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THE STUDY OF SCHOOLCHILDREN TRANSPORTATION EFFICIENCY IN LITHUANIA

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Abstract. The system of transportation of schoolchildren should also be transformed with the aim of more rational use of resources and vehicles taking children in and out of schools. Rational structure of school network and a system of children transportation will help to save the money allocated on education as well as to ensure various educational services, taking into account social, economic, cultural and demographic changes. The research revealed considerable differences in operational costs of school buses in Lithuania. To account for this spread of values (up to 5 times), a more detailed analysis is needed. Considerable spread of operational costs of buses is questionable because they are in a good (or perfect) technical state. The repay time of the bus depends on the difference between the cost of carrying students by private and public transport covered by local government institutions and the relative expenses of busing a student per one kilometer by buses.

Keywords: system of schoolchildren transportation; school network; "yellow" bus; school bus; turnover of student kilometres; fuel consumption.

1. Introduction

Since the demographic situation in Lithuania is constantly changing, the problem of optimizing the network of comprehensive schools, especially those in the rural locality, arose [1]. Some schools have to be closed, while the others are restructured to reduce state expenditures to education. This implies that the system of transportation of schoolchildren should also be transformed with the aim of more rational use of resources and vehicles taking children to and from schools [2].

Transportation of schoolchildren means their bussing to and from schools. A school bus is a vehicle used to take children to and from school usually belongs to local authorities or a school itself. A "yellow" bus is a transport facility for bussing children to and from school funded according to a special program developed by the Government of Lithuania. The number of children to be transported largely depends on the density of population, the network of schools in the countryside and the infrastructure of public transport with respect to the network of schools [3]. However, international and local routes will never be laid on account of regional school networks. The solution of this problem may be achieved developing an alternative system of schoolchildren transportation including the fleet of school or "yellow" buses as well as restructuring the network of schools on account of local needs for children transportation and more rational use of the available public transport.

Rational structure of a school network and a system of children transportation will help to save the money allocated to education as well as to ensure various educational services, taking into account social, economic, cultural and demographic changes [4]. This in turn will help to cut the number of financed positions in comprehensive schools, especially in the village and to restructure the system of transporting school children living there so that they could be safely taken to schools located far from their homes.

The problem to be solved consists of three parts: the development and introduction of methods of school network restructuring in the institutions of local government; the organisation of students bussing; the rational use of money saved by the above measures.

Restructuring of school network and transportation of students is a complicated process which may cause social tension [5, 6]. The present research was fulfilled by the order of the Ministry of Science and Education of Lithuania.

2. The Analysis of Schoolchildren Transportation

Six institutions of local government located in vari-

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ous regions of Lithuania having non – uniform density of population and infrastructure have been selected for the analysis.

In Fig 1 we can see that the largest proportion of bussed students falls to Kaunas and Varėna regions, while the smallest part – to the city of Klaipėda. The number of transported students largely depends on the development of transport network and the density of schools and population in the particular region.

The spread of transported students based on the grades (forms) is shown in Fig 2.

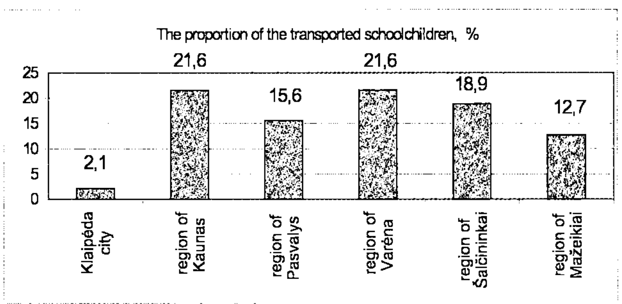

Fig 1. The proportion of the transported schoolchildren

Fig 2 shows that most of transported students are of 5 – 8 grades (forms). This means that the parents of younger children (of 1 – 4 grades) should be persuaded to rely more on "yellow" buses and allow their offsprings to take them for getting to school as well. It is obvious that complete safety should be ensured.

The number of students overcoming the distance of more than 3 km to school on foot is given in Fig 3.

From the data given in Fig 3 we can see that the number of students overcoming the distance more than 3 km makes 26 and 5, respectively, in Kaunas and Varėna regions, while in Mažeikiai region it is as large as 137 students. Therefore, the system of transportation of students in the latter area should be optimised to reduce the number of children going on foot over long distances. Relative expenses of bus fuel are given in Fig 4.

As we can see from Fig 4, relative expenses of the local authorities of school bus fuel make 0,09 – 0,16 Lt/km in Šalčininkai, Mažeikiai and Pasvalys regions, while the local government institution of Klaipėda city spends twice as much of it. The expenditures of the local authorities of Varėna region are even 4 times as large, reaching 0,47 Lt/km. To account for this spread of expenses a more detailed study is needed.

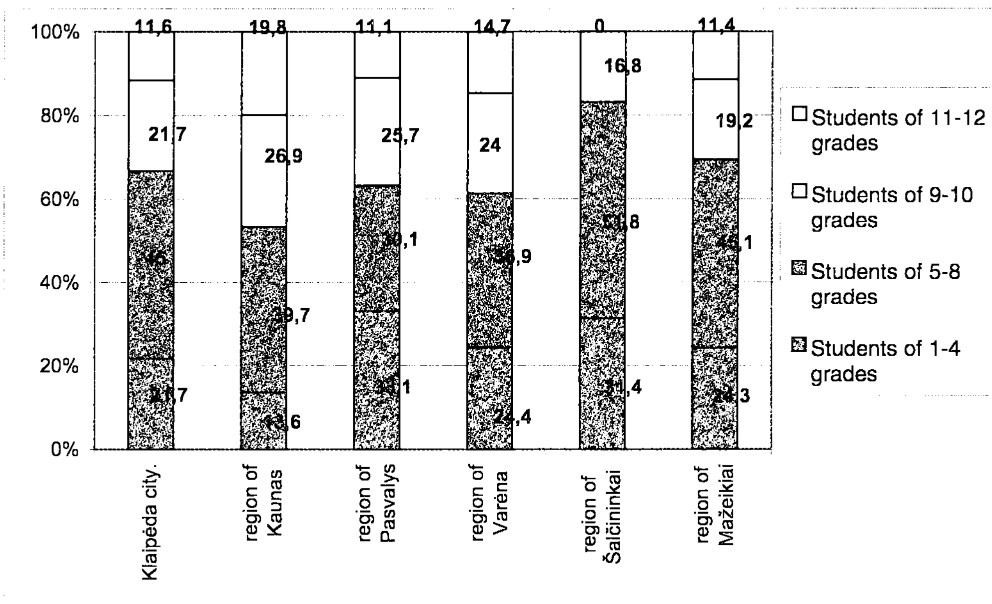

Fig 2. Distribution of transported students based on the year at school

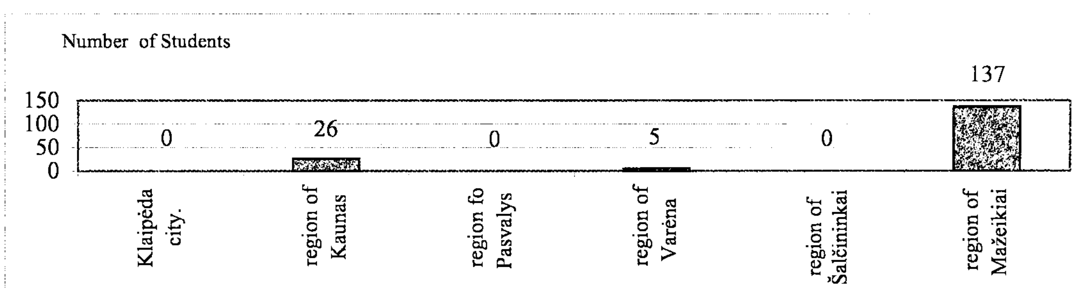

Fig 3. The number of students overcoming the distance more than 3 km

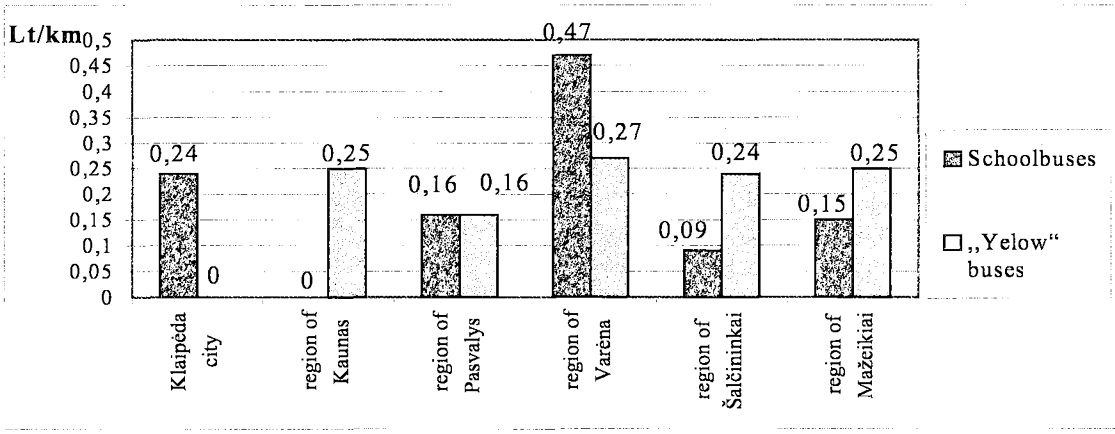

Fig 4. Relative expenses on school and "yellow" bus fuel

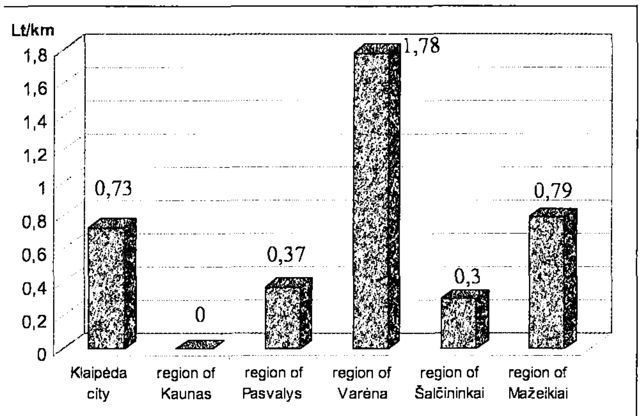

Fig 5. Relative expenses of 1 km run of a school bus

Relative expenses of 1 km run of a school bus are presented in Fig 5.

In this figure it is shown that the highest expenses of 1 km run by a school bus are in Varėna region (1,78 Lt/km), while the lowest expenditures fall to Šalčininkai region (0,3 Lt/km).

Relative expenses of 1 km run by "yellow" buses are given in Fig 6[1]. As we can see in Fig 6, relative expenses of 1 km of "yellow" bus run range from 0,36 Lt/km in Pasvalys region to 1,68 Lt/km in Šalčininkai region.

Relative monthly expenses on bussing one student by a school bus are given in Fig 7. From this figure we can see that relative monthly expenses on bussing a student range from 17,8 Lt (the city of Klaipėda) to 54,2 Lt (Pasvalys region). This may be accounted for different technical state and service time of school buses as well as by various length of the route in different regions.

3. Optimization of Students Bussing System

3.1. Optimisation of students bussing expenses

The diagram of the model determining the structure of expenses in general is given in Fig 8.

Envisaging further development of a school network, the dependence function is minimised by determining each

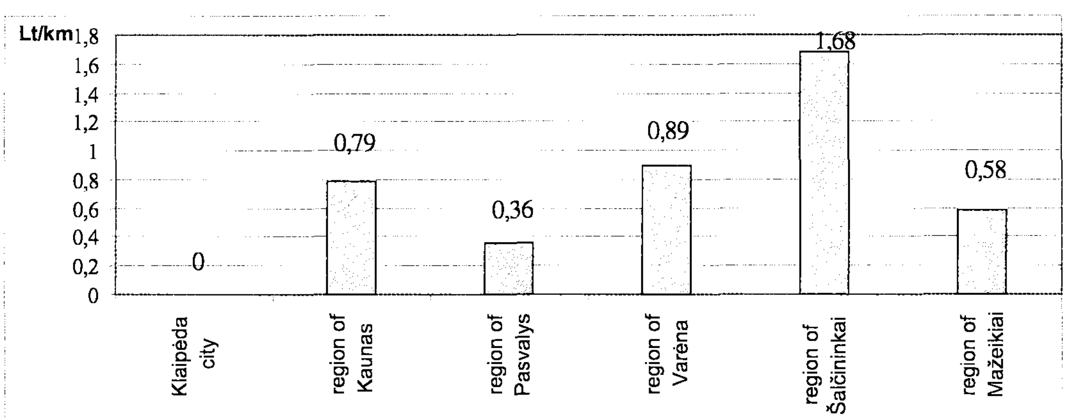

Fig 6. Relative expenses of 1 km of "yellow" bus run, Lt/km

[1] *It should be noted that in the region of Kaunas there is no school bus, while Klaipėda has no "yellow" bus.*

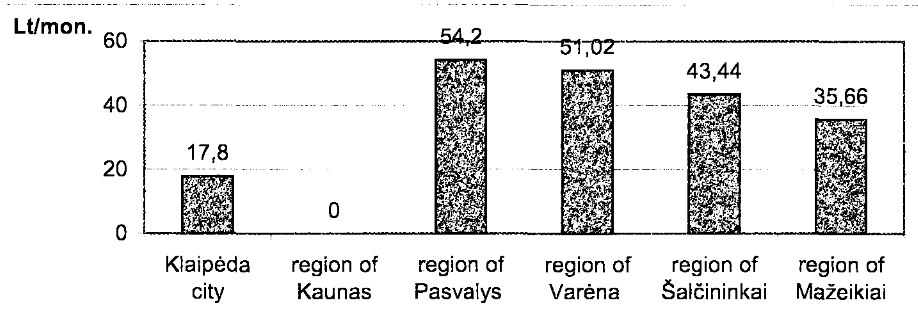

Fig 7. Relative monthly expenses of bussing the students by school buses

term, depending on functional relationship of the particular parameters as well as in compliance with the requirements of traffic safety.

The effectiveness function is the minimisation of expenses on students bussing [5, 7]. The structure of the above expenses may be expressed mathematically in the following way:

$$I = I_g + I_m + I_{pr} + I_{vis} + I \; ; \qquad (1)$$

here,

I_g – relative expenses of transporting students by "yellow" buses, Lt/student. km;

I_m – relative expenses of transporting students by school buses, Lt/student. km;

I_{pr} – relative expenses of transporting students by private transport facilities, Lt/student km;

I_{vis} – relative expenses of transporting students by public transport, Lt/student km;

I_t – relative expenses of transporting students by transport facilities of their parents or tutors, Lt/student km.

3.2. Time optimisation of students bussing

In terms of time the effectiveness of students transportation to school is expressed by the average time of bussing one student:

$$T = \frac{\sum t_g n_g + \sum t_m n_m + \sum t_{pr} n_{pr} + \sum t_{vis} n_{vis} + \sum t_t n_t + \sum t_p n_p}{\sum n_i}, \qquad (2)$$

here,

t_g – average time of transporting a student by "yellow" buses, s;

t_m – average time of transporting a student by school buses, s;

t_{pr} – average time of transporting a student by private transport, s;

t_{vis} – average time of transporting a student by public transport, s;

t_t – average time of transporting a student by transport facilities of his/her parents or tutors, s;

t_p - average time of student's walking on foot, s;

n_g – number of students carried by "yellow" buses;

n_m – number of students carried by school buses;

n_{pr} – number of students carried by private transport;

n_{vis} – number of students carried by public transport;

n_t – number of students carried by transport facilities of their parents or tutors;

n_p – number of students walking to school on foot;

n_i – i – th number of students.

The following constraints are imposed on the function:

1) a student shouldn't walk on foot more than 3 km to or from school;

2) time of carrying a student to and from school (t_g, t_m, t_{pr}, t_{vis}, t_t) should not exceed $t_{leistinas} = 2$h.

A number of students carried by "yellow" buses is calculated by the formula:

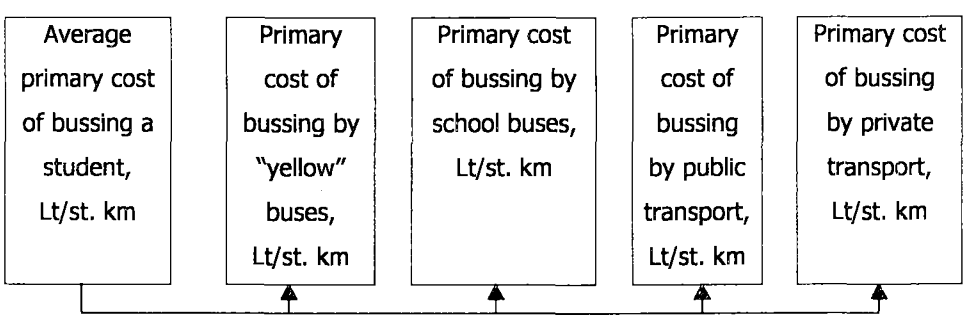

Fig 8. The structure of average expenses of bussing a student

$$n_g = \sum n_{ti \geq tleistinas} + \sum n_{l \geq 3km} . \quad (3)$$

Number of routes is as follows:

$$N_{maršrutų} \geq \frac{t_{maršruto}}{t_{leistinas}} ; \quad (4)$$

here:

$t_{maršruto}$ – time of covering the distance of the particular route, s.

Time of covering the distance of the particular route depends on the number of students transported, their density in the area and the length of the route:

$$t_{maršruto} = f(n_g ; l_{maršruto}, v, x) ; \quad (5)$$

here:

v – average speed on the particular route, km/h;

l – length of the route, km;

x – spreading of students in the area, student/km^2.

The number of "yellow" buses recommended for the particular route is obtained from the formula:

$$N_{maršrutų} \geq \frac{f(n_g ; l_{maršruto}, v, x)}{t_{leistinas}} . \quad (6)$$

Taking into account that the average bus speed and length of the route are fixed in the particular institution of local government, the time of covering the distance on the particular route by one bus will be:

$$t_{maršruto} = \frac{l_{maršruto}}{v} + \sum t_s ; \quad (7)$$

$$N_{maršrutų} \geq \frac{l_{maršruto}}{v \times t_{leistinas}} . \quad (8)$$

The effectiveness of using school or "yellow" buses and their repay time depend on the work performed transporting students for a certain amount of kilometres (turnover).

In order to develop a mathematical model of optimal students bussing, the minimum and maximum value of the distance by which one student was carried should be determined.

The minimum distance of student transportation is 3 km. The maximum distance is assumed to be 60 km, based on the carried out research.

Another criterion is the number of students carried by buses per day. In modelling it is assumed that the minimum number of students carried by a bus per day is 4, because the smaller number makes transportation ineffective in terms of economy. Based on the analysis made, the maximum number of students carried by a bus per day is assumed as 100. Then the lowest value of the turnover is 12 st km, while the highest is 6000 st km.

The repay time of a "yellow" bus depends on the turnover based on the number of students and the kilometres run. The repay time is conversely proportional to the difference between the sum of money paid by local governments for bussing students by public or private transport and the relative expenses of transporting a student per one kilometre (Lt/st km) by "yellow" buses. For example, if the local government institution pays private operators c_i = 0.12 Lt/st km for one kilometre, while student bussing by a "yellow" bus costs c_g = 0.08 Lt/st km, then the repay time of a bus will be:

$$A_g = \frac{I_g}{N_d \cdot A_{md} \cdot (c_i - c_g)} ; \quad (9)$$

here,

I_g – purchasing cost of a "yellow" bus, Lt;

N_d – number of transportation days per year;

A_{md} – day turnover, st km;

c_i – cost of 1 km carriage of students by public or private transport, Lt/s km;

c_g – cost of 1 km carriage of students by a "yellow" bus, Lt/st km.

For example, if the difference ($c_i - c_g$) is 0,04 Lt/st. km, while bus costs 100 thous. Lt and its turnover is 2000 st km per day, with 200 transportation days per year, the repay time would be as follows:

A_g = 100 000/2000 × 200 × 0,04 = 6,25 years.

The dependence of the "yellow" bus repay time (under the conditions specified) on the difference ($c_i - c_g$) is shown in Fig 9.

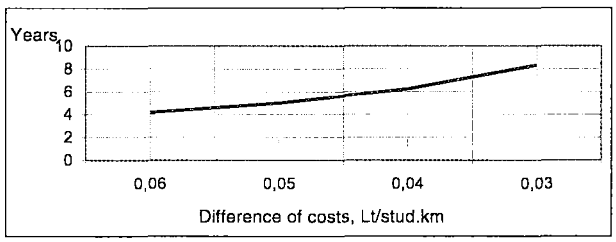

Fig 9. The dependence of the "yellow" bus repay time on different student, km cost ($c_i - c_g$)

4. Conclusions

1. Mathematical expressions (1) and (2) optimising the expenses and the time of bussing may be applied by the particular local government institutions and their departments when schools and roads of these institutions (regions) are interlinked into a single computing network.

2. The research revealed considerable differences in operational costs of school buses in Lithuania. To account for this spread of values (up to 5 times), a more detailed analysis is needed.

3. Considerable spread of operational costs of "yellow" buses is questionable because they are in a good (or perfect) technical state.

4. Assuming that a "yellow" bus turnover per day is about 2000 students kilometres (based on the carried out tests) and the average expenses on it are by 0,04 Lt/st. km

lower than those of other vehicles (see Fig 9), it will repay in 6 – 7 years.

5. The repay time of the "yellow" bus depends on the difference between the cost of carrying students by private and public transport covered by local government institutions and the relative expenses of bussing a student per one kilometre by "yellow" buses.

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