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WAYS TO EFFECTIVELY ADDRESS PROBLEMS EXISTING IN THE URBAN PASSENGER TRANSPORT SYSTEM

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Abstract: At present, public transport needs to be managed using the different models, which will take into account health problems, passenger transport problems, refinement of technical parameters of buses and their adaptation to urban operating conditions, which would be one of the preventive measures in the context of combating the coronavirus pandemic. The article discusses the issues of optimizing the routeing scheme of buses and minibuses in the conditions of a three-level transport network in large cities. Measures for the performance of the city bus routes have been developed. It has been established that the qualification of a driver and the selection of urban passenger vehicles are central issues in terms of fuel efficiency and reducing the number of harmful substances in exhaust gases.

1 Introduction

One of the fundamental conditions for the socio-economic development of the country is the effective functioning of the transport system equipped with modern technologies.

Starting from the second half of the twentieth century in the world, including Georgia, we are witnessing the process of intensive motorization. The increase in the number of vehicles has resulted in two pronounced and contradictory trends. In particular, the high level that motorization has reached predetermines the development of the economic potential of society and ensures maximum satisfaction of the transport needs of the people [1,2]. On the other hand, it has contributed to the increased magnitude of the negative impact on society and the environment, which has resulted in environmental degradation.

Today, the problem of the rational use of our country's fuel and energy resources has acquired special economic significance because Georgia is one of the countries whose motor transport consumes only imported fuel and energy resources.

As oil and oil-origin fuel reserves are not renewable, and sooner or later, these reserves are expected to be exhausted, but the number of vehicles in the country is growing at a rapid pace, and the problem of fuel economy of vehicles continues to be a priority.

A successful resolution to this problem will depend on the level of perfection of automobile designs and scientific and technological progress in searching for and using alternative fuels in motor transport.

Today, addressing the transport problems through the improvement of technical parameters of vehicles is not having a great effect. It is necessary to explore the issues related to the theory of travel service administration and vehicle traffic, that is, to review the issues of the transportation process management itself under conditions of rapid motorization. Therefore, there has recently been a growing interest of researchers in the urban transport system, and the theories of passenger traffic simulation have been created. They are aimed at improving road infrastructure and creating systems of quality passenger service [3].

1.1 The major components of the system of urban passenger transport

In large cities, there are numerous routes providing transport for passengers. Acquisition of specific information on these routes (provision of reliable data on passenger flows and distributing them according to day and night hours and days of the week) is further processing, selection of the optimal route, and the number of vehicles (buses, minibuses) should be carried out systematically, taking into account the context combating the coronavirus pandemic**.**

In order to solve this problem, it is necessary to study the urban routes, analyze the operating parameters, process the information obtained from the experiments and provide sound guidance. This methodology will allow us to calculate the real parameters for a particular route and thereby increase the performance effectiveness of vehicles. It is necessary to take into account the volumes of traffic and passenger flows, as well as the operating characteristics of vehicles. In view of the foregoing, the definition of operation parameters on urban bus routes should be based on the establishment of characteristic parameters of these routes taking into account passenger flows, which will eventually improve the quality of

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passenger services and increase the efficiency of the transport process [1,4].

The best rational option is considered that perfectly meets the needs of the population and high rates of passenger transport in terms of environmental performance and the minimum risk of coronavirus spreading.

The route and vehicle driving on this route should meet the major requirements. In particular, they must: be adequate to the volume of passenger flow; have sufficient manoeuvrability and a rapid response capacity to the volatility of flows and the disruption to traffic; be coordinated with other types of urban passenger transport; be correctly adapted to the length of flow, direction, and time, as well as to the rational distribution of terminal and intermediate stops.

A step forward in this regard is the introduction of a three-level transport network. The first level is the 10 main corridors, where passenger flow is large and passes through all the main big streets and avenues of Tbilisi. It is fed by two additional types of corridors - the second and third-level lines, respectively - the so-called "city lines" for traffic between the blocks, the so-called "block lines".

2 Methodology

2.1 Designing the passenger transport system development programs

As we have mentioned, the main goal of the urban passenger transport system is to ensure the qualitative, timely and cost-effective displacement of the population with a minimum level of coronavirus spreading and with minimum environmental pollution. In this regard, one of the most important is the qualification of a driver, which depends on the economical methods of bus driving and increases the efficiency of the transport process [11].

2.2 Studies of the city route operating parameters

We have conducted a research investigation on the operational parameters of the intracity line by involving the drivers with varied work experiences and levels of qualifications [22]. The results of the experiments that reflect the influence of driver's qualification on the operational parameters of a bus are given in Table 1.

Operating indicators	Operating conditions	Drivers with work experience of less than 1 year	Drivers with work experience of more than 5 years
Average speed, km/h	Urban	30	31.7
The number of stops, km^{-1}	Urban	1.55	1.5
Fuel consumption per line	Urban	24.7	24

Table 1 The influence of driver's qualification on the operational indicators of a bus

2.3 The review of the experiment

Following analysis of our experiment, we can conclude that during the operation of the bus on the city route, which runs on the first from the three-level transport network, that is, on one of the 10 main corridors, on a special bus line, in the case of drivers with different amounts of experience, the difference between the average speeds of traffic does not exceed 5%. This proves that even under conditions of rapid growth in traffic flows, the average speed of the bus is practically determined by a driver and not by the traffic flow, and it is almost the same for drivers with different amounts of experience on the city route [4,5,22].

The difference between the costs of line fuel reaches 2.8%, and it practically does not depend on the qualifications of a driver [8].

A very important factor is the impact of the number of stops on the performance of buses. However, as can be seen from the analysis of the values given in the table, in the case of drivers with different amounts of experience on the city routes, the difference between the values of specific quantities of stops is small and reaches just 3% [9,10].

The analysis shows that in the case of the special bus lane, the performance indicators do not depend on the qualification of a driver, which should be taken into account by transport companies in general in order to increase efficiency. On the second-and third-level lines, on the other hand, the qualification of a driver is of high importance. In the case of drivers with different amounts of experience, the qualifications of a driver, particularly his driving style, impact operating parameters – fuel consumption by rolling stock, environmental safety and the efficiency of a transport company in general [6].

It is necessary to retrain drivers with a fuel-saving criterion, and it has been computed that through retraining drivers in the motor transport enterprise, it is possible to achieve greater fuel economy.

It is known that the energy of rolling stock, in terms of phases and the amount of fuel consumption, correlates with the number of stops. The study showed that allocating a special line for buses, reducing the number of stops and increasing the runway length led to a reduction in fuel consumption, which is less dependent on the qualification of a driver. This leads to a reduction in the number of exhaust gases, which improves the environmental safety of road transport. Therefore, one of the main factors that do not affect the operating cost of rolling stock fuel and environmental safety is the qualification of a driver [7,9].

One of the main ways to reduce fuel consumption and increase its environmental friendliness, is proper organization of the transport process and improvement of management. Through improvements in science and technology, it would be possible to ensure efficient fuel

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consumption. Fuel consumption depends on the following conditions:

- Operating conditions.
- Technical condition of vehicles.
- Organizational–technical measures.

For its part, each of these conditions also depends on a number of factors. For example, fuel economy depends to a large extent on road conditions, traffic modes, weather conditions, seasonality and so on. Allocating a special line for buses is a step forward in this regard.

An example of the effect of a vehicle's operating cycle on the operating cost of fuel (frequency of stops) can be the relationship between fuel consumption and long-distance travel. Cyclicity of operating modes leads to disruption of the established thermodynamic processes in the engine, increases fuel consumption and reduces power. This is proved by the experimental results. This is illustrated by the experimental data on the increase in fuel consumption by the road transport moving on the second and third-level lines of the city by 10-15% compared to the transport moving outside the city, while for buses moving on the first-level lines, this margin is within 5-7%.

An analysis of numerous studies revealed that one of the most important factors affecting fuel consumption is road conditions.

The variable nature of road conditions is taken into account when adjusting the norms and standards of technical operation of vehicles. At the same time, operating conditions have an impact on the operation mode of the vehicle. In accordance with the state of the road surface, fuel consumption may vary by 15-20%. In this regard, the existence of the first three-level transport network is a step forward. The rational organization of road traffic allows for reducing fuel consumption by 15%.

Fuel consumption in cities is affected by the presence of regulated and unregulated intersections on the route and their number, the presence of road signs, correct markings and so on.

The influence of the factors acting on the fuel consumption along with the operating properties is manifested in the formation of the operating modes of rolling stock.

The gains in productivity of urban passenger transport would be achieved through the reduction in fuel consumption, which is based on the management of the operating fuel costs of buses. In order to develop the mentioned measures, it is necessary to collect data on fuel consumption for each city bus route and to provide their computer processing. Based on the analysis of the obtained data, the decision is taken on the need to adjust the operating fuel costs and for adopting the route standards.

This will improve the efficiency of urban motor transport companies on the basis of the route standards of fuel costs by adjusting the existing standards of fuel consumption of buses.

Equally important to enhancing the efficiency of passenger transport and the successful functioning of the transport process is the correctly chosen city route. The main goal is to provide transport of passengers in the shortest possible timeframe. Experience demonstrates that the transport network routing in major cities is a very complex and ambiguous process [14,15].

2.4 City route choice

Equally important to enhancing the efficiency of passenger transport and the successful functioning of the transport process is the correctly chosen city route. The main goal is to provide transport of passengers in the shortest possible timeframe. Experience demonstrates that the transport network routing in major cities is a very complex and ambiguous process.

Proper planning of stops on the city route is of high importance.

The calculation of the operating parameters of the bus routes and the provision of rational organization of passenger transportation should be based on the study of the actual passenger flow on the route.

The aim of the research is to obtain reliable data on the passenger flows on the bus routes and to distribute them according to the hours of the day and days of the week, which allows us to rationally organize the work on the bus lines, to establish their timetable, to choose the type of rolling stock, and to distribute the vehicles [12,13].

The study of passenger flows can be complex and selective [18]. Different methods are used for passenger flow study: surveys, questionnaires, coupons, visual methods and so on. A traffic flow study is also possible through the analysis of revenue from a particular route by the number of tickets sold during the transportation of passengers [19,20]. The information received on passenger flows is processed by specially designed programs using computer technologies.

The information obtained as a result of transportation of passengers must be redistributed according to the hours of the day and the stops on the route. It is schematically represented by diagrams. The diagrams allow us to visualize the distribution of passenger flows in each direction on the route at certain times of the day, as well as the values of passenger flow at "peak" hours, according to which the maximum number of buses is determined. The diagrams have been constructed using the day-to-day flow distribution tables (Table 2).

The distribution of passenger flows in both directions of one of the routes of the city (№14) according to the hours of the day is given in the table, and the diagram is shown in Figure 1.

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Table 2 Distribution of passenger flows on the urban bus routes in both directions by day-night hours

Distribution of passenger flows by day-night hours					
Day-night hours	Number of passengers		Day-night hours	Number of passengers	
	Direction			Direction	
	Forward	Backward		Forward	Backward
5-6	45	21	14-15	370	374
6-7	455	483	15-16	382	420
7-8	591	562	16-17	440	575
8-9	692	722	17-18	577	547
9-10	623	421	18-19	741	605
10-11	505	310	19-20	363	421
11-12	301	173	20-21	192	222
12-13	240	204	21-22	70	51
13-14	466	155	-	-	
				7053	6266
				13319	

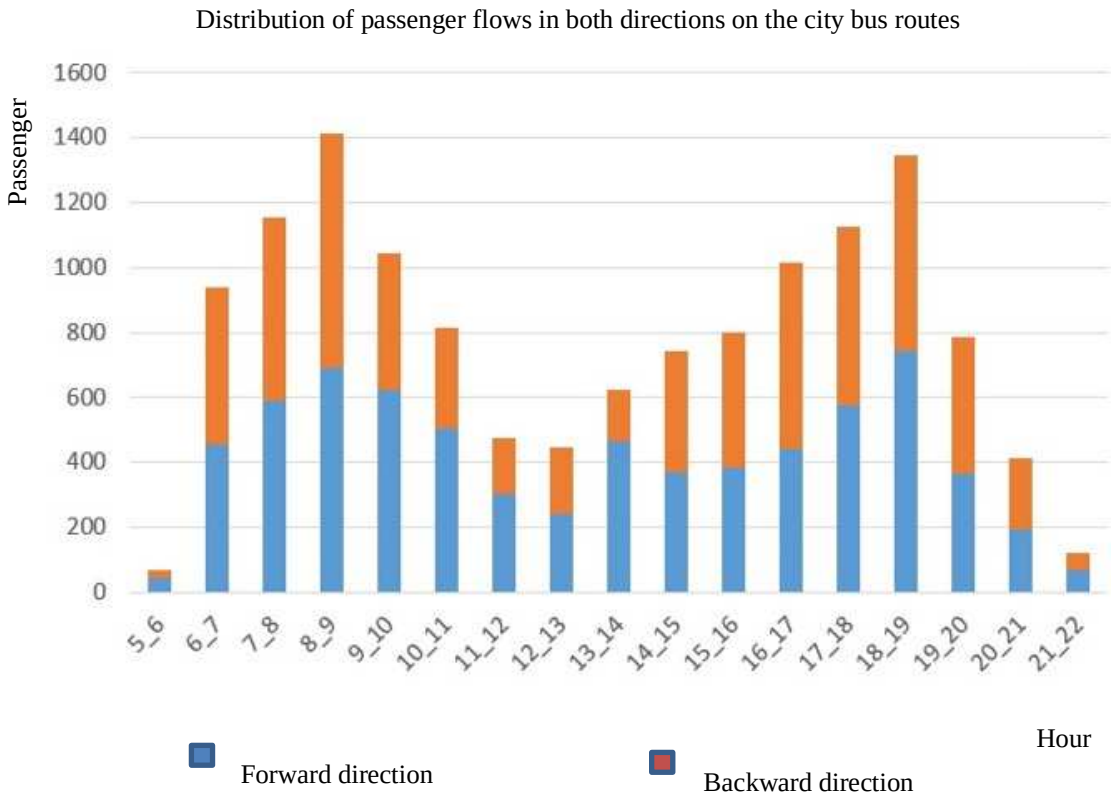

Figure 1 Schematic distribution of passenger flows to the hours of the day and the stops on the routes in forwards and backwards directions

As can be seen from the diagram, the maximum values of passenger flows on a given route are 8-9 and 18-19 hours. As a result of the adjustment of road infrastructure, it is estimated that all the ten first-level lines of the city will increase passenger flow by 1.5-2 times, so the maximum number of buses should be calculated according to passenger flows at these hours. During the remaining hours, the number of buses on the route should be redistributed to ensure timely, safe and comfortable passenger services.

Thus, the analysis shows that in order to effectively organize the traffic of urban passenger vehicles and to

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determine their optimal number on specific routes, it is necessary to establish the patterns of change in passenger flows. Analysis of the various methods of passenger flow study allows us to select any of them according to a specific purpose, which will provide efficient passenger transport services.

A modern type of bus produced by leading companies with a large capacity (90 seats, 12 m long) was selected.

In order to determine the fuel efficiency and environmental friendliness, the operation study was conducted on several city routes in Tbilisi.

The data of the conducted operation experiment were processed using computer technologies, and the numerical values of some important parameters are given in Table 3.

Table 3 Some operating parameters of routes

Parameters	Arbitrary notations	Route number			
		N 150	N 14	N 47	N 54
The length of the route, km	L	13.3	8.1	13.5	11.9
Specific quantity of stops, km^{-1}	N_0	1.95	1.97	1.92	1.93
Specific quantity of light signs, km^{-1}	N_L	2.7	3.1	2.8	3.3
Specific quantity of stops near the light signs, km ^{1}	N	0.9	0.98	0.96	1
Operating speed, km h	V_S	20.1	17.5	22.2	19.7

Analysis of these data showed that the length of the route has a significant impact on the effectiveness of the vehicle's environmental safety, and if it is reduced, fuel consumption increases while traffic speed decreases. This is explained by the increased number of stops (N_0, km^{-1}). In the case of the short-distance routes, it almost doubles, and this result confirms the correctness of what we have said above.

A step forward in this regard is the regulation of road infrastructure, which envisages the creation of a special line for buses. The example of Tbilisi City shows that all the ten first-level lines belong to congested areas, and the creation of special bus lines on them will lead to a partial reduction of traffic congestion; timely transportation of passengers and increased passenger flows by 1.5-2 times; obvious improvement of environmental conditions, which is manifested in the reduction of the number of stops, the number of traffic lights and the number of stops with traffic lights, an increase in the route length, and an increased operating speed.

2.5 Passenger traffic route profitability

The cost-effectiveness of passenger transportation largely depends on the correct selection of rolling stock. First of all, before choosing a rational-capacity bus, it is necessary to remember that buses are classified according to two major criteria - destination and capacity. During urban passenger transportation, urban and large-capacity buses are regarded as a preferred solution [21].

An important parameter is the capacity of the bus, which primarily affects the bus filling factor and the comfort of passengers. When determining this factor, the values of passenger flows (in one direction) and their unequal distribution according to the hours of the day and night should be taken into consideration. Under the current conditions, in the context of combatting the coronavirus pandemic, there was a significant reduction in the bus filling factor, and its value was 0.5. In this regard, it is necessary to make some changes in the industry standard.

With improving the road infrastructure, according to the existing methodology, the bus was selected according to the existing methodology, and the bus traffic interval, frequency and all the necessary parameters were determined.

The number of public transport and the location of stops were theoretically determined according to the major indicators, according to the distance travelled by pedestrians and the speed of public transport [16,17].

Finally, we can conclude that in the current environment, in a manner fully consistent with the standard and for people with disabilities, the requirements are met by large-capacity buses at peak hours at intervals of 3 minutes, while during off-peak hours - by the withdrawal of buses.

Thus, the analysis shows that the efficient operation of the city bus routes is influenced by a large number of factors, the maximum account of which ensures safe, quality and timely transportation of the population.

3 Result and discussion

The analysis allowed us to systematize and generalize the efficiency criteria of urban passenger transport companies, identify indicators that characterize the quality of transport services for the city population, as well as the performance effectiveness of transport companies and the specifics of routes.

In order to select the appropriate urban passenger vehicles for the specific routes, as well as to determine their optimal number, the patterns of variability of passenger flows and the distribution of the number of vehicles

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selected on their basis according to the hours of the day were established.

The article analyses and establishes the operational factors affecting the fuel efficiency and environmental safety of road transport and focuses on qualification of a driver and the effective methods of driving to ensure the efficiency of the transport process.

It has been established that when creating a model for managing the urban passenger transport system, it is advisable for the municipal government to maximally investigate the city population's demand, study passenger flows and establish routes and timetables, as well as provide the timetable monitoring and scheduling system.

There has been established the nature of the variability of the operating parameters (average speed, fuel consumption, etc.) during the operation of buses in urban conditions, which is due to frequent stops, high saturation of obstacles, and increased frequency of unsteady traffic modes, and so on. As a result, there has been justified the need to improve the professional skills of drivers to increase the effective performance of transport companies and use the methods of their material incentives.

In urban traffic, the number of stops per kilometre of the route is large, which increases the share of unsteady bus traffic on the line, resulting in a significant increase in fuel consumption, increasing emissions and deteriorating environmental conditions in the city. A step forward in this regard is the improvement of road infrastructure, which envisages the construction of ten first-level roads in the city with special bus lines that will pass through all busy areas or streets of the city, thereby extending the bus lines and reducing the number of intermediate stops.

In terms of increasing the productivity of transport companies, it should be noted that, using the example of Tbilisi city, road infrastructure has been conditionally divided into two parts, the first of which, which includes ten first-level sections, has less dependence on qualification of a driver, the driver's choice of economy modes, namely, on his driving style, the reduction in the number of stops automatically led to the reduction in fuel consumption, it is no longer necessary to train drivers on the criteria of fuel efficiency.

The nature of the variability of its performance indicators in the vehicle's operation process in the conditions of Georgia has been established, which is due to frequent stops, high saturation of obstacles, increased frequency of unsteady traffic modes, and so on. As a result, with a view to improving fuel efficiency and environmental friendliness, there has been justified the appropriateness of motor vehicles.

The studies that we conducted on the urban route operating parameters and the results of the experiments involving the drivers with different amounts of experience and qualifications when driving on different categories of roads and in various transport network conditions show that the effective performance of transport companies varies between 55-60% depending on the qualification of a driver.

As can be seen from the analysis, it would be wrong to suggest that the economical driving of the vehicle is associated with the average speed of traffic and, consequently, with the reduction in the transport work performed. Therefore, when operating in these typical conditions, the driver's ability to maintain the optimal operating modes of the vehicle in terms of fuel economy comes first.

4 Conclusions

The article discusses and elaborates the measures of operation of city bus routes in the conditions of a three-level transport network in big cities, thus ensuring timely, safe and comfortable service of passengers, in a relatively ecologically clean environment, with minimal economic costs.

- The regularity of the change of passenger flows has been established.
- The bus scheme of minibuses and minibuses was optimized.
- Urban passenger vehicles were selected, and their optimal number was determined.
- The number of vehicles was distributed according to the day and hours.

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