Estimation of the public transport system in Kaunas city

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Abstract

The public transport system is an important urban problem in every city. The ecological situation, congestion and modernization of public transport in the center of Kaunas are the main problems. Today the whole public transport system in Kaunas requires radical technical, organizational reformation, renewal of the means of transport, etc. Most public transport routes cross the center of the city. An investigation was performed to identify the priorities and requirements of organizational reorganizations by determining the passenger flows on public transport routes and the demands and attitudes of passengers. An observation method for determining passenger flows and questionnaires for passengers’ demands were applied. A mathematical model was created evaluating the specific mode of public transport – minibuses with the stochastic, undetermined stops differently to other modes of public transport (this mode of public transport is popular in Lithuanian cities due to mobility, frequency, “stopping anywhere”). The influence of these stops on the traffic flows and environmental characteristics was investigated.

Keywords: public transport, traffic flows.

1 Introduction

Rapid quantitative changes in the urban transport system in Kaunas have challenged a lot of rising issues in quality of air, transportation, social environment etc. According to data of Lithuanian Road Administration number of cars has increased 57% in Lithuania from 1991. Predominant number of cars is registered in the main cities – Vilnius (20.9%) and Kaunas (13.7%). Public transport system almost haven’t been reorganised during this period.
It is considered that proportion of public transport in the total transport flow must be 10% – 20% with variation in time. Influence of public transport to the total traffic flow in the zones or the streets in certain time periods could be forecasted and determined since public transport is regulated by the timetables of every transport mode (with condition of following the timetable) [1].

In Kaunas there are 16 trolleybus and 49 bus routes. The quantity of vehicles corresponds to 132 trolleybuses and 125 buses. Their service runs together with a great number of minibuses. There are 51 regular minibus routes in Kaunas. Kaunas is described as a specific town comparing with other European cities due to large amount of minibuses. Almost 1000 of the route minibuses are operating in the streets of Kaunas at the same time.

Our task was to estimate quality of present public transport system, public transport routes and public transport in traffic flows in Kaunas.

2 Methods

Analysis of public transport system in Kaunas consisted of two estimation parts:

- Public transport (service quality, routes etc.)
- Traffic flows in the city centre

Complex evaluation of these two parts was indicated and performed.

Several transport modes operate in public transport system – buses, trolleybuses, minibuses, taxes. Classification of these transport modes according to the dependence on the timetables, meeting the passengers’ demand and the stops [2] is presented in fig. 1. We analysed only the timetable public transport.

Analysis of traffic flows and public transport was performed in the streets in Kaunas centre with occasionally observed congestions during the peak hours. Intensity of traffic flows was recorded within three peak intervals – 7.30 – 8.30, 12.30 – 13.30 and 16.30 – 17.30 with registration frequency – 15 min.

![Classification of public transport modes](image)

**Figure 1:** Classification of public transport modes according to the dependence on the timetables, meeting the passengers’ demand and the stops of public transport modes.
Traffic flows in Kaunas were analysed applying the created macroscopic traffic flow model. Mathematical model was created for the street segment. Traffic density dependence on the traffic flow entering to the segment and velocity is analysed. According to this dependence (fundamental traffic diagram) precondition, that velocity $v$ is related with the function of the traffic density $\rho$, conservation of vehicles is described by the equation:

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x} \left( \rho v(\rho) \right) = 0,$$

here $\rho$ – traffic density, vehicles/km; $x$ – length of the street segment, km; $t$ – time, min.

User-class is defined by the principle of Hebling’s gas-kinetic equations system [3]. Traffic density $\rho(x, t, v, v^0)$ expresses number of the transport means in the road segment at the position $x$ at time moment $t$. In the model for estimation of public transport in the traffic flow we analysed two user-classes – public transport and private cars. Traffic flow of one user-class can be defined by gas-kinetic equation with the continuity condition:

$$\frac{\partial \rho_0}{\partial t} + \nabla_y \cdot \left( \rho_u \frac{dy_u}{dt} \right) = \left( \frac{\partial \rho_u}{\partial t} \right)_{nt},$$

here $y_u = \begin{pmatrix} x \\ v \\ v^0 \end{pmatrix}$, $\nabla_y = \begin{pmatrix} \partial / \partial x \\ \partial / \partial v \\ \partial / \partial v^0 \end{pmatrix}$, $\rho_0$ – general traffic density, $\rho_u$ – $u$ user-class traffic density [4].

Analysing changes in traffic flow there were assumed that passive and active interaction of the vehicles groups causes these changes:

$$\left( \frac{\partial \rho_u}{\partial t} \right)_{nt} = \left( \frac{\partial \rho_u}{\partial t} \right)^{\text{passive}} + \left( \frac{\partial \rho_u}{\partial t} \right)^{\text{active}},$$

Shock wave originates in traffic characteristics due to the various changes in traffic. This causes inlinearity in traffic density function. Values of parameters describing traffic instantly changes and this process is characterised by this equation:

$$\frac{dx_s}{dt} = \frac{\rho_2 v(\rho_2) - \rho_1 v(\rho_1)}{\rho_2 - \rho_1}. $$
with the precondition that traffic density consist of two continuous traffic density functions $\rho_1$ and $\rho_2$, which are separated by shock wave. The value of the critical density $\rho_{\text{crit}}$ to the model was introduced, which can’t be overpassed, as a boundary condition.

Movement of minibuses on the routes is analysed as a public transport class, but with the integrated special stochastic component which describes stops of this transport means anywhere and anytime. Moment of minibus stop is

$$m = \sum_{j_1=1}^{k_1} \sum_{j_2=1}^{k_2} f_{(j_1,j_2)} s_{(j_1)} z_{(j_2)}$$

(5)

$k_1$ – number of the seats in a minibus, $k_2$ – number of the minibuses in the analysed route, $s$ – passengers’ requirement, $z$ – minibus stop, $f$ – probable frequency of stops [5]. Stop moments of minibuses are randomly generated in the model.

Our performed assessment of public transport quality was based on two types of the questionnaires: extra answers (“small” questionnaire) at the stops of the public transport and wider-ranger questionnaire delivered via internet. Questionnaires were formed according to the eight main groups – quality determinants in urban public transport: availability, accessibility, information, time, customer care, comfort, security and environment [1, 6, 7]. Questions of the “small” questionnaire are the subset of the wider-ranger questionnaire questions. Questionnaires were anonymous. Comprehensibility and eligibility of the questions were verified during the pilotage investigation. Two groups of respondents were separated: transport specialists and ordinary public transport passengers. Aim of our study was to find out the opinion about the public transport service in Kaunas city.

Quality of service is gathered by main points such as routes, scheduler information, location of the stops, service conditions in the transport means. Answers data were processed using the Microsoft Excel ir Epi Info 2002 software. Criterions $t$ and $\chi^2$ were used for the estimation of reliability of results.

3 Results

Main routes in the Kaunas centre were included into the analysis records. Performed analysis of traffic intensity indicated that the extreme peaks are on the bridges. Here traffic intensity exceeds 2.7 times the average day traffic intensity. Consist of the traffic flows in one of the analysed street segment is shown in fig. 2 and average of private cars in traffic flows is 75.71%. It is determined that 30–40% of passengers use buses, 60–70% – minibuses in the routes without trolleybuses. In the routes with all public transport modes distribution of modes demand vary 16%–70% for trolleybuses, 3%–22% for buses, 18%–62% for minibuses.

The model can be run using real statistical data of the entering flow and all characteristics of traffic within the investigated time period are obtained, fig. 3.
Determination of traffic density allows analysis and prognoses of traffic conditions. Difficulties arise determining minibuses with the stochastic, undetermined stops modelling and analysing traffic flows, public transport system, because they do not have stops intervals, time etc. and are under influence of human factors – wish, demand, need etc. These parameters are evaluated stochastically, eqn. (5), undetermined time intervals in the method of shock wave formation. Performed comparable computation and analysis of traffic densities of the streets with minibuses’ routes there was determined that frequency of shock wave formation in traffic density characteristic is 1.5–2 times higher than without. Theoretically determined value of critical density was not reached in the analysed street segments during the time of investigation. But possible tendencies are forecasted estimating the augmented traffic volumes, number of trips (today the average number of trips per day is 2.51, the forecasted one is up to 3 trips per day) etc. This analysis allowed us to conclude that part of the traffic could be rerouted to the streets with less traffic density, better permeability and where it is possibilities to introduce the bus lanes.

![Bar chart: Consist of traffic flow.](image)

Quality of public transport service is a crucial factor in transport mode option. 365 respondents answered to the “wider-ranger” questionnaires, delivered via internet, which consist of 19 main questions about the public transport service in Kaunas. 618 respondents answered to the questions of the “small” questionnaires at the bus–stops.

64% of respondents use public transport every day and 40% of them use it to reach their working places. These results show that despite to the increasing number of private cars in the city, public transport is main transportation mean for every day regulated travels in the city. 71% of citizens give priority to minibuses, 12% – to buses and 17% – to trolleybuses.
49% of everyday public transport passengers are satisfied by the existing routes, 30% of them are partly satisfied and 19% indicated that they would wish changes in the existing route scheme of public transport in Kaunas city. Comprehensive information about the public transport service determines choice and permanent of temporary usage of this service. 45% of the respondents indicated that this information is not sufficient, 41% – partly sufficient and only 14% of respondent answered that they have enough information of public transportation (p<0.05).

Figure 3: Traffic density in one of analysed street segments (7.30-8.30 a.m.).

Continuity of traffic flows in the cities determines traffic safety, reduced air pollution, forecasting of traffic situations. But unpredicted stops of the minibuses prevent solution of the enumerated problems. Opinion of all respondents about the fixed minibus stops in the Kaunas centre is parted: 51% answered – yes and 49% – no. 31% of the respondents who prefer use of the minibuses’ service indicated that fixed minibus stops are not necessary. But the permanent passengers of buses and trolleybuses indicated that such types of stops are necessary. It is possible to conclude that passengers perennially using service of the minibuses are not tending for any changes. 32% “everyday” passengers of the public transport indicated that fixed stops are necessary.

4 Conclusions

Created mathematical traffic flow model, which evaluates stops of the minibuses, allows analysis of general traffic situation in the street segments. Obtained results prove that stochastic stops of the minibuses increase discontinuity of traffic flows, formation of congestion etc.

Questionnaires were formed to ascertain the requirements and opinions of public transport passengers and results of the performed analysis allowed to determine passengers’ priorities for transport modes. Priority is given for the
mobile, user’s requirements satisfying transport mode – route taxes (minibus). Passengers’ quality requirements for public transport and approbation to construct new public transport routes to warranty traffic flow continuity were determined.

According to the created mathematical model there were determined the public transport routes which require reorganization due to the insufficient amount of the passengers, destructive influence on continues traffic flows in city center and possibilities to optimize routes of the minibuses reducing number of them crossing the city center by rerouting around.

References