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MODELLING OF TRAFFIC FLOW IN AN URBAN TRANSPORTATION SYSTEM

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Summary. The present study covers proposals related to the formation of the traffic flow in an urban transportation system. An analysis was also presented of the traffic flow in a urban transportation system within two selected days of the week.

Key words: urban transportation system, traffic flow.

INTRODUCTION

The movements of city dwellers in a transport system of a given city is represented by the traffic flow through the junctions and arcs of the urban transport network. The traffic flows to the transport network through those points that constitute the flow sources, it moves through the individual indirect junctions and connections in the transport network and leaves the network at the outlet point of the traffic flow. In the case of travels in the city area, the residents move from sending points (set *A*) through a number of intermediate points (set *V*) to collection points (set *B*) (Fig. 1). There occurs a condition between the individual points [1, 2, 3, 4, 5]:

$$W = A \cup V \cup B, \tag{1}$$

where:
W – set of components urban transport network,
A – set of sending points,
V – set of intermediate points,
B – set of collection points.

The relationship between an ordered pair of points from sets *A* and *B* constitutes a transport relation [3, 5, 7]:

$$A \subset W, \quad B \subset W. \tag{2}$$

On this basis, we can define a set of all transport relations E in the urban transport network [2, 3, 5]:

$$E \subset (A \times B) = \{(a,b):\ a \in A,\ \ b \in B\}. \tag{3}$$

At the same time, for each transport relation, a set of connections between the individual vertices of the graph of the urban transport network is defined. This set is marked as P^{ab}, where P is the set of all the routes in the urban transport network [2, 3, 5]:

$$P = \bigcup_{(a,b)\in E} P^{ab}. \tag{4}$$

The size of the traffic flow in the urban transport network between a distinguished pair of vertices *(a, b)* on the set of transport relations E is defined as:

$$x(a,b) \equiv x^{ab} \tag{5}$$

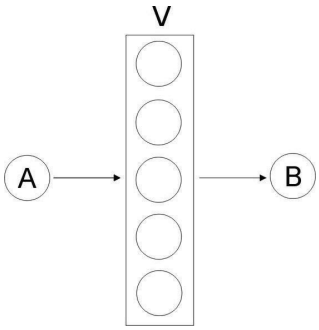

Fig. 1. Diagram of the movement of the traffic flow in the urban transport network:
A – set of sending points, V – set of intermediate points, B – set of collection points

INVESTIGATION THE TRAFFIC FLOW IN THE URBAN TRANSPORTAION SYSTEM

The investigations into the traffic flow in the urban transportation system were divided into two stages:

- the first stage is the definition of the basic parameters which characterize the traffic flow,
- the second stage is a direct analysis of the communication behaviors of city dwellers.

Stage 1

At the same time, the graph in the following form represents the transport tasks realized on Saturdays and Sundays [6] (Fig. 2):

$$G2 = \langle W2, L2 \rangle, \tag{6}$$

where:
W2 – set of components of graph *G2*:

$$W2 = \{w2_1, w2_2, w2_3, w2_4, w2_5, w2_6\}, \tag{7}$$

where:
$w2_1$ – home,
$w2_2$ – purchase,
$w2_3$ – amusement,
$w2_4$ – school,
$w2_5$ – workplace,
$w2_6$ – other,

L – set of connections of graph *G2*:

$$L2 = \{l2_1, l2_2, l2_3, l2_4, l2_5, l2_6, l2_7, l2_8\}, \tag{8}$$

where:
$l2_1$ – connection $w2_1$-$w2_2$; $w2_2$-$w2_1$,
$l2_2$ – connection $w2_4$-$w2_1$,
$l2_3$ – connection $w2_5$-$w2_1$,
$l2_4$ – connection $w2_1$-$w2_3$; $w2_3$-$w2_1$,
$l2_5$ – connection $w2_1$-$w2_6$; $w2_6$-$w2_1$,
$l2_6$ – connection $w2_2$-$w2_3$,
$l2_7$ – connection $w2_4$-$w2_3$,
$l2_8$ – connection $w2_3$-$w2_5$.

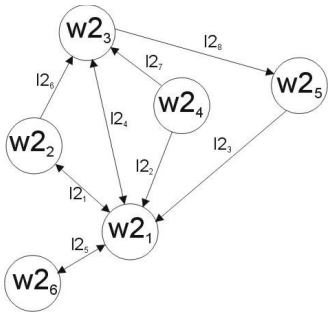

Fig. 2. The graph *G2* in the following form represents the transport tasks realized on Saturdays and Sundays

In the research carried out, four parameters were defined which have a direct influence on the traffic flow. These parameters include the following: time of the day, transport distances, the duration time of a transport task and the type of the means of transport.

Time of the day.

We assume that on Cartesian product $X^{ab} \times W \times W$, *dt* representation is given of the following form:

$$dt : X^{ab} \times W \times W \to R^{+}, \tag{9}$$

where quantity *dt(a, b)* is a non-negative real number with an interpretation of time interval *(i, j)* which determines the time of the day in the relation of transport *(a, b)*. For the purpose of clarity, we will use the notation as below:

$$\mathrm{dt}\big((\mathrm{a},\mathrm{b}),(\mathrm{i},\mathrm{j})\big) \equiv \mathrm{dt}^{(\mathrm{a},\mathrm{b})}, \qquad \mathrm{dt}^{(\mathrm{a},\mathrm{b})} \geq 0. \tag{10}$$

Transport distances.

Quantity *d(a, b)* is a non-negative real number with an interpretation of the distance covered *(i, j)* in the relation of transport *(a, b)*:

$$\mathrm{d}: \mathrm{X}^{\mathrm{ab}} \times \mathrm{W} \times \mathrm{W} \to \mathrm{R}^{+}, \qquad \mathrm{d}\big((\mathrm{a},\mathrm{b}),(\mathrm{i},\mathrm{j})\big) \equiv \mathrm{d}^{(\mathrm{a},\mathrm{b})}, \qquad \mathrm{d}^{(\mathrm{a},\mathrm{b})} \geq 0. \tag{11}$$

Duration time of a transport.

Quantity *t(a, b)* is a non-negative real number with an interpretation of the duration time of a transport *(i, j)* of the relation of transport *(a, b)*:

$$\mathrm{t}: \mathrm{X}^{\mathrm{ab}} \times \mathrm{W} \times \mathrm{W} \to \mathrm{R}^{+}, \qquad \mathrm{t}\big((\mathrm{a},\mathrm{b}),(\mathrm{i},\mathrm{j})\big) \equiv \mathrm{t}^{(\mathrm{a},\mathrm{b})}, \qquad \mathrm{t}^{(\mathrm{a},\mathrm{b})} \geq 0, \tag{12}$$

Means of transport.

Quantity *mt(a, b)* is a non-negative real number with an interpretation of the selected means of transport *(k)* in the relation of transport *(a, b)*:

$$\mathrm{mt}: \mathrm{X}^{\mathrm{ab}} \times \mathrm{W} \times \mathrm{W} \to \mathrm{R}^{+}, \qquad \mathrm{mt}\big((\mathrm{a},\mathrm{b}),(\mathrm{k})\big) \equiv \mathrm{mt}^{(\mathrm{a},\mathrm{b})}, \qquad \mathrm{mt}^{(\mathrm{a},\mathrm{b})} \geq 0, \tag{13}$$

Stage 2

The investigations into the traffic flow were carried out based on the monitoring of social attitudes concerning a sustainable transport [8], they covered an analysis of the communication behavior of city dwellers. The research was narrowed down to two days of the week, i.e. Saturday and Sunday.

The largest traffic flow which moves at the connections of *G2* graph was observed in *d1* transport distances and involved 274 people. Out of this, 27% of people moved on foot and 70% of people traveled by passenger car (Fig. 3).

When analyzing the traffic flow moving on Saturday and Sunday on the connections of *G2* graph, an observation was made that every third transport task fell into in *t2* time interval, i.e. from 6 to 10 minutes. Out of this, 34% people moved on foot and 24% people traveled by car. The remaining data with respect to the duration time of the transport task taking into consideration the type of the means of transport can be found in fig. 4.

While taking into account *dt* parameter, i.e. time of the day, it was observed that during the day, the majority of transport tasks (82-87%) were realized by passenger car (Fig. 5). In the evening and at night, 79% and 74% of transport tasks respectively were performed with the use of a passenger car (Fig. 5).

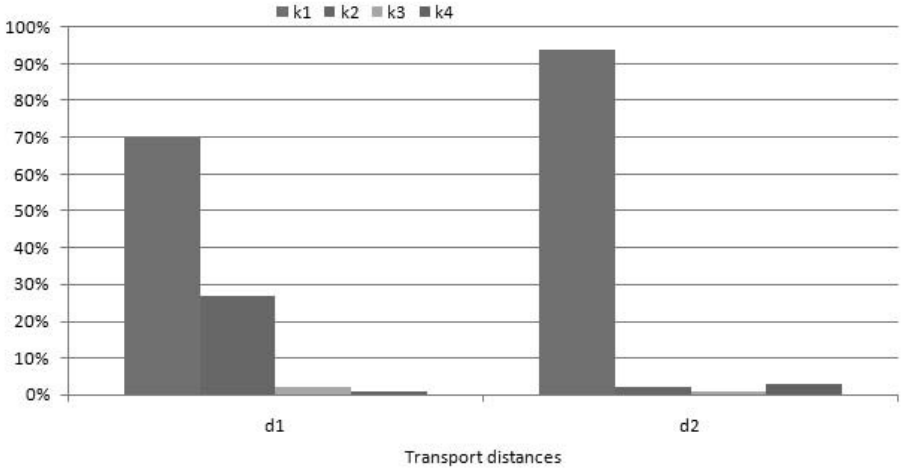

Fig. 3. The percentage share of those means of transport which are used to satisfy the transport needs of city dwellers – transport distances [8]: d1 – up to 5 km, d2 – over 5 km, k1 – passenger car, k2 – on foot, k3 – public transport, k4 – other

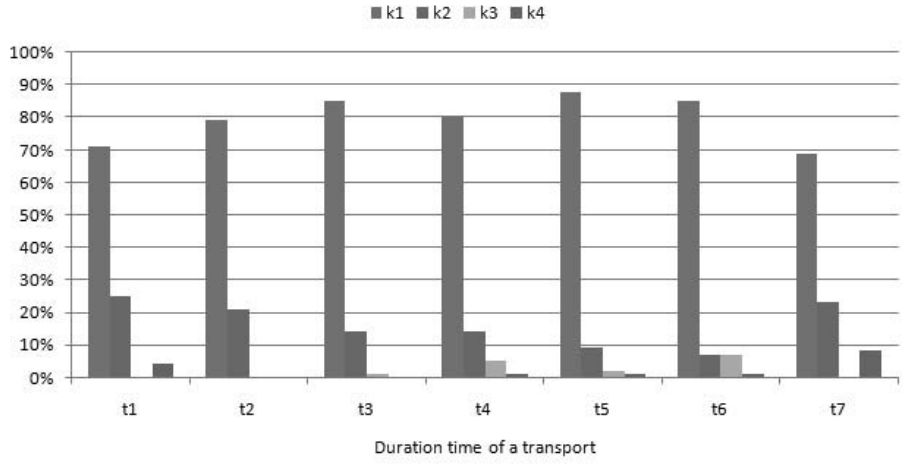

Fig. 4. The percentage share of those means of transport which are used to satisfy the transport needs of city dwellers – duration time of a transport [8]: t1 – up to 5 min, t2 – 6-10 min, t3 – 11-15 min, t4 – 16-20 min, t5 – 21-30 min, t6 – 31-60 min, t7 – over 60 min, k1 – passenger car, k2 – on foot, k3 – public transport, k4 – other

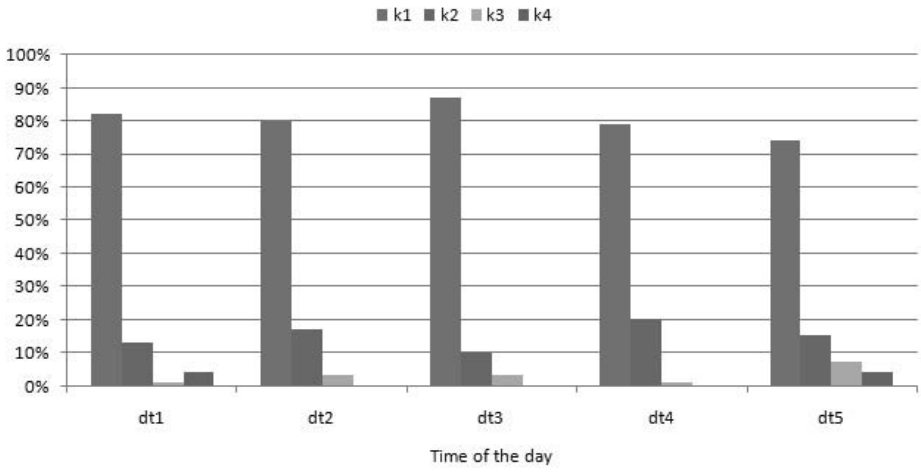

Fig. 5. The percentage share of those means of transport which are used to satisfy the transport needs of city dwellers – time of the day [8]: dt1 – 6:00am-9:59am, dt2 – 10:00am-2:59pm, dt3 – 3:00pm-5:59pm, dt4 – 6:00pm-9:59pm, dt5 – 10:00pm-5:59am, k1 – passenger car, k2 – on foot, k3 – public transport, k4 – other

CONCLUSIONS

The formation process of the traffic flow in a urban transportation system which is presented in the study constitutes a separated fragment of a larger project whose task is to build a sustainable urban transportation system. Research concerning the traffic flow in a urban in relation to the four parameters distinguished, i.e. time of the day, transport distances, the duration time of a transport task, the type of the means of transport, is one the constituents of the construction of a sustainable urban transportation system. The results of these investigations were also presented in the study.

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MODELOWANIE POTOKU RUCHU W MIEJSKIM SYSTEMIE TRANSPORTOWYM

Streszczenie. W pracy przedstawiono propozycje kształtowania potoku ruchu w miejskim systemie transportowym. Zaprezentowano również analizę potoku ruchu w miejskim systemie transportowym w przeciągu dwóch wybranych dni tygodnia.

Słowa kluczowe: miejski system transportowy, potok ruchu.