZE SŁOWACKIEGO				
Bus line	Interval	Average value of deviation for interval [min]	Average value of deviation for bus line [min]	Average value of deviation for point of measurement [min]
6	6.00-8.00	-2’53”	-2’07”	-2’31”
	8.00-13.00	-1’18”		
	13.00-18.00	-3’10”		
	18.00-23.00	-0’58”		
280	6.00-8.00	-0’55”	-2’06”	
	8.00-13.00	-1’32”		
	13.00-18.00	-3’02”		
	18.00-23.00	-0’53”		
617	6.00-8.00	-1’56”	-1’56”	
	8.00-13.00	-1’49”		
	13.00-18.00	-2’23”		
	18.00-23.00	-0’39”		
840	6.00-8.00	-5’53”	-3’40”	
	8.00-13.00	-4’05”		
	13.00-18.00	-3’10”		
	18.00-23.00	-0’50”		

Positive aspect, which was noticed during the analysis of the coefficient, is insignificant occurrence a deviation typical of acceleration. The passengers don’t like it very much. Very large deviations typical of delay occur in both directions for the bus line 840. At the Zabrze Skargi bus station this value essentially influences average value for the point of measurement. For this bus line these values are unacceptable to passengers. In remaining cases the delays are tolerated by users of public transport.

3.2. Tolerance

Tolerance is an interval, in which occurring departure times are recognized as punctual, despite that, they may be delayed no more than $\mathbf{t_{min}}$ and accelerate no more than $\mathbf{t_{max}}$ [3].

KZKGOP currently postulates 2 minute delay independently of the season of the year. One minute tolerance of this interval is acceptable [5].

In static method of measurement we may present the tolerance as a change of deviation in time. It has been presented in fig.2a and fig.2b.

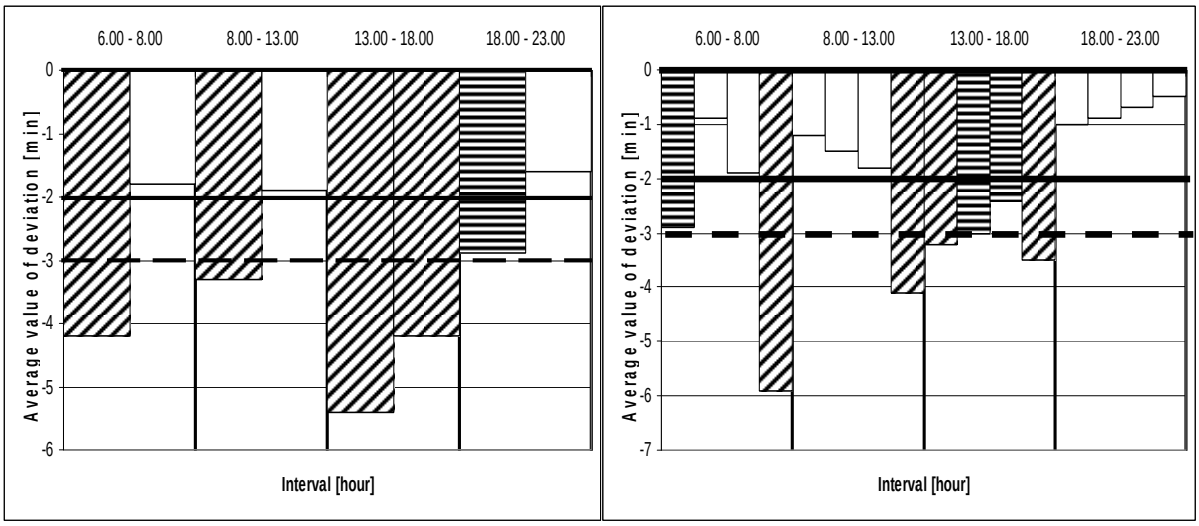

Fig.2a Fig.2b

Fig.2a. Average value of tolerance in all intervals at the Zabrze Skargi bus station
Rys.2a. Średnia tolerancja odchyłek na przystanku Zabrze Skargi we wszystkich przedziałach pomiarowych
Fig.2b. Average value of tolerance in all intervals at the Zabrze Słowackiego bus station
Rys2b. Średnia tolerancja odchyłek na przystanku Zabrze Słowackiego we wszystkich przedziałach pomiarowych

Legend:

bus course which is included in tolerance borders (punctual)

bus course which is included in tolerance error borders (punctual)

bus course which isn't included in tolerance borders (unpunctual)

The biggest delay had occurred in the interval 13.00 – 18.00. The smallest delay occurred in the evening hours. It is a result of the smallest traffic intensity. Maximal delays were noted for the bus line 840.

3.3. Coefficient *U* – arduousness of unpunctuality

In case of public vehicle delay one of the effects is lengthening of waiting time. On the other hand, when the vehicle departs earlier, then the part of passengers will not be served. Then passenger experiences a large waste of time.

Arduousness of unpunctuality expresses excessive waiting time. It is a difference between a waste of time for a chosen deviation and a waste of time for an ideal punctuality [2]. This coefficient defines a waste of time, which is a result of appearance of deviation from bus schedule.

Excessive waiting time is a subjective measure of arduousness of unpunctuality, which is well perceived by passengers. The value of coefficient *U* is marked for individual cases of deviation [2]:

$$U = \begin{cases} -1{,}3 \cdot d - 1{,}6 & for \quad d \le -2 \\ -0{,}5 \cdot d & for \quad -2 \le d \le 0 \\ 0{,}162 \cdot h \cdot d & for \quad 0 \le d \le 6 \\ 0{,}97 \cdot h & for \quad d \ge 6 \end{cases} \tag{2}$$

where: *d* – deviation from bus schedule, which is defined in minutes („+" means acceleration , „-„ means delay), *h* – average interval between vehicles, which is defined in minutes

Rudnicki [2] proposes to assign an estimate for arduousness of unpunctuality to range of coefficient *U* value. It has been presented in the table 2.

Tab. 2

Scale of estimate for arduousness of unpunctuality

Range of coefficient *U*[min]	Estimate
0,0÷0,9	very good
1,0÷1,9	good
2,0÷3,9	satisfactory
4,0 and more	unsatisfactory

The larger value of coefficient *U* is, the worse the punctuality is.

The arduousness of unpunctuality *U* value has been presented in the table 3.

Tab. 3

The arduousness of unpunctuality *U* value and its estimate

	Interval								Estimate for point of measurement [min]	
	5.00 – 8.00		8.00 – 13.00		13.00 – 18.00		18.00 – 23.00			
Bus line	Average value U [min]	Estimate U	Average value U [min]	Estimate U	Average value U [min]	Estimate U	Average value U [min]	Estimate U	Average value U [min]	Estimate U
ZABRZE SKARGI										
6	1,74	good	2,41	sat.	4,33	unsat.	2,77	sat.	3,01	sat.
840	4,03	unsat.	3,28	sat.	5,49	unsat.	5,49	unsat.	4,28	unsat.
All	2,89	sat.	2,84	sat.	4,91	unsat.	3,16	sat.	3,66	sat.
ZABRZE SŁOWACKIEGO										
6	2,56	sat.	3,30	sat.	2,57	sat.	7,20	unsat.	3,32	sat.
280	2,31	sat.	1,80	good	3,28	sat.	6,05	unsat.	2,89	sat.
617	2,24	sat.	2,97	sat.	1,92	sat.	6,94	unsat.	2,86	sat.
840	6,14	unsat.	4,19	unsat.	3,17	sat.	7,22	unsat.	4,46	unsat.
All	3,36	sat.	3,27	sat.	2,75	sat.	7,02	unsat.	3,44	sat.

During the analysis of average coefficient *U* value for Zabrze Skargi bus station it has been noticed, that estimate „satisfactory" had occurred most often. This estimate had also occurred for point of measurement. The „unsatisfactory" estimate has appeared the most often for the bus line 840. It shows that the bus schedule for this bus line is not proper fitting into traffic conditions.

At the Zabrze Słowackiego bus station it has also been noticed that the most often estimate is „satisfactory". This is an estimate for this point of measurement. It depends on two factors: a big interval between vehicles in bus schedule and small frequency of coursing.

3.4. Coefficient *Q* – degree of punctuality

Every man feels, that the borders between punctual departures and departures, which are considered as unpunctual are diverse. In reality this is a subjective estimate. Therefore a fuzzy set is proposed to use as a measure of punctuality. It is described with the help of the affiliation function *Q*. This function has been constructed at following foundations [3]:

- $Q = 1$ for departures with small deviation (acceptable by passengers),
- $Q = 0$ for departures with big deviation (unacceptable by passengers),
- $Q \in (0,1)$ in the other cases:
  - when *Q* is closer 1 then the degree of punctuality is high,
  - when *Q* is closer 0 then the degree of punctuality is low

The value of coefficient *Q* for individual observation may be estimated from [3]:

$$Q_i = \begin{cases} 0 & for \quad d_i < d_1, \quad d_i > 2 \\ \dfrac{d_i - d_1}{d_2 - d_1} & for \quad d_1 \le d_i < d_2 \\ 2 - d_i & for \quad 1 < d_i \le 2 \\ 1 & for \quad d_2 \le d_i \le 1 \end{cases} \tag{3}$$

where: d_i – value of deviation $d_1 = -\dfrac{2h+150}{45}$; $d_2 = -\dfrac{h+75}{45}$, h – average interval between arrivals

Rudnicki proposes to assign an estimate for degree of punctuality to a range of coefficient *Q* value. It has been presented in the table 4 [3]

Tab. 4

Scale of estimate for degree of punctuality

Range of coefficient *Q*	**Estimate**
0,86÷1,00	very good
0,71÷0,85	good
0,41÷0,70	satisfactory
0,40 and less	unsatisfactory

The larger value of coefficient *Q* is, the better the punctuality is.

The degree of punctuality *Q* value has been presented in the table 5.

Tab. 5

The degree of punctuality *Q* value and it estimate.

Bus line	Interval								Estimate for point of measurement [min]	
	5.00 – 8.00		8.00 – 13.00		13.00 – 18.00		18.00 – 23.00			
	Average value Q	Estimate	Average value Q	Estimate	Average value Q	Estimate	Average value Q	Estimate	Average value Q	Estimate
ZABRZE SKARGI										
6	0,86	v.good	0,74	good	0,41	sat.	0,95	v.good	0,67	sat.
840	0,31	unsat.	0,53	sat.	0,13	unsat.	0,75	good	0,40	sat.
All	0,58	sat.	0,64	sat.	0,31	unsat.	0,85	good	0,53	sat.
ZABRZE SŁOWACKIEGO										
6	0,64	dost.	0,73	good	0,66	sat.	0,63	sat.	0,70	good
280	0,90	v.good	0,94	v.good	0,54	sat.	0,63	sat.	0,71	good
617	0,71	good	0,73	good	0,78	good	0,70	sat.	0,74	good
840	0,17	unsat.	0,53	sat.	0,57	sat.	0,79	good	0,52	sat.
All	0,60	sat.	0,70	good	0,64	sat.	0,76	good	0,66	sat.

For the Zabrze Skargi bus station the most often occurring estimate is „satisfactory". This estimate has been also appeared for the point of measurement. The occurrence of estimation „very good" for the bus line 6 in the mornings and evenings is a positive aspect, which has been noticed during the analysis of this coefficient. The bus line 840 has the worse values of this coefficient than the bus line 6. It is a second argument, which shows, that the bus schedule for the bus line 840 is not proper fitting into traffic conditions.

For the Zabrze Słowackiego bus station the most often occurring estimate is „satisfactory". Average value of degree of punctuality for the point of measurement is also „satisfactory". Generally, the estimate of *Q* is better for the lines, which course on shorter routes (280 bus line and 617 bus line) than for the others.

4. CONCLUSIONS

The analysis of punctuality has been a subject of this article. The measurements have been conducted by static method of research. The Silesian area has turned out to be a perfect place to make it. During the measurements the departure times of public transport have been registered exact to a second. On the basis of research the numbers of coefficients have been estimated and the complex analysis has been conducted.

The analysis of the measurement results shows that punctuality depends on many factors. One of them is the traffic intensity, which has changed during the day. It also shows the value of deviation, which is acceptable in the evening hours and unacceptable in the morning and afternoon hours. Bad adaptation the bus schedule into prevailing traffic conditions is another factor. The analysis of tolerance has presented the problem. The bus schedule for the bus line 840 has to be updated. Apart of these presented earlier factors, there is several of them like: human factor, random factor, state of bus fleet.

The very important coefficients which have been analyzed are: arduousness of unpunctuality *U* and degree of punctuality *Q*. These two measures estimate punctuality in measurable manner. In major types of analysis the estimate "satisfactory" dominates: for intervals, for bus lines and for the points of measurements. Summing up the estimate of punctuality in Silesian area is satisfactory.

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