ATTRACTIVENESS OF PUBLIC TRANSPORT AS AN ALTERNATIVE OF PRIVATE CAR

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Abstract: The features of attractive public transport are presented. Methods of quality improvement for public transport in order to increase its attractiveness are described. The importance of travel comfort for passengers is discussed. The volume of passengers and the level of travel comfort are compared. Influence of punctuality on volume of passengers in public transport vehicles was presented. The relationship between punctuality and volume of passengers are investigated. Statistical analysis of the influence of deviations from time-table and intervals between vehicles in succession of selected lines on volume of passengers are presented. As a result of analysis polynomial and regression models for selected bus line are described.

1. Introduction: What are the causes and the results of communication problems in cities?

Improvement of level of inhabitants' life and increasing fashion on private car leads to more and more larger motorizing of society. Motorization coefficients in big cities in Poland crossed value of 300 private cars (for example: Warsaw, Cracow) per 1000 inhabitants. More and more number of vehicles is reason of fag of streets capacities and parking spaces, what extorts continuous extension of street sections and necessity of search of new forwarding corridors. This is an effect called "Vicious circle", which is driven by extension of transportation infrastructure (Fig.1.).

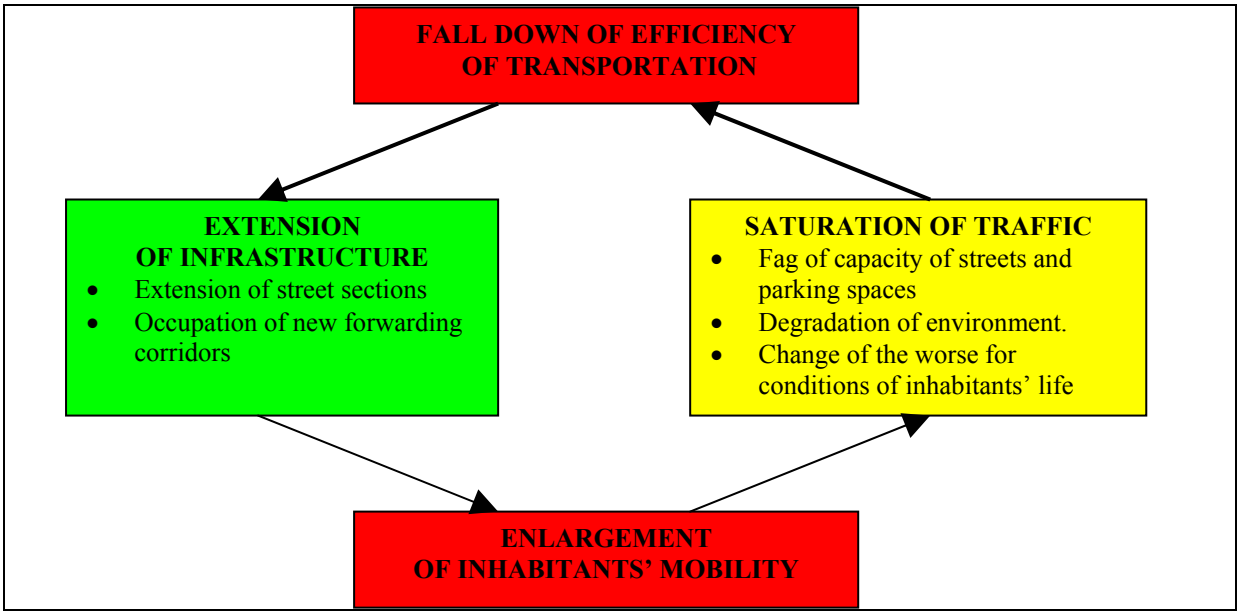

Fig. 1. Effect of "vicious circle".

It joins this with environmental threats, such as: emission of fumes, noise, cutting of neighbourly ties, destruction of scenery, road accidents, what influence into the change of worse conditions for inhabitants' life. Only one rational way to heal of situation is creation an attractive and efficient public transport.

2. What are the features of attractive public transport?

Most important guilds of attractive transport, are (2):

- Public transport network fitted to main passengers' streams.
- Possibility of transport how largest number of passengers, large accessibility of public transport.
- High efficiency and reliability of public transport.
- High level of passengers' trip comfort (small crowd, modern fleet).
- Public transport high frequency, particularly in areas with limited access for individual transport.
- Attractive connections with stations, terminals and stops of country transport, good connections with strategic car parks (Park and Ride, Kiss and Ride).
- Approach to public buildings, such as hospitals, universities, schools, markets, etc.
- Co-ordination of urban and suburban public transport lines.
- Co-ordination of different means of public transportation (bus, tram, trolley bus, underground).
- Minimization of number of changes - assurance of directness connections for largest passengers streams. Friendly for passenger changing knots.
- Convenient fare system (low prices, diverse ticket offer).
- Open to the public information for passengers.

3. What meanings are to improve public transport functioning?

There are many means of transport continuous improving. The most important are:

- Transportation policy - option of sustainable development, share of public transport in modal split (60-75%), restricted areas for private cars, especially in a city centres.
- Accommodation offer of public transport companies to user preferences (taking into consideration new trip generators such as new housing estates , trade complexes etc):
  - Modification of existing urban transport network.
  - Realistic time-tables.
  - Dispatching activities.
  - Modernizing of buses, trams, stops, etc.
  - Adaptation of suitable type of vehicles.
  - Enlarging of running frequency.
  - Exact information in vehicles and stops.
- Privilege for public transport vehicles in urban traffic:
  - Separate lanes for trams and buses (also common bus-tram lanes).
  - Priorities in traffic lights.
  - Streets only for public transport.
  - Restrictions for private cars.
  - Public transport lines on major streets.
  - Priority for public transport vehicles on junctions.

4. What is the meaning of trip comfort?

- One of the most important requirements, together with quality and accessibility.
- Lack of sufficient comfort of trip can be the reason of resignation from public transport.
- Often identified with overcrowding.
- 6 levels of comfort, with critical values of vehicle occupancy (Tab.1).

Description of comfort levels (3):
Level A - All passengers have sitting places, but without direct neighbourhood of other persons. Possibility of easy transport of luggage, trolleys etc.
Level B - All sitting places are occupied. Possibility of easy transport of luggage, trolleys etc.
Level C - Few passengers stand, possibility of free moving inside vehicle. Easy access to ticket puncher.
Level D – Not very large overcrowding, limited possibility of free moving inside vehicle. Not easy access to ticket puncher.

Tab.1. Character of levels of comfort for all types of public transport vehicles.

Level of comfort	Occupancy of vehicle N [pas/veh]	
	Lower value	Upper value
A	$0,10 \cdot C_1$	$0,70 \cdot C_1$
B*	$0,70 \cdot C_1$	C_1
C	C_1	$C_1+0,299 \cdot C_2$
D	$C_1+0,299 \cdot C_2$	$C_1+0,597 \cdot C_2$
E	$C_1+0,597 \cdot C_2$	C_1+C_2
F	C_1+C_2	$C_1+1,493 \cdot C_2$
where: N – Occupancy of vehicle, C_1 - Number of sitting places, C_2 - Number of standing places. * also when $N < 0,10 \cdot C_1$		

Level E - Large overcrowding, very difficult access to ticket puncher (cases of giving up places for persons, who wants to get out).
Level F - Very large overcrowding, ticket punching is impossible, difficult to close the vehicle doors (cases of damage of closing device), necessity of giving up places for persons, who wants to get out.

5. Definition of trip conditions using the results of occupancy measurements.

Investigations of occupancy were made in April of 2003 year, during average working day. They were led inside vehicles after boarding, across the line. Lines taken into consideration:

- Line number 105 – length 5,5 km, radial character, connecting city centre with suburban area. Line served by articulated buses SCANIA CN94U (Fig.2.) and MAN NG313.
- Line number 115 – length 15,5 km, diameter character, crossing the city centre. Line served by buses SCANIA 113 CLL.
- Line number 501 – length 22 km, fast line with diameter character, crossing the city centre. Line served by buses IKARUS 280.
- Line number 502 – length 21 km, fast line with diameter character, crossing the city centre. Line served by buses JELCZ 121M.

Measure tests for selected lines and calculation results of essential characters are presented in table 2.

Tab.2. Calculation results of vehicle occupancy [pas/veh]:

Line	Number of observation	Range [pas/veh]	Average	Standard deviation	95% confidence interval	
					Lower limit	Upper limit
105	197	3 - 97	43	20	41	47
115	51	0 - 69	26	18	21	31
501	152	0 - 100	35	19	32	38
502	128	4 - 93	36	17	33	39
All	528	0 - 100	38	20	36	40

Range of occupancy is very wide. It is caused by fact of small passenger streams on the first and last bus-stops (on diameter lines). Average values of occupancy are rather small although, that investigation was led among the passengers, on popular public transport lines.
Very useful to qualification of conditions in vehicle is degree of vehicle occupancy $\mathbf{n_c}$, which involve the capacity of vehicle. It is described by formula:

$$n_c = \frac{N}{C}$$

where: N – Occupancy of vehicle, C – Capacity of vehicle: C = C1 + C2

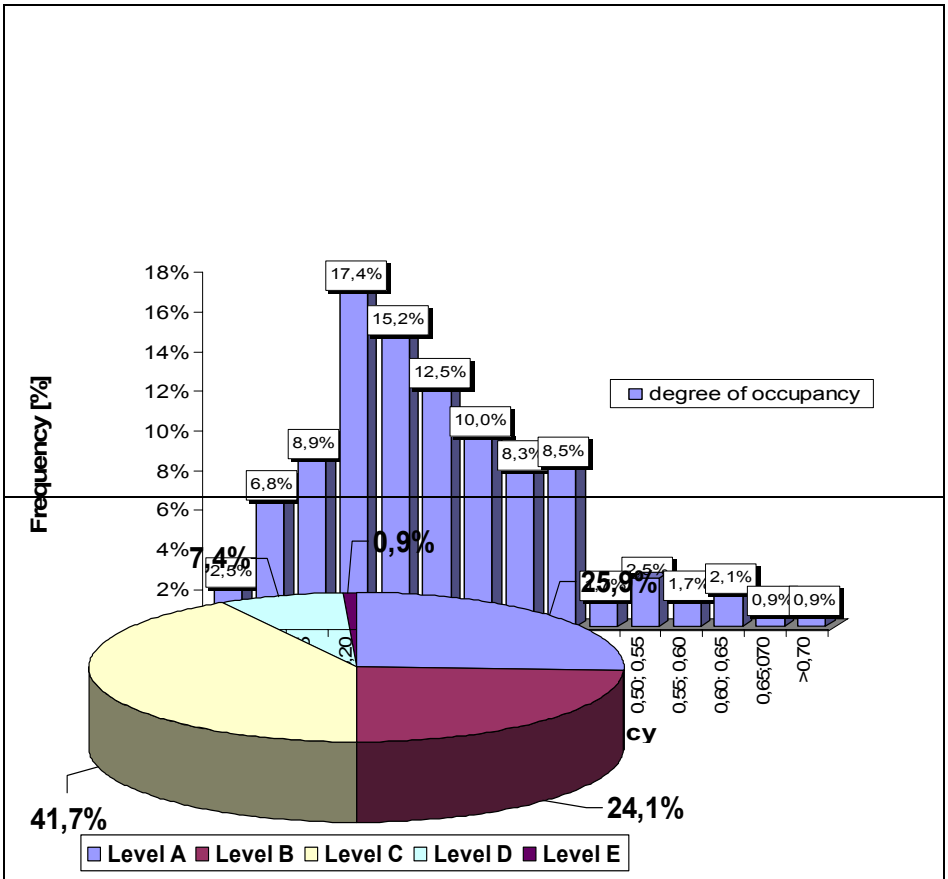

Fig. 2 and 3. Degree of occupancy histogram for all lines and frequency of comfort levels for chosen lines.

Frequency histogram of occupancy degree for all selected lines together, was presented on the figure 2. Values of degree are ranged between 0,15 - 0,35 because of small occupancies. Frequency of comfort levels was presented in the figure 3. The biggest group of results was determined by cases of level C (41,7%), smallest - level F.

6. What is the deviations influence from time-table, distance from beginning of line and interval from next two departures on occupancy of buses.

Deviation "d" - difference between time of departure t_r provided in time-table, and real time of departure t_e, defined by formula:

$$d = t_r - t_e \text{ [min]}.$$

Positive values of deviations refer to early departures, negative values - delays of departure.
In Cracow, punctually departure is from maximum 1-minute early and maximum 3-minutes delay.
Basic calculation results of deviations from time-table are presented in table 3.

Tab.3. Calculation results [min]:

Line	Number of observation	Range	Average value	Standard deviation	95% confidence interval	
					Lower limit	Upper limit
105	197	-3,98 ÷ 1,72	-1,62	1,10	-1,77	-1,46
115	51	-16,70 ÷ 1,38	-5,73	5,87	-7,34	-4,12
501	152	-10,38 ÷ 4,15	-2,51	3,32	-3,02	-2,00
502	128	-10,45 ÷ 7,02	0,01	3,35	-0,58	0,59
All	528	-16,70 ÷ 7,02	-1,90	3,49	-2,20	-1,60

Simple, polynomial and multiple regression models, which describe dependence of degree of occupancy from deviation and distance from beginning of line for selected lines and group of lines are presented in table 4 (1).

Tab.4. Dependence of degree of occupancy from deviation and distance from beginning of line:

Line	Regression model	Correlation coefficient R[%]
105	n_c=0,255-0,016d	-14,6
	n_c=0,219-0,034d+0,006d^2	-17,0
115	n_c=0,194-0,012d	-39,6
	n_c=0,127-0,060d+0,003d^2	-51,8
501	$n_c=e^{0,242+0,007d}$	-20,9
	n_c=0,242-0,002d+0,0014d^2	-26,6
502	n_c=0,364-0,017d	-33,3
	n_c=0,362-0,016d+0,00014d^2	-33,2
All	n_c=0,269-0,0014d	-3,2
Line	**Multiple regression model**	**Determination coefficient R^2[%]**
105	n_c= -0,073d+0,000036s_0	70,2
115	n_c= -0,014d+0,000016s_0	61,2
501	n_c= -0,00089d+0,000014s_0	49,7
502	n_c= -0,023d+0,000028s_0	68,9

where: nc – degree of occupancy, d – size of average deviation for next two departures [min].
s_0 – distance from beginning of line.

Dependence of degree of occupancy from deviation and interval from two next departures:

Multiple linear regression model for line 105:

$$n_c = 0{,}0229 \cdot h - 0{,}018 \cdot d$$

where: n_c – degree of occupancy, d – size of average deviation for next two departures [min].
h – size of average interval from next two departures [min].
Determination coefficient for this model R^2 = 83,9%, and 95% confidence intervals for coefficient estimates:

0,0201 < h < 0,0258 -0,033 < d < -0,003

7. Main conclusions

1) Only attractive and efficient public transport can rival with private car.
2) Large number of meanings how to improve functioning of public transport.
3) Assurance of high level of comfort is one of the most important features of good public transport (according to passengers).
4) Comfort level can be treated as a basis for optimum selection of vehicles and frequencies of running.
5) High diverse of overcrowding, appearing across the line.
6) Divergence in results of occupancy for different lines, as a result from differences of vehicle, character and length of line.
7) Weak dependence size of deviations and size of occupancy, particularly in case of group of lines.
8) Considerably higher standard deviation of deviations from time-table for diameter line, then lines crossing through the centre.
9) Enough high dependence of degree of occupancy from deviation and distance from beginning of line, even in case of group of line.
10) In case of line 105, statistically significant relationship between degree of occupancy and independent variables: intervals and deviations, at the 99% confidence level.
11) For settlement of general models, it is necessary to obtain larger measure test, during realization of investigations for larger number of lines.

References:

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(2) Rudnicki A.: Jakość komunikacji miejskiej. Kraków 1999.