

Keywords: bus; efficiency; comfort; model; service quality; passenger traffic; urban transport; system

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WAYS TO ADDRESS THE CHALLENGES IN PASSENGER TRAFFIC WITHIN THE URBAN TRANSPORT SYSTEMS

Summary. The paper dwells on developing the measures required for the effective functioning of urban bus routes, which are of great practical importance.

As the analysis shows that in order to effectively organize urban passenger traffic and determine their optimal number on the routes, it is necessary to determine the pattern of changes in passenger flows, and on this basis, to distribute the number of buses in accordance with day–night hours.

Based on this, an analysis of factors has been carried out affecting urban bus transport, and we have developed the measures aiming at increasing the effectiveness of passenger transport in transport companies.

1. INTRODUCTION

An essential requirement for the country's socioeconomic development is the effective functioning of the transport system equipped with modern technologies, since there is no sector of economic or social sphere, whose normal operation and development are independent of transport. Transport is a technological part of the functioning of these sectors. All of the foregoing indicates the need for the priority development of the sectors within the transport system, in particular—road transport. Starting in the second half of the twentieth century, in the world, including Georgia, we are witnessing the process of intensive motorization. The increase in vehicle numbers has resulted in two pronounced and contradictory trends. In particular, the high level that motorization has reached determines the development of the economic potential of society and ensures the maximum satisfaction of the population's transport needs [1, 2]. On the other hand, it has contributed to the increased magnitude of the negative impact on society and environment, which has caused environmental degradation.

Transport provides an opportunity for the functioning of a city as an integrated system in its administrative, economic, cultural, educational, and other areas. The demand for urban transport is continuously growing, which leads to the development of passenger transport motor power and to the increased demands placed on them. However, it often happens that the modern requirements exceed the technical capabilities of urban passenger transport and their actual use.

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

Since oil and oil-origin fuel reserves are not renewable, and they will be exhausted sooner or later, but the number of the country's motive power is growing at a rapid pace [9, 10], the problem of the fuel efficiency of vehicles is a priority.

A successful resolution to this problem will depend on the level of sophistication of automobile designs, as well as on scientific and technological progress in the field of search and use of alternative fuel for motor transport.

Today, the solution to the transport problems by improving the technical parameters of motive power, does not produce a great effect. It is necessary to develop the issues relating to the theory of travel service administration and vehicle traffic, that is, under conditions of rapid motorization, to review the issues of the transportation process management itself. Therefore, there has recently been a growing interest of researchers in the urban transport system, and the theories of passenger traffic modeling have been created [7, 8]. They are aimed at improving road infrastructure, and creating the systems of quality passenger service, providing passenger comfort using the minimum time [3, 4].

2. THE MAIN ELEMENTS OF THE SYSTEM OF URBAN PASSENGER TRANSPORT

The effective functioning of urban passenger transport companies depends on vehicles and their technical state; providing with suitably qualified staff; the presence of the necessary legislative base; and compliance with its requirements.

Vehicle is one of the main elements of the system of urban passenger transport. The main elements of the urban passenger transport system are road infrastructure with its equipment and devices; motive power; facilities and devices for storage, maintenance, and repair of motive power; premises and devices for fuel and energy supply of motive power; transport management tools; etc. [5, 6]. Of particular importance are the methods of modern logistics, which are used for road transport [30].

Rational route choices, using the operating parameters and proper methods for the organization of road traffic, are major for the effective functioning of urban bus routes. The rational option is the one that perfectly ensures high performance of passenger transport and meeting people's needs. In particular, the maximum safety traffic speed; maximum passenger comfort; the minimum time for passenger service; satisfactory working conditions for drivers are required.

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

3. DEVELOPING THE PASSENGER TRANSPORT SYSTEM DEVELOPMENT PROGRAMS

Passenger transport companies should meet high-quality standards of service, for which much attention should be paid to the needs of passengers with a corresponding financial cost.

It should be taken into consideration that people's needs for transport should be predictable and manageable; urban passenger transport should ensure the integrity of the city as a geographical unit; the operational characteristics of motive power should comply with requirements from consumers, relevant level, and comfort; the cost of transportation by public transport for the socially vulnerable population must be affordable for political reasons.

At the municipal level, the development of the passenger transport system development programs; formulation of social mandate; the development and approval of the city's transport scheme; coordination between transport modes; studying the passenger traffic requirements; the establishment of a route network; tariff determinations; and so on are currently occurring.

One of the most important things is a driver qualification, which depends on methods for driving buses, and it makes it possible to improve the efficiency of the transport process.

Vehicle plays an essential role in creating environmental threats to humans and the environment. It is sufficient to say that more than 80% of air pollution comes from harmful substances emitted by

vehicle engines. Since vehicle numbers are growing at a rapid pace, their negative environmental impact is a global ecological problem [11, 13].

The driver is a central figure affecting bus maneuvering during starting acceleration, and by the effectiveness of transmission speeds, on fuel efficiency and reduction of harmful substances in exhaust gases.

4. STUDIES OF THE CITY ROUTE OPERATING PARAMETERS

We have carried out research investigation on the operational indicators of urban route with the participation of drivers with the differences in work experience and various levels of qualifications. The results of the experiments that reflect the influence of driver's qualification on the operational indicators of a bus are given in Tab. 1.

Table 1

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

Operating indicators	Operating conditions	Drivers with less than 1 year of work experience	Drivers with more than 5 years of work experience
Average speed, km/h	Urban	21,1	22.6
The number of stops, km ⁻¹	Urban	5,9	3,8
Fuel consumption on the line	Urban	44,8	37.9

5. THE REVIEW OF THE EXPERIMENT

Based on the review of the experiment, we can conclude that while operating a bus on the city route, in the case of the drivers with the different driving experiences, the difference between the average speeds of traffic is 7%, showing that the average line speed of buses, even in the conditions of the rapid growth in the traffic flow, is determined not by the driver, but by traffic flow, and it is almost the same on the city routes for the drivers with the different driving experiences, while the difference between the line fuel costs depends in practice on a driver qualification [12, 14] and reaches 16%.

The important factor is the impact of a specific number of stops on the operational characteristics of buses. Analysis of the magnitudes given in the table shows that the difference between the values of specific numbers of stops on the city routes in the case of the drivers with the different driving experiences, is large and reaches 36%.

Considering the above, the urban passenger transport companies are required to pay maximum attention to the ways of improving professional skills of drivers and use methods of material incentives.

Of particular importance is selecting the cost-effective mode of motion by the driver, because the value of the rate of kinetic energy accumulated the vehicle acceleration, and the share of its scattering in the braking equipment of motive power, under certain conditions, is controllable by the driver. This allowed us for formulating the main objective of efficient management of motive power according to the fuel consumption rate [15, 16]. The study also showed that the energy of motive power according to the phases, and of course, the fuel consumption rate is correlated with the number of stops. It has been revealed that during the motion of vehicles in urban areas, the number of stops per kilometer of the length of the route is much higher than during operation under intercity, highway, or other conditions.

It is necessary to retrain drivers with a fuel-saving criterion, and it has been computed that by retraining of drivers at the motor transport enterprise, it is possible to save a large amount of fuel.

The analysis shows that the impact of a driver qualification is significant in the case of the drivers with the different driving experiences, which affects the operational parameters and the performance of the transport company, in general.

In order to control the actions of the driver, tachographs are used. They serve as log books, record the distance covered and the velocity–time diagram, as well as serve the driver as a speedometer and a watch. Information recorded on the tachograph's boss assembly allows for assessing the driver's performance while choosing the mode of motion and route, and also represents a self-control tool.

An essential direction in reducing the operating fuel consumption rate and in increasing environmental friendliness, is proper organization of the transport process and improvement of management. On the basis of the achieved scientific–technical progress, it would be possible to ensure efficient fuel consumption.

Fuel consumption depends on the following reasons:

- Operating conditions;
- Technical condition of vehicles;
- Organizational–technical actions;
- Driver qualification.

For its part, each of these reasons depends on a number of factors.

Fuel saving depends to a large extent on road conditions, traffic modes, state of access roads, weather conditions, seasonality, loading, and so on.

The nature of the dependence of the fuel consumption change on road conditions has been studied by a number of researchers, and the pilot studies show that the minimum fuel consumption will be ensured on slightly ascending roads.

A change in the fuel costs on a vehicle depends on the speed. The increase in fuel consumption, when the speed increases, is due to the increase in resistance of air and hydraulic resistance in the engine and transmission mechanisms. At low speeds, the movement of vehicles with a carburetor engine can be explained by the fact that a considerable opening of a throttle leads to enrichment of a mixture and the excess fuel consumption that increases in turn, environmental pollution by exhaust gases [17, 18].

The load mode, as well as the speed mode, has a great impact on the operating fuel consumption rate of the vehicle. With an increase in vehicle load, the operating fuel consumption rate increases as well. This is explained by the increase in resistance to the movement, which is proportional to the weight of the vehicle. At the same time, the specific fuel consumption is substantially reduced.

The state of access roads will have significant implications for fuel consumption. For example, during the poor access roads, the number of maneuvers increases with loading and unloading, and the movement is carried out at low speeds, which significantly increases fuel costs.

An example of the impact of a cycle (stopping frequency) of the vehicle's run mode can be the relationship between the fuel consumption rate long-distance travel. The cycling nature of the run modes leads to a violation of the established thermodynamic processes, increases fuel costs, and reduces the power. This is confirmed by the experimental findings on a 10-15% increase in fuel costs by urban road transport, in comparison with transport running outside the city.

The atmospheric conditions and seasonality have a significant impact on fuel consumption. The change in atmospheric conditions will significantly affect road conditions and the state of road surface, which in turn increases or reduces the operating fuel consumption rate. The fuel costs when using a vehicle are formed due to the following reasons: vehicle's technical condition, organizational technological measures, operating conditions, and the quality of a driver's performance. For its part, each of the reasons depends on a number of factors.

On the basis of the carried-out analysis, the operating factors affecting the vehicles fuel efficiency and environmental safety have been established, and they have been classified into two groups: managed and unmanaged factors. The managed factors include driver qualification, vehicle's technical condition, organizational–technical measures, and so on. The unmanaged factors influencing vehicles fuel efficiency and environmental safety are road, climatic, seasonal, and other factors. Considering them in further surveys will enhance environmental safety vehicles. A diagrammatic representation of the factors influencing vehicles fuel efficiency and environmental safety is presented in Figure 1.

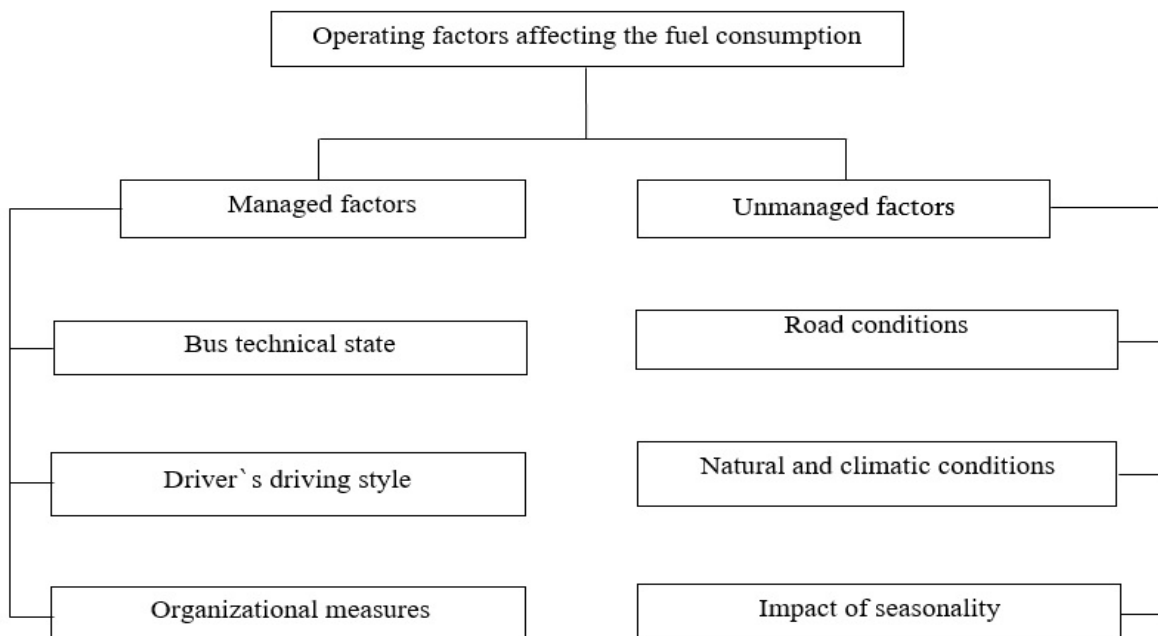


Fig. 1. Scheme of the operating factors affecting the fuel consumption rate

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

The changeable nature of road conditions is taken into account by category, when adjusting the maintenance norms and standards of vehicles. At the same time, conditions for the operation have an impact on the operation mode of the vehicle. In accordance with a state of the road surface condition, fuel consumption rate can be changed by 15-20%. The rational organization of road traffic allows for reducing fuel consumption by 15%.

Fuel costs in urban areas are affected by the existence of the signalized and non-signalized junctions on routes, as well as their number, road signs, etc. During the movement in urban areas, the vehicle's fuel consumption rate increases by 20-30%, due to a large number of brakes and accelerations and decelerations.

Weather and seasonal conditions have a significant impact on the fuel costs.

The impact of factors affecting the fuel costs, together with the operating properties, is revealed during the establishment of the operation modes of motive power. The technical state of vehicles is deteriorated under the influence of the operation modes, and the maintenance service of motor

transport enterprise provides its recuperation to the required level. The operation modes of vehicles are established not only by its technical state, but by the impact of factors, such as operating conditions and driver qualifications [19, 20, 23].

The operation modes of motive power and fuel consumption rates allow for analyzing the pattern of the formation of fuel costs with greater precision, determining the technical condition of the vehicle by fuel consumption rate and driver qualification, and on the basis of an objective analysis and control of the transport process on route - for operatively managing fuel consumption and the environmental safety parameters.

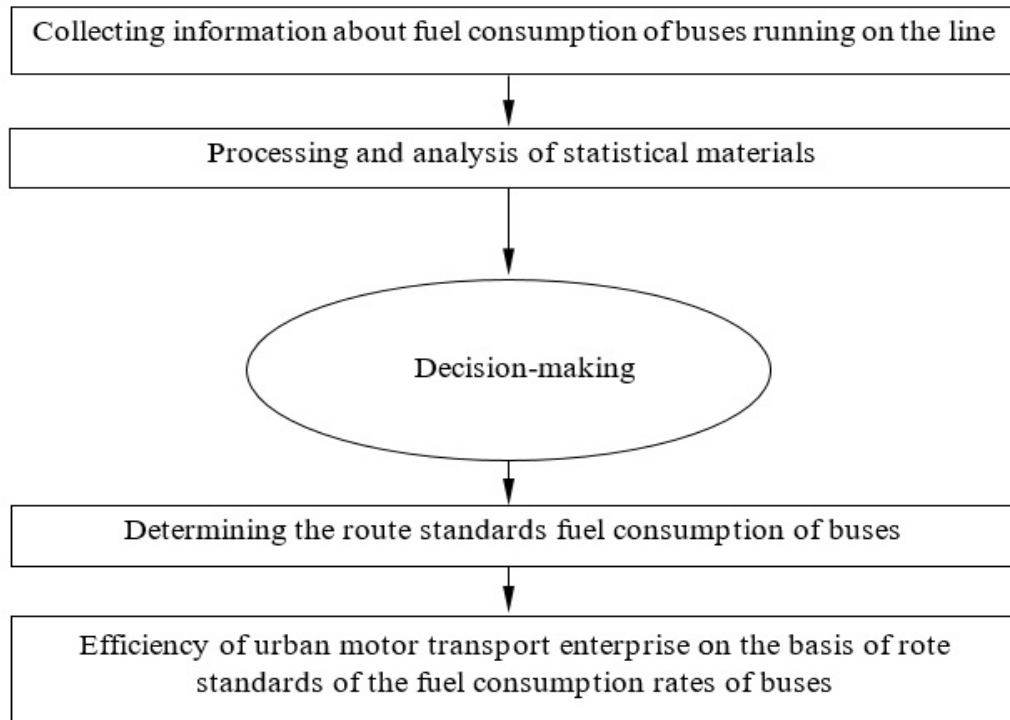


Fig. 2. Management scheme of the operating fuel costs of buses

The gains in productivity of urban passenger transport are possible 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 information on the fuel consumption rates for each city bus route, and to provide its computer processing. Based on the analysis of the obtained data, the decision is taken on the need for adjusting 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. Figure 2 illustrates the management scheme of the operating fuel costs of buses.

Enhancing the efficiency of passenger transport and the correctly chosen city route is no less important for the effective operation of the transport process. The main purpose and selection criterion is to provide rapid transport of passengers. Experience shows that in major cities, the transport network routing is a very complex and ambiguous process.

6. CITY ROUTE CHOICE

For the successful functioning of the transport process and for the improvement of urban passenger traffic, the correctly chosen city route is no less important. The main purpose and criterion of choosing is to provide transportation of people with minimum time-spending. In the large cities, the transport network routing is a very complex and ambiguous process.

Route choice is made in accordance with the following requirements: the bus route lines should pass through the points, required and specified for passengers, which are located at the shortest distance from each other; the minimum time for passenger transportation must be ensured; to ensure passenger safety, they must be provided with comfortable conditions and the opportunity for changing transport mode.

Proper planning of the stops is of high importance on the city routes. Stops help passengers to board a bus and go to a different route. At the place of stop, there should be a bus stop pavilion for passengers, and the existence of seating and infrastructure needed for the disabled persons would be appropriate. All stops must be equipped with signs, illuminated at night and should contain information necessary for passengers. These signs should indicate the route scheme, information on the stop names, and the final stop. Route numbers must be indicated which are brought together at this stop, interval between services during the day, and so on [24-28].

Calculation of operational parameters of bus routes and ensuring the rational organization of passenger transport should be based on the study of actual passenger traffic flows on the route.

The research is aimed at obtaining the reliable data on passenger traffic flows on the bus routes, and distributing them in accordance with day–night hours and weekdays, which enables us to provide rational organization of the operation of buses on the lines, draw up correctly their timetable, choose the type of motive power, allocate buses on routes, and locate purposefully the bus stops.

The complex and sampling studies of passenger traffic flows have been used. The complex studies are carried out on all types of vehicles, or on all bus routes simultaneously, to solve common problems. They are aimed at developing the transport network, improving coordination of the operation of different types of vehicles, allocation of motive power on routes, and so on.

The sampling study is carried out on selected routes for solving specific issues relating to a change in the location of stops, changing in a bus route timetable made for the effective use of buses on certain lines, determining the passenger turnover, and so on.

Various methods are used for studying the passenger traffic flows: polling method, questionnaire method, coupons, visual methods, and so on.

The polling method is based on the study of passengers in buses. The essence of the research by this method is that the researcher finds out from passengers, which bus stop they travel to, and so, the passenger's movement between the stops on the route is determined.

The questionnaire method is based on completing the forms by the population, which is ensured by the inspectors. The study is carried out by direct polls in accordance with the place of residence, job, and educational institutions, whose data are recorded on the card. The studies of passenger traffic flows by the questionnaire method can also be carried out through passenger surveys at route terminals, and the obtained information is written down on the form by the inspectors. This method of studying the passenger traffic flows is extremely laborious and cannot reflect the real conditions of the passenger traffic movement on the route, and it is used to create a new, adjusted transport network or to improve the operation of vehicles on its selected nodes and routes. This method, as compared with other methods, enables us to answer the more interesting broader questions, and in spite of the existing transport network, to identify the population's need for moving in different directions.

The coupon-based method, allows us, along with the basic indicators of passenger traffic flows, for determining the passengers' corresponding movements between the bus stops on the routes. During the studies by this method, the passengers, when getting in and getting off the bus, hand in special coupons, which indicate the numbers of the taking up and setting down stops, as well travel time.

The studies with the visual method are aimed at collecting data by the bus stop, where the instructors visually determine the number of passengers, filling the buses and enter these data in special tables. The visual method is based on counting the passengers at the bus stops or in the buses.

The studies of passenger flows by the visual method and processing of information obtained does not take considerable time and resources, but the obtained research materials are used for operational purposes: determining motive power on routes, correction of the route timetable, checking the quality of service at the selected routes and sections, and so on.

The studies of passenger flows are also possible during the analysis of the route revenues, by the number of tickets sold to passengers. Information about sold tickets allows us to determine the number of passengers transferred along the route, and the change in passenger flows on the route. To get complete data, except those passengers who have one-way tickets, it is necessary to take those passengers into consideration who have seasonal, daily, and different types of travel tickets and incentives.

Processing of received information on passenger flows is carried out using specifically developed programs with the use of computer technologies [21, 22, 29].

Information obtained as a result of passenger transport must be redistributed according to day-night hours and the route stops. It is represented schematically in diagrams.

Redistribution of passenger traffic flows in both directions on one of the city's routes by day-night hours is shown in the table below, but the diagram is shown in Fig. 2.

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	29	11	14-15	196	199
6-7	242	252	15-16	202	221
7-8	307	291	16-17	231	299
8-9	356	371	17-18	301	284
9-10	320	222	18-19	380	313
10-11	266	165	19-20	191	222
11-12	162	98	20-21	107	121
12-13	130	111	21-22	40	32
13-14	244	86	-	-	-

As shown in the diagram, the maximum magnitudes of passenger flows on the route are observed at 8-9 and 17-18 o'clock, so the maximum number of buses should be calculated according to passenger flows in-between these times. In the remaining hours, the number of buses on the route should be distributed to ensure timely, safe, and comfortable service for passengers.

Thus, the analysis shows that in order to effectively organize the movement of urban passenger vehicles and determine their optimal number on the particular routes, it is necessary to determine the pattern of the change in passenger flows. Analysis of different proposed methods of studying the passenger flows allows us for choosing one of them depending on a particular goal that ensures effective transport services for passengers.

For the purpose of determining fuel efficiency and environmental friendliness, the operating experiment was conducted on several routes in Tbilisi City.

The data of the operating experiment have been processed using computer technologies, and numerical values of some significant parameters are given in Table 3.

Analysis of these data showed that the length of the route affects the efficiency of environmental safety of the vehicle, and in the event of a reduction in its value, fuel consumption increases, while the speed of movement goes down. This is explained by an increase in the specific quantity (N_0, km^{-1}). In the case of a short route, it almost doubles, and this result confirms the correctness of the aforementioned that, along with the increasing specific number of stops, the share of a bus moving and slowing down goes up, which is characterized by a reduction in the speed, increased fuel consumption, and an increase in exhaust gas emissions.

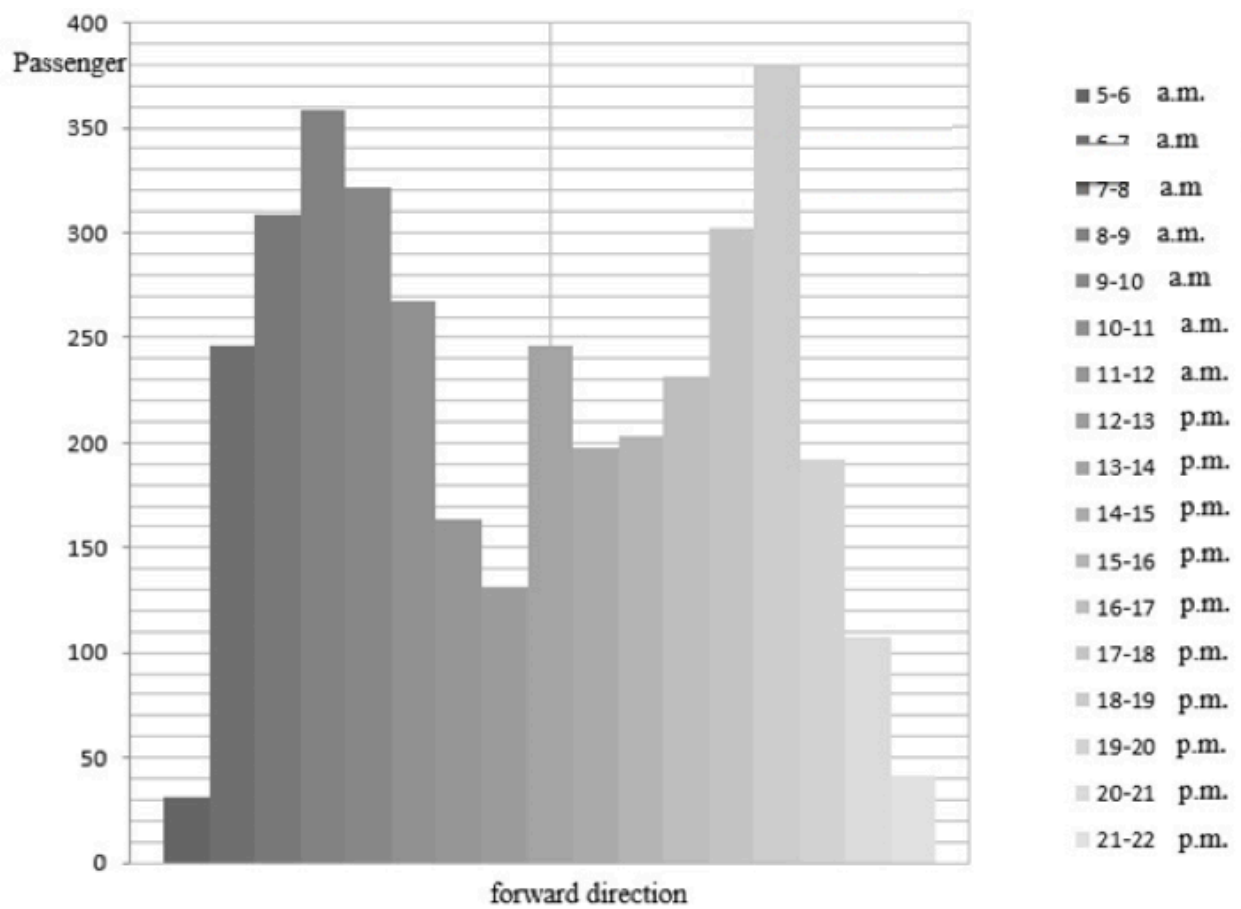


Fig. 3. Schematic distribution of passenger flows on the route in forward direction by day–night hours

Table 3

Some operating parameters of routes

Parameters	Arbitrary notations	Route number		
		№1	№2	№3
The length of the route, km	L	19,2	10,9	22,7
Specific quantity of stops, km ⁻¹	N ₀	1,94	2,33	1,74
Specific quantity of light signs, km ⁻¹	N _s	1,31	1,48	0,84
Specific quantity of stops near the light signs, km ⁻¹	N	0,73	0,96	0,65
Operating speed, km h	V _s	19,7	17,5	22,2

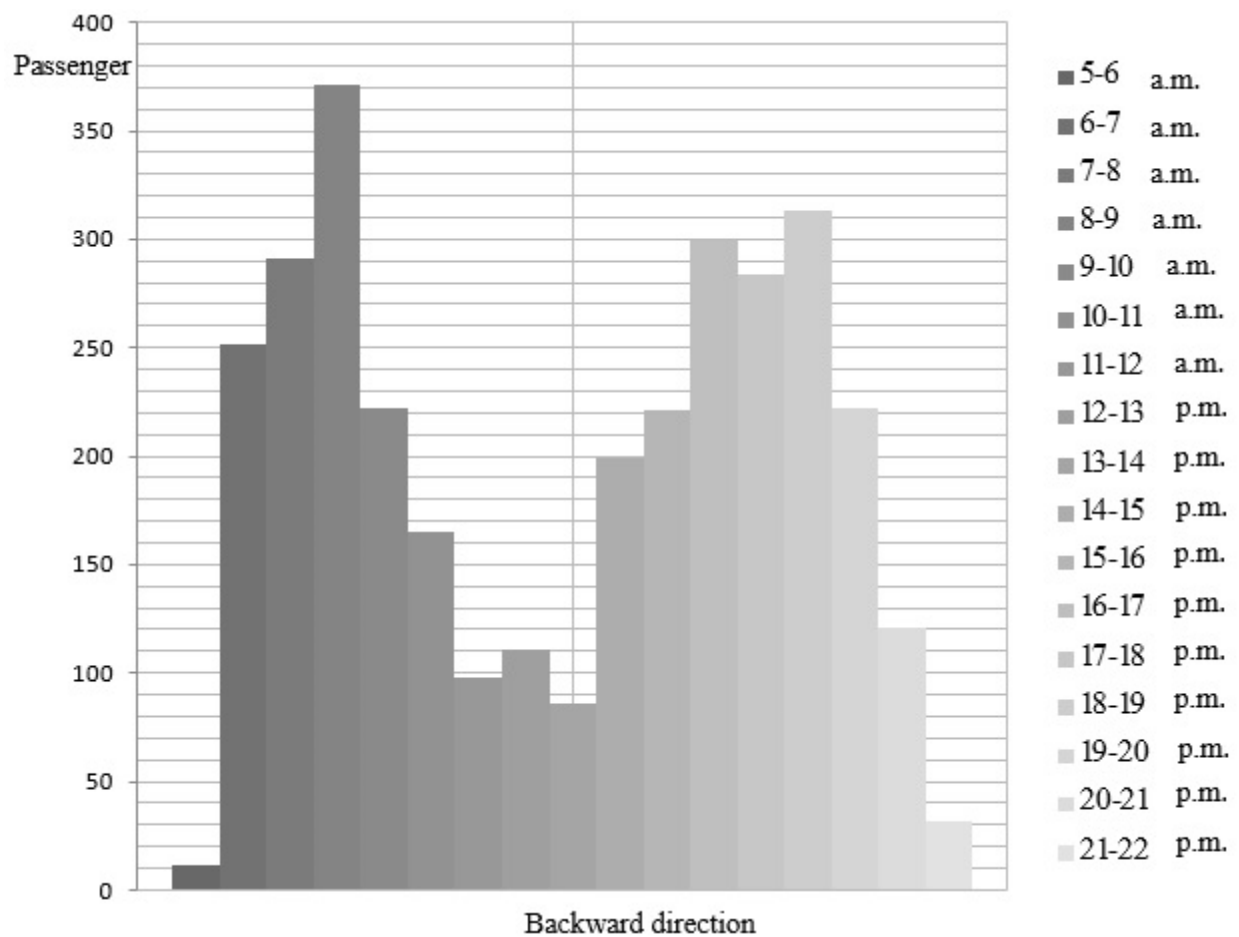


Fig. 4. Schematic distribution of passenger flows on the route in backward direction by day-night hours

7. PASSENGER TRAFFIC ROUTE PROFITABILITY

The choice of motive power depends on passenger traffic route profitability. Before we choose a bus with rational carrying capacity, it should be recalled that buses are classified according to their purpose and carrying capacity. In the urban route traffic, the preference is given to the city and large carrying capacity buses.

The carrying capacity affects the bus occupancy rate and passenger comfort. When determining this rate, the values of passenger flows in one direction and its uneven distribution by day–night hours should be taken into consideration, as well as the intervals between the bus services.

The analysis shows that a large number of factors have a significant impact on the effective functioning of the urban bus routes, maximal account of which will ensure safe, comfortable, and timely transportation of people.

8. CONCLUSION

Analysis has revealed the parameters characterizing the quality of urban passenger transport service, and the systemization and generalization of effectiveness criteria for urban passenger transport companies have been provided, and the effectiveness of the functioning of carrier companies and specifics of routes have been determined.

The article analyzes and identifies operating factors affecting fuel efficiency and environmental safety of motor transport, and the emphasis is placed on driver qualifications and techniques of effective control of the vehicle, which will enhance the efficiency of the transport process.

It has been established that the municipal authorities, when creating a management model of the urban passenger transport system, have to explore to a full extent the needs of urban population, to study passenger traffic, and on that basis, to establish the routes and travel schedules, to monitor these schedules, and to adopt the motivational system for carrier companies to adhere these schedules.

It has also been established that the nature of variation of the performance characteristics of buses in urban conditions stems from the increased frequency of unsteady motion modes, frequent stoppages, and so on. As a result, an argument was made for improving fuel efficiency and the environmental situation. It is necessary to provide material incentives for them.

It has been revealed that the number of bus stops on the length of 1 km of the bus route in urban conditions is too high, which increases the share of unsteady motions of buses, resulting in a significant increase in fuel consumption, increased exhaust gas emissions, and environmental degradation in the city.

It has been determined that the nature of the variability of the performance characteristics of a motor in Georgia is too high, which is due to frequent stoppages, increased frequency of unsteady motion modes, and so on. As a result, an argument was made for improving fuel efficiency and environmental performance of vehicles, as well as the expediency motor vehicle traffic according to the following motion modes: acceleration in the transport traffic through a minimal buildup of kinetic energy and by its maximal use when slowing down, through management of these processes by the driver.

As is apparent from the analysis, efficient driving of the vehicle is associated with reduction of the average speed, and subsequently, the reduction of the transport load performed.

Thus, when driving in these typical conditions, the first place goes to the driver's skills and the ability to maintain the optimal operation modes of vehicles in terms of fuel efficiency.

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